XXXV MOOREXCURSION

of the INSTITUTE OF PLANT SCIENCES
UNIVERSITY OF BERN
Department of Biogeography and Paleoecology
Adam Mickiewicz University, Poznań, Poland

NE POLAND

AUGUST 21 – 28 2011

EXCURSION GUIDE

Krystyna Milecka, Krystyna Szeroczyńska, Kazimierz Tobolski, Adam Walanus, Danuta Drzymulska, Natalia Piotrowska, Izabela Zawiska, Mariusz Gałka,

List of participants

Bas van Geel
Research Group Paleoecology and Landscape Ecology
Faculty of Science, Universiteit van Amsterdam
Visiting address: Science Park 904, 1098 XH Amsterdam
Postal address: P.O. Box 94248, 1090 GE Amsterdam, The Netherlands

Willy Tinner
Institute of Plant Sciences, University of Bern
Altenbergrain 21, CH-3013 Bern, Switzerland

Pim van der Knaap
Institute of Plant Sciences, University of Bern
Altenbergrain 21, CH-3013 Bern, Switzerland

Jacqueline van Leeuwen
Institute of Plant Sciences, University of Bern
Altenbergrain 21, CH-3013 Bern, Switzerland

Julian Wiethold
Chargé opération et recherche
Institut national de recherches archéologiques préventives (INRAP)
Direction interrégionale Grand-Est Nord
Laboratoire archéobotanique 12, rue de Méric, CS 80005, F-57063 Metz cedex 2, France

Ruth Drescher-Schneider
Institut of Plant Sciences, Karl-Franzes-University,
Holteigasse 6, 8010 Graz, Austria

Anton Drescher
Institut of Plant Sciences, Karl-Franzes-University,
Holteigasse 6, 8010 Graz, Austria

Christoph Schwörer
Oeschger Centre for Climate Change Research & Institute of Plant Sciences
University of Bern, Altenbergrain 21, CH-3013 Bern, Switzerland

Karl-Ernst Behre
Niedersaechsisches Institut fuer historische Kuestenforschung
Viktoriastrasse 26-28, D-26382 Wilhelmshaven

Adam Hölzer
Staatliches Museum für Naturkunde - Botanik und Herbarium -
Erbprinzenstr. 13, D-76133 Karlsruhe, Germany

Vlasta Jankovska
Institute of Botany, Academy of Sciences of the Czech republic,
Lidicka 25/27, 602-00 Brno, Czech Republic

Andreas Grűnig
Federal Department of Economic Affairs DEA
Agroscope Reckenholz-Tänikon Research Station ART

Noëmi Zweifel
Institute of Plant Sciences, University of Bern
Altenbergrain 21, CH-3013 Bern, Switzerland

Fabian Rey
Institute of Plant Sciences, University of Bern
Altenbergrain 21, CH-3013 Bern, Switzerland

Milena Obremska
Institute of Geological Sciences, Polish Academy of Sciences,
Twarda 51/55, 00-818 Warszawa, Poland

Invited speakers

Krystyna Szeroczyńska
Institute of Geological Sciences, Polish Academy of Sciences,
Twarda 51/55, 00-818 Warszawa

Izabela Zawiska
Institute of Geography and Spatial Management, Polish Academy of Sciences,
Twarda 51/55, 00-818 Warszawa

Danuta Drzymulska
Institute of Biology, University in Białystok
Świerkowa 20B, 15-950 Białystok

Natalia Piotrowska
Institute of Physics, Centre for Science and Education Silesian University of Technology
ul. Bolesława Krzywoustego 2, 44-100 Gliwice

Adam Walanus
Faculty of Geology, Geophysics and Environment Protection, University of Science and Technology
Mickiewicza 30, 30-059 Kraków

Kazimierz Tobolski
Mariusz Gałka
Krystyna Milecka
Departament of Biogeography and Paleoecology, Adam Mickiewicz University
Dzięgielowa 27, 61-680 Poznań

Itinerary

SUNDAY 21.08.2011
Arrival to Warsaw (plane or train)
17.00 bus from Central Warsaw Railway station
18.00 bus from Okecie Airport
Travel to Plock ~ 2 h
Dinner and welcome meeting at the Hotel Soczewka

MONDAY 22.08.2011
Lake Gościąż
8.00 breakfast
9.00 leaving for the Lake Gościąż
Pollen analysis, Cladocera analysis, isotopes, chronology
Responsible: Adam Walanus, Krystyna Szeroczyńska, Krystyna Milecka
12.30 lunch
13.30 departure to Białowieza
20.30 dinner
Accommodation: Guest rooms BNP

TUESDAY 23.08.2011
Białowieża Forest
8.00 breakfast
9.00 excursion to Białowieża Primeval Forest (*Tilio-Carpinetum*, *Sphagno girghensoni-Piceetum*, mires of Białowieza Forest:)
Pollen analysis, macrofossils, chronology
Responsible: Krystyna Milecka
13.00 lunch in the field
19.00 dinner
Accommodation: Guest rooms BNP

WEDNESDAY 24.08.2011
Białowieza Forest, animals protected by law: European bison and European lynx
8.00 breakfast
9.30 meeting in Mammal Research Institute
11.00 European Bison Show Reserve
13.00 lunch
14.15 Nature-Forest Museum
16.15 trip to Hajnowka (Eastern Orthodox Church) – optionally
Responsible: Rafal Kowalczyk, Krystyna Milecka
Accommodation: Guest rooms BNP

