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VEGETATION RESPONSES TO CLIMATIC CHANGES DURING THE LATE GLACIAL ACCORDING TO PALAEOBOTANICAL DATA IN WESTERN LITHUANIA; A PRELIMINARY RESULTS

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Abstract. The organic-rich material has been studied from the bottom part of lacustrine sediments of the Lake Kasuciai, western Lithuania. Radiocarbon dates and palaeobotanical data showed that these sediments accumulated between 13,500 and 9000 ^{14}C yr BP. The Late Glacial interstadial is defined by the dominance of Characeae and accumulation of carbonate. The Bølling is characterized by the pioneer taxa and the communities of open habitats. During the Allerød pine replaced the light demanding taxa that show development of a closer woodland habitat and dryness of climate. The short period between Bølling and Allerød with increasing representation of *Betula* and plants typical for the highly eroded habitats could be correlated with Older Dryas. The onset of the Younger Dryas is marked by degradation of the forest cover and expansion of heliophytic grasses. Entire vegetation cover with birch and pine forest was settled during the Preborial. Formation of calcareous sediments and appearance of thermophilous taxa confirm the climatic amelioration.

Key words: environmental changes, pollen and plant macroremains, Late Glacial, western Lithuania.

INTRODUCTION

In Lithuania the rich data set describing the main features of the Younger Dryas and Allerød environment was collected after the decades of the intensive survey (Seibutis, 1974; Blazauskas *et al*., 1998; Kabailiene, 1998; Stancikaite *et al*., 1998; Bitinas *et al*., 2002; Stancikaite *et al*., 2002). However the earliest periods of the Late Glacial e.g. Older Dryas, Bølling and the Oldest Dryas are lacking or scarcely represented in mostly of the earlier investigated cores. Complex investigation of the Kasuciai Lake (Fig. 1), West Lithuania, core (pollen and plant macroremain survey, ^{14}C dating) presents uninterrupted reconstruction of the vegetation cover, lake level changes and ecological regime of this area since the 14,000 ^{14}C uncalibrated BP and until the end of the last termination.

The Lake Kasuciai with a coring place (E 21°18'26", N 55°59'28") is situated in the West Lithuania in the lowering of basal moraine. The valley of River Akmena stretch to the East from the lake. It is filled up with glaciofluvial deposits. Slopes of the lake are well expressed and abraded. Glacigenic deposits forming gently undulating landscape with predominating small hills stretches westwards from the lake and glaciolacustrine plains are waterlogged here.

METHODS

Coring and sampling. Samples for the palaeobotanical survey and ^{14}C dating were taken using a Russian sampler and sub-sampled every 25 cm.

Dating. Two bulk samples were dated at the Kiev Radiocarbon Laboratory. The radiocarbon calibration program CalPal (Jöris, Weninger, 2000) with the INTCAL98 data set (Stuiver *et al*., 1998) was used for the calibration of radiocarbon dates. Dates are expressed in calendar years BP (0 = 1950).

Pollen investigations. Pollen preparation followed the standard procedure described by Erdtman (1936) and Grichiuk (1940) with the improvements suggested by Stockmarr (1971). More than 1000 terrestrial pollen grains were counted for each

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Fig. 1. Location of the investigated site (Lake Kasuciai)

level and APNAP sum based the percentage calculation of the spectra. The pollen and plant macrofossils percentage diagrams were plotted with the TILIA (version 2) and TILIA-Graph (version 2.0 b.4) programs (Grimm, 1991). Chronostratigraphical zonation of the diagrams is based on the results of ^{14}C dating and changes in local pollen assemblage zones (LPAZ). LPAZ have been correlated with those established for Lithuania and chronozones of Late Glacial and Holocene (Mangerud *et al*., 1974; Kabailiene, 1998). Pollen and spore identifications were based on Moe (1974), Fægri and Iversen (1989) and Moore *et al*. (1991).

Plant macroremains analysis. 36 samples with a volume of 230 cm^3 were sieved through screens with a mesh size of 0.25 mm and material left on screens analysed using dissecting microscope. The identification of plant macrofossils was based on Beijerinck (1947), Berggren (1969, 1981) and Grigas (1986) in combination with the plant macrofossil and modern seed collections (Institute of Geology and Geography). The taxa have been sorted into ecological groups to aid interpretation and reconstruction of the vegetation.

