Geological Quarterly, 2002, **46** (4): 391–409

Environment and man around Lakes Dūba and Pelesa, SE Lithuania, during the Late Glacial and Holocene

Miglė STANČIKAITĖ, Meilutė KABAILIENĖ, Tomas OSTRAUSKAS and Rimantė GUOBYTĖ

Stančikaitė M., Kabailienė M., Ostrauskas T. and Guobytė R. (2002)— Environment and man around Lakes Dūba and Pelesa, SE Lithuania, during the Late Glacial and Holocene. Geol. Quart., **46** (4): 391–409. Warszawa.

Interdisciplinary investigations (pollen and diatom analysis, ^{14}C dating and geological-geomorphological and archaeological data) around Lakes Dūba and Pelesa, in SE Lithuania, have elucidated the environmental history and human impact throughout the Late Glacial and Holocene. Aerial photograph interpretations indicate that both lakes are residual basins of one Post-Glacial palaeolake outside the morainic relief of the Nemunas (Weichselian) Glaciation. Pollen assemblages from lacustrine deposits date back to the Older Dryas (Lake Dūba) and Alleröd (Lake Pelesa) and cover all chronozones of the Post-Glacial. Diatom analysis has illustrated the palaeoecological conditions in the lakes and helped reconstruct successive water levels throughout the last 12300 radiocarbon years. Diatom abundance and the distribution of the planktonic, benthic and epiphytic species suggest a lowering of Lake Dūba and Lake Pelesa at (*e.g.*) 11900–10900 ^{14}C BP, (*e.g.*) 10000–8100 ^{14}C BP and (*e.g.*) 3700–2500 ^{14}C BP. Pollen data suggest that the earliest signs of human impact and local forest clearances data from about (*e.g.*) 8400–8300 ^{14}C BP. The first record of cereal pollen in sediments dates from earlier than (*e.g.*) 6000 ^{14}C BP. Therefore, agriculture was introduced into the area not earlier than the second half of the Midle Neolithic, at about (*e.g.*) 5000–4400 ^{14}C BP. Continous indications of agriculture and progressive clearing of woodland is consistent with the increasing role of a farming economy during the Bronze Age. Since the 1800–1900 ^{14}C BP formation of an open canopy, increasing soil erosion and changes in vegetation emphasize the remarkable human impact on the environment.

Miglė ÎõÒãčikaitė, Institute of Geology and Geography, T. Ševčenkos 13, LT 2600, Vilnius, Lithuania; e-mail: migle@geologin.et; Meilutė Kabailienė, Department of Geology and Mineralogy, M. K. Čiurlionio 21/27, LT 2600, Vilnius, Lithuania; e-mail: neilute.kabailiene@gf.vu.lt; Tomas Ostrauskas, Institute of History, Kražių 5, LT 2000, Vilnius, Lithuania; e-mail: tomasos@takas.lt; Rimantė Guobytė, Geological Survey of Lithuania, S. Konarskio 35, LT 2600, Vilnius, Lithuania; e-mail: rimante.guobyte@lgt.lt *(received: December 20, 2001; accepted: May 6, 2002).*

Key words: SE Lithuania, Holocene, Late Glacial, environmental changes, human impact.

INTRODUCTION

Southeastern Lithuania is important both from environmental and archaeological points of view. Lying beyond the marginal ridge of the Nemunas (Weichselian) Glaciation, it provides an excellent window into Post-Glacial history. Studies have been made of the retreat of the ice sheet of the last glaciation (Basalykas, 1958, Baltrūnas *et al.*, 1984), environmental changes throughout the Late Glacial and Holocene (Kabailienė, 1965; Seibutis, 1974; Blažauskas *et al.*, 1998) and the role of human impact (Savukynienė, 1974, 1976; Seibutis and Savukynienė, 1998).

Since the end of the 19th century, numerous archaeological investigations have provided much information on the Late Palaeolithic, Mesolithic, Neolithic and historical times (Szukiewicz, 1907; Rimantienė, 1971, 1994).

This study focuses on the environmental and land-use history of the area around Lakes Dūba and Pelesa during the Late Glacial and Holocene. Bio- and chronostratigraphical results are integrated with geological and archaeological data to examine the role man played on landscape development.

STUDY AREA

Lake Dūba (54°02′ N, 24°41′ E) and Lake Pelesa (54°00′ N, 24°46′ E) are situated about 70 km south-east of Vilnius, on of the South-east Outwash Plain (Basalykas, 1965) (Fig. 1). Eutrophic Lakes Dūba (+124 m a.s.l.) and Pelesa

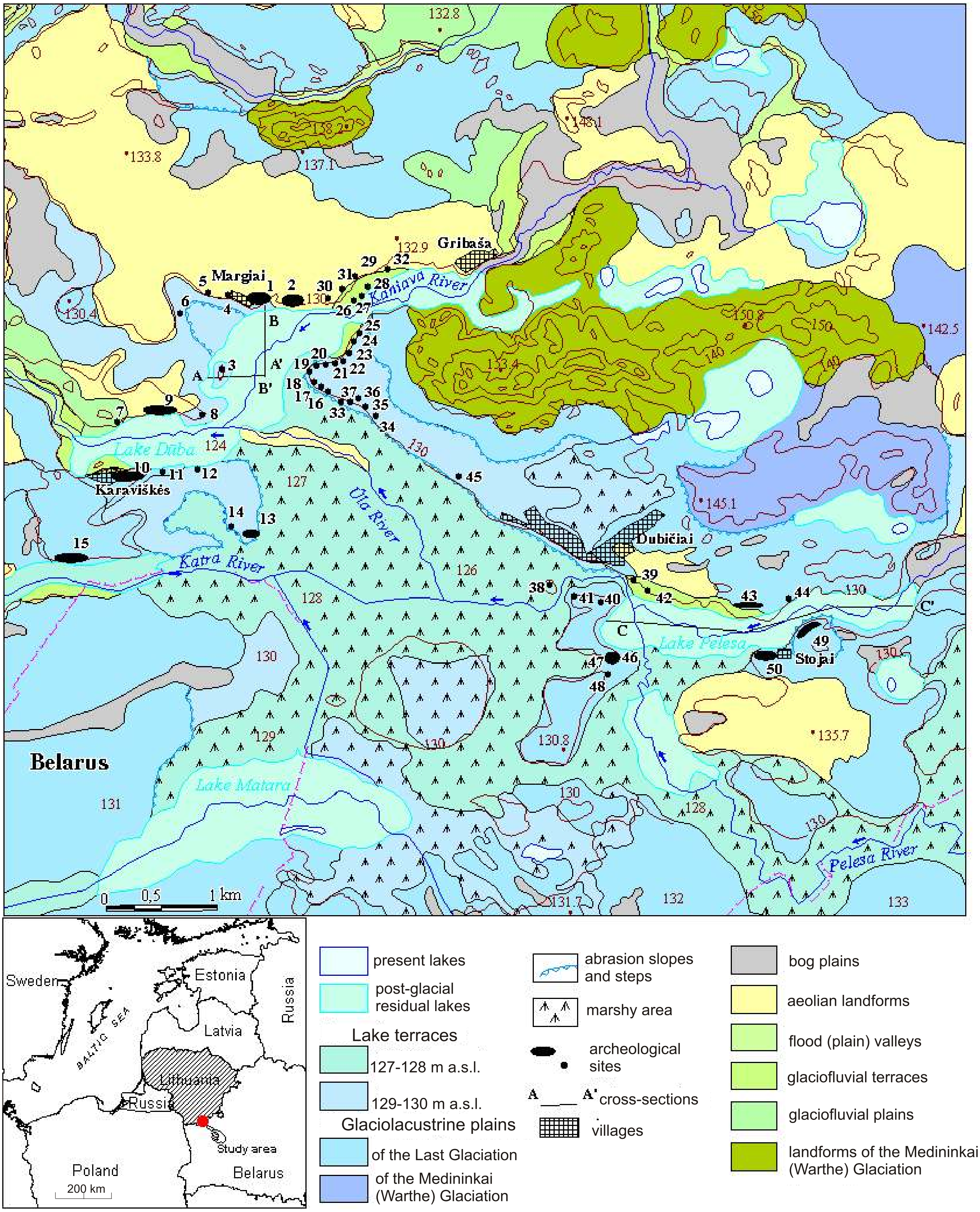

Fig. 1. Palaeogeographical map of Post-Glacial Lakes Dūba and Pelesa showing the distribution of archaeological sites

See Table 1 for the description of the archaeological signatures

Table 1

Chronological and cultural attribution of prehistoric sites in the Dūba-Pelesa area

No.	Site	Palaeolithic			Mesolithic					Neolithics				Early metal per.		
		Lyngby type	Vilnius group	Swidry Culture	Kunda Culture	Kudlajevka C.	Janislawice C.	Mesol.-Neol. *	Dubièiai type	Narva C.	Nemunas C.	GAC	CWC	Bronze Age	Tscinec C.	Stroked Cer. C.
1	Margiai 1		X?	X		X	X		X		X		X			X
2	Margiai 2			X		X	X				X		X			
3	Margiai 4		X	X				X						X		X
4	Margiai 6													X		
5	Margiai 7							X								
6	Margiai 8							X			X					
7	Karaviškes 1							X								
8	Karaviškes 3							X								
9	Karaviškes 4								X							
10	Karaviškes 6A			X	X	X			X		X		X			
11	Karaviškes 6B				X				X					X		
12	Karaviškes 7													X		
13	Katra ištakos 1			X		X	X		X		X	X	X	X	X	
14	Katros senvage										X					
15	Katra 1								X		X					X
16	Gribaša 1A							X								
17	Gribaša 1B							X	X							
18	Gribaša 1C							X						X		
19	Gribaša 1D		X	X?					X		X					
20	Gribaša 1E			X?				X	X							
21	Gribaša 1F								X							
22	Gribaša 1G							X	X							
23	Gribaša 1H								X		X					
24	Gribaša 1I							X								
25	Gribaša 1J															X
26	Gribaša 2A						X									
27	Gribaša 2B										X					
28	Gribaša 2C												X			
29	Gribaša 3										X					
30	Gribaša 4			X			X		X	X	X		X			
31	Gribaša 5							X								
32	Gribaša 6							X								
33	Barzdis 1	X?		X		X?			X		X				X	X
34	Barzdis 2						X									
35	Barzdis 2A								X		X					
36	Barzdis 2B								X							
37	Barzdis 2C							X								
38	Dubičiai 1			X							X		X	X		X
39	Dubičiai 2			X			X		X		X		X			
40	Dubičiai 3			X					X					X		
41	Dubičiai 4							X								
42	Dubičiai 5			X			X							X		
43	Dubičiai 6			X				X	X							
44	Dubičiai 7							X								
45	Dubičiai 8							X								
46	Dubičiai 9A							X								
47	Dubičiai 9B						X	X			X					X
48	Dubičiai 10							X								
49	Stojai 1**			X			X	X						X		
50	Stojai 2							X			X					

sites or occupation periods not identified more precisely
finds from W. Szukiewicz collection included

(+130 m a.s.l.) were drained at the end of the 19th century and only areas of wet, boggy ground now indicate the extent of these former lakes. The area of Lake Dūba was 221 ha in 1850, but in 1900 it was only 20 ha. The small Kaniava stream crosses the former Lake Dūba from the NNE to the SSW and then flows into the Ūla River. Water from the area of the former Lake Pelesa also flows into the Ūla River.

Wet meadows and pastures, small bushes and dry pine forest with juniper as well as arable land dominate the catchment of the lakes. The villages of Margiai, Karaviškės, Gribaša, Dubičiai and Stojai are situated on their shores.

SETTLEMENT HISTORY

Favourable conditions for settlement around Lakes Dūba and Pelesa were already present during the Bölling and Alleröd (Kabailienė, 1990). Two arrow heads from the Margiai 1 site may date to the end of the Alleröd or beginning of the Late Dryas (Fig. 1; Table 1). Abundant settlements from the colder Late Dryas period are ascribed to two cultural groups. Vilnius group material was found in the W. Szukiewicz collection (Gribaša 1D?) and was encountered during the excavation of the Margiai 4 site. Swiderian cultural material was found at the Dubičiai 1–3, 5, 6 and Katra ištakos 1 sites. During the Late Palaeolithic, the people subsisted mainly on the migrating reindeer herds (Zaliznyak, 1995).

When the forest belt became established in South Lithuania at the beginning of the Mesolithic, the hunter groups adapted to the changed environmental conditions and became northern woodland hunters. The descendants of the Swiderian culture along the upper Nemunas River, in South Lithuania and in North-west Bolerus created a unique Early Mesolithic Kunda culture (Ostrauskas, 2000). The Kunda culture left behind characteristic flint artefacts collected during excavations at Karaviškės 6A and 6B. However, the Kunda culture people were soon (during the first half of the Preboreal) pushed out of the Dūba-Pelesa Lake area by the communities of the Kudlajevka culture. This culture originated in the Polesse in the Late Palaeolithic from Gravettian cultures and moved north following the expansion of favourable environmental conditions of the northern woodland belt. A Kudlajevka culture campsite was encountered at Katra ištakos 1.

Emigrants from southern Scandinavia Maglemosian culture groups began penetrating into this area at the end of the Preboreal and at the beginning of the Boreal (Rimantienė, 1971; Ostrauskas, 2000). In Eastern Europe their heritage is referred to as the Janislawice culture. That the hunters and fishers of these mixed forests lived here the longest, for a few thousand years, suggested by the numerous sites of this culture: Dubičiai 2, 5, 9 and others (Fig. 1; Table 1). In the 5th millennium BC, the Janislawice communities adopted a ceramic vessel manufacturing technology, although their material culture (flint working industry and tool types) and their way of life did not change with this innovation. Janislawice culture sites with ceramics in South Lithuania are traditionally called the Dubičiai type (Dubičiai 2, 3, 6, Karaviškės 4, 6A, 6B sites and others). Over time, different pottery and flint forms as well as stone tool manufacturing techniques were adopted from Central Europe. In this way, the Nemunas and Narva forest belt type of Neolithic cultures developed from local variants of the Janislawice culture in the 4th millennium BC. The Dūba-Pelesa Lake area belonged to the northern edge of the Nemunas culture area (Barzdis 1, 2A sites and others). However, sometimes this area found itself under the influence of the Narva culture (Gribaša 4). That the Narva culture expanded in this area at the beginning of the Bronze Age is evident by finds of Late Narva culture pottery at the Katra ištakos 1 site. The peoples of the Nemunas and Narva cultures intensively exploited the rich resources of this environment.

Groups of people of the Corded Ware Baltic Coast culture (Dubičiai 1, 2, 3 and others) and Globular Amphorae culture (Katra ištakos 1) reached Lake Dūba and Lake Pelesa in the 3rd millennium BC (Fig. 1; Table 1). These communities already raised domesticated animals and possibly worked the land. However, farming began to consolidate only at the beginning of the Bronze Age when the influence of the Trzciniec culture reached southern Lithuania, starting with the Dūba-Pelesa Lake area. Large settlements of this culture have been excavated at the Katra ištakos 1 and Barzdis 1 sites. A few others are known along the shores of the Katra River, a little further downstream. The heritage of the Stroked Pottery culture, at the settlements of Margiai 1, 4 and elsewhere, may be dated to the 1st millennium BC and the first centuries AD. Iron Age settlements with remains of rustic pottery have been found at the Dubičiai 1, 9 and Gribaša 1D sites.

The hillfort in Dubičiai near the site of Dubičiai 4 and the visibly fortified settlement on the Margiai 4 hill can be dated to the time of battles with the Teutonic knights. Moreover, pottery of the Middle Ages has been found at the Dubičiai 1–3 and Stojai 2 sites; this reflects intensive settlement and extensive farming then. In the middle of the 16th century, with the valakas land reform, the village of Dubičiai took on its present appearance. An estate was created where the hillfort stands beside the village.

The prehistoric settlements in this area are concentrated at an elevation of 129 m a.s.l. New cultural influences and innovations reached this area the fastest along the Katra River.

METHODS

AERIAL PHOTO INTERPRETATION

Geological and geomorphological interpretations of the area were made using a set of black-white stereoscopic aerial photos (scale 1:17 000; 1952). Former shorelines, river terraces and areas reworked by aeolian activity were identified on the glaciolacustrine plain. The results of the aerial photo interpretation were checked in the field.

CORING AND SAMPLING

The deposits of Lake Dūba and Lake Pelesa were cored using a Russian corer improved at the Department of Quaternary Geology, Lund University (Sweden). A tube 1 m in length and 5 cm in diameter was used. Two profiles (N–S and E–W direction) were made in Lake Dūba and material from previous investigations dealing with the lithostratigraphy of Lake Pelesa was examined (Fig. 1). The core from Lake Dūba and one core from Lake Pelesa were subsampled at 5 cm intervals for pollen and diatom analysis and at 5–15 cm intervals for ^{14}C dating.

POLLEN ANALYSIS

Pollen analysis was carried out at 5 and 10 cm intervals. Chemical preparation followed the standard procedure described by Grichiuk (1940) and Erdtman (1936). The volume of samples was measured and *Lycopodium* spores added in order to evaluate the pollen concentration (Stockmarr, 1971). More than 1000 terrestrial pollen grains were counted per sample. The results of the pollen analysis are given as a percentage pollen diagram. The basic sum for calculations was the sum of arboreal (∑AP) and non-arboreal (∑NAP) taxa (∑AP+∑NAP=∑P). 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 the Late Glacial and Holocene (Mangerud *et al.*, 1974; Kabailienė, 1998). Pollen and spore identifications were based on Moe (1974), Fægri and Iversen (1989), and Moore *et al.* (1991) in conjunction with the reference collections of the Botanical Institute, Bergen University and the Department of Geology and Mineralogy, Vilnius University.

The pollen and diatom spreadsheets and percentage diagrams were prepared using the computer programs "*TILIA*" (version 2) and "*TILIA–GRAPH*" (version 2.0 b.5) (Grimm, 1990, 1992).

In discussing the interaction of anthropogenic and natural influences, changes in the following indicators were taken into consideration:

— fluctuations in the pollen curves reflecting forest clearance/regeneration (Aaby, 1986);

— the occurrence of plant species related with the specific characters of human activity (Behre, 1981, 1988; Berglund and Ralska-Jasiewiczowa, 1986);

— fluctuations in charcoal representation (Tolonen, 1986).

The construction of the human impact diagrams is based on groups of taxa established by Behre (1981, 1988), with modification suggested by Berglund and Ralska-Jasiewiczowa (1986) and Veski (1998) (Table 2).

Table 2

Land-use categories and plants-indicators

Land-use category	Indicators
Cultivated land	*Cerealia*, *Avena* L., *Hordeum* L., *Triticum* L., *Secale* L., *Polygonum persicaria* L., *Centaurea cyanus* L., *Linum* L., *Cannabis sativa* L., Brassicaceae
Ruderal communities	*Artemisia* L., Chenopodiaceae, *Urtica* L., *Plantago major* L./*media* L.
Wet meadows and pastures	*Plantago lanceolata* L., *Rumex acetosa* L./*acetosella* L., *Ranunculus acris* L., *Potentilla* L., Ranunculaceae, Asteraceae, Plantaginaceae, Caryophyllaceae
Dry pastures and grazed forest	*Calluna* L., *Pteridium* Kuhn, *Juniperus communis* L.

DIATOM ANALYSIS

Diatoms were extracted from the sediments in the conventional manner (Battarbee, 1986). For the removal of the mineral material, flotation in heavy liquids additionally was carried out. The samples were centrifuged a solution of S.G. 2.4 — potassium iodide (KI) and cadmium iodide (CdI_2) — for about 10 minutes at 1.000–1.500 rpm. The supernatant containing the diatoms was decanted and collected. The diatoms then were recovered by diluting the supernatant with distilled water and mounted into Naphrax Liquid. A total of 500 frustules was counted in the central part of each slide. Identification to species was based on Krammer and Lange-Bertalot (1988; 1991*a*, *b*; 1997) as well as Hustedt (1991). The results of the analyses are shown as a diagram showing the succession of the most frequent and ecologically important taxa. Diatom species were grouped according to two criteria in the diagrams: life habit (the proportions of planktonic, benthic and epiphytic diatoms) and pH (alkaliphilic, acidophilic and indifferent groups).

RESULTS

GEOLOGICAL SETTING

The surroundings of Lake Dūba and Lake Pelesa are situated on the distal part of the Southeast Outwash Plain (Fig. 1). In the area investigated, the outwash plain had become a glaciolacustrine plain. The glaciolacustrine plain lies at several levels, the highest one, formed during the Medininkai (Warthe) Glaciation, is located at +142–+145 m a.s.l. Morainic hills that lie at about +160–+170 m a.s.l. are of the same age. The glaciolacustrine plain of the last glaciation lies at about +132–+133 m a.s.l. and is nearly everywhere underlain by

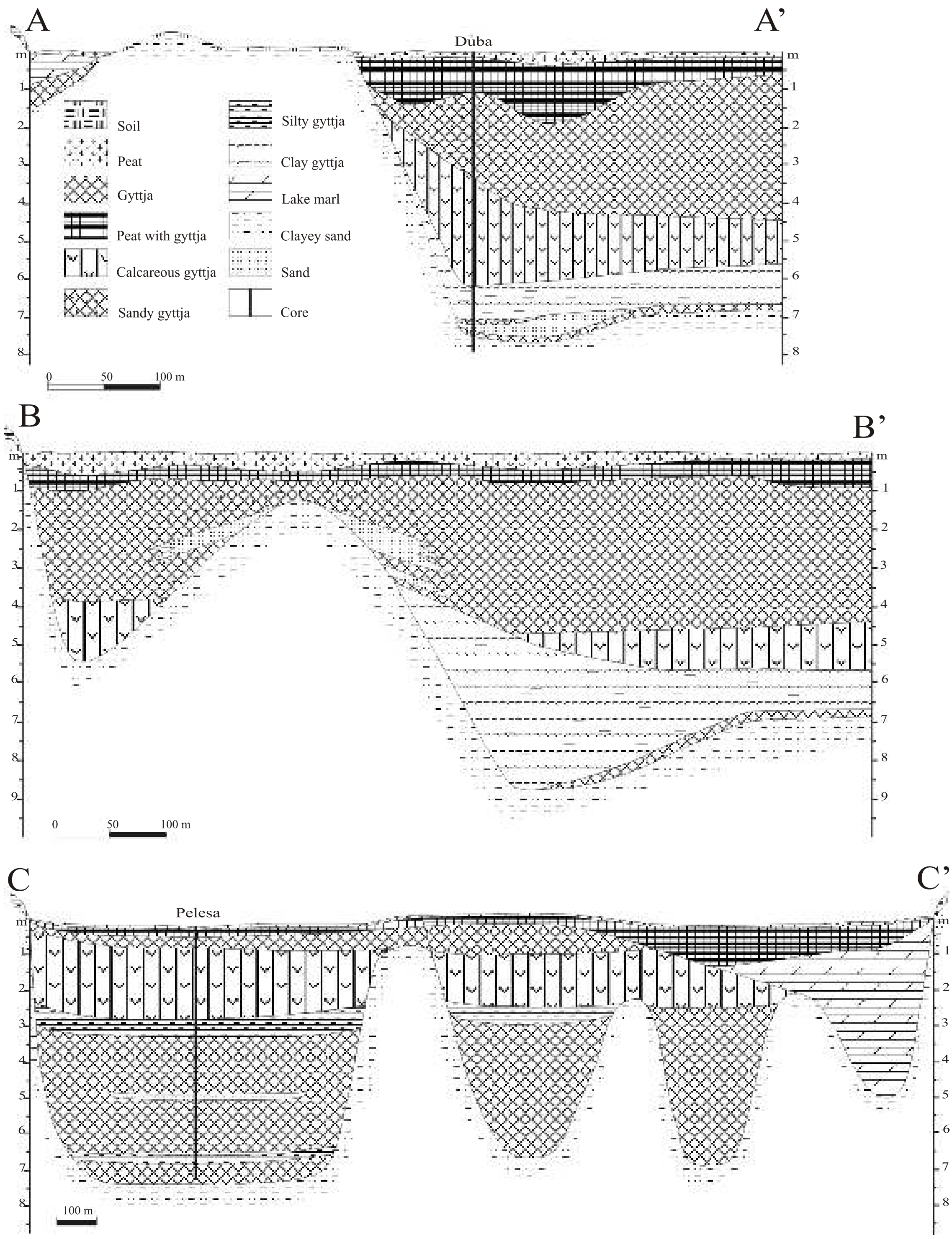

Fig. 2. Lithological sequences of the cross-sections A–A' and B–B' (Lake Dūba) and C–C' (Lake Pelesa)

fine-grained sand. The three lowest levels of the plain are interpreted as terraces of the Post-Glacial Lake. Numerous palaeolakes, i.e. Dūba, Pelesa and Matara, were formely present in their deepest parts. The shorelines of their sedimentary basins are well expressed on the photo images and located at +124–+130 m a.s.l.

SEDIMENT LITHOLOGY

The lithologies of the main cores investigated are described in terms of organic and clastic content (Fig. 2). The sampling points are located in the deepest parts of the lakes and detailed lithological descriptions of the cores investigated accompanies all presented diagrams.

Table 3

Uncalibrated ^{14}C dates from Lake Dūba

Depth [cm]	Sediment	Uncalibrated ^{14}C years BP	Laboratory code	Dating object
180–185	sandy gyttja	2580±70	Ki-7602	SB/SA transition
265–270	sandy gyttja	3740±80	Ki-7603	rise in *Cerealia* curve
480–485	calcareous gyttja	5430±70	Ki-7604	AT/SB transition

Table 4

Uncalibrated ^{14}C dates from Lake Pelesa

Depth [cm]	Sediment	Uncalibrated ^{14}C years BP	Laboratory code	Dating object
200–205	calcareous gyttja	3250±100	Ki-9269	peak in *Cerealia*
310–315	silty gyttja	4380±90	Ki-9270	opening of landscape
375–385	gyttja	5265±70	Ki-9271	AT/SB transition
600–615	gyttja	8430±80	Ki-9272	spread of deciduous trees

CHRONOLOGY

During this study, three conventional ^{14}C dates were produced from Lake Dūba and four from the Lake Pelesa section. The conventional ^{14}C dates from the bulk samples were obtained in the Kiev radiocarbon laboratory (Tables 3 and 4). Environmental changes and human impact are discussed using uncalibrated ^{14}C dates BP.

POLLEN STRATIGRAPHY

The pollen composition and sequences have been described in terms of local pollen assemblage zones (LPAZ) and correlated with pollen zones established in Lithuania and associated chronozones (Mangerud *et al.*, 1974; Kabailienė, 1998).

Pelesa. The pollen diagram from the Lake Pelesa succession is divided into 11 LPAZ (Fig. 3).

— P-1 (*Pinus* LPAZ; 738.5–732 cm), Alleröd.

AP (arboreal pollen) (95.1%) prevail and *Pinus* (91.5%) is dominant. *Betula* is also significant (3.7%) and single pollen grains of other trees were registered. *Artemisia* (1.3%), Chenopodiaceae (0.5%), Cyperaceae (2.2%) and Poaceae (1.4%) predominate among NAP (non-arboreal pollen). The charcoal curve is very low throughout the zone. The concentration of pollen increases upwards.

— P-2 (Poaceae-Cyperaceae-*Artemisia*-*Betula*-*Juniperus* LPAZ; 732–700 cm), Younger Dryas.

The share of NAP increases up to 14% at the beginning of the zone. *Pinus* drops down to 75.7% and *Betula* reaches 13.3%. An absolute maximum of *Juniperus* (1.2%) was registered and *Artemisia* (4.4%) together with Chenopodiaceae (1.6%), Cyperaceae (4.6%) and Poaceae (7.2%) culminate. The charcoal curve rises at the beginning of the zone (7.9%). The concentration of pollen rises throughout this zone.

— P-3 (*Betula* LPAZ; 700–675 cm), Preboreal.

An increase of AP and decrease of NAP represent this zone. A maximum of *Betula* (23.3%) is registered. *Ulmus* is represented continuously. The total amount of NAP pollen decreases from 3.4 to 0.6%. The value of all the predominant species (*Artemisia*, Chenopodiaceae, Cyperaceae and Poaceae) is lower in comparison with the previous LPAZ. The total value of the charcoal curve is lower in comparison with the previous zone. The concentration of pollen rises.

— P-4 (*Pinus* LPAZ; 675–641 cm), Early Boreal.

The determination of this zone is based on changes in the *Pinus* curve. *Pinus* rises up to 87.6% and the total amount of AP (96.9%) is the highest in the diagram. The *Corylus*, *Ulmus* and *Picea* curves rise upwards. The NAP value drops down to 0.5% and is represented mainly by Cyperaceae (max. 1%), Poaceae (max. 2.1%) and *Artemisia*. The charcoal curve reaches 12.2%. The concentration of pollen decreases in the second part of the zone.

— P-5 (*Corylus*-*Alnus* LPAZ; 641–595 cm), Late Boreal.

Pinus reaches 83%. The same trend is *Corylus* representation (8%). The total amount of AP stays as high as

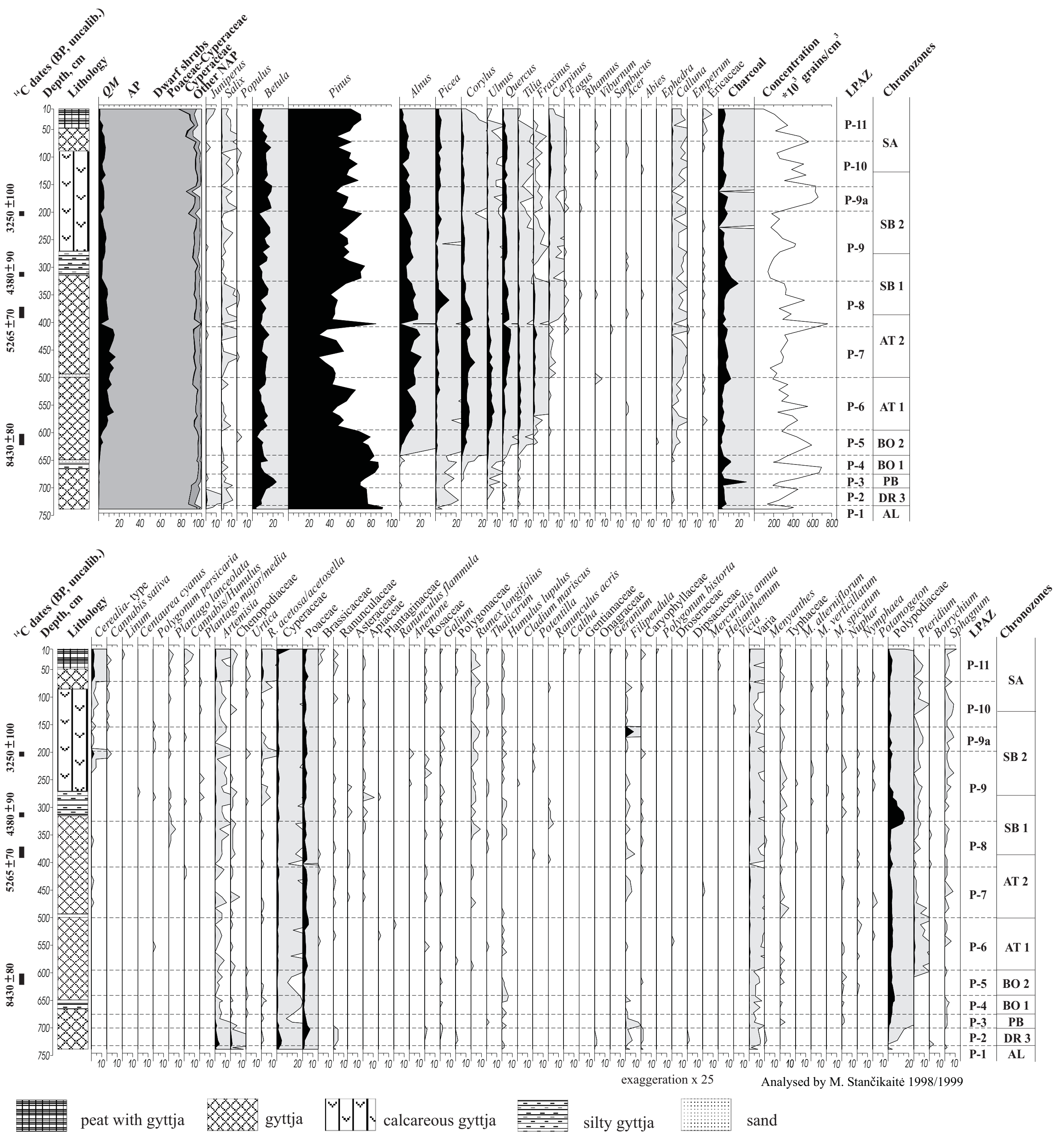

Fig. 3. Percentage pollen diagram, Lake Pelesa

before. The continuous increase in *Ulmus* and *Picea* curves is fixed. Scattered pollen grains of *Ephedra*, *Salix* and *Carpinus* occur. *Artemisia*, Cyperaceae and Poaceae prevail among the NAP. The charcoal curve increases (5.4%). The maximum concentration of pollen is observed in the middle of the zone.

— P-6 (*Ulmus-Tilia-Corylus-Alnus* LPAZ; 595–500 cm), Early Atlantic.

This zone is characterised by a rise in *QM*, a decrease in *Pinus* and increasing NAP. *Ulmus* culminates (7%). Peaks in *Alnus* and *Corylus* occur simultaneously. *Betula* reaches 14.7%. The total amount of NAP is higher in comparison with the previous zone. Poaceae increases (4.8 and 5.8%) close to the upper limit of the zone. Pollen of Chenopodiaceae, *Polygonum persicaria* and Brassicaceae are found. *Pteridium* culminates in this zone (1.3%). The charcoal value reaches 12.2%. The pollen concentration gradually decreases.

— P-7 (*Alnus-Quercus-Corylus* LPAZ; 500–408 cm), the first part of the Late Atlantic.

A *QM* culmination characterises this zone. A drop in *Pinus* (29.2%) coincides with a culmination of *Quercus* (8.1%) and *Alnus* (19.9%). The amount of *Carpinus* rises gradually. The total amount of NAP rises upward, but only Cyperaceae and Poaceae have continuous curves. The first grains of *Cerealia* type pollen are registered in this zone. The concentration of pollen rises throughout the zone.

— P-8 (*Picea-Pinus* LPAZ; 408–325 cm), Late Atlantic-Early Subboreal.

This zone is characterised by a rise in *Pinus*, a gradual decrease *QM* and culmination of *Picea* (13.2%). *Pinus* shows 55.8%. A decrease in nearly all *QM* curves was registered. *Carpinus* reaches 1.2%. *Artemisia* increases upwards and shows 0.6%. Poaceae reaches 4.3%. Chenopodiaceae, *Plantago lanceolata* and *Rumex longifolius* DC increase together with *Cerealia* type pollen. A peak in the charcoal curve was registered (19.3%). The pollen concentration drops at the beginning of the zone.

— P-9 (*Pinus-Betula-Quercus-Alnus* LPAZ; 325–198 cm), Early Subboreal-Late Subboreal.

Pinus increases up to 70.6% in this zone and *QM* rises up to 7.3%. A distinct rise is seen in the *Betula* curve (17.3%). *Cerealia* type pollen shows a peak (2.6%). *Artemisia*, Cyperaceae and Poaceae form the largest portion of the NAP. *Rumex longifolius*, *Rumex acetosa/acetosella* and Chenopodiaceae increase. Plantaginaceae, *Centaurea cyanus* and *Plantago major/media* are represented by single pollen grains. The charcoal curve drops throughout the zone. The pollen concentration shows a peak in the middle of the zone.

— P-9a (*Betula* LPAZ; 198–154 cm), Late Subboreal.

Changes in AP composition and a few peaks in NAP representation (up to 15%) characterise this zone. *Betula* rises up to 18.3%. A small peak in *Quercus* was registered at the beginning of the zone. The Poaceae curve increases up to 4%. The charcoal curve shows an increase (9.2%). The pollen concentration is high throughout this zone.

— P-10 (*Pinus-Picea-Carpinus* LPAZ; 154–74 cm), Late Subboreal-Subatlantic.

This zone is characterised by an increase of AP (93.4%). *Pinus* reaches 67.9%. *Carpinus* culminates (2.4%), as does *Picea* (5.2%). *QM* species decrease in the first half of the zone, but rise slightly afterwards. A rise in *Calluna* and *Salix* was registered. *Cerealia* type forms a continuously increasing curve. *Thalictrum*, *Rumex longifolius*, *Rumex acetosa/acetosella*, *Artemisia* and *Pteridium* rise simultaneously. The charcoal curve is higher at the beginning of the zone and then decreases. The pollen concentration slightly drops.

— P-11 (*Pinus-Cerealia* LPAZ; 74–15 cm), Subatlantic.

A rise in the NAP curve was registered in this zone. *Pinus* (70.6%) and *Picea* (5.6%) show peaks. A small peak of *Juniperus* (0.4%) is registered close to the upper limit. *Calluna* culminates (1.1%) and *Cerealia* type reaches 3.1%. *Artemisia* (1.7%) and *Rumex acetosa/acetosella* (2.1%) culminate simultaneously. Chenopodiaceae, Brassicaceae, *Urtica*, *Cannabis/Humulus* and *Plantago lanceolata* increase. The charcoal curve remains stable. The pollen concentration is higher in the first half of the zone, but a decrease occurs later.

Dūba. The pollen diagram from the Dūba section is divided into 9 local PAZ (LPAZ) (Fig. 4).

— D-1 (*Pinus-Juniperus*-Cyperaceae LPAZ*;* 792.5–750 cm), Older Dryas.

Pinus plays the dominant role in this zone (80.4%). AP reaches 94.6%. *Betula* shows a high value and single pollen grains of *Alnus*, *Picea*, *Ulmus* and *Tilia* were registered. *Juniperus* has a maximum of 1.8%. NAP mainly consists of *Artemisia*, Cyperaceae (8%) and Poaceae. *Botrychium* and *Selaginella selaginoides* are represented sporadically. The charcoal representation is low.

— D-2 (*Pinus* LPAZ; 750–725 cm), Alleröd.

Pinus culminates at 87%. The Poaceae and Cyperaceae representation is particularly low. Other herbs are represented sporadically. The charcoal curve increases.

— D-3 (*Betula*-Poaceae LPAZ; 725–715 cm), Younger Dryas.

Betula increases up to 22%. *Picea* forms a continuous curve. *Artemisia*, Cyperaceae and Poaceae predominate among the NAP and the share of Chenopodiaceae and Asteraceae is also high. Other herbs (Ranunculaceae, *Rumex acetosa/acetosella* and *Thalictrum*) are represented by single grains only. The charcoal curve increases upward.

— D-4 (*Betula* LPAZ; 715-665 cm), Preboreal-Boreal.

Betula shows a very high value (28.6%). *Pinus* decreases, but still stays above 50%. *Ulmus*, *Tilia* and *Quercus* have continuously increasing curves. *Picea* increases at the beginning of the zone and decreases close to the upper boundary. *Calluna* increases towards the topmost samples. The zone is characterised by a decrease of NAP down to 8.4%. The charcoal curve has a peak at the beginning of the zone, but then gradually decreases.

— D-5 (*Ulmus-Corylus-Alnus-Tilia* LPAZ; 665–510 cm), Early Atlantic-Late Atlantic.

This zone is represented by a culmination of AP and particularly low values of NAP. *Pinus* stays consistently above 50%. *Alnus* (13.5%) and *Corylus* (7.8%) have high values and culminate, as do *Tilia* and *Ulmus*. *Picea* gently rises upward. Most of the herb pollen decreases or even disappears in the middle of the zone. *Artemisia* and Chenopodiaceae are represented sporadically. A single grain of *Avena* type was registered. The charcoal curve is low, not exceeding 2.4%.

— D-6 (*Picea*−*Pinus* LPAZ; 510−305 cm), Late Atlantic-Early Subboreal.

This zone is characterised by an increase in NAP (up to 5%). *Picea* culminates (up to 11%) close to the lower limit. *Pinus* stays at more than 60%. *Alnus* has a high (12%) continuous curve. *QM* representation is low and *Corylus* clearly decreases. *Artemisia*, Cyperaceae, Chenopodiaceae and Poaceae form low continuous curves. A single pollen grain of *Triticum* type was found. Charcoal culminates (5.6%) at the beginning of the zone.

— D-7 (*Betula-Quercus* LPAZ; 305−150 cm), Late Subboreal-Early Subatlantic.

AP dominates the pollen, but the amount of NAP increases. *Betula* representation is high as is that of *Alnus* (11.8%) and

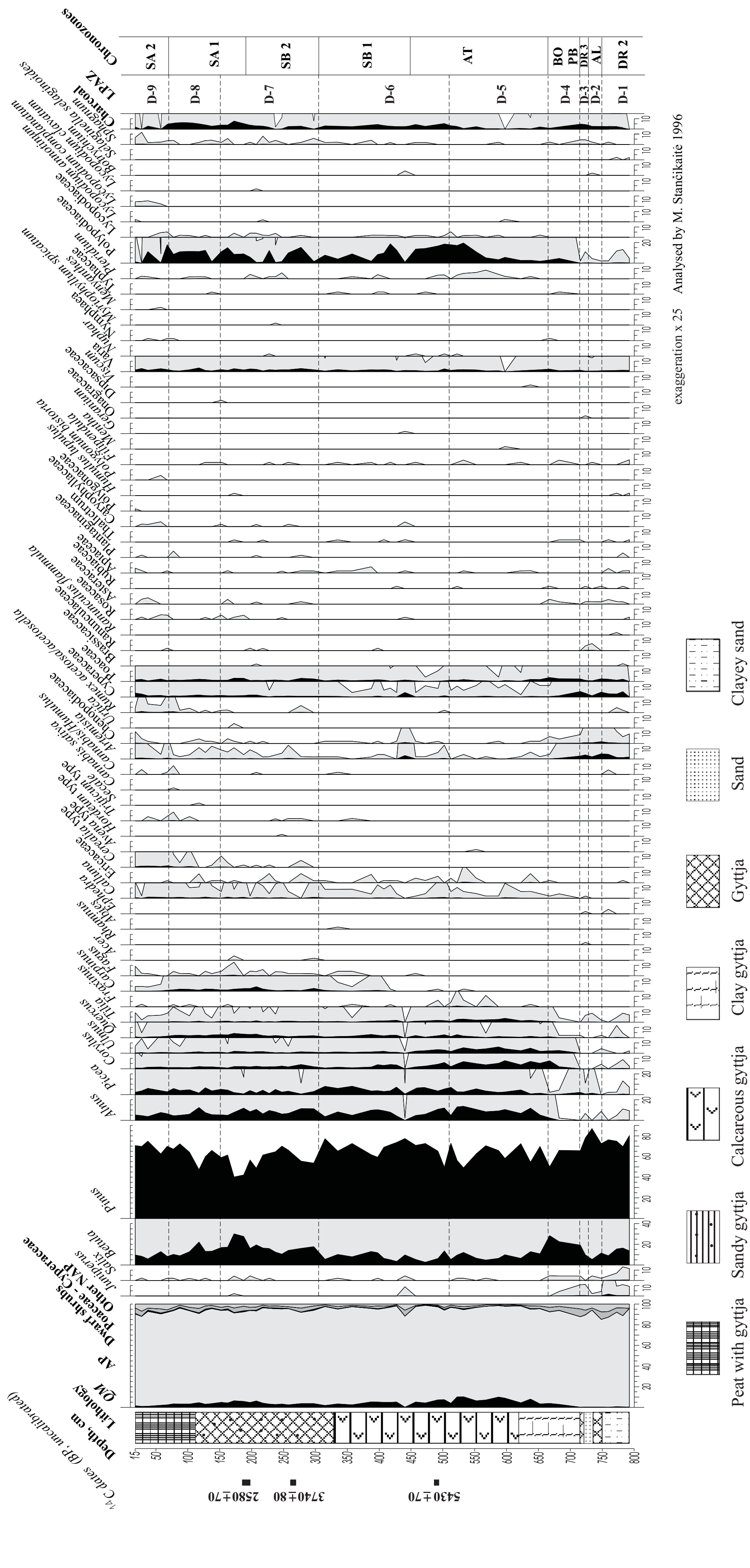

Fig. 4. Percentage pollen diagram, Lake Dūba

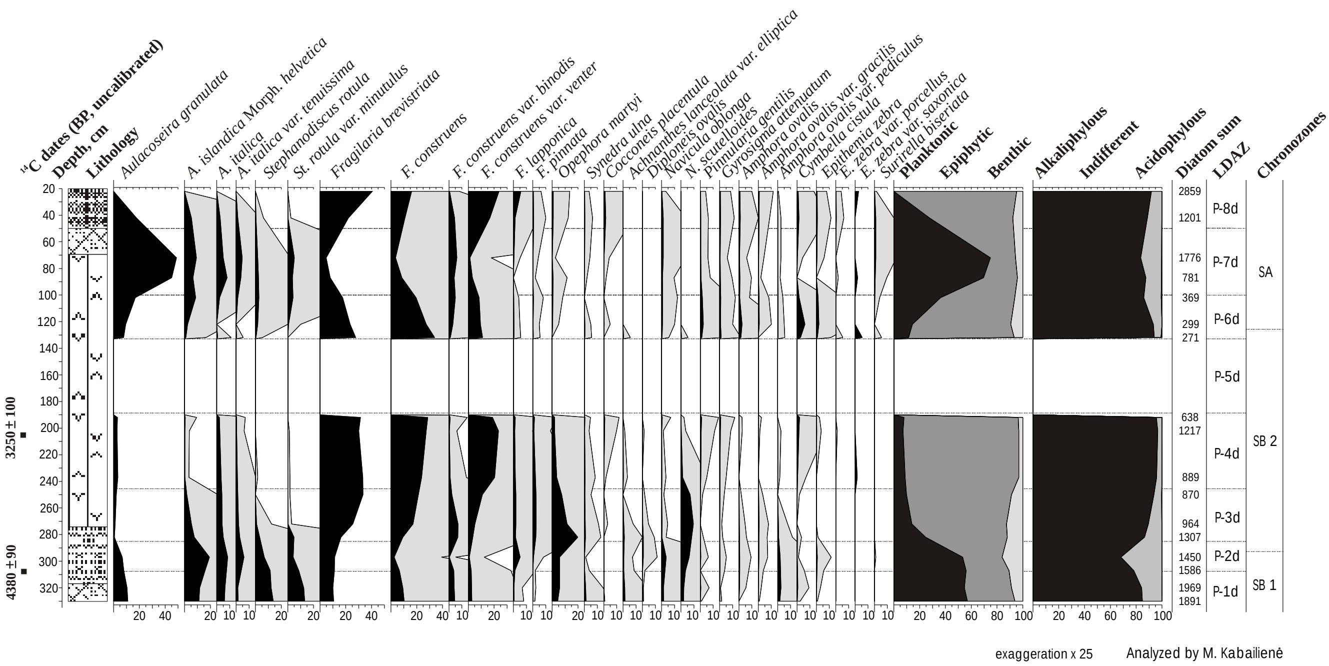

Fig. 5. Diatom diagram from Lake Pelesa

For lithological explanations see Fig. 3

Quercus (4.2%). *Picea* drops at the beginning of the zone, but increases afterward. *Cerealia* type, *Triticum* type and *Hordeum* type pollen are represented in some samples. *Artemisia* increases, especially in the upper part and the same is true for Cyperaceae and Poaceae. The charcoal curve decreases at the beginning, but then reaches 8.0%.

— D-8 (*Pinus-Picea* LPAZ; 150−70 cm), end of the Early Subatlantic.

The amount of NAP increases. *Pinus* shows 84% and *Picea* (up to 9%) has a rather uniform curve. *QM* decreases toward the upper limit. *Calluna* increases slightly. *Cerealia* type forms a continuous curve (up to 0.5%). Poaceae, Chenopodiaceae, Cyperaceae and *Artemisia* have a high frequency. The charcoal curve has a high value (6.6%).

— D-9 (*Pinus-Cerealia* LPAZ; 70−17.5 cm), Late Subatlantic.

Pinus has a high value (74.9%) in the upper part and *Picea* increases in the middle of the zone. *Betula* and *Alnus* decrease toward the upper limit. The *Calluna* curve culminates in the middle of the zone (1.1%). *Cerealia* type culminates at a depth of 67.5 cm (1.4%) and *Triticum* type has a high value. *Artemisia* and Chenopodiaceae show high values in the upper part of the zone. The charcoal curve decreases.

DIATOM STRATIGRAPHY

Pelesa. The diatom diagram from the Lake Pelesa deposits was divided into 8 LDAZ (Fig. 5).

— P-1d (*Aulacoseira-Stephanodiscus-Fragilaria* LDAZ, 340–300 cm), Late Atlantic-Early Subboreal.

Planktonic diatoms *Aulacoseira* (*A. granulata*, *A. islandica* morph. *helvetica*, *A. italica*) and *Stephanodiscus* (*S. rotula*, *S. rotula* var. *minutulus*) prevail, their total sum being about 60%. The representation of *Fragilaria* (*F. brevistriata*, *F. construens*) is lower (about 30%). *Opephora martyi*, characteristic of lacustrine littoral zones reaches 10%.

— P-2d (*Aulacoseira islandica* morph. *helvetica-A. italica* et var. *tenuissima-Fragilaria lapponica* LDAZ, 300–285 cm), the first part of the Late Subboreal.

Aulacoseira islandica morph. *helvetica* plays the dominant role (up to 23%). The representation of *Aulacoseira italica* et var. *tenuissima* (10%) and *Fragilaria lapponica* (4%) is lower.

— P-3d (*Fragilaria-Opephora martyi-Navicula scutelloides* LDAZ, 285–245 cm), Early Subboreal.

Fragilaria brevistriata is dominant (up to 30%). The representation of *Fragilaria construens* et var. *binodis* (23%) and *Navicula scutelloides* (6%) is lower. A small peak in *Opephora martyi* (17%) was registered in this zone.

— P-4d (*Fragilaria* LDAZ, 245–180 cm), Early Subboreal-Late Subboreal.

Fragilaria brevistriata plays the dominant role (40%). The representation of *Fragilaria construens* et var. *venter* (38%) is lower. Small peaks in *Opephora martyi* (6%) and *Navicula scutelloides* (12%) are registered at the beginning of the zone.

— P-5d (*Fragilaria-Navicula-Cymbella-Pinnularia* LDAZ, 180–135 cm), Late Subboreal.

Single shells of the above taxa were discovered in this zone.

— P-6d (*Fragilaria-Cymbella cistula-Epithemia zebra* var. *saxonica* LDAZ, 135–100 cm), the end of the Late Subboreal-Early Subatlantic.

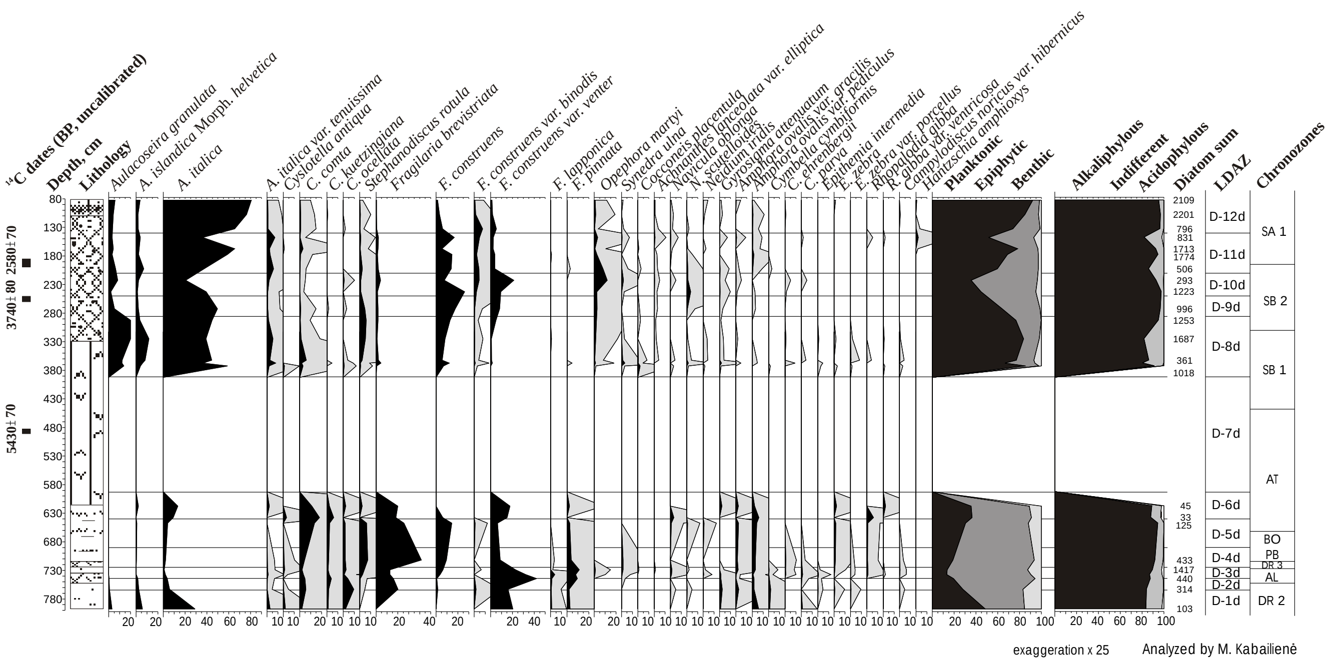

Fig. 6. Diatom diagram from Lake Dūba

For lithological explanations see Fig. 4

Fragilaria taxa (*F. brevistriata*, *F. construens* et var. *venter*, total sum 75%) predominate. Small peaks of *Cymbella cistula* (6%) and *Epithemia zebra* var. *saxonica* (4%) characteristic of lacustrine littoral zones, were registered.

— P-7d (*Aulacoseira-Stephanodiscus* LDAZ, 100–50 cm), Early Subatlantic.

Planktonic diatoms (*Aulacoseira*) culminate in this zone. *Aulacoseira granulata* reaches 48%, and *A. islandica* morph. *helvetica* shows 11%, and *A. italica* about 5%. *Stephanodiscus* (*S. rotula*, *S. rotula* var. *minutulus*) increases up to 4%.

— P-8d (*Fragilaria* LDAZ, 50–20 cm), Late Subatlantic.

Fragilaria taxa (*F. brevistriata* 41%, *F. construens* 16%, *F. construens* var. *venter* 21%, *F. lapponica* 4%) determine this zone.

Dūba. The diatom diagram from the Dūba section was divided into 12 LDAZ (Fig. 6).

— D-1d (*Aulacoseira-Amphora ovalis* var. *pediculus* LDAZ, 800–765 cm), Older Dryas.

Planktonic diatoms of the genus *Aulacoseira* are dominant in this zone. *Aulacoseira italica* predominates (32%). *Aulacoseira islandica* morph. *helvetica* has a maximum of 8% at the beginning of the zone, as has *Amphora ovalis* var. *pediculus* (7%). *Fragilaria construens* var. *venter*, an epiphytic diatomt predominatly in habiting littoral lake environments reaches 23% in the lower part of the zone.

— D-2d (*Cyclotella-Fragilaria brevistriata* LDAZ, 765–745 cm), Older Dryas-beginning of Alleröd.

Planktonic diatoms of the genus *Cyclotella* (*C. ocellata* 5%, *C. kuetzingiana* 2%) are characteristic of this zone. *Fragilaria brevistriata* reaches 23% and *F. construens* var. *venter* 19%. Benthic diatoms (*Opephora martyi*, *Gyrosigma attenuatum*, *Amphora ovalis* var. *pediculus* and others) are sporadic.

— D-3d (*Fragilaria construens* var. *venter-Fragilaria pinnata* LDAZ, 745–725 cm), Alleröd.

Diatoms characteristic of the littoral lake zone (*Fragilaria construens* var. *venter* 42%, *F. pinnata* 13%, *F. lapponica* 4%) predominate in this zone.

— D-4d (*Fragilaria brevistriata-Stephanodiscus rotula* LDAZ, 725–690 cm), Younger Dryas–beginning of Preboreal.

Epiphytic diatoms are dominant in this zone. *Fragilaria brevistriata* reaches 40%, *F. construens* 10% and *F. pinnata* 2%. *Stephanodiscus rotula* increases up to 7%.

— D-5d (*Fragilaria contruens-Amphora ovalis* var. *pediculus* LDAZ, 690–640 cm), Boreal–beginning of Early Atlantic.

This zone is characterised by a combination of epiphytic and benthic diatoms which flourish in littoral lake conditions (*Fragilaria construens* 17%, *Amphora ovalis* var. *pediculus* 6%, *Rhopalodia gibba* 6%, *Navicula oblonga* 2%).

— D-6d (*Cyclotella-Aulacoseira-Fragilaria* LDAZ, 640–600 cm), Boreal–beginning of Early Atlantic.

An increasing content of planktonic diatoms was found in this zone: *Cyclotella* (*Cyclotella comta* 19%, *C. kuetzingiana* 4%) and *Aulacoseira* (*A. italica* et var. *tenuissima*, *A. islandica* morph. *helvetica*). *Fragilaria* species have high values too (mainly *F. brevistriata* 22% and *F. construens* var. *venter* 20%).

— D-7d (LDAZ without diatoms, 600–390 cm), Atlantic.

No diatoms or diatom fragments were found in eight samples taken from a bed of calcareous gyttja.

— D-8d (*Aulacoseira-Cyclotella-Stephanodiscus rotula*, 390–285 cm), Early Subboreal.

Aulacoseira taxa predominate (*A. italica* 50–60%, *A. granulata* 22%, *A. islandica* morph. *helvetica* 11%) in this zone. *Cyclotella* is represented by *C. comta* (up to 5%). *Stephanodiscus rotula* does not exceed 4%.

— D-9d (*Aulacoseira italica-Fragilaria construens*, 285–245 cm), Late Subboreal.

Aulacoseira italica (50%) and *Fragilaria construens* (20%) show high values.

— D-10d (*Aulacoseira italica-Fragilaria construens-Opephora martyi*, 245–210 cm), Late Subboreal-Early Subatlantic.

This zone is characterised by an increase in *Aulacoseira italica* (up to 45%), *Fragilaria contruens* (up to 25%) and *Opephora martyi* (10%).

— D-11d (*Aulacoseira italica* et var. *tenuissima-Fragilaria construens*, 210–140 cm), Early Subatlantic.

Aulacoseira italica shows a high value (75%) in the lower part of the zone, but decreases (47%) near its top. In upper part of the zone distinct peaks of *Aulacoseira italica* var. *tenuissima* (8%), *Fragilaria construens* (20%), *F. construens* var. *binodis* (4%) and *F. construens* var. *venter* (3%) were registered.

— D-12d (*Aulacoseira italica-Fragilaria construens* var. *binodis* et var. *venter*, 140–80 cm), latest Early Subatlantic

This zone is characterised by the culmination of *Aulacoseira italica* (80%). Small peaks of *Fragilaria construens* var. *binodis* (7%) and *F. construens* var. *venter* (5%) were registered in the lower part of the zone.

ENVIRONMENTAL HISTORY AND VEGETATION DYNAMICS

HISTORY OF THE LAKES

The Southeast Outwash Plain was formed by streams of meltwater that flowed along the outer margin of the Baltic Upland (Basalykas, 1965). Glaciolacustrine origin topography formed in the distal part of the plain (Baltrūnas, 2001), that around Lake Dūba and Lake Pelesa being related to the retreat of the Nemunas (Weichselian) Glaciation (Fig. 1).

The glaciolacustrine basin was formed after the retreat of the ice sheet of the last glacial. The deepest parts of the glaciolacustrine basin coincide with areas of numerous lakes, i.e. Dūba, Pelesa and Matara. These lakes are sited on the lowermost level of the lacustrine plain, suggesting that the earliest Post-Glacial sediments may be found there. The bottoms of the lakes investigated were influenced by thermokarst activity and deep hollows occurred locally (Fig. 2).

In the earliest phases of the Late Glacial (The Oldest Dryas and Bölling), one sedimentary basin existed on the present area of Margiai, Karaviškės and Dubičiai (Fig. 1). The shore of this basin lay at about +132 – +133 m a.s.l. Clastic deposition then prevailed, of clayey or silty sand.

Similar processes operated in the Older Dryas, and, as recorded in Lake Dūba, pollen and diatom concentrations were low. The diatom assemblages indicate that during the Older Dryas the water was cold, clear and the water level was high.

The beginning of the Alleröd coincides with remarkable water level changes observed in most of the lakes, including Lakes Dūba and Pelesa. Here the water level dropped down to +127–+128 m a.s.l. and terraces lying at about +129–+130 m a.s.l. became dry land (Fig. 1). Diatoms characteristic of the littoral zone predominated. The water drained via the Katra River. The formation of gyttja started, while intense erosion is indicated by the high clastic content of the beds. The sudden deepening of the lakes has been linked with thermokarst activity that started as temperatures increased during the Alleröd (Seibutis and Sudnikavičienė, 1960). There are two layers of gyttja separated by sand of solifluction origin in Lake Dūba. Deposits of Alleröd age are rich in pollen and diatoms and constitute a key stratigraphic horizon.

While water level rose somewhat in the oligotrophic lakes where the planktonic diatoms reach their Late Glacial maximum in the Younger Dryas, clastic deposition predominated. A high content of sand and appearance of individual sand beds suggest increasing soil erosion and sand drift. During the Younger Dryas, rapid filling of the basins by aeolian sand occurred (Seibutis, 1974). The continental dune fields that occur around Lakes Pelesa and Dūba may be of Younger Dryas age.

During the Preboreal, water level reached the lowest point of the entire Holocene (Kabailienė, 1990). Layers of gyttja and clayey gyttja were formed in the lakes investigated during this period. The deposits that formed at about (*e.g.*) 10000–8100 ^{14}C BP are marked by a significant decrease in diatom content. Epiphytic and benthic species predominated. The lakes become mesotrophic and overgrown by aquatic plants. Some lakes possibly became isolated from the large palaeolake that included Lakes Dūba, Pelesa and Matara during the Late Glacial. Clastic deposition decreased as vegetation covered the surrounding land and aeolian activity decreased (Blažauskas *et al.*, 1998).

During the Boreal, sediments accumulated in a way similar to those discussed for the Preboreal. The water level was still low. Clayey gyttja, gyttja and a sand interlayer have been recognised in the investigated lakes.

Remarkable changes in sedimentation conditions took place throughout the Atlantic. A rise in water level is indicated by the diatom assemblages that show a predominance of planktonic species from (*e.g.*) 8100 ^{14}C BP, the water level reaching +129 m a.s.l. Connections between the earlier separated basins were re-established and a large eutrophic palaeobasin reappeared. The accumulation of gyttja enriched in calcium carbonate characterised Lake Dūba throughout the Atlantic. Detritus gyttja with a thin sand interlayer then accumulated in the Pelesa basin.

The end of the Atlantic and beginning of the Subboreal coincide with environmental changes. While the water level in Lake Pelesa remained high throughout the Early Subboreal, it later dropped to +124–+125 m a.s.l., as indicated by the diatom assemblages. Epiphytic and benthic forms prevailed in the lakes. Silty and calcareous gyttja accumulated. The formation of sandy gyttja started in Lake Dūba in the Late Subboreal.

Lakes still existed in the deep hollows, while the area around them became wet and boggy.

Continuous sedimentation took places in Lakes Pelesa and Dūba throughout the Subatlantic. A slight rise of the water level has been detected in Lake Dūba at the beginning of this period, while after that the water level dropped again. The deposits of the Late Subatlantic have less planktonic and more epiphytic and benthic diatoms. At the end of the Early Subatlantic, sandy gyttja was replaced by peat with gyttja in Lake Dūba, while in Lake Pelesa gyttja and peat replaced calcareous gyttja at the beginning of the Subatlantic. Both lakes disappeared at the end of the 19th century and only wet land indicates the outlines of the former basins today.

PATTERNS OF VEGETATIONAL CHANGE

The oldest deposits discovered in the Lake Dūba section are of Older Dryas age. The pollen stratigraphy shows that deposits of the Oldest Dryas and of Bölling age are absent in the sections investigated. Earlier investigations, indicate that tundra or forest-tundra vegetation then thrived in southeastern Lithuania (Kabailienė, 1998).

OLDER DRYAS (12300–11900 ^{14}C BP)

Betula, *Pinus*, *Juniperus*, Cyperaceae and *Artemisia* predominate in the pollen spectra of this period. It is most likely that the pine and birch pollen were transported, and only the shrubs and herbs may be assumed to be of local origin. A high representation of Cyperaceae, *Artemisia*, Chenopodiaceae and Poaceae is typical of tundra vegetation (Aleksandrova, 1983). Open tundra-like vegetation, composed of a variety of shrubs and probably with some admixture of birch in the later stage of the period, thrived around Lakes Dūba and Pelesa. A thin bed of organic material dating back to (*e.g.*) 12130±2780 ^{14}C BP (Vs–1092) was investigated at Zervynos, about 17 km NNW from the region investigated (Blažauskas *et al*., 1998). A predominance of open tundra with willows and juniper was typical of neighbouring regions (Pawlikowski *et al.*, 1982; Noryśkiewicz and Ralska-Jasiewiczowa, 1989; Zernitskaya, 1999).

ALLERÖD (11900–10900 ^{14}C BP)

The further development of the vegetation cover mirrors the great changes that took place in the palaeoenvironment throughout the Alleröd. The share of herbs dropped and trees, especially pine, expanded. Already at about (*e.g.*) 11880±150 ^{14}C BP (Vs-952), pine was growing in this region, fossil fragments of this tree having been discovered locally (Stančikaitė *et al*., 1998). Open dry areas were overgrown by juniper. A high representation of juniper before the climatic deterioration of the Younger Dryas was recognised in the Polish Lake District (Ralska-Jasiewiczowa and Latałowa, 1996). Pine predominated in dry land with sandy soils and birches thrived on damp, silty beds or morainic hills. The lake basins were surrounded by a dense willow belt. *Artemisia*, Chenopodiaceae and Cyperaceae formed the underbrush. Open pine/birch forest with rich underbrush vegetation existed from the beginning of the Alleröd in the region investigated.

YOUNGER DRYAS (10900–10000 ^{14}C BP)

The Alleröd forests were transformed by the climatic deterioration of the Younger Dryas, as the climate got colder and dryer (Kabailienė, 1965). The forest cover thinned and mixed herb vegetation explanded. Juniper spread on sandy habitats all over the South-east Plain, including the area investigated. Sandy soils encouraged rapid expansion of different herb vegetation. *Artemisia*, Chenopodiaceae and Poaceae predominated; typical tundra plants such as *Selaginella selaginoides* have been recognised. Pine-birch forests were replaced by open herb vegetation with some tundra elements. The proportion of herbaceous plant pollen decreased during the second part of the Younger Dryas. These changes coincide with the climatic amelioration, which started slightly before the beginning of the Holocene (Walker, 1995).

PREBOREAL (10000–9000 ^{14}C BP)

In the Preboreal, birch first dominated and then was gradually replaced by pine. Open sandy areas were covered by heath. Of significance is the immigration of new tree species such as elm and hazel. A continuous elm curve seems to have formed earlier than (*e.g.*) 9300 ^{14}C BP in this part of Lithuania (Kabailienė *et al.*, 1997). Hazel expansion started with some delay and at about (*e.g.*) 8400 ^{14}C BP this tree was well represented in the area. These data are in good agreement with the results of investigations carried out in north-east Poland where the earliest rise in the *Corylus* pollen curve started at about (*e.g.*) 9300 ^{14}C BP and *Ulmus* spread at about (*e.g.*) 9000 ^{14}C BP (Ralska-Jasiewiczowa, 1983; 1989). The second part of the period is distinguished by the formation of a closed forest canopy. These changes represent climatic amelioration.

BOREAL (9000–8000 ^{14}C BP)

The woodland evolved further in the area throughout the Boreal. Open pine-birch forest thrived at the beginning of the period, and then birch was gradually replaced. The second part of the Boreal shows an increase in hazel representation (Kabailienė, 1998). Wet areas around Lake Dūba and Lake Pelesa favoured the spread of hazel and of alder, the latter expanding at about (*e.g.*) 8300 ^{14}C BP around Lakes Dūba and Pelesa. The end of the Boreal period coincides with the spread of *Tilia* and *Quercus*. Herbs were excluded from the forest and some genus only (Cyperaceae, Poaceae and Chenopodiaceae) survived on the shores.

ATLANTIC (8000–5000 ^{14}C BP)

The pollen composition of the Early Atlantic spectra suggests a culmination of *Alnus* and *Corylus* on wet habitats and *Ulmus* on fertile soils. Elm and hazel superseded birch and

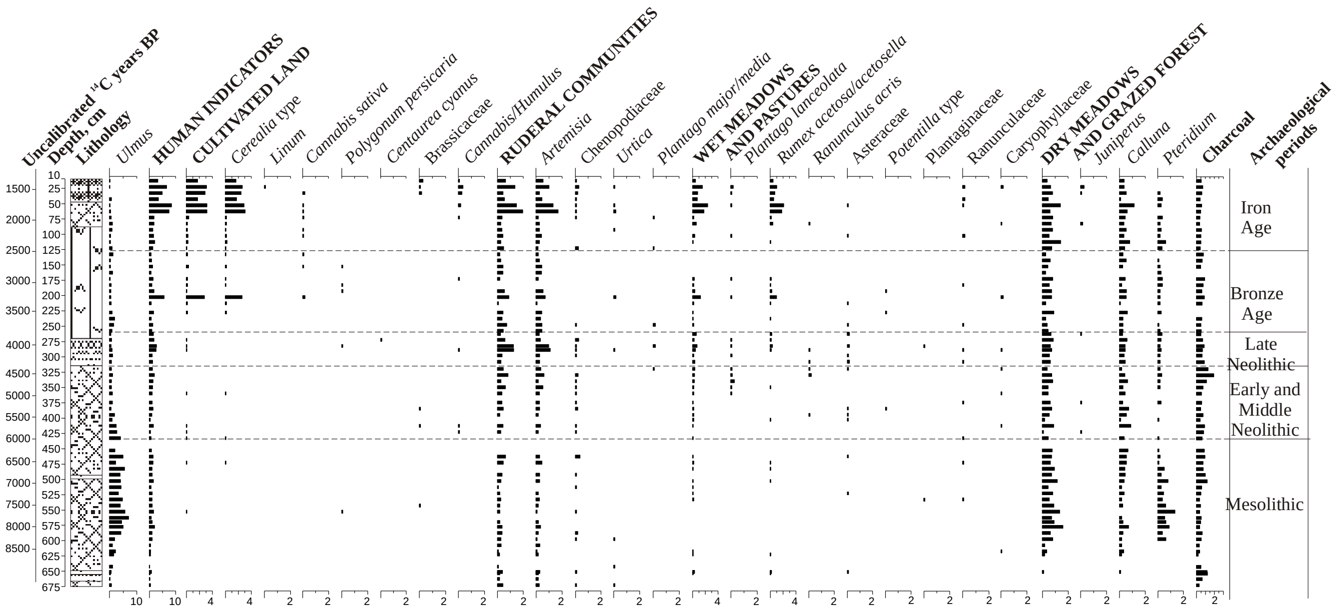

Fig. 7. Human impact diagram from Lake Pelesa

For lithological explanations see Fig. 3

suppressed pine. Otherwise, pine forests were still widely represented in the area, on sandy soils. An increasing representation of heath, likely as underbrush, emphasizes the importance of pine forest in the area. The second part of the Atlantic period is characterised by an increasing role of oak and lime. Generally, a culmination of broad-leaved forests took place in the middle of the Atlantic, at about (*e.g.*) 6600–6800 ^{14}C BP. The local vegetation around Lake Pelesa reflects the formation of forest glades or openings near the shore during the Late Atlantic. These changes were followed by a distinct drop in elm and sometimes lime. Around the lakes, the earliest declines in elm, lime and oak took place at about (*e.g.*) 5500–5700 ^{14}C BP. At the end of the Atlantic, at about (*e.g.*) 5100 ^{14}C BP, *Carpinus* migrated into South-east Lithuania (Kabailienė, 1965; Stančikaitė, 2000). The development of broad leaved trees indicates increasing mean temperatures and humidity during the Atlantic.

SUBBOREAL (5000–2500 ^{14}C BP)

The forest composition changed at the beginning of the Subboreal. A decline in the *QM* constituents was followed by a spread of other tree taxa. Damp habitats were occupied by birch, willow and alder, while the dry areas were overgrown by pine forest with a rich heath underbrush. A spread of spruce was also accelerated by the diminishing role of broad leaved trees. Spruce had earlier, shown slight expansion, which became more pronounced at (*e.g.*) 4500–4700 ^{14}C BP. At about (*e.g.*) 4300 ^{14}C BP broad leaved trees were in continuing decline and pine immediately expanded into the region. There were a few intervals during the Late Subboreal (about (*e.g.*) 3200 ^{14}C BP and (*e.g.*) 2600–2700 ^{14}C BP) when the representation of different herbs, including cultivated plants, increased considerably in the Lake Pelesa region. Changes in the tree pollen composition and in the AP/NAP ratio reveal an opening of the forest during the Late Subboreal. These changes were caused partly by the climatic deterioration and decreasing humidity, though increasing human impact may also have played a part.

SUBATLANTIC (2500–0 ^{14}C BP)

Pine, birch and alder predominated in the forest vegetation during the Subatlantic, while an increasing opening of the landscape is indicated by the NAP evidence. Broad leaved species were still present in the forests, but their value was considerably lower in comparison to earlier periods. The large participation of anthropochors during the second part of the Subatlantic indicates an increasing human impact. Cultivated fields and vegetation typical of disturbed habitats — especially those rich in nitrogen — were common in the area. Willows spread along the lake shores, while the open sandy areas were favourable to juniper. Both species are light-demanding and their occurrence confirms the opening of the area.

HUMAN IMPACT

An integration of the environmental data with archaeological information has served as the main tool for the reconstruction of landscape history and the evaluation of human impact. Human impact diagrams (Figs. 7 and 8) show the levels of human activity during the different periods of prehistory.

Environmental conditions during the warm Late Glacial periods (Bölling and Alleröd) were favourable for the earliest inhabitants. Even throughout the cold Younger Dryas, people lived in Lithuania (Rimantienė, 1996), though there is no palaeobotanical evidence to support this. High representation

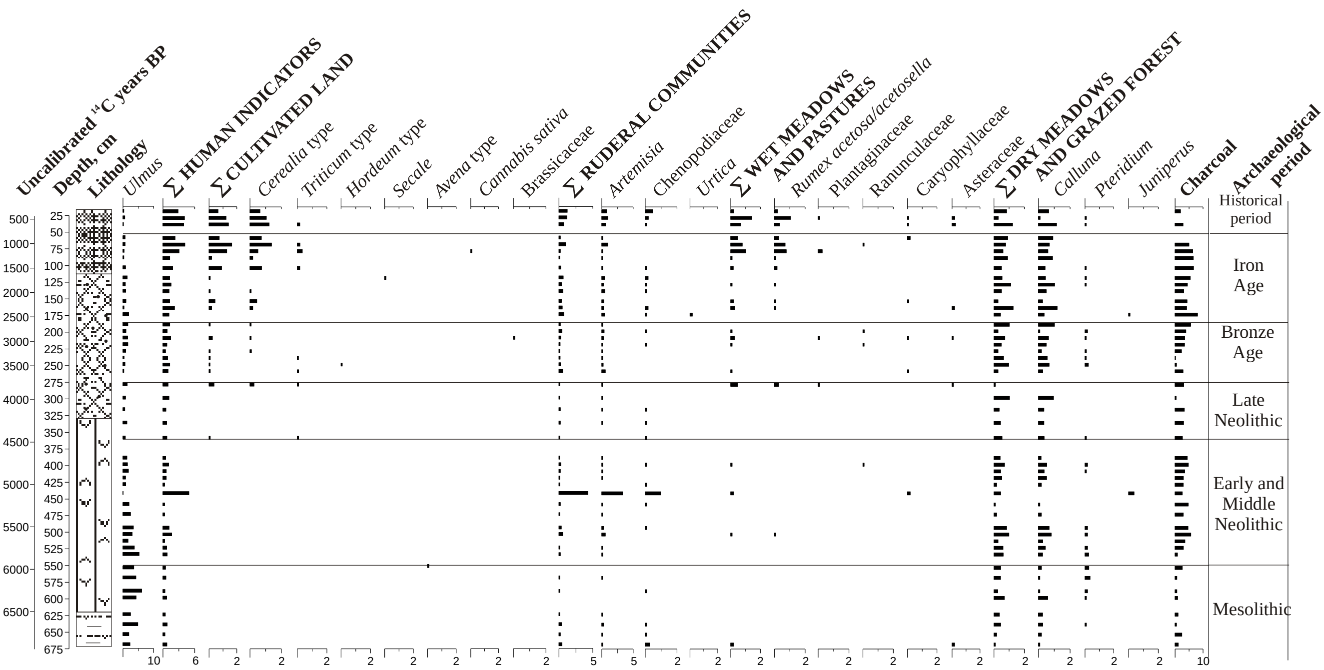

Fig. 8. Human impact diagram from Lake Dūba

For lithological explanations see Fig. 4

of open area indicators may simply be due to the open forest, tundra and forest/tundra vegetation.

MESOLITHIC (> 6000 ^{14}C BP)

The earliest signs of local environmental changes that could be ascribed to human activity occurred at about (*e.g.*) 8400 ^{14}C BP in the Lake Pelesa section (Fig. 7). Even earlier in this section some possible indicators of human activity, (ruderal plants, plants of wet and dry meadows) as well as a thin layer of clastic material, have been found, and these may relate to the numerous Mesolithic sites that occur on the shores of the lakes.

At about (*e.g.*) 8400–8300 ^{14}C BP, changes in the vegetation cover include a sudden spread of *Pteridium*. This plant is interpreted as a species typical of open land or grazed forest and is favoured by fire (Behre, 1981; Berglund, 1985; Peglar, 1993). The abundance of *Pteridium* was long-lived and followed by the spread of *Calluna*. Forest fires and a subsequent thriving of heath, especially in sandy areas, provide a reasonable explanation for these changes (Latałowa, 1992). In Britain and Germany, a spread of heath due to the activity of Mesolithic man has been widely recorded (Robinson, 1987; Kloss, 1990). An increasing number of charcoal particles as well as changes in the tree curves suggest the influence of fire upon the vegetation. The occurrence of *Salix* and spread of *Betula* as well as the drop in *Ulmus* representation are typical of forest clearances and subsequent regeneration (Vuorela, 1986). Woodland disturbances initiated a supply of nutrients that favoured a growth of ruderals — *Artemisia* and Chenopodiaceae. The first grain of *Cerealia* pollen was discovered in sediments deposited at about (*e.g.*) 6500 ^{14}C BP in Lake Pelesa and at about (*e.g.*) 5900 ^{14}C BP in Lake Dūba (Fig. 8). These pollen may have originated from non-cultivated grasses with pollen morphology similar to the *Cerealia* (Beug, 1961; Poska and Saarse, 1999). Otherwise, the earliest grains of *Cerealia* pollen in Lake Woryty in the Lake District in northern Poland are also slightly older then *c.* 5500 BP (Ralska-Jasiewiczowa and Latałowa, 1996). These data suggest a burning of forests and subsequent changes in plant communities that may be related to the activity of Mesolithic man. Conclusions based on pollen data are supported by the archaeological information. A great number of sites attributed to the Mesolithic have been excavated in the area.

EARLY–MIDDLE NEOLITHIC (6000–4400 ^{14}C BP)

Further vegetational changes confirm the increasing human influence on the environment around Lake Dūba (Fig. 8) and Lake Pelesa (Fig. 7). From (*e.g.*) 6000 ^{14}C BP until (*e.g.*) 4400 ^{14}C BP, the number of human indicators increases in both diagrams. The increasing representation of wet meadow and dry pasture indicators as well as the rise in charcoal follow the occurrence of a single grain of *Cerealia* pollen (about (*e.g.*) 6000 ^{14}C BP and (*e.g.*) 5100 ^{14}C BP) in the Lake Pelesa section. The drop in *QM* representation that occurred at about (*e.g.*) 5600 ^{14}C BP was caused by intense human activity. A drop in elm pollen values dating to about (*e.g.*) 5200–5300 ^{14}C BP may correlate with the “classic” *Ulmus* decline registered all over Northwest Europe (Fægri, 1944; Iversen, 1973; Huntley and Birks, 1983). The simultaneous spread of willow and birch is remarkable. Changes in forest composition suggest the formation of forest glades occupied by ruderal and wet meadow plants. At about (*e.g.*) 5000 ^{14}C BP wet and dry pastures spread; the *Plantago lanceolata* pollen curve in particular rises in the Pelesa section. According to Iversen (1973), *Plantago lanceolata* is one of the most important plants in old-fashioned rough pastures, but it will not grow in grazed forests because of its high light requirements. Behre (1981) emphasized that this plant plays an important role in the recolonisation of fallow land and hence is a diagnostic species of an earlier system of rotational farming. Being an indicator of fallow land which usually was used as pasture, *Plantago lanceolata* indirectly indicates former cultivation, which can often be difficult to demonstrate (Behre, 1981, 1986) due to the poor dispersal of *Cerealia* pollen (Vuorela, 1973). Thus, a rather high continuous *Plantago lanceolata* curve indicates cattle breeding and possible cultivation at about (*e.g.*) 5000–4400 ^{14}C BP in the area investigated. The continuous appearance of the earliest cereal pollen in an area just to the south-west, in Poland, also coincides with the Middle Neolithic (Ralska-Jasiewiczowa and Latałowa, 1996). Cattle breeding undoubtedly played a major role in the economy, while crop cultivation also was practised.

LATE NEOLITHIC (4400–3700 ^{14}C BP)

The transition from the Middle to the Late Neolithic — (*e.g.*) 4500–4600 ^{14}C BP coincides with a short-lived drop in human activity around the lakes. In this area the latest stages of the Late Neolithic are mostly represented archaeologically (Rimantienė, 1999). In the Lake Dūba section, a single *Triticum* pollen grain was found in deposits dated back to (*e.g.*) 4400−4500 ^{14}C BP. The subsequent rise in cultivated land and indicators of ruderal communities are dated to about (*e.g.*) 4300 ^{14}C BP in the Pelesa section. The area of wet meadows increased throughout the Late Neolithic. This could be related with a gradual spread of cultivation and the use of former cultivated fields as pasture. Archaeological investigations at the Margiai−1 site were supplemented by an osteological survey that confirmed the presence of domestic animals while some of the artefacts were interpreted as tools used for tillage (Rimantienė, 1999). The deposition of a gyttja layer enriched in clastic material at Lake Dūba confirms active soil erosion probably initiated by human activity. Still, a high representation of dry pastures and grazed forest indicators could be explained on the basis of geological data. Due to the predominance of sandy soils, the area of wet meadows was restricted. In this region of Lithuania, woodland is used for grazing domestic animals even today.

BRONZE AGE (3700–2500 ^{14}C BP)

The transition from the Late Neolithic to the Bronze Age was characterised by some decrease in human activity, with intens colonisation of the territory shortly thereafter. An increase in the pollen of ruderal taxa coincides with the culmination of the charcoal curve, reflecting activity associated with numerous Bronze Age settlements situated in the vicinity of the lakes. Open areas were used for cultivation, as denoted by the occurrence of a continuous *Cerealia* curve since (*e.g.*) 3300–3600 ^{14}C BP onward. Simultaneously, the *Rumex acetosa/acetosella* curve culminates. This plant is an indicator of open disturbed biotopes that occur in cultivated areas and heaths which are being stripped as part of the plaggen process, as well as in newly cleared woodlands (Behre, 1981). Dry pastures must have been fairly common at that time. A remarkable rise of the NAP curve confirms deforestation over large areas. A general opening of the area was followed by the culmination of the *Cerealia* curve up to 2.6 % at about (*e.g.*) 3200–3000 ^{14}C BP, which suggests continuous and intensive cultivation. Cultivation became more and more important. Increasing areas of fallow land were used for cattle breeding and as dry sandy pastures. Gradually increasing agriculture demanded new open areas, and forests were burned.

IRON AGE (2500 ^{14}C BP–800 AD)

Human impact on the environment throughout the first half of the Iron Age (from (*e.g.*) 2500 ^{14}C BP and until (*e.g.*) 1600–1800 ^{14}C BP) was similar to that observed for the Bronze Age. A high representation of ruderal plants and a continuous *Cerealia* curve indicates the existence of settlements and cultivated land nearby. Dry pastures were still present. The subsequent periods of the Iron Age are characterised by a rise in the *Cerealia* curve and an appearance of *Secale* pollen at about (*e.g.*) 1700–1600 ^{14}C BP in the deposits of Lake Dūba. Simultaneously, the charcoal curve increases considerably, which is typical of the active burning of forests and development of slash-and-burn cultivation (Vuorela, 1986). These changes indicate the formation of a cultural landscape with increasing anthropogenic pressure on the environment. Indicators of wet meadows rise together with indicators of cultivated land which together denote cultivation and pastoral activities. The pollen data from this period (except for its early beginning) may be considered as a representation of continuous cultivation and intensive cattle breeding that are also typical for neighbouring countries (Gaillard and Berglund, 1988).

HISTORICAL PERIOD (AFTER 800 AD)

A clear prospering of both crop cultivation and animal husbandry is registered throughout the Historical Period. Strong human impact is seen in AP representation. A drop in nearly all the tree curves undoubtedly was caused by human activity. A high continuous representation of *Cerealia* indicates intensive cultivation and the great number of pasture indicators may be related with the development of various types of pastures. An open landscape including arable plots and open woodland occurred in the area.

CONCLUSIONS

1. Several stages in the development of the palaeobasin that existed beyond the marginal ridge of the Nemunas

(Weichselian) Glaciation and included Lake Dūba and Lake Pelesa have been determined. One basin (+132–+133 m a.s.l.) existed here throughout the Oldest Dryas and the Bölling and was drained at about (*e.g.*) 11900 ^{14}C BP (+127–+128 m a.s.l.). At about 10000 ^{14}C BP, the next drop in the water level took place. The terraces formed after this water level change were destroyed by the Atlantic transgression (<+129 m a.s.l.). The third drop in water level (+124–+125 m a.s.l.) was dated back to the second half of the Subboreal ((*e.g.*) 3700–2500 ^{14}C BP). Both lakes ceased to exist at the end of the 19th century.

2. In the second half of the Boreal (about (*e.g.*) 8400 ^{14}C BP), deciduous trees became a substantial component of the forest. Vegetation changes indicating the formation of open areas and a thinning of the forest in separate plots occurred from the Early Atlantic onward.

3. The earliest small forest changes that may be related to the influence of Mesolithic communities were dated back to (*e.g.*) 8400–8300 ^{14}C BP. Throughout the succeeding stages of the Mesolithic, a continuous and increasing impact of man on to the environment can be detected.

4. The representation of *Cerealia* pollen and continuous *Plantago lanceolata* (since (*e.g.*) 5000 ^{14}C BP) curve suggest the introduction of farming throughout the second part of the Middle Neolithic around Lakes Dūba and Pelesa.

5. An increasing opening of the landscape as well as the rising intensity of cattle breeding and cultivation (a continuous *Cerealia* curve occurred at about ((*e.g.*) 3300–3600 ^{14}C BP) were observed throughout the second part of the Late Neolithic, Bronze Age and the first half of the Iron Age.

6. Since the earlier part of the Iron Age ((*e.g.*) 1600–1800 ^{14}C BP), intensive crop cultivation and animal husbandry took place. Fields and pastures as well as open forest became an important component of the landscape.

Acknowledgements. We thank Dr. P. Šinkūnas, Dr. J. Tamošaitis, P. Aleksa and M. Milkevičius for their help in the field. Our thanks also go to Prof. D. Moe and J. Berg (Institute of Botany, Bergen University) for their assistance with pollen analysis. Anonymous referees are thanked for helpful comments. We thank Dr. I. Antanaitis-Jacobs and J. Zalasiewicz for linguistic revision of the text. Financial support was received from the Lithuanian Science and Studies Foundation whom we gratefully acknowledge.

REFERENCES

ALEKSANDROVA V. (1983) — Vegetation of the northern areas of the Soviet Union (in Russian). Nauka.

AABY B. (1986) — Trees as anthropogenic indicators in regional pollen diagrams from western Denmark. In: Anthropogenic Indicators in Pollen Diagrams (ed. K. -E. Behre). Balkema.

BALTRŪNAS V., VONSAVIČIUS V., MIKALAUSKAS A., JURGAITIS A. and MELEŠYTĖ M. (1984) — About the limit of the Last Glaciation in South-east Lithuania (in Russian). In: Paleogeography and Stratigraphy of the Quaternary Period in Baltic States and Surrounding Regions. Mokslas. Vilnius.

BALTRŪNAS V. (2001) — Stone Age in South Lithuania (in Lithuanian with English summary). Vilnius.

BASALYKAS A. (1958) — The physical geography of Lithuania. I part (in Lithuanian). Mokslas. Vilnius.

BASALYKAS A. (1965) — The physical geography of Lithuania. II part (in Lithuanian). Mokslas. Vilnius.

BATTARBEE R. W. (1986) — Diatom analysis. In: Handbook of Holocene Palaeoecology and Palaeohydrology: 527–570 (ed. B. E. Berglund). John Wiley and Sons. Chichester.

BEHRE K. -E. (1981) — The interpretation of anthropogenic indicators in pollen diagrams. Pollen and Spores., **23** (2): 225–245.

BEHRE K. -E. (1986) — Anthropogenic indicators in pollen diagrams. Balkema. Rotterdam.

BEHRE K. -E. (1988) — The role of man in European vegetation history. In: Vegetation History: 633–672 Handbook of vegetation science 7 (eds. B. Huntley and T. Webb III). Kluwer, Dordrecht.

BERGLUND B. E. (1985) — The early agriculture in Scandinavia. Norw. Archaeol. Rev., **18**: 77–105.

BERGLUND B. E. and RALSKA-JASIEWICZOWA M. (1986) — Pollen analyses and pollen diagrams. In: Handbook of Holocene Palaeoecology and Palaeohydrology: 455–484 (ed. B. E. Berglund). John Wiley and Sons. Chichester.

BEUG H. J. (1961) — Leitfaden der Pollenbestimmung für Mitteleuropa und angrenzende Gebiete. Lieferung 1. Fisher, Stuttgart.

BLAŽAUSKAS N., KISIELIENĖ D., STANČIKAITĖ M., KUČINSKAITĖV., ŠEIRIENĖ V. and ŠINKŪNAS P. (1998) — Late Glacial and Holocene sedimentary environment in the region of Ūla River. Geologija, **25**: 20–30.

ERDTMAN G. (1936) — New methods in pollen analysis. Svensk Bot. Tidsskr., **30**:154–164.

FÆGRI K. (1944) — On the introduction of agriculture in western Norway. Geol. Fören Förhandl. Stock., **66**: 449–462.

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

GAILLARD M. -J. and BERGLUND B. E. (1988) — Land-use history during the last 2700 years in the area of Bjoresjo, Southern Sweden. In: The Cultural Landscape — Past, Present and Future (eds. H. H. Birks *et al*.) Cambridge Univ. Press. 409–429.

GRICHIUK V. P. (1940) — Processing of deposits poor in organic material for pollen analysis. In: Problems of the Physical Geography. Moscow.

GRIMM E. C. (1990) — TILIA and TILIA. GRAPH: PC spreadsheet and graphics software for pollen data. INQUA Commission for the Study of the Holocene, Working Group on Data-Handling Methods. Newsletter, **4**: 5–7.

GRIMM E. C. (1992) — TILIA and TILIA. GRAPH: PC spreadsheet and graphics program. 8th International palynological Congress. Program and abstracts. Aix-en-Provence, France. P. 56.

HUNTLEY J. and BIRKS H. J. B. (1983) — An atlas of past and present pollen maps for Europe: 0–13.000 years ago. Cambridge University Press. Cambridge.

HUSTEDT N. (1991) — Die Kieselalgen. Deutschlands, Österreichs und der Schweiz unter Berücksichtigung der übrigen Länder Europas sowie der angrenzenden Meeresgebiete. Bremen.

ISAENKO V. F. (1976) — The Neolithic in the Polessye of Pripiat (in Russian). Kiev.

IVERSEN J. (1973) — The development of Denmark's nature since the Last Glacial. Danm. Geol. Unders., V, **7-C**.

KABAILIENĖ M. (1965) — Some questions on stratigraphy and palaeogeography of Holocene in SE Lithuania (in Russian). In: Stratigraphy of Quaternary Deposits and Palaeogeography of SE Lithuania. Proce. Geol. Inst., **2**: 302–355.

KABAILIENĖ M. (1969) — Formation of the pollen spectra and reconstruction of palaeoflora. Proce. Geol. Inst., **11**.

KABAILIENĖ M. (1990) — Holocene of Lithuania (in Lithuanian). Mokslas. Vilnius.

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

KABAILIENĖ M., STANČIKAITĖ M. and OSTRAUSKAS T. (1997) — Living conditions and activity of man in the environs of Lake Grūda in the end of Late Glacial and Holocene. Geologija, **21**: 32–43.

KLOSS K. (1990) — Anthropogenic indicators in early Mesolithic vegetation in north-east Germany. Abstracts of lectures and posters, Symposium 15–17.09.1990 in Wilhelmshaven, INQUA — Commission for the study of the Holocene, Working group: Impact of Prehistoric and Medieval Man on Vegetation. P. 2.

KRAMMER K. and LANGE-BERTALOT H. (1988) — Bacillariophyceae. 2. Teil: Bacillariaceae, Epithemiaceae, Surirellaceae. In: Süßwasserflora von Mitteleuropa 2/2. (eds. Ettl H. *et al*.), Stuttgart. Gustav Fischer Verlag.

KRAMMER K. and LANGE-BERTALOT H. (1991*a*) — Bacillariophyceae. 3. T0eil: Centrales, Fragilariaceae, Eunotiaceae. In: Süßwasserflora von Mitteleuropa 2/3. (eds. Ettl H. *et al*.), Stuttgart. Gustav Fischer Verlag.

KRAMMER K. and LANGE-BERTALOT H. (1991*b*) — Bacillariophyceae. 4. Teil: Achnanthaceae. Kritische Ergänzungen zu Navicula (Lineolate) und Gomphonema. In: Süßwasserflora von Mitteleuropa 2/4. (eds. Ettl H. *et al*.), Stuttgart. Gustav Fischer Verlag.

KRAMMER K. and LANGE-BERTALOT H. (1997) — Bacillariophyceae. 1. Teil: Naviculaceae. In: Süßwasserflora von Mitteleuropa 2/1. (eds. Ettl H. *et al*.), Stuttgart. Gustav Fischer Verlag.

LATAŁOWA M. (1992) — Man and vegetation in the pollen diagrams from Wolin Island (NW Poland). Acta Palaeobotanica, **32** (1): 123–249.

MANGERUD J., SVEND T., BERGLUND E. B. and 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. and COLLINSON M. E. (1991) — Pollen analysis. Oxford; Blackwell.

NORYŚKIEWICZ B. and RALSKA-JASIEWICZOWA M. (1989) — Type region P-W: Dobrzyń-Olsztyn Lake Districts. Acta Palaeobot., **29** (2): 85–93.

OSTRAUSKAS T. (1998) — Some aspects about the development of the human economy in Lithuania (2000 BP) (in Russian). "Trzciniec": system kulturowy czy interkulturowy proces: 269–271. Poznań.

OSTRAUSKAS T. (2000) — Mesolithic Kunda culture. A glimpse from Lithuania. Muinasaja teadus., **8**: 167–180.

PAWLIKOWSKI M., RALSKA-JASIEWICZOWA M., SCHÖNBORN W., STUPNICKA E. and SZEROCZYŃSKA K. (1982) — Woryty near Gierzwałd, Olsztyn Lake District, NE-Poland — vegetation history and lake development during the last 12 000 years. Acta Palaeobot., **22** (1): 85–116.

PEGLAR S. M. (1993) — The development of the cultural landscape around Diss Mere, Norfolk, UK during the past 7000 years. Rev. Palaeobot. Palynol., **76**: 1–47.

POSKA A. and SAARSE L. (1999) — Holocene vegetation and land-use history in the environs of Lake Kahala, northern Estonia. Veget. Hist. Archaeobot., **8**: 185–197.

RALSKA-JASIEWICZOWA M. (1983) — Isopollen maps for Poland: 0–11 000 years B. P. New Phytol., **94**: 133–175.

RALSKA-JASIEWICZOWA M. (1989) — Type region P-x: Masurian Great Lakes District. Acta Palaebot., **29** (2): 95–100.

RALSKA-JASIEWICZOWA M. and LATAŁOWA M. (1996) — Poland. In: Palaeoecological Events During the Last 15000 Years: Regional Syntheses of Palaeoecological Studies of Lakes and Mires in Europe (eds. B. E. Berglund *et al*.). 403–472.

RIMANTIENĖ R. (1971) — The Palaeolithic and Mesolithic in Lithuania (in Russian with German and Lithuanian summaries). Vilnius.

RIMANTIENĖ R. (1994) — Die Steinzeit in Litauen. Bericht der Römish — Germanishen Kommission 75. Main am Rein. 23–198.

RIMANTIENĖ R. (1996) — Stone Age in Lithuania. 2nd edition (in Lithuanian with English summary). Vilnius.

RIMANTIENĖ R. (1999) — Margiai 1 site (in Lithuanian with Russian and English summaries). Lithuania archaeology., **16**: 109–170.

ROBINSON D. E. (1987) — Investigations into the Aukhorn mounds, Keiss, Caithness: pollen, plant macrofossil and charcoal analysis. New Phytol., **106**: 185–200.

SAVUKYNIENĖ N. (1974) — Die Entwicklung der Synantropischen vegetation im Südöstlichen Litauen (in Lithuanian with Russian and German summaries). Geographisches Jahrbuch., **13**. 37–48.

SAVUKYNIENĖ N. (1976) — Die Entwiklungszüge des Ackerbaus in der Ungebung vom Čepkeliai–Moor (in Lithuanian with Russian and German summaries). Geographisches Jahrbuch., **14**. 169–175.

SEIBUTIS A. (1974) — Das Rätsel der Entstehung von interstadialischen schichten in âlaTal (in Lithuanian with Russian and German summaries). Geographisches Jahrbuch., **13**. 23–36.

SEIBUTIS A. and SUDNIKAVIČIENĖ F. (1960) — Über den Beginn der holozäne Moorentschtehung in Litauen. (in Lithuanian with Russian and German summaries). Geographisches Jahrbuch. III. Vilnius. 299–263.

SEIBUTIS A. and SAVUKYNIENĖ N. (1998) — A review of major turning points in the agriculture history of the area inhabited by the Baltic peoples, based on palynological, historical and linguistic data. PACT, **54**: 51–60.

STANČIKAITĖ M. (2000) — Natural and human initiated environmental changes throughout the Late Glacial and Holocene in Lithuania territory. Abstract of doctoral dissertation 2000. Vilnius.

STANČIKAITĖ M., ŠEIRIENĖ V. and ŠINKŪNAS P. (1998) — New results of Pamerkys outcrop investigations, South Lithuania. Geologija., **23**: 77–88.

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

SZUKIEWICZ W. (1893) — A paper of W. Szukiewicz about archaeological sites in Lida and Trakai districts (in Russian). In: Proceedings of Vilnius Department of Moscow's Preliminary Committee for Preparation of the IX Archaeological Congress in Vilnius. Vilnius.

SZUKIEWICZ W. (1907) — Poszukiwania archeologiczne w powiecie Lidzkim gub. Wileńskiej. Materiały Komisji antropolog.-archeolog. i etnogr. Akademii Umiejętności w Krakowie, **10**.

TOLONEN M. (1986) — Charred paricle analysis. In: Handbook of Holocene Palaeoecology and Palaeohydrology: 485–496. (ed. B. E. Berglund). John Wiley and Sons.

VESKI S. (1998) — Vegetation history, human impact and palaeogeography of western Estonia. Pollen analytical studies of lake and bog sediments. Striae., **38**.

VUORELA I. (1973) — Relative pollen rain around cultivated fields. Acta Botan. Fen., **102**: 1–27.

VUORELA I. (1986) — Palynological and historical evidence of slash-and-burn cultivation in South Finland. In: Anthropogenic Indicators in Pollen Diagrams: 53–64 (ed. K. -E. Behre). Balkema, Rotterdam.

WALKER M. J. C. (1995) — Climatic changes in Europe during the last Glacial/Interglacial transition. Quatern. Internat., **28**: 63–76.ZALIZNYAK L. L. (1991) — Population of the Polessye in Mesolithic (in Russian). Kiev.

ZALIZNYAK L. L. (1995) — The Swidrian Reindeer-Hunters of Eastern Europe. Beiträge zur Ur-und Frühgeschichte Mitteleuropas **5**. Wilkau-Hasslau.

ZERNITSKAYA V. P. (1999) — Stratigraphy of the Late – Glacial and Holocene of Belarus. Fourth Baltic stratigraphical Conference. Abstracts. 112–113.