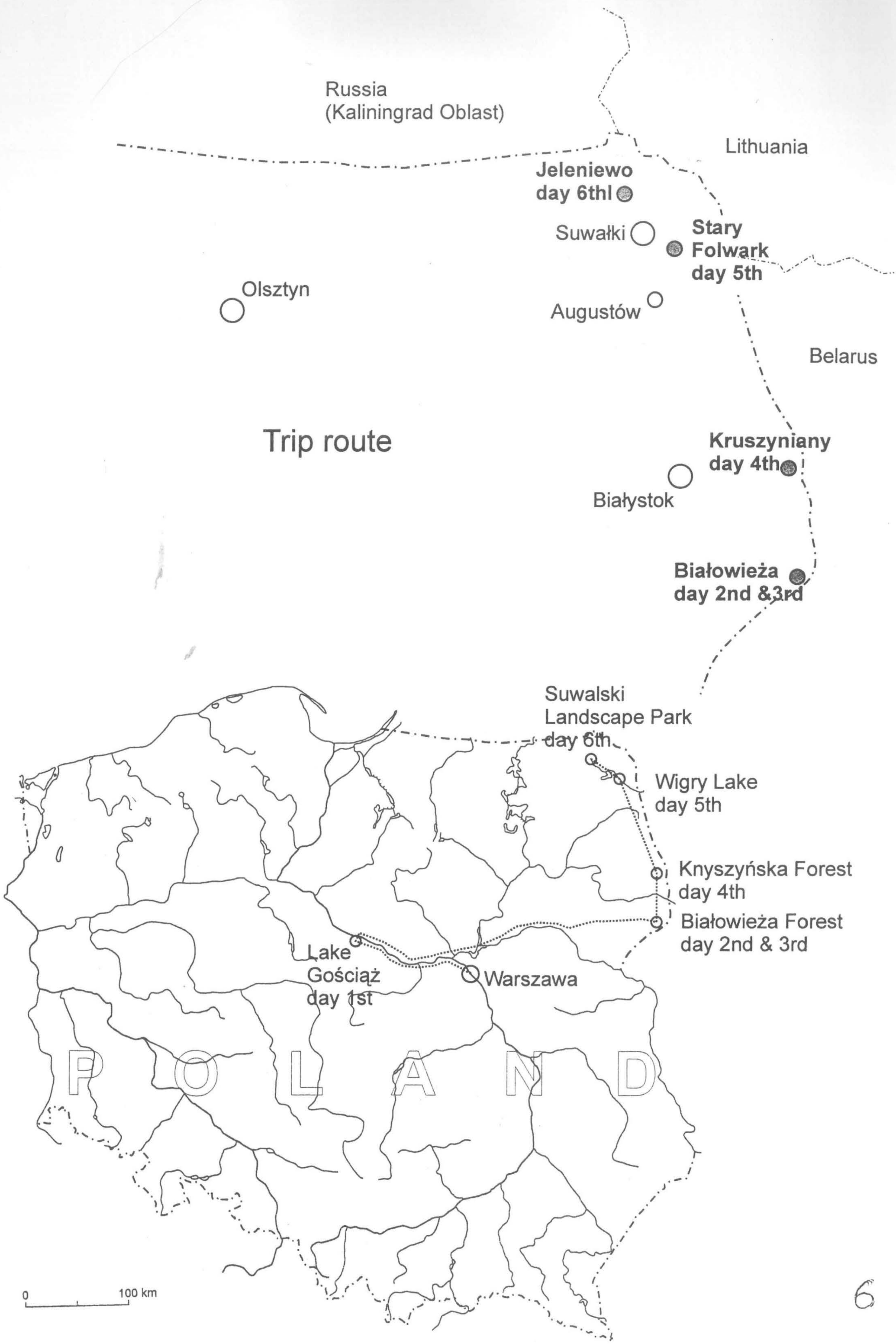
THURSDAY 25.08.2011
Knyszynska Forest
7.00 breakfast
8.00 departure to Knyszyńska Forest
9.30 Lake Gorbacz, raised bog
Palynology, macrofossils, chronology,
12.00 Kruszyniany – Tatar settlement, mosque
13.15 lunch, restaurant "Pod lipami"

15.30 mires Taboly and Kladkowe Bagno
Palynology, macrofossils, chronology
Responsible: Danuta Drzymulska,
17.30 departure to Stary Folwark
20.00 dinner – grill/campfire (depending on the weather)
Accommodation: hotel Holiday, Stary Folwark

FRIDAY 26.08.2011
Lake Wigry
8.00 breakfast
9.15 Lake Wigry,
Palynology, macrofossils, Cladocera, isotopes and chronology
Responsible: Lech Krzysztofiak, Izabela Zawiska, Danuta Drzymulska, Natalia Piotrowska, Krystyna Milecka
13.00 lunch
14.00 Wigry Museum
16.00 maiden voyage by „Kamedula" on Lake Wigry (depending on the weather)
18.30 dinner
Accommodation: hotel Holiday, Stary Folwark

SATURDAY 27.08.2011
Suwalski Landscape Park (SLP)
7.30 breakfast
8.30 departure to SLP
Lake Linowek
Lake Hańcza
13.30 lunch in Jeleniewo
Lake Kojle Perty:
sediments, palinology, macrofossils, Cladocera, chronology,
responsible: Kazimierz Tobolski, Mariusz Galka, Krystyna Milecka
19.00 dinner
Accommodation: hotel Holiday, Stary Folwark

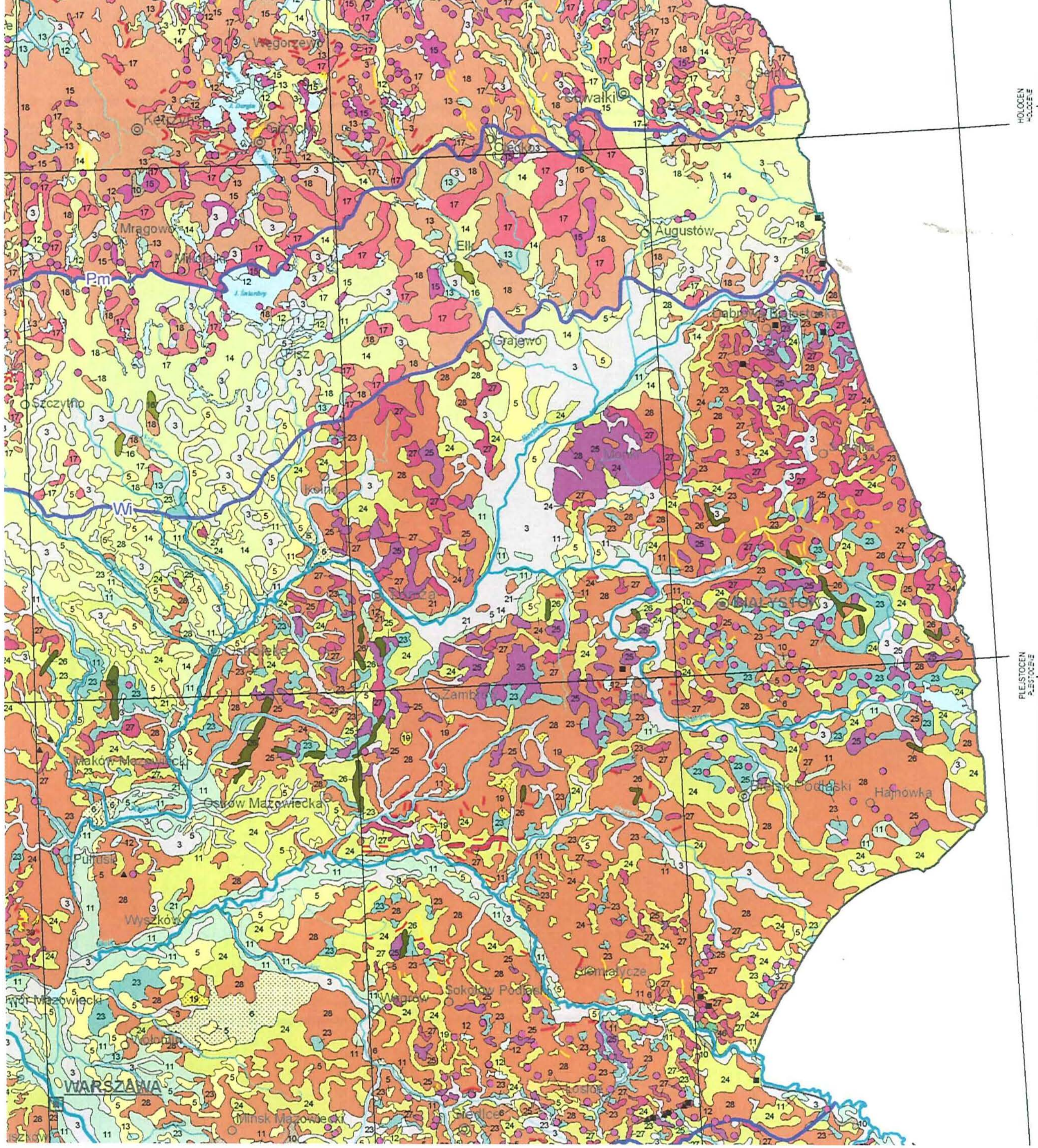
SUNDAY 28.08.2011
7.00 breakfast
8.00 departure to Warsaw (ca 6 h)



Russia
(Kaliningrad Oblast)
Lithuania
Jeleniewo
day 6thl
Suwałki
Stary
Folwark
day 5th
Olsztyn
Augustów
Belarus
Trip route
Kruszyniany
day 4th
Białystok
Białowieża
day 2nd &3rd
Suwalski
Landscape Park
day 6th
Wigry Lake
day 5th
Knyszyńska Forest
day 4th
Białowieża Forest
day 2nd & 3rd
Lake
Gościąż
day 1st
Warszawa
P O L A N D
0
100 km

Introduction to NE Poland

Geology
Geomorphology
Climate
Distribution of mires and lakes
Geobotanical division
Flora and vegetation
Isopollen maps
Boreal fauna

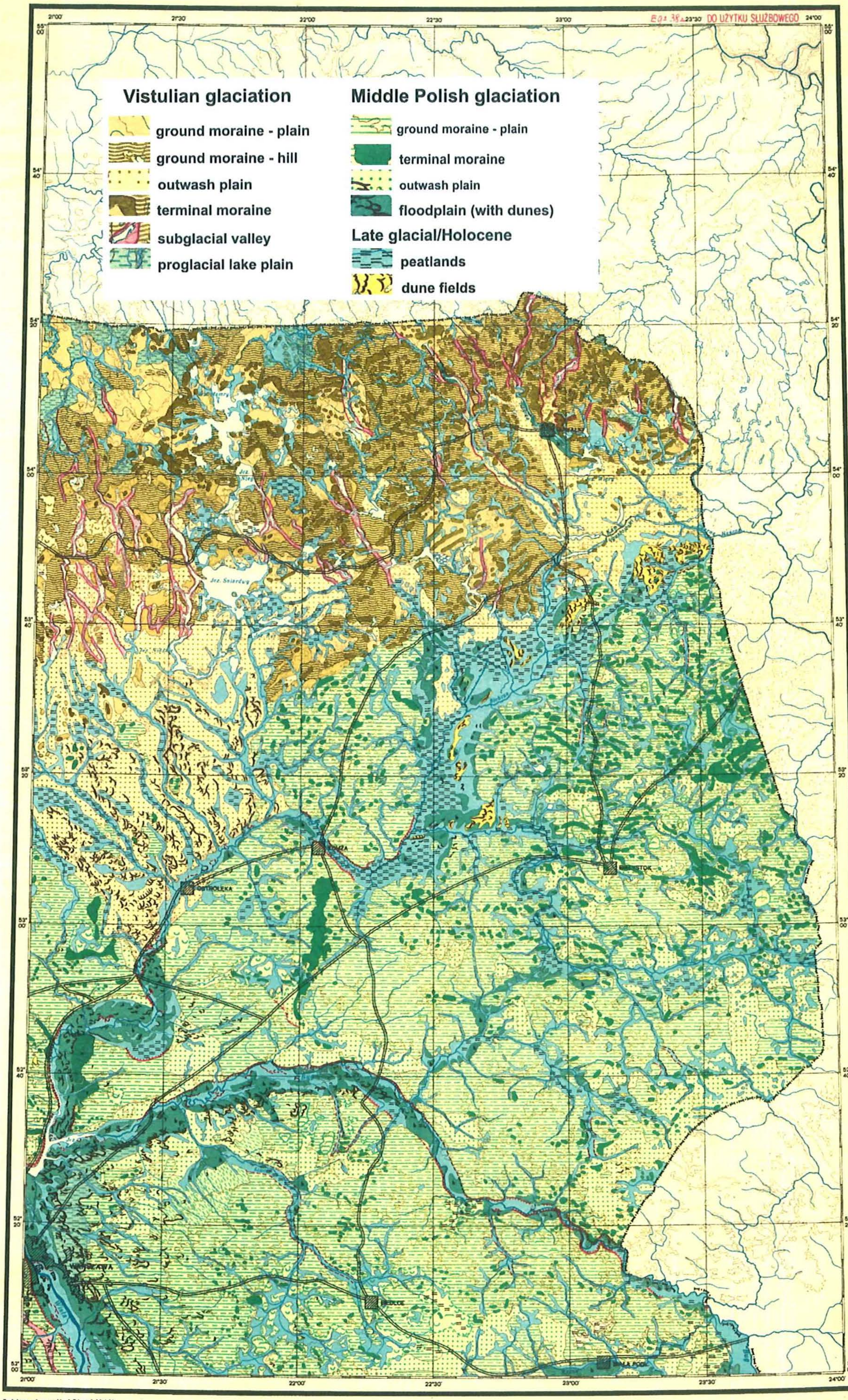


HOLOCEN / HOLOCENE	1	Piaski, mułki, iły i gytie jeziorne / *Lake sands, silts, clays and gyttjas*	
	2	Mułki, piaski i żwiry morskie / *Marine silts, sands and gravels*	
	3	Piaski, żwiry, mady rzeczne oraz torfy i namuły / *Fluvial sands, gravels, muds, peats and organic silts*	
	4	Koluwia osuwiskowe / *Landslide colluvium*	
	5	Piaski eoliczne, lokalnie w wydmach / *Eolian sands, locally in dunes*	
	6	Piaski i żwiry stożków napływowych / *Alluvial fan sands and gravels*	
	7	Piaski, żwiry i rumosze skalne stożków usypiskowych i tarasów kemowych w Karpatach / *Sands, gravels and rock rubbles scree fans and kame terraces in the Carpathians*	
	8	Lessy / *Loess*	
	9	Lessy piaszczyste i pyły lessopodobne / *Sandy loess and loess-like silts*	
PLEJSTOCEN / PLEISTOCENE	10	Gliny, piaski i gliny z rumoszami, soliflukcyjno-deluwialne / *Deluvial loams, sands and loams with rock rubbles*	
	11	Piaski, żwiry i mułki rzeczne / *Fluvial sands, gravels and silts*	ZLODOWACENIA PÓŁNOCNOPOLSKIE / NORTH POLISH GLACIATIONS
	12	Piaski i mułki jeziorne / *Lake sands and silts*	
	13	Iły, mułki i piaski zastoiskowe / *Ice-dam clays, silts and sands*	
	14	Piaski i żwiry sandrowe / *Outwash sands and gravels*	
	15	Piaski i mułki kemów / *Kame sands and silts*	
	16	Piaski, mułki i żwiry ozów / *Esker sands, silts and gravels*	
	17	Żwiry, piaski, głazy i gliny moren czołowych / *End moraine gravels, sands, boulders and tills*	
	18	Gliny zwałowe, ich zwietrzeliny oraz piaski i żwiry lodowcowe / *Tills, weathered tills, glacial sands and gravels*	
	19	Torfy, gytie, kreda jeziorna, iły, mułki oraz piaski, żwiry i mułki rzeczno-jeziorne / *Peat, gyttjas, lake chalk, clays, silts and sands, fluvioalcustrine gravels and silts*	INTERGLACJAŁ EEMSKI / EEMIAN INTERGLACIAL
	20	Piaski i żwiry stożków napływowych / *Alluvial fan sands and gravels*	ZLODOWACENIA ŚRODKOWOPOLSKIE / MIDDLE POLISH GLACIATIONS
	21	Piaski, żwiry i mułki rzeczne / *Fluvial sands, gravels and silts*	
	22	Piaski i mułki jeziorne / *Lake sands and silts*	
	23	Iły, mułki i piaski zastoiskowe / *Ice-dam clays, silts and sands*	
	24	Piaski i żwiry sandrowe / *Outwash sands and gravels*	
	25	Piaski i mułki kemów / *Kame sands and silts*	
	26	Piaski, mułki i żwiry ozów / *Esker sands, silts and gravels*	
	27	Żwiry, piaski, głazy i gliny moren czołowych / *End moraine gravels, sands, boulders and tills*	
	28	Gliny zwałowe, ich zwietrzeliny oraz piaski i żwiry lodowcowe / *Tills, weathered tills, glacial sands and gravels*	

INSTYTUT GEOGRAFII
I PRZESTRZENNEGO ZAGOSPODAROWANIA PAN

PRZEGLĄDOWA MAPA GEOMORFOLOGICZNA POLSKI

ARKUSZ WARSZAWA



Redaktor arkusza: Józef Edward Mojski
Autorzy: H. Maruszczak, J. E. Mojski, S. Piętkiewicz
Wykorzystano także materiały H. Bałuk, A. Bera, M. Domosławskiej-Baranieckiej, M. Bogackiego, J. Kondrackiego, S. Masłoka, Z. Michalskiej, J. Nowak, A. Nowickiego, Z. Sarnackiej, W. Słowańskiego, K. Straszewskiej

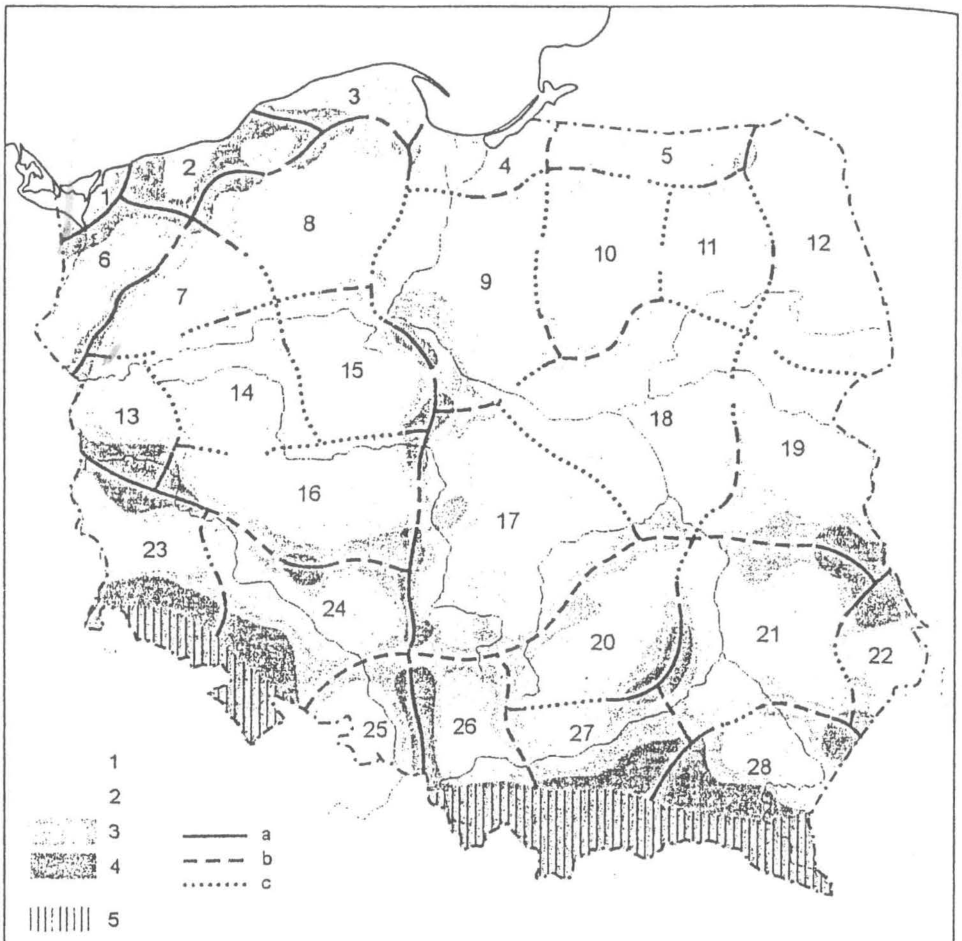
km 10 0 5 10 20 30 km

Climate

Woś A. 2010. Klimat Polski w drugiej połowie XX wieku. (Climate of Poland in second half of XXth century). Wydawnictwo Naukowe UAM, Poznań.

NE Poland - climatic region 12:

- least number of sunny days
- the coldest region in Poland, mean annual temperature is only 6,7°C
- the highest amplitude of mean monthly temperatures 21,4°C
- mean, annual total cloud cover is 67%
- mean, annual vapour pressure is 8,9 hPa (the lowest in Poland)
- mean, annual number of days with snow cover is 86 (the highest in Poland)

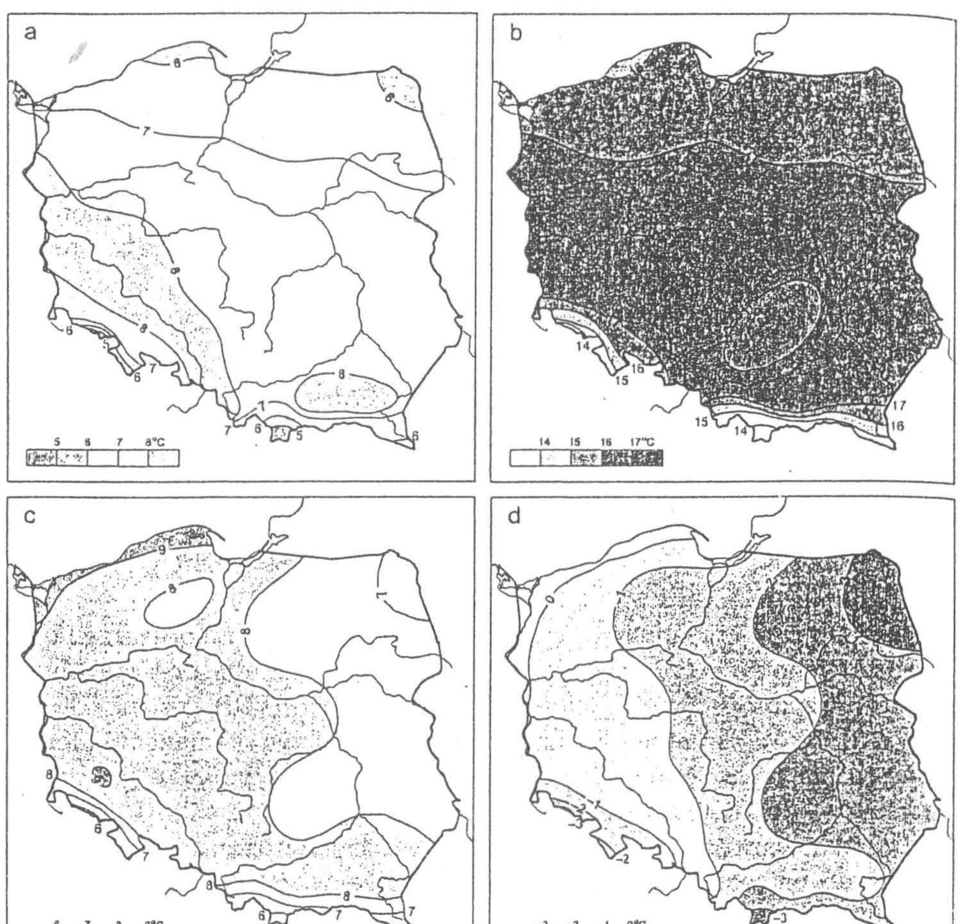


Ryc. 7.4. Regiony klimatyczne Polski. Strefy o różnej zmienności częstości występowania poszczególnych typów pogody: 1 - bardzo mała, 2 - mała, 3 - duża, 4 - bardzo duża, 5 - obszary górskie; granice regionów: a - bardzo wyraźne, b - wyraźne, c - mało wyraźne

Fig. 7.4. Climatic regions of Poland. Zones of variability of the frequency of the particular weather types: 1 - very low, 2 - low, 3 - high, 4 - very high, 5 - mountain areas; boundaries of regions: a - very distinct, b - distinct, c - indistinct

Ryc. 4.1. Średnia roczna temperatura powietrza [°C]. Dane z lat 1951-2000

Fig. 4.1. Mean annual air temperature [°C]. Data for the years 1951-2000



Ryc. 4.2. Średnia temperatura powietrza w kalendarzowych porach roku [°C]: a - wiosna (III-V), b - lato (VI-VIII), c - jesień (IX-XI), d - zima (XII-II). Dane z lat 1951-2000

Fig. 4.2. Mean air temperature in calendar seasons [°C]: a - spring (III-V), b - summer (VI-VIII), c - autumn (IX-XI), d - winter (XII-II). Data for the years 1951-2000

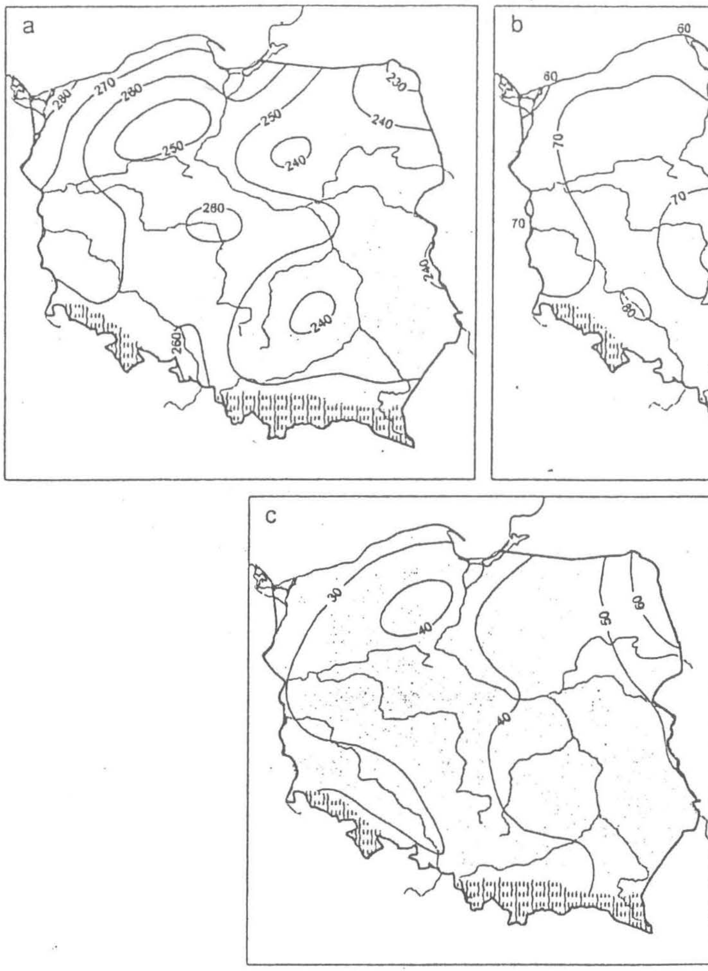


Fig. 4.5. Mean annual number of days: a – warm, b – with ground frost, c – with frost. Data for the years 1951–2000

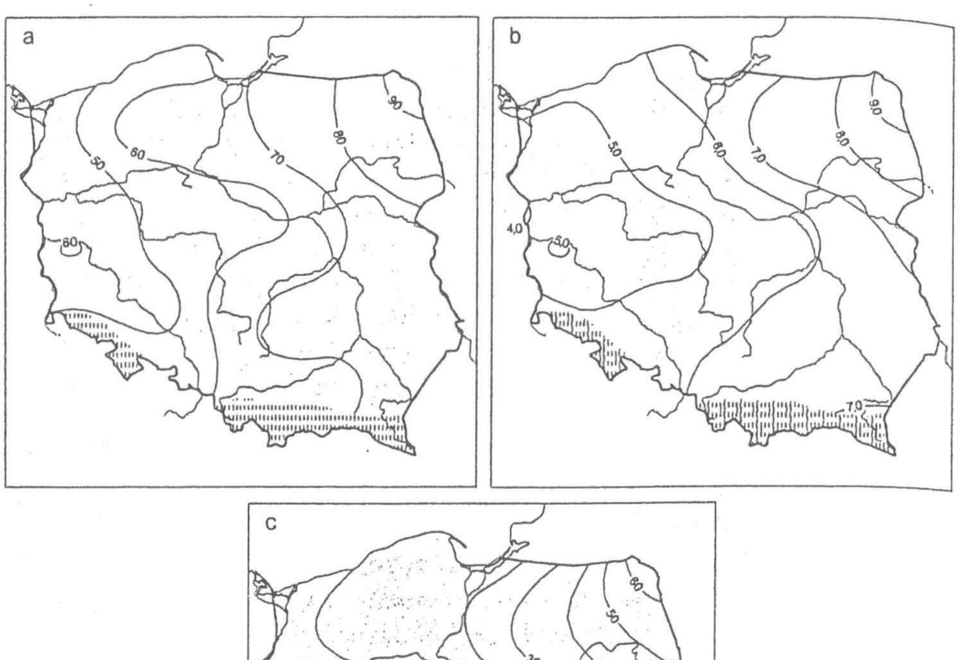
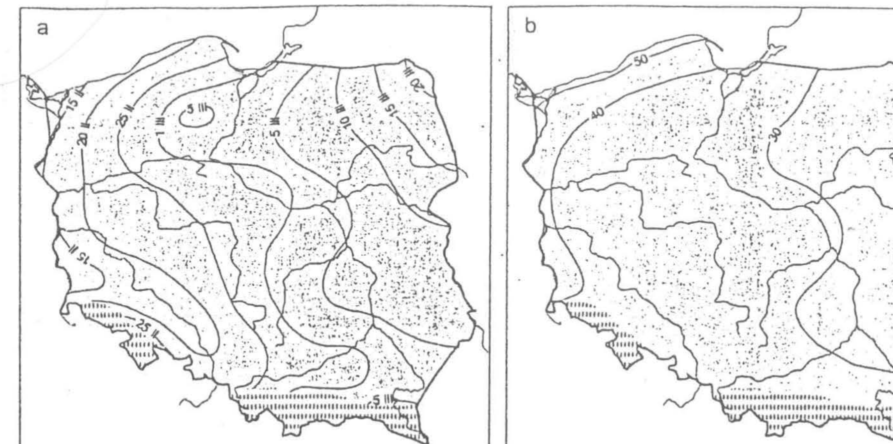
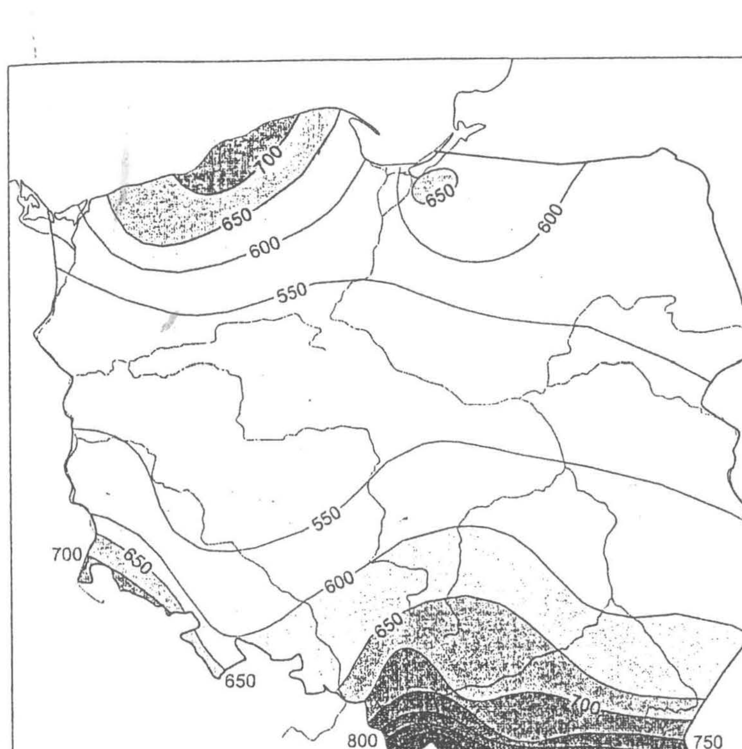


Fig. 4.34. Snow cover: a – real number of days with snow cover, b – mean thickness of snow cover on days when it occurs [cm], data for the years 1951–1990, c – frequency of 'snowy winters' in percent (after Paczos 1990)



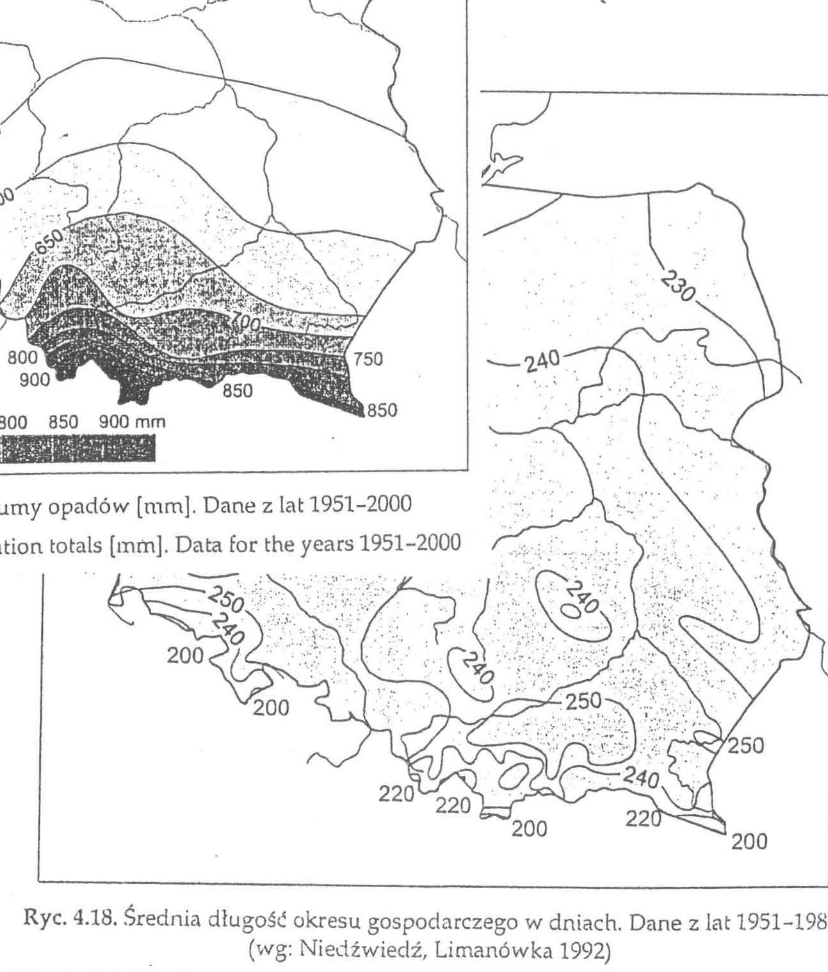
Ryc. 4.8. Termiczne pory roku: a - średnie daty początku przedwiośnia, b - średnia długość przedwiośnia w dniach. Dane z lat 1951-2000

Fig. 4.8. Thermal seasons: a - mean beginning dates of early spring, b - mean duration of early spring in days. Data for the years 1951-2000



Ryc. 4.28. Średnie roczne sumy opadów [mm]. Dane z lat 1951-2000

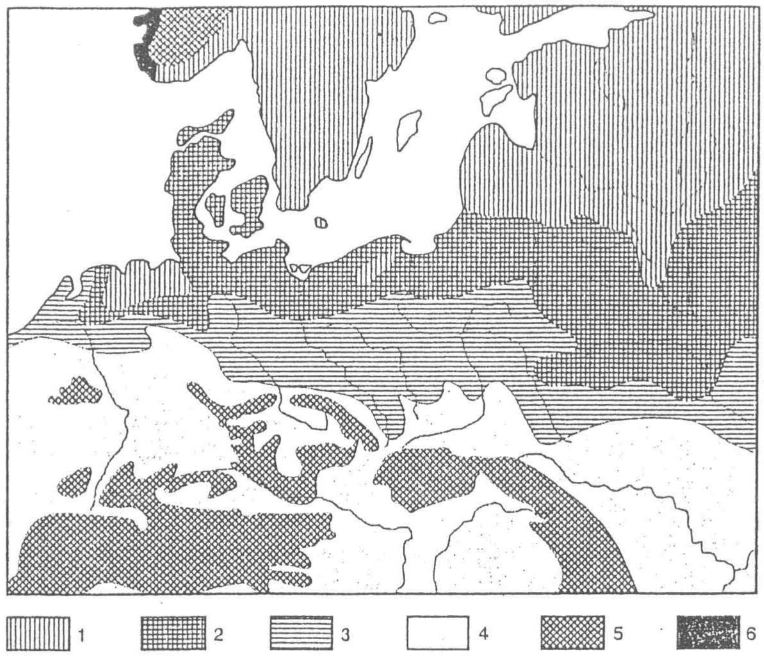
Fig. 4.28. Mean annual precipitation totals [mm]. Data for the years 1951-2000



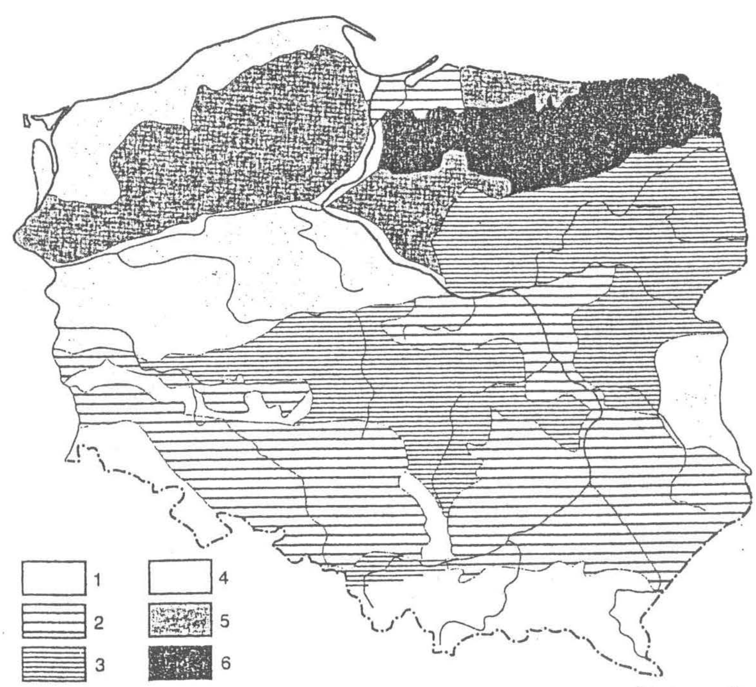
Ryc. 4.18. Średnia długość okresu gospodarczego w dniach. Dane z lat 1951-1980 (wg: Niedźwiedź, Limanówka 1992)

Fig. 4.18. Mean length of the farming season in days. Data for the years 1951-1980 (after Niedźwiedź, Limanówka 1992)

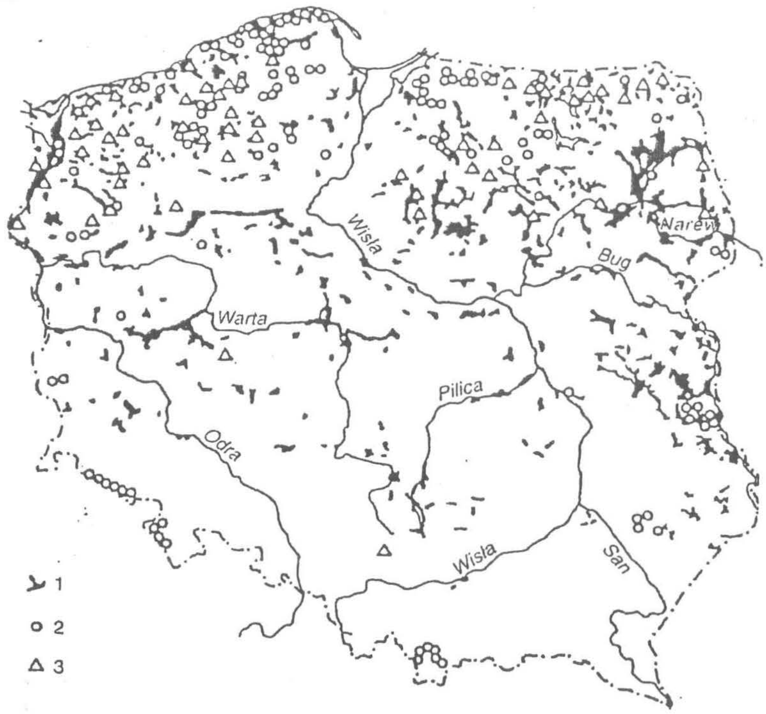
Mires



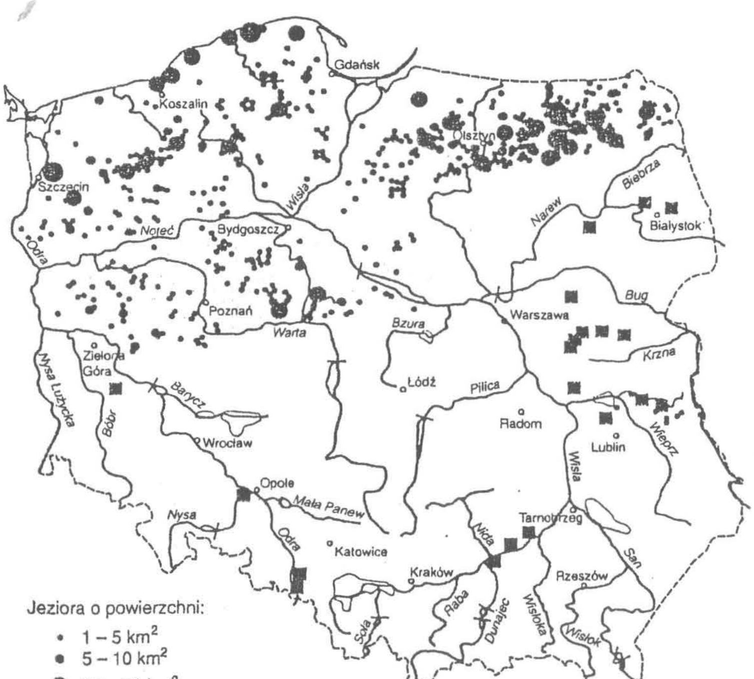
Zonation of mires in Central Europe (acc. to Żurek 1987, simplified): 1 – bogs at lowland; 2 – bogs and fens; 3 – fens; 4 – areas poor in mires; 5 – mountain bogs; 6 – blanket mires (after Tobolski 2000)



Peat sediments on 100 km^2 in Poland (acc. to Żurek 1987, simplified): 1 - less than 1 deposit; 2 – 1-5 deposits; 3 – 5-10 deposits; 4 – 10-25; 5 – 25-50; 6 – more than 50 deposits (after Tobolski 2000)



Distribution of big wetlands in Poland acc. Herbichowa 1998): 1 – fens > 200 ha; 2 – bogs > 100 ha; 3 – spring mires (after Tobolski 2000)



IDistribution of big lakes, ponds and reservoirs in Poland (acc. to Dobrowolski et al. 1998)

1972

GEOBOTANICZNY PODZIAŁ POLSKI

1:2000000

0 50 100 km

Państwo: Holarktyda

Obszar: Euro-Syberyjski

Prowincja: Niżowo-Wyżynna, Środkowoeuropejska *

A. Dział: Bałtycki

A₁ Poddział: Pas Równin Przymorskich i Wysoczyzn Pomorskich

1. Kraina: Brzeg Bałtyku
   - a. Okręg Zachodni
   - b. Okręg Środkowy
   - c. Okręg Wschodni
2. Kraina: Pobrzeże Bałtyckie
3. Kraina: Nizina Szczecińska
4. Kraina: Żuławy Wisły
5. Kraina: Pojezierze Pomorskie
   - a. Okręg Myśliborski
   - b. Okręg Wałecko-Drawski
   - c. Okręg Kartuski
   - d. Okręg Iławski
   - e. Okręg Olsztyński
6. Kraina: Pomorski Południowy Pas Przejściowy
   - a. Okręg Brzegu Pradoliny Noteckiej
   - b. Okręg Wysoczyzny Złotowskiej
   - c. Okręg Borów Tucholskich
   - d. Okręg Wysoczyzny Dobrzyńskiej

A₂ Poddział: Pas Wielkich Dolin

7. Kraina: Wielkopolsko-Kujawska
   - a. Okręg Notecki
   - b. Okręg Lubuski
   - c. Okręg Poznańsko-Gnieźnieński
   - d. Okręