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BALTICA Volume 19 Number 2 December 2006 : 80-90

Lateglacial environment inferred from palaeobotanical and ^{14}C data of sediment sequence from Lake Kašučiai, West Lithuania

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Šeirienė V., Stančikaitė M., Kisielienė D. and Šinkūnas P., 2006. Lateglacial environment inferred from palaeobotanical and ^{14}C data of sediment sequence Kašučiai, West Lithuania. Baltica, Vol. 19 (2), 80–90. Vilnius. ISSN 0067–3064.

Abstract A sediment core from Lake Kašučiai was analysed for pollen, plant macrofossils and diatoms to reconstruct the environmental changes. Age control was provided by ^{14}C dating. The obtained data shows the establishment of sparse vegetation before 14,300 cal BP. The short lasted climatic deterioration was registered at about 14,300–14,100 cal BP and caused the reduction of the vegetation cover. Following climate amelioration started before 13,700 cal BP and influenced forestation of the region, rise of water level and the beginning of lake eutrophication. The period of 13,700–13,400 cal BP is considered being the warmest during palaeolake development. Successive climate cooling registered during 12,600–11,100 cal BP period. Eventually, after 11,100 cal BP climate warming started.

Keywords *Pollen, macrofossils, diatoms, radiocarbon (^{14}C), environment changes, lateglacial, Lithuania.*

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INTRODUCTION

In Lithuania the broad-scale patterns of environmental variation during the lateglacial have been identified primarily from palynological and diatom studies (Kabailienė 1998, 2006 c). However, the chronological attribution of the registered environmental changes and the temporal resolution were rather restricted. Only during the last decade more attention has been paid to the reliability of the age determinations of palaeo-events (Stančikaitė 2000; Stančikaitė *et al.* 2003, 2004; Kabailienė 2006a,b,c).

The main aim of this study was to obtain a modern lacustrine palaeobotanical record supported by a reliable ^{14}C chronology and to establish a supplement lateglacial environmental model with data of higher resolution. Multiproxy investigations of the Lake Kašučiai core (pollen, plant macrofossil and diatom survey, ^{14}C dating) presents uninterrupted reconstruction of the vegetation cover, lake level changes and ecological regime of the area since about the 14,000 ^{14}C uncalibrated BP until the beginning of the Holocene.

STUDY SITE AND METHODS

The coring site (55°59’28” N, 21°18’26” E) is located in the southeastern part of Lake Kašučiai, West Lithuania (Fig. 1). Lake covers a 0.1 km^2 surface area with a maximum depth about 3 m and is partly overgrown. Located in the inter-hill depression (35 m a.s.l.) it is surrounded by boggy plots predominated by birch and alder. Agriculture fields and pastures dominate the catchments. Lake has an outflow stream originating from its western part and connecting it with the Dubupys River. Landscape is predominated by small hills (~40 m a.s.l.) formed by till deposits with sandy depressions of glaciolacustrine and glaciofluvial origin.

Multiple sediment cores were obtained from near the southeastern shore of the lake using a Russian corer. The core covering 100–300 cm depth interval was sub-sampled at 2 cm resolution for pollen and diatom analyses. The two parallel cores were combined and sub-sampled for plant macrofossil study (every 5 cm). Bulk samples of 4–5 cm were taken for ^{14}C dating.

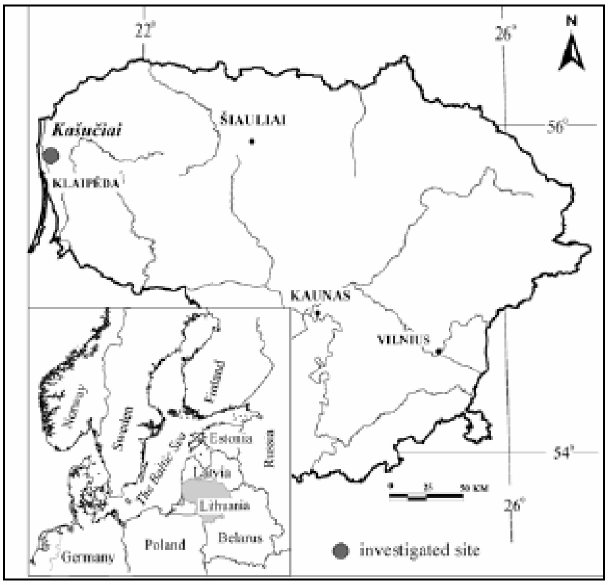

Fig. 1. Location of the study site.

Pollen analysis

Sub-samples for pollen analyses comprise 3 cm^3 of the sediments. Chemical preparation followed the standard procedure described by Grichiuk (1940) and Erdtman (1936), which includes treating the sediments with a heavy liquid (CdJ_2+KJ). *Lycopodium* tablets were added to estimate pollen concentration (Stockmar 1971) in the Kašučiai core. More than 500 terrestrial pollen grains were counted for each sample. Pollen and spore identification was based on Moore *et al*. (1991) and Moe (1974). To calculate the percentage pollen values the sum of arboreal ($\sum$AP) and non-arboreal ($\sum$NAP) taxa ($\sum$AP+$\sum$NAP=$\sum$P) was used.

Plant macrofossil analysis

Plant macrofossils were extracted from sediment samples (volume of 230 cm^3) by wet sieving on a screen with a mesh size of 0.25 mm. The identification of macrofossils was based on Beijerinck (1947), Velichkevich (1973) and Grigas (1986). The percentage of the plant macrofossils presented in the constructed diagram is calculated using the total sum of the identified taxa subdivided according its habitat classifications (trees and shrubs, xeromesophytes, aquatics, wetland plants).

Diatom analysis

Diatom frustules were extracted from the sediments in the conventional manner described by Battarbee (1986), Miller & Florin (1989). HCl was added to remove the carbonates and 35% H_2O_2 to oxidise organic material. Decanting and flotation in heavy liquids were applied to remove clay particles and mineral material. Afterward, the diatom frustules were mounted into Naphrax liquid and examined under a light microscope with an oil immersion objective at a magnification of 1000 x. The identification of species was based on Krammer & Lange–Bertalot (1988, 1991a,b, 1997), counting a total of 500 frustules in the central part of each slide. The succession of the most frequent and ecologically important taxa is presented in the percentage diagram based on the total sum of the identified diatoms.

All spreadsheets as well as the percentage diagrams for all above mentioned palaeobotanical analysis were plotted using the programs TILIA and TILIA–GRAPH (Grimm 1992). The diagrams were subdivided into local plant assemblage zones using sum–of–squares cluster analysis (Grimm 1987).

Radiocarbon (14C) dating

Seven bulk samples of the sediments were dated. Samples were analyzed in the Kiev Radiocarbon Laboratory, Ukraine. The radiocarbon calibration program OxCal v3.10 (Bronk Ramsey & Allen 1995; Bronk Ramsey 2001) with INTCal calibration curve (Stuiver *et al*. 1998) was used for the calibration of radiocarbon dates. Time scales were constructed on the basis of the linear interpolation between available dates and all ages are given as calibrated years before 1950 AD (cal BP). The results of ^{14}C dating were presented in the Table 1.

Table 1. List of the radiocarbon dates from the Lake Kašučiai sediment sequence.

No.	Depth, cm	Dated material	Reference laboratory	^{14}C yr BP	Calibrated time, cal yr BP	
					95.4%	68.2%
1	120–125	Peat	Ki–11410	3580±70	4090–3690	3980–3820 (58.4%)
2	150–155	Gyttja	Ki–12169	9740±80	11,350–10,750	11,250–11,080
3	190–194	Gyttja	Ki–10913	10,160±200	12,650–11,150	12,150–11,350
4	225–230	Gyttja	Ki–11411	11,660±130	13,800–13,250	13,670–13,380
5	255–260	Gyttja	Ki–11412	11,860±100	13,940–13,450	13,840–13,600
6	275–280	Gyttja	Ki–12170	12,240±120	14,750–13,800	14,360–13,920
7	294–298	Gyttja (carbon)	Ki–10914	15,450±250	19,250–18,050	18,990–18,550
8	294–298	Gyttja (organic)	Ki–10914a	14,150±650	18,750–15,250	18,050–16,050

RESULTS

Lithology. The core sediments were subdivided into eight lithological units according to its visual description (Table 2). The lowermost part (300–289 cm) of the core is presented by grey silty compact gyttja lying on the till surface with sharp boundary. An admixture of silt in this layer points on intensive input of minerogenic material into the basin. An overlaying bed of gyttja (289–126 cm) contains varying content of mollusk shells and changes in colour and structure throughout the bed. It implies a more permanent lacustrine sedimentation. The bed of dark-brown massive peat having the sharp lower boundary overlies the gyt-

Table 2. Description of lithological composition.

Depth, cm	Sediment unit	Description
100–126	8	Dark-brown massive peat, sharp lower boundary
126–160	7	Light-grey diffusely laminated gyttja with mollusc shells in upper part (126-145 cm), gradual lower boundary
160–185	6	Brownish-grey diffusely laminated gyttja, sharp lower boundary
185–195	5	Grey massive gyttja, gradual lower boundary
195–270	4	Greenish-grey laminated gyttja with mollusc shells (206-270 cm), gradual lower boundary
270–276	3	Grey massive gyttja, gradual lower boundary
276–289	2	Brownish-grey massive gyttja, gradual lower boundary
289–300	1	Grey silty compact gyttja

Table 3. Description of local pollen assemblage zones distinguished at Kašučiai Lake.

LPAZ	Depth, cm	Description
K_p–6	100–126	This zone is characterized by the predominance of AP (88%) and *Pinus* (55%) together with *Betula* (39%) predominate among them. NAP sum shows up to 19% and Cyperaceae (12%) together with Poaceae (5%) are the best represented. Only *Filipendula* is registered continuously while other NAP taxa occurred sporadically. Pollen concentration has a peak of 125x10^2 grains/cm^3.
K_p–5	126–154	*Betula* (59%) culminates in this zone and AP sum (94%) is the highest throughout the diagram. Dwarf shrubs e.g. Ericaceae are well represented at the beginning of K_p-6. In compare with K_p-5 number of NAP (33%) markedly decreases. Remarkable decline is registered in *Artemisia* and Cyperaceae percentages while Poaceae has continuous steady curve. Pollen concentration increases to 100x10^2 grains/cm^3.
K_p–4	154–206	This zone is characterized by the culmination of NAP reaching more then 44%. Cyperaceae shows 23% and *Artemisia* has a peak of 19% and the same is true for Chenopodiaceae. *Betula* has steady value and *Pinus* percentages increases to 53% in the second half of the zone. *S. selaginoides* spores continuously registered in this zone. Pollen concentration shows up to 20x10^2 grains/cm^3 in the first half of the zone and lowers afterwards.
K_p–3	206–256	Determination of this zone is based on the high *Pinus* representation (up to 84%). *Betula* reaches 29% in the first half of the zone and decreases approaching the end. Gradual lowering of the mostly NAP coincided with the rising variety of NAP species. Cyperaceae, Poaceae, *Artemisia* and Chenopodiaceae are represented continuously while the rest taxa occur sporadically. Concentration of the pollen grains increases up to 50x10^2 grains/cm^3 in the first half of the zone and drops down afterwards.
K_p–2	256–272	This zone is determined by the changes in AP/NAP composition. Rising *Pinus* (73%) value coincides with the gradual lowering of mostly NAP while the variety of NAP species increase in compare with K_p-1. *Artemisia* (14%) and Chenopodiaceae (4%) have peaks close to the lower limit of K_p-2. Pollen concentration raises upwards reaching 38x10^2 grains/cm^3.
K_p–1	272–299	*Betula* reaches 30% and *Pinus* shows up to 52% in K_p-1. Cyperaceae (18%) is the best represented among NAP and *Artemisia* increases to 9%. Poaceae together with Chenopodiaceae are registered continuously while mostly of other NAP occur in separated spectra. Concentration of the pollen grains varies around 10x10^2 grains/cm^3.

tja in the upper part of the core. The formation of peat may indicate a partial overgrowth of the lake.

Pollen analysis. Six local pollen assemblages zones (LPAZ) were recognized in the investigated section (Table 3). Only selected taxa were shown in the presented diagram (Fig. 2).

Plant macrofossil data. Examination of sediments revealed the presence of plant macro remains belonging to 47 taxa (fruits, seeds, oospores and needles). Identified taxa were grouped according to their habitats: aquatics (10 taxa), wetland plants (19 taxa), trees and shrubs (6 taxa) and xeromesophytes (6 taxa). Three

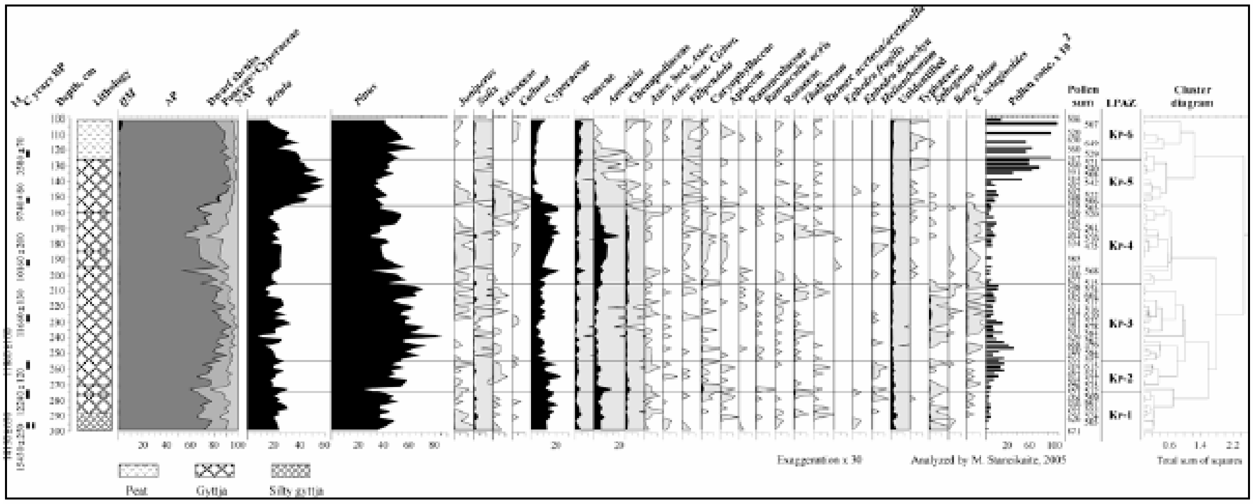

Fig. 2. Pollen diagram of selected taxa for the Lake Kašučiai sediment sequence.

Table 4. Description of local plant macrofossil zones distinguished at Kašučiai Lake.

LMRZ	Depth, cm	Description
K_M–3c	100–135	Determination of this zone is based on the high number and diversity of species representing wetland habitats. Total sum of the represents increases up to 70% in the second half of the zone. Rising number of the tree's macro remains (up to 35%) is also typical for the spectra. *Betula* sect. *Albae* (up to 13%) and *Alnus glutinosa* (L.) Gaertn. are the best represented. Total value of xeromesophytes shows 5%. Number of water plants decreases from 42% to 2% upwards.
K_M–3b	135–155	Remains of the wetland species (*Lycopus europaeus* L. and *Carex* sp.) are better represented in the first half of the zone while sum of the trees where *Alnus glutinosa* (L.) Gaertn. predominates shows 75% afterwards.
K_M–3a	155–170	Predomination of *Potamogeton natans* L. macro remains based the determination of this zone. *Alnus glutinosa* (L.) Gaertn increases up to 50% in this zone.
K_M–2	170–210	Representation of water plants is still high in the first half of the zone (*Chara* sp. varies from 32 to 73%, *P. filiformis* – 6-12%, *P. natans* L. – 7%). Whereas the number of wetland species increases from 15% to 100%. Respectively *Carex* sp. shows 6-18% close to lower limit of the zone and increases up to 61-70% afterwards. Number of *Alisma plantago-aquatica* L. and *Selaginella selaginoides* (L.) Link varies from 4 to 28%. The total sum of trees increases up to 35% in the second half of the zone. *Picea* sp. varies from 4 to 8%, *Alnus glutinosa* (L.) Gaertn and *Alnus incana* (L.) Moench – 9-12% and *Betula* shows up to 30%.
K_M–1c	210–265	Sum of the water plants is high in this zone (from 97 to 100%) and *Chara* sp. remains predominate among them. *Typha* sp., *Lycopus europaeus* L. and *Menyanthes trifoliata* L. registered in the first half of the zone. Amount of *Batrachium* sp. and *P. filiformis* varies from 0.5 to 1%. *Betula nana* L. and *Alnus glutinosa* (L.) Gaertn remains occur sporadically.
K_M–1b	265–280	Macro remains of *Chara* sp. still predominates in this zone. Simultaneously seeds of *Betula nana* L. were discovered. Increasing number of *Nymphaeae alba* L., *Schoenoplectus lacustris* (L.) Palla and *Armeria* sp. that varies from 2 to 5% is recorded.
K_M–1a	280–300	Remains of water plants predominate in this zone where value of *Chara* sp. oospores varies from 91 to 100%. Scattered seeds of *Potamogeton filiformis* Pers., *P. vaginatus* Turcz. and *Betula nana* L. (up to 2%) and low amount of *Juncus* sp., *Carex* sp., *Comarum palustre* L. discovered in the beginning of the zone.

local macrofossil zones (LMAZ) were distinguished according to their compositional changes across the section (Table 4; Fig. 3).

Diatom analysis. 70 different diatom taxa were observed in the sediment samples analysed. Section is dominated by freshwater, alkaliphilous, epiphytic and benthic diatom species. According to diatom compositional changes throughout the section five local diatom zones (LDAZ) were distinguished (Table 5). The most characteristic and dominant taxa were shown in the presented diagram (Fig. 4).

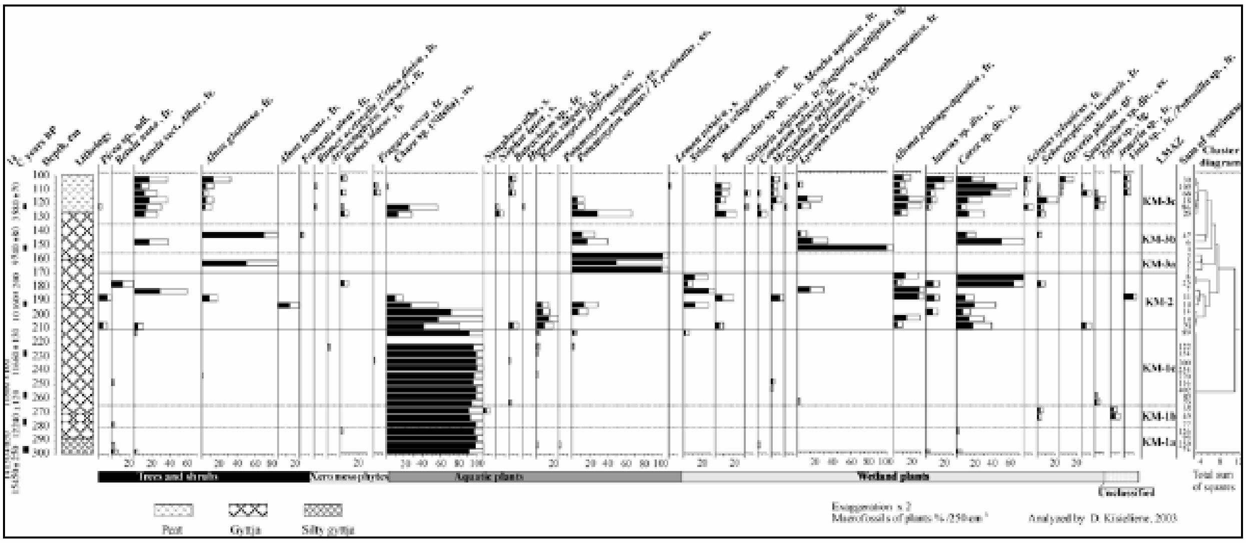

Fig. 3. Plant macrofossil diagram for the Lake Kašučiai sediment sequence.

Table 5. Description of the diatom zones distinguished at Kašučiai Lake.

LDAZ	Depth, cm	Description
K_D-5	125-156	The highest variety of species is observed in this zone. The plankton species reached their maximum throughout the section (up to 50%) and are dominated by *Cyclotella ocellata, C. comensis, C. radiosa, C. kutzingiana.* Bottom species are most abundant in this zone as well and species *Navicula diluviana, N. tuscula, Epithemia goeppertiana, Eunotia praerupta* prevail among them. Representatives of rheophilous "running water" species – *Meridion circulare, Gomphonema parvulum* and others increased in the upper part of the zone as well as acidophilous species of genus *Eunotia.* Meanwhile the diatom concentration decreased.
K_D-4	156-210	Plankton species reduced to single frustules. Number of species markedly decline. Section is dominated mainly by epiphytic *Fragilaria pinnata, Fr. brevistriata, Fr. leptostauron.*
K_D-3	210-244	Considerable increase of diversity of species noticed. Plankton species of *Cyclotella* genus: *C. ocellata, C. radiosa, C. glabriuscula, C. meneghiniana, C. antiqua* appeared and reached about 20% of total sum of species. Among epiphytic species representatives of genus *Cocconeis, Gomphonema, Cymbella, Epithemia* are most numerous. *Navicula tuscula, Amphora pediculus* prevail on the bottom of the palaeobasin. *Fragilaria* species are still common in the section.
K_D-2	244-272	Number of species slightly increased. Among epiphytic *Fragilaria, Cocconeis* and *Achnanthes* genus species prevail. *Navicula crucicula, Amphora pediculus, A. thumensis* are most abundant benthic species.
K_D-1	272-300	*Fragilaria* spp. dominates and constitutes over 90 % of the total flora.

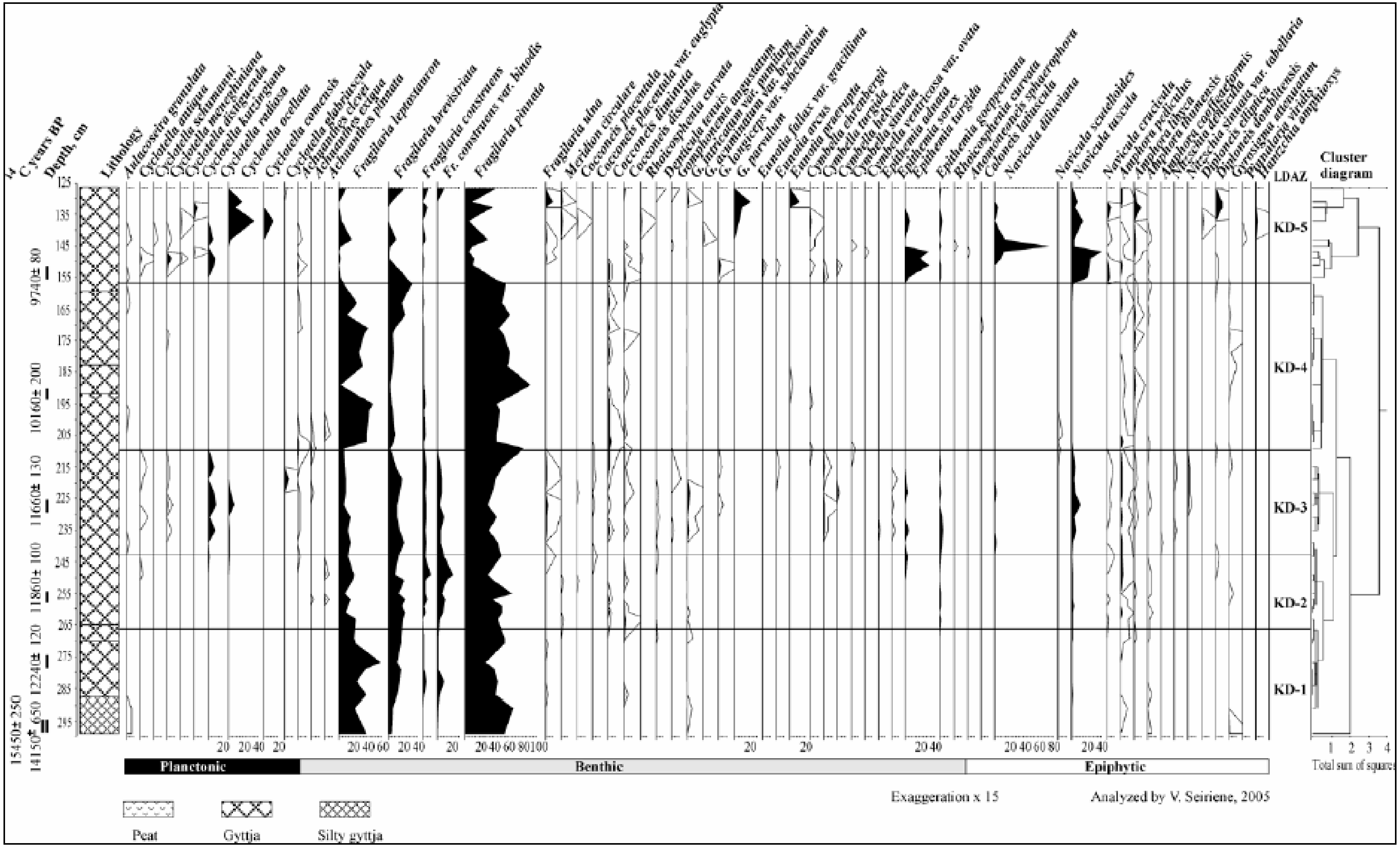

Fig. 4. Diatom diagram of selected taxa for the Lake Kašučiai sediment sequence.

RECONSTRUCTION OF ENVIRONMENTAL CHANGES

Five time periods of different environments could be distinguished on the basis of available data (Fig. 5).

>14,300 cal years BP

Diatom composition dominated by *Fragilaria* genus species (Fig. 4), which often has mass occurrence during the initial phase of the lake development (Marciniak 1979; 1981; Robertsson 1973; Haworth 1976; Miller 1977). *Fragilaria* are eurytopic taxa occurring in littoral as well as pelagic biotopes. They are often found in alkaline, slightly brackish water rich in dissolved mineral salts, oxygen and calcium (Cholnoky 1968; Hustedt 1937–39). Noted ecological conditions were favorable for the flourishing of *Chara* sp. and for cold water tolerant plants, such as *Potamogeton vaginatus* Turcz., *P. filiformis* Pers. (Aiken *et al.* 1999) (Fig. 3).

Betula and *Pinus* pollen is dominated among trees and *Artemisia,* Cyperaceae pollen among herbs (Fig. 2). The low pollen concentration and pollen influx suggests the scarcity of local vegetation and possible the re-deposition or long-distance origin of the discovered pollen grains. However, the finds of *Betula nana* L. and *Betula* sect. *Albae* macrofossils (Fig. 3) points that these species had started to colonize the surroundings. The continuous presence of Cyperaceae, Poaceae and *Artemisia* along with *Salix* and *Juniperus* suggests the formation of open tundra-like vegetation predominated by herbs/grasses and shrubs in the surroundings of the lake. The high frequency of Chenopodiaceae and *Artemisia* may serve as evidence of unstable surrounding soils. Minimum July temperatures might be about 4°C, enough for the survival of *Betula nana* (Hulten & Fries 1986).

Obviously, the sedimentation of gyttja layer took place in shallow oligotrophic lake with poor aquatic flora. The presence of minerogenic matter in the gyttja layer indicates an intensive in-wash of clastic sediments possibly by inflow streams and intense erosion processes. Vegetation composition points on rather cold and dry environment during the earliest stages of lateglacial.

14,300–13,700 cal years BP

Increasing number and variety of diatom species reflects the higher amount of biomass production in the palaeobasin. It is confirmed by the lithological composition of the sediments, where the part of organic material increased. Nevertheless, the lake remained rather shallow, with epiphytic (*Cocconeis diminuta, C. disculus*) and benthic (*Amphora pediculus, A. lybica)* cold water species.

Rising number of NAP (*Artemisia*, Chenopodiaceae and Cyperaceae) and low pollen concentration reflects the scarcity of vegetation cover. The findings of *Armeria* sp. macrofossils could be related with a decrease in temperature and the outspread of sandy habitats, whereas the minimum January temperature might be

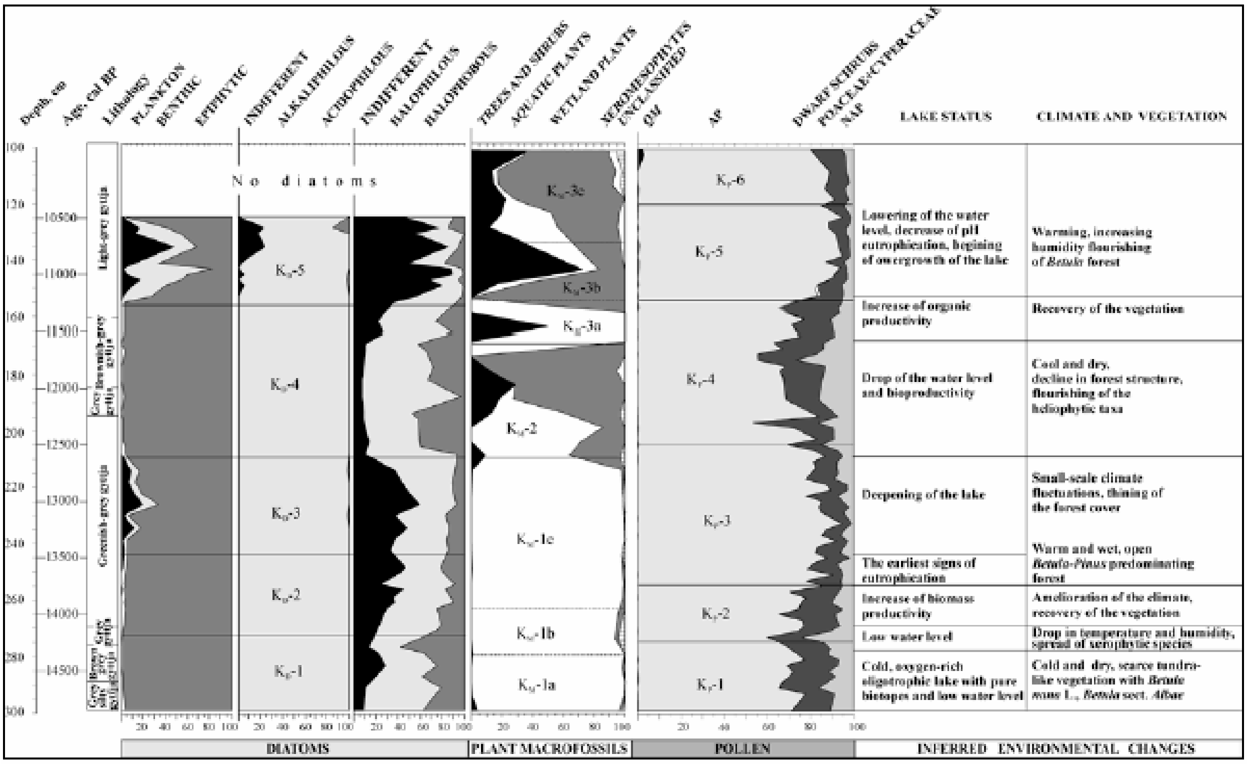

Fig. 5. Summary chart of the reconstructed palaeoenvironmental and palaeoclimatic development.

about -8°C (Kolstrup 1980). Climatic deterioration is also confirmed by a drop in tree pollen percentages. Likely, it lasted very short and approximately at about 14,100 cal BP increasing number of tree pollen and pollen concentration indicates an improvement of climatic conditions. The minimum July temperatures might be about 12°C, because of presence of *Nymphaea alba* L. (Kolstrup 1980) and *Pinus silvestris* L. (Bos *et al*. 2001).

13,700–12,600 cal years BP

After 13,400 cal BP the sum of the plankton diatom species of *Cyclotella* and *Aulacoseira* genus increases up to 20% of total diatom sum indicating a deepening of a basin. Considerable rise in number and variety of diatoms was registered showing an increase in organic productivity. Also, the appearance of *Typha* sp. and *Menyanthes trifoliata* L. (K_M-1c; Fig. 3) could be related with the beginning of eutrophication occurring in the shallow oligotrophic lake after 13,700 cal BP.

A rise of *Pinus* pollen, as well as the total concentration and pollen influx (K_P-3; Fig. 2) may be related with the growing density of vegetation cover between 13,700–13,400 cal BP. Chenopodiaceae and *Artemisia* taxa still were of major importance in the local vegetation, pointing to the existence of an open forest structure and soil instability. The flourishing of open vegetation as indicated by presence of *Selaginella selaginoides*, *Betula nana*, *Juniperus* and other light-demanding taxa continued until 12,650 cal BP. However, the decreasing pollen concentration as well as the rising number of NAP pollen (end of K_P-3; Fig. 2) registered shortly before the end of period could be taken as evidence of some instability in the vegetation cover.

12,600–11,100 cal years BP

A noticeable decrease of plankton (to 0–5%) and the predominance of epiphytic diatom species indicate a significant drop in water level (K_D-4; Fig. 4) at about 12,600 cal BP. At this time there was a flourishing of alkaliphilous benthic *Fragilaria* species, suggested to be more competitive in lakes with long periods of ice cover and in extremely oligotrophic or nutrient-limited environments (Gronlund & Kauppila 2002). Substantial reduce in number of diatom species confirms the lack of nutrients. The extended wet shores and littoral zone were overgrown by wetland plants and aquatic habitats, e.g. *Alisma plantago-aquatica* L., *Carex* sp., *Juncus* sp. and *Menyanthes trifoliata* L. (K_M-2; Fig. 3). The water was rather cold, as *Potamogeton filiformis* Pers. typical of severe conditions (Aiken *et al*. 1999) flourished in it as well as north-alpine diatom species such as *Cocconeis diminuta, C. disculus* and others. The high representation of *Potamogeton natans* L. (K_M-3a; Fig. 3) after about 11,500 cal BP could be taken as evidence of the eutrophication.

The pollen spectra is dominated by NAP species, e.g. *Artemisia*, Cyperaceae, Poaceae and Chenopodiaceae (K_P-4; Fig. 2) after 12,650 cal BP, which coincides with the decline of pollen influx and concentration (K_P-4; Fig. 2). The decrease in tree pollen, especially *Pinus*, suggest the decline of the forest and the formation of open herb-grass-shrub vegetation although birch (*Betula nana* L. and *Betula* sect. *Albae*) was present in the scarce local vegetation. The finds of *Alnus incana* (L.) Moench, *Picea* sp. and *Alnus glutinosa* (L.) Gaertn macrofossils (K_M-2; Fig. 3) may have been re-deposited, because of the increased value of minerogenic material in to sediments (Table 2). No accompanying pollen grains of these plants or thermophilous species were discovered. Interpretation of these macrofossil finds is rather difficult at this time, though the possibility of lateglacial occurrence of alder has been mentioned by Polish scientists (Środoń 1981). Recently *Alnus* sp. macroremains were discovered in the lateglacial sediments in northern Poland (Latałowa, Borówka 2006).

From about 11,500 cal BP onward, the tree pollen values started to increase simultaneously with the decline of *Artemisia* and Cyperaceae (K_P-4; Fig. 2). A minor increase in pollen concentration and influx values is accompanied by the occurrence of *Alnus glutinosa* (L.) Gaertn (K_M-3a; Fig. 3) macrofossils. Reforestation of the investigated area initiated the reduction of herbs, grasses and light-demanding taxa (upper part of K_P-4; Fig. 2).

The grey gyttja may indicate a lower supply of organic material. Later, from 11,600 cal BP the deposition here became more organogenic, which produced the brownish-grey colour gyttja beds.

< 11,100 cal years BP

Number of plankton species increases indicating a rise in the water depth. Simultaneously, the variety of species increased showing the enrichment of the water in nutrients and gradual eutrophication of the lake. In the uppermost part of the section the acidophilous and aerophilous (soil predominating) species expanded. It might be caused by overgrow of the lake shores. The presence of rheophilous species, e.g. *Rhoicosphenia curvata*, *Gomphonema parvulum* and *Meridion circulare* points on the existence of inflow streams.

The vegetation of this period is characterized by an expansion of *Betula* and decreasing number of herbs and grasses, including Cyperaceae, *Artemisia* and Chenopodiaceae (K_P-5; Fig. 2). Macrofossil finds of *Betula* sect. *Albae* and *Alnus glutinosa* (L.) Gaertn (K_M-3b; Fig. 3) show their growth around the lake. However, according to the low pollen concentration in sediments (first half of K_P-5; Fig. 2), the vegetation cover was rather scarce. Most probably, an open birch forest with glades favoured by herbs and grasses dominated the lake catchment.

The grey gyttja was gradually changed to a light-grey peat gyttja. A peat bed overlays gyttja and it can indicate a partial overgrowth of the lake (Table 2). A sharp contact between gyttja and peat layers may reflect sedimentation hiatus. Radiocarbon date (4090–3690 cal BP, Ki-11410; Fig. 5) confirms this presumption and points to the late Holocene as the age of the covering peat.

CHRONOSTRATIGRAPHY

The chronology of environmental changes is based on the results of ^{14}C dating (Fig. 5). Two ^{14}C dates were obtained from the lowermost part of the section (294–298 cm) and indicate the Late Weichselian time. The estimated date of the carbonate part of the bulk sample reaches 19,250–18,050 cal BP. The results obtained from dating the organic constituent indicate the similar age (Table 1). Whereas the considerable presence of AP and *Betula nana* L. pollen at the beginning of K_P-1 as well as *Betula* sect. Albae macrofossils in K_M-1a zone reflect the sedimentation of silty gyttja layer during the relatively warm climate period. Obviously this could be correlated with Bølling biozone.

The rising number of heliophytic herb pollen (*Artemisia* and Chenopodiaceae, K_P-2) and appearance of cold tolerant *Armeria* species (K_M-1b) registered in the sediments of 256–272 cm depth indicate the thinning of the vegetation cover at about 14,350–13,800 cal BP. This event could be related with short-lasting Older Dryas climate deterioration.

Following increase in AP pollen, e. g., *Pinus* and drop in NAP, especially heliophytic species (K_P-3; K_M-1c) registered at about 13,940–13,450 cal BP associates with Allerød biozone.

The shift in pollen composition, an increase in herbaceous pollen and decrease in tree pollen between K_P-3 and K_P-4 zones (Fig. 2) suggests about scarce vegetation cover. It is confirmed by declining number of tree macrofossils and pollen concentration. Registered vegetation changes correlate well with the Allerød/Younger Dryas biozone boundary and took place at about 12,650–11,150 cal BP.

The subsequent rise in AP pollen, e.g. *Betula* (transition between K_P-4–K_P-5; Fig. 2), an increase in *Alnus glutinosa* (L.) Gaertn macrofossils (K_M-3b; Fig. 3) points on the reforestation of the area at about 11,350–10,750 cal BP. Registered changes of vegetation cover coincide with Younger Dryas/Preboreal biozone boundary.

The uppermost part of the section, peat layer may have been deposited after sedimentation hiatus, whereas the peat strata dated back to 4090–3690 cal BP.

CONCLUSIONS

The Lake Kašučiai sequence provides a new uninterrupted palaeoenvironmental record during entire lateglacial period. During the earliest stages of lateglacial sedimentation took place in the shallow oligotrophic sedimentary basin under cold and dry climatic conditions and intensive surface erosion. Vegetation composition predominated by pioneer, cold-tolerant species, including a patchy occurrence of birch trees. Scarce aquatic flora was represented mainly by *Chara* sp. and *Fragilaria* genus diatom species which are suggested to be more competitive in oligotrophic, cold water lakes.

At about 14,300–14,100 cal BP the rapid fall in the mean temperature and humidity was registered. The presented data indicates a reduction in the vegetation cover. The minimum January temperature might be about -8°. This period could be related with short Older Dryas climatic degradation.

After 14,100 cal BP a gradual amelioration of climatic conditions started. The environmental conditions became more favourable for the formation of a dense vegetation cover and for the immigration of a new tree species as well. The minimum July temperatures might be about 12°C. The period of 13,700–13,400 BP can be characterized as the warmest stage in palaeolake development. Rising mean temperatures and humidity influenced the increasing water depth and organic production. It caused the beginning of eutrophication processes in the basin. The flourishing of open pine–birch predominating forest indicates a rather stable environment. This period reflects the Allerød Interstadial environment.

Shortly before 12,650 cal BP climatic deterioration was registered. Altogether, the proxy data indicates a drop in water level coincident with the reduction of the forest cover and development of an open herb/grass-predominated landscape. Mentioned environmental changes could be related with the Younger Dryas climatic deterioration.

Following improvement of the climatic conditions registered from 11,500 cal BP. It caused an increase in organic productivity and the rise in the lake's water level. However water eutrophication may cause overgrow of the lake. The rise in temperature and humidity were favourable for the flourishing of the birch. This period coincides with the beginning of the Holocene, Preboreal period.

Acknowledgements

This study was carried out within the frame of the IGCP 490 and IGCP 518 projects and financed by the Lithuanian State Science and Studies Foundation (V-05033 and V-05069). Professor Meilutė Kabailienė, Lithuania, and an anonymous reviewer are thanked for constructive remarks on the manuscript.

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