RESULTS

Chronology. Age of the investigated samples show the Late Glacial age (12,660–11,020 cal BP; 18,150–15,070 cal BP) of the sediments (Table 1).

T a b l e 1

Results of radiocarbon dating

Laboratory No	Depth [m]	Dated material	^{14}C BP	cal BP
Ki-10913	190–194	gyttja	10,160 ± 200	12,660–11,020
Ki-10914a	294–298	organic material	14,150 ± 650	18,150–15,070

Pollen assemblages. The pollen material has been described in terms of pollen assemblage zones. Six pollen zones are recognised in the investigated section (Table 2, Fig. 2). The main features of the vegetation development are described in discussion.

Plant macroremains zones. Examination of lacustrine sediments in the Kasuciai section (the interval of 125–300 cm) revealed the presence of plant macroremains belonging to 40 taxa (fruits, seeds and their parts, oospores, needles, etc.) (Fig. 3). A few groups of plants were distinguished according to their habitats: aquatics (9 taxa), wetland and shores (16 taxa), woodland and scrubland (10 taxa). The plant demand for ecological conditions in the woodland and scrubland groups may slightly differ. However this group is important for comparison of spores and pollen analysis data. Five local zones of macroremain assemblage (LMAZ) were distinguished according to their distribution across the section.

LMAZ-1 is distinguished in the lower part of the section (the interval of 215–300 cm) of sapropel sediments predomi-

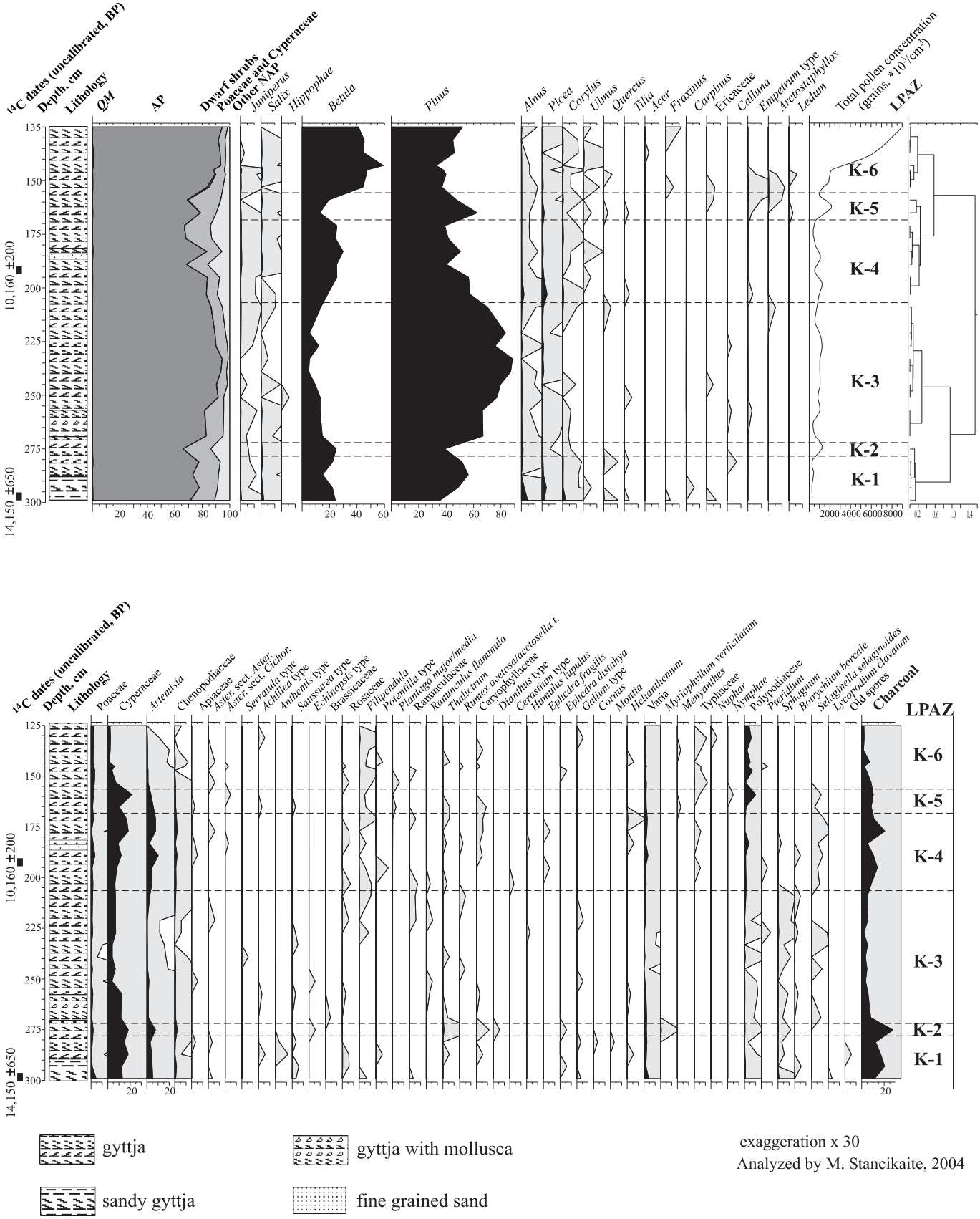

Fig. 2. Pollen diagram of Kasuciai core

T a b l e 2

Description of pollen assemblages

Pollen zone	Depth [cm]; Age [kyr ^{14}C BP]	Description
K-1	278–299 13.5–12.3	This local pollen assemblage zone is characterized by the predominance of *Betula* (24%) and *Pinus* (56%). *Alnus*, *Picea* and *Corylus* have increased at the beginning of the zone and declines afterwards. NAP sum varies from 10.9% to 6.8% and Cyperaceae (18.3%) together with Poaceae (4.6%) and *Artemisia* (5.2%) are the best represented. Old pre-Quaternary taxa occurred sporadically. Low and steady pollen concentration is registered throughout the zone where charcoal number has a peak of 20.3%.
K-2	272–278 12.3–11.9	Increase in percentages of *Betula* is marked in LPAZ K-2 while number of the *Pinus* pollen decreased simultaneously. Total sum of NAP rises in compare with the previous zone and *Artemisia* reaches 7.7%. Pollen concentration increases in compare with the previous pollen zone and charcoal value reaches 27.9%.
K-3	206–272 11.9–10.9	This zone is characterized by the culmination of *Pinus* reaching more then 88%. Other AP, including *Betula* (max. 14.3%) are much suppressed in spectra and the same is true discussing the number of NAP which varies from 4.8% to 5.2%. *Selaginella selaginoides* (0.5%) spores registered. Pollen concentration varies around 1000 grains/cm^3. Charcoal representation is minor.
K-4	168–206 10.9–10.5	*Betula* (29.8%) increased in this zone that coincides with the gradual lowering of the *Pinus* (38.9%). *Alnus* (1.8%) and *Picea* (3.6%) peaks are registered close to the lower boundary. Increasing representation of NAP (up to 33.1%) is the outstanding feature of this zone. Cyperaceae composes up to 18% and *Artemisia* reaches 10.1%. *Selaginella selaginoides* has a continuous curve with a peak of 0.6%. Pollen concentration has a few peaks about 1064 grains/cm^3 and charcoal value culminates showing 20.6%.
K-5	156–168 10.5–10.0	Rising *Pinus* representation (62.7%) and lower *Betula* (12.8%) are typical for this zone. Number of *Alnus*, *Picea* and *Corylus* is minor and *Quercus* together with *Tilia* represented sporadically. Mostly of NAP species lowers gradually except the Cyperaceae, which has a peak of 21.4%. *Selaginella selaginoides* is represented continuously. Pollen concentration has a peak of 1064 grains/cm^3. Charcoal number lowers gradually throughout the zone.
K-6	125–156 10.0–9.0	Determination of this zone is based on the high *Betula* representation (59.2%). *Pinus* reaches 52% in the upper part of the zone. Remarkable drop (from 14.8% to 5.5%) is registered in NAP number. Concentration of the pollen grains increased up to 8000 grains/cm^3 close to the upper limit of the zone.

nated by aquatic plants. The latter account for 95–98% of the total of detected macroremains. Spores *Chara* sp. are absolute dominants (90–95%) over the whole section indicating that the water body at the time of growing was deep and the water was rich in carbonates. LMAZ-1 can be subdivided into three subzones Ia, Ib and Ic. The subzone Ic is characterized by *Betula nana* L. and various *Carex* species – *tundra* type plants of open habitats liking acid soils (Ellenberg *et al*., 1991). The plants of Ic subzone are common in character. It also includes the plants of open shores (*Selaginella selaginoides* (L.) Link, *Typha* sp., *Lycopus europeus* L.) and scanty remains of aquatic plants – *Batrachium* sp., *Potamogeton filiformis* Pers. The subzone Ib was distinguished in a small interval between the mentioned subzones. *Nymphaeae alba* L. and *Schoenoplectus lacustris* (L.) Palla indicate the changes in the basin biocoenosis while *Armeria* sp. (perhaps *A. maritima*) may be associated with the appearance of dry sandy habitats in the basin environment.

LMAZ-II was distinguished in the interval of 193–215 cm and is a reflection of another stage of lake evolution when the first signs of overgrowing appeared. The dominant *Chara* of this group was gradually replaced by various *Potamogeton* species (*P. filiformis* Pers., *P. natans* L., *P. pectinatus* L.). The shore and wetland plants occur in greater abundance. Various species of sedges (*Carex*), common water-plantains (*Alisma plantago-aquatica* L.) and rushes (*Juncus articulatus* L.) were widespread in the water-saturated shores. The scanty tree remains (*Picea* sp., *Betula* sect. *Albae, Alnus incana* (L.) Moench) contained in sediments imply that the shores of this zone at that time were not as open as the shores of LMAZ-I basin.

The composition of LMAZ-III (the interval of 174–193 cm) macroflora contains no aquatic plants implying the fall of water level in the basin. The plants of wetlands — in greatest abundance represented by *Carex, Alisma plantago-aquatica* L., *Lycopus europaeus* L. macroremains — are dominant. Megaspores of *Selaginella selaginoides* (L.) Link and fruits of *Betula nana* L. – found together with the tree remains (*Alnus glutinosa, Betula* sect. *Albae, Picea*) – not only imply the existence of forests but also of open habitats and cool climatic conditions.

LMAZ-IV (the interval of 158–174 cm) sediments only contain macroremains of black alder (*Alnus glutinosa* (L.) Gaertn) and floating pondweed (*Potamogeton natans* L.), which are typical for basin shores. The macroflora of this zone poorly reflects the type of vegetation. Yet the reappearance ofaquatic plants suggests the probable water level fluctuations.

The plant species diversity increases in the LMAZ-V zone (the interval of 125–158 cm). Black alder and birch dominate among the tree macroremains. The sediments also contain remains of spruce and European alder buckthorn (*Frangula alnus* Mill.). Birch and spruce were probably spread in drier areas in the immediate surroundings, while black alder and European alder buckthorn, strongly water-tolerant taxa, may have been growing close to the basin. A large portion of macroremains is represented by wetland herbs (*Alisima plantago-aquatica* L., *Lycopus europaeus* L., *Carex* sp., etc.). Yet the abrupt appearance of *Chara* sp. and *Nuphar* sp. in the upper part of the interval indicates the rise of the water level. These taxa suggest that the water level could have been up to 3 m deep, but was more likely around 1 m deep. As was mentioned above, *Chara* indicates that conditions were calcareous and the presence of *Nuphar* suggests an eutrophic water status.

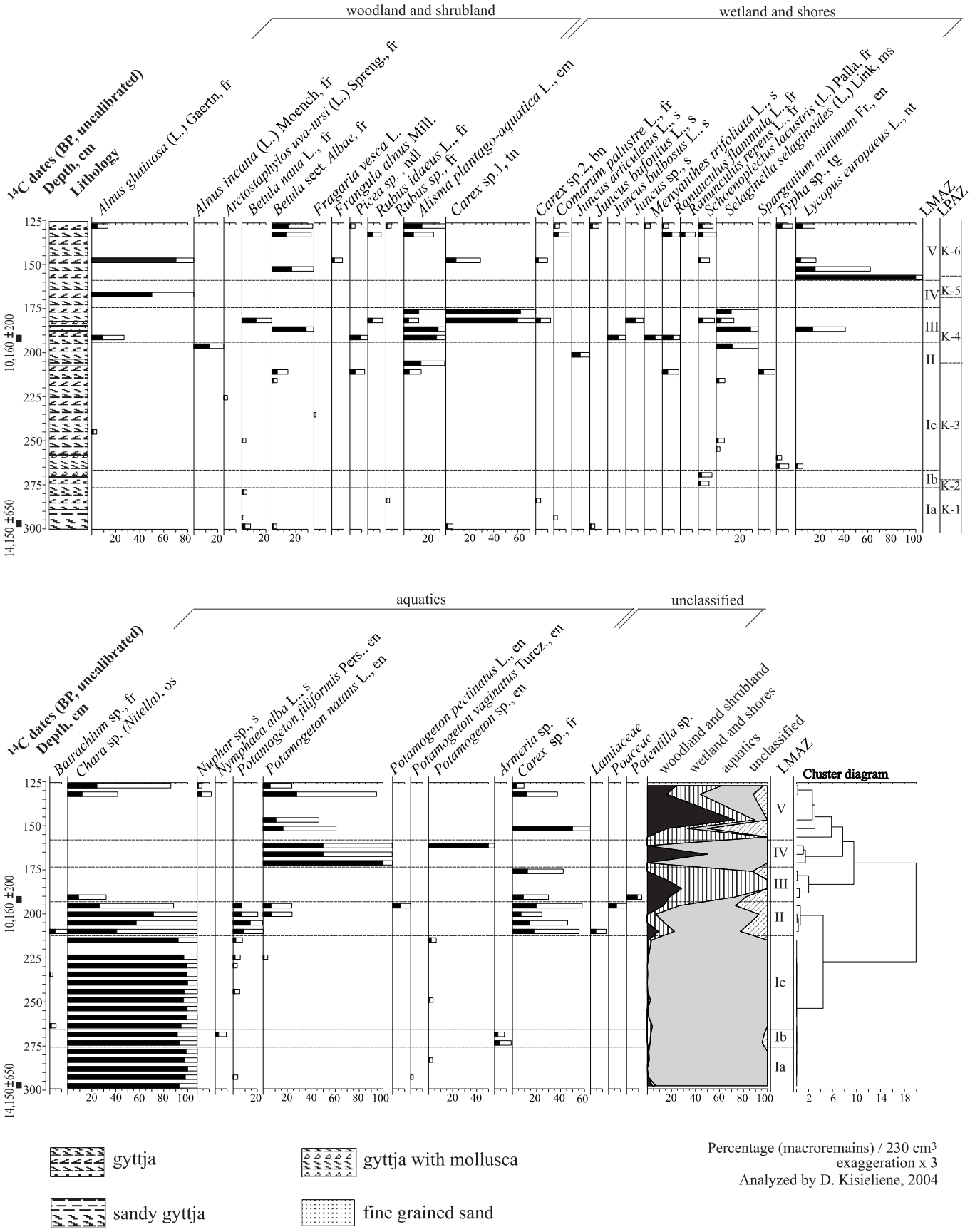

Fig. 3. Plant macroremains from Kasuciai core deposits

DISCUSSION OF ENVIRONMENTAL CHANGES

The present habitat requirements of the plants indicate a very consistent local environmental picture, which is recorded in the sediments of the investigated water basin. Existence of the *Betula* and *Pinus* stands in area already at the beginning of the sediments formation have been confirmed by the high percentages at the bottom (LPAZ K-1) of Kasuciai pollen diagram (Fig. 2). According to Huntley and Birks (1983) *Betula* pollen values over 25% can indicate local birch dominated woodland while *Pinus* pollen values >50% may indicate local dominance of the pine. Whereas pollen grains of deciduous tress and spruce, most probably, were transported from the habitats situated in a distance from investigated site. Areas with barren ground were presented around the sedimentary basin as shown by the deposition of minerogenic-enriched sediments and flourishing of pioneer species — *Artemisia*, Chenopodiaceae and *Salix*. The flora with similar composition was discovered in Zervynos outcrop, SE Lithuania. It was dated back to 12,130 ±2,780 BP (Blazauskas *et al*., 1998). The vegetation of open habitats (Asteraceae, *Thalictrum*, Caryophyllaceae, Rosaceae and etc.) and scattered dwarf-shrub communities (with *Betula nana*) were also common. Wet shores of the basin were favoured by different species of sedges and rush. *Chara* accompanied by *Potamogeton vaginatus* Turcz. and *P. filiformis* L. occupied water basins with predominating calcareous sedimentation environment (Fig. 3). Climatic conditions were rather mild and wet as a pollen spectrum includes the species with rather high moisture and temperature demands. Bio- and chronostratigraphic data suggests the deposition of the K-1 during the Bølling chronozone.

The further development of the pollen spectra shows a spread of plants typical for highly eroded habitats (LPAZ K-2). *Betula* raised on the expanses of the *Pinus* and number of NAP increased at the same time. Decline in deciduous trees and spruce representation can be related with the increasing distance from the habitats to the investigated basin. Rising number of *Artemisia*, *Thalictrum* and Chenopodiaceae pollen grains in spectra and finds of *Armeria* seeds could be related with some dryness of the climate though wet habitats still existed in area as it was confirmed by flourishing of Cyperaceae. Drop of the water level in the investigated lake can not be excluded because plants of deep water were recorded. Formation of K-1 LPAZ and LMAZ-Ib could be related with short Older Dryas climatic degradation.

K-3 local pollen assemblage zone is characterized by the flourishing of pine which was of the primary importance for the local vegetation successions. In Western Europe the expansion of *Pinus* during the Late Glacial is taken as a sign of continental conditions (Bohncke, 1993), but it could be associate with the edaphic settings as well. Culmination of the pine was especially obvious in the areas where dry soils prevailed, e.g. South-East Lithuania (Blazauskas *et al*., 1998; Stancikaite *et al*., 1998). *Pinus* stands from Pamerkiai outcrop were dated back to the early Allerød, 11,880 ±150 ^{14}BC (Stancikaite *et al*., 1998). The decreasing number of light demanding taxa such like *Juniperus* could be related with the increasing density of the vegetation cover though open habitats elements such as *Selaginella selaginoides*, *Betula nana* are still common near the shores. The total sum and variety of NAP species is lowermost in the middle of the LPAZ and even Cyperaceae shows remarkable drop, confirming dryness of the surrounding habitats. Vegetation cover has prevented erosion processes and amount of the organic matter in the sediments increased. According to the vegetation composition where pine has predominated climatic conditions were favourable but rather dry that could be related with the Allerød environment.

The remarkable changes in the vegetation composition were registered in the LPAZ K-4, LMAZ-II and LMAZ-III. Rise of the NAP suggests increasing opening of the vegetation and degradation of the forest cover where *Betula* has repleaced *Pinus*. Culmination of *Artemisia* and high representation of others heliophytic grasses coincides with the increasing soil erosion which was confirmed by high mineroclastic material and formation of the sand interlayer. Aquatics were reduced in the LMAZ-III and that could be related with changes of the water level. Open wet habitats were suitable for *Salix*. *Ephedra* and *Juniperus* gained more ground in sandy areas. Continuous representation of *Selaginella selaginoides* suggests rather low average temperature of the year. The mentioned zones could be correlated with the first half of the Younger Dryas climatic deterioration.

Restoration of the vegetation cover and contemporaneous expansion of pine is registered in the pollen spectra of K-5 LPAZ. *Betula* decreased in number and the same is true for mostly of NAP taxa. Despite the continuous representation of deciduous trees e.g. *Alnus* and *Corylus* as well as appearance of scattered *Quercus* and *Tilia* these pollen grains most probably are of long-distance origin. The high Cyperaceae representation and presence of aquatic taxa e.g. *Typhaceae*, *Nymphaea*, *Menyanthes trifoliata* and *Potamogeton natans* have confirmed increasing water balance at least in the lake. Rise in pollen concentration also suggests the increasing density of the vegetation cover though variety of plant macrofossils flora in LMAZ-IV is greatly reduced. Discussed peculiarities of the vegetation cover are typical for the end of the Younger Dryas chronozone when the possible signs of the climatic amelioration has also been reported from other sites in Europe and dated back to about 10.5×10^3–10.4×10^3 ^{14}C BP (Goslar *et al*., 1993; Berglund *et al*., 1994; Birks *et al*., 1994). Vegetation pattern points to a gradual reforestation of the investigated region. Similar subdivision of the Younger Dryas chronozone into cold first half and warmer and wetter second half have been reported from some other European sites (Goslar *et al*., 1993; Birks *et al*., 1994; Pokorny, 2002).

The upper most part of the pollen diagram shows a rapid formation of birch-pine forests. Birch was of a primary importance and pine composed a pronounced part in the forest successions. Degradation of cold-tolerant taxa coincides with drop in light-demanding species confirming closing of the forest. Number and variety of deciduous trees increased also while representation of NAP became minor. Mostly of early well-represented families and species such like *Artemisia*, Cyperaceae, Chenopodiaceae were nearly diminished while

finds of aquatics and plants of wetlands have got richer. The re-colonisation of the water basin by *Chara* indicates increasing in carbonate accumulation. Those could be partly related with the changes of the water regime and the most essential condition for the registered changes was ongoing climatic amelioration. The finds of therophilous taxa such as *Nuphar* and *Typha* also confirm warming. Formation of soil cover prevented erosion activity. LPAZ K-6 and LMAZ-V could be correlated with the Preboreal.

CONCLUSIONS

Palaeobotanical survey has provided the vegetation history since the Bølling up to the Preboreal. The Late Glacial interstadial is defined by the dominance of Characeae and accumulation of carbonate that points to an ameliorating climate. The Early Interstadial (Bølling) period is characterised by the pioneer taxa (*Artemisia*, Chenopodiaceae, *Salix*) and the communities of open habitats (with Asteraceae, *Thalictrum*, Caryophyllaceae, *Betula nana* and etc.) withal *Betula* and *Pinus* stands existence. During the later stages of the Interstadial (Allerød) the light demanding taxa is replaced by pine reflecting the development of a closer woodland habitat and dryness of climatic conditions. The short period with increasing *Betula* representation and rising number of plants typical for the highly eroded habitats is recorded between Bølling and Allerød and could be correlated with Older Dryas.

The onset of the Younger Dryas is marked by degradation of the forest cover (*Betula* has replaced *Pinus*) and expansion of heliophytic grasses. Restoration of the vegetation cover, contemporaneous expansion of pine and increasing of water balance are typical for the end of the Younger Dryas.

A sharp rise in pollen concentration documents formation of entire vegetation cover during the Preboreal. Birch and pine compose the forest successions. The calcareous conditions and appearance of thermophilous taxa in the water basin confirmed the climatic amelioration.

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REFERENCES

BEIJERINCK W., 1947 — Zadenatlas der Nederlandsche Flora. Wageningen.

BERGGREN G., 1969 — Atlas of seeds and small fruits of Northwest European plant species with morphological descriptions. Cyperaceae 2. Stockholm.

BERGGREN G., 1981 — Atlas of seeds and small fruits of Northwest European plant species with morphological descriptions. Salicaceae–Cruciferae 3. Arlöw.

BERGLUND B.E., BERGSTEN H., BJORK S., KOLSTRUP E., LEMDAHL G., NORDBERG K., 1994 — Late Weichselian environmental change in southern Sweden and Denmark. *J. Quatern. Sc.*, **9**, 2: 127–132.

BIRKS H.H., PAUS A., SVENDSEN J.L., ALM T., MANGERUD J., LANDVIK J.Y., 1994 — Late Weichselian environmental change in Norway, including Svalbard. *J. Quatern. Sc*., **9**, 2: 133–146.

BITINAS A., DAMUSYTE A., STANCIKAITE M., ALEKSA P., 2002 — Geological development of Nemunas River Delta and adjacent areas, West Lithuania. *Geol. Quart*., **46**, 4: 375–389.

BOHNCKE S.J.P., 1993 — Lateglacial environmental changes in the Netherlands: spatial and temporal patterns. *Quatern. Sc. Rev*., **12**: 707–717.

BLAZAUSKAS N., KISIELIENE D., KUCINSKAITE V., STANCIKAITE M., SEIRIENE V., SINKUNAS P., 1998 — Late Glacial and Holocene sedimentary environment in the region of the Ula River. *Geologija*, **25**: 20–30.

ERDTMAN G., 1936 — New method in pollen analysis. *Svensk Botanisk Tidskrift* **30**: 154–164.

ELLENBERG H. *et al*., 1991 — Zeigerwerte von Pflanzen in Mitteleuropa. *Scripta geobotanica*, **18**: 248 pp.

FÆGRI K., IVERSEN J., 1989 — Texbook of pollen analysis. 4th edition (revised by K. Fægri, P.E. Kaland & K. Krzywinski). John Wiley & Sons Ltd. Chinchester.

GOSLAR T., KUC T., RALSKA-JASIEWICZOWA M., RÓŻAŃSKI K., ARNOLD M., BARD E., van GEEL B., PAZDUR M. F., SZEROCZYŃSKA K., WICIK B., WIĘCKOWSKI K., WALANUS A., 1993 — High-resolution lacustrine record of the Late Glacial/Holocene transition in central Europe. *Quatern. Sc. Rev*. **12**: 287–294.

GRICHIUK A.I., 1940 — The preparation methodology of the organic poor sediments for the pollen analysis. *Problems of physical geography 8*. Moscow, (in Russian).

GRIGAS A., 1986 — Seeds and fruits of Lithuania's plants. Vilnius (in Lithuanian).

GRIMM E.C., 1991 — TILIA and TILIA. GRAPH. Illinois State Museum, Springfield, USA.

HUNTLEY J., BIRKS H.J.B., 1983 — An atlas of past and present pollen maps for Europe: 0–13,000 years ago. Cambridge University Press, Cambridge.

JÖRIS O., WENINGER B., 2000 — ^{14}C-Alterskalibrationen und die absolute Chronologie des Spätglazials. *Archäologisches Korrespondenzblatt*, **30**: 461–471.

KABAILIENE M., 1998 — Vegetation history and climate changes in Lithuania during the Late Glacial and Holocene, according pollen and diatom data. *PACT*, **54**: 13–30.

MANGERUD J., SVEND T., BERGLUND E.B., DONNER J.J., 1974 — Quaternary stratigraphy of Norden, a proposal for terminology and classification. *Boreas*, **3**: 109–128.

MOE D., 1974 — Identification key for trilete microspores of Fennoscandia pteridophyta. *Grana*, **14**: 132–142.

MOORE P.D., WEBB J.A., COLLINSON M.E., 1991 — Pollen analysis. Blackwell, Oxford.

POKORNY P., 2002 — A high resolution record of Late Glacial and Early Holocene climatic and environmental change in Czech Republic. *Quatern. Intern*., **91**: 101–122.

SEIBUTIS A., 1974 — Das Ratsel der Entstehung von interstadialischen Schichten in Ula-Tal. *Geografijos metrastis*, **13**: 23–36. (in Lithuanian with Russian and German summaries).

STANCIKAITE M., SEIRIENE V., SINKUNAS P., 1998 — The new results of Pamerkys outcrop, South Lithuania investigations. *Geologija*, **23**: 77–88.

STANCIKAITE M., KABAILIENE M., OSTRAUSKAS T., GUOBYTE R., 2002 — Environment and man in the vicinity of Lakes Duba and Pelesa, SE Lithuania, during the Late Glacial and Holocene. *Geol. Quart*., **46**, 4: 391–409.

STOCKMARR J., 1971 — Tablets with spores used in absolute pollen analysis. *Pollen et Spores*, **13**: 615–621.

STUIVER M., REIMER P.J., BARD E., BECK J.W., BURR G.S., HUGHEN K.A., KROMER B., McCORMAC G., van der PLICHT J., SPURK M., 1998 — INTCAL98 Radiocarbon Age Calibration, 24.0000 cal BP. *Radiocarbon*, **40**, 3: 1041–1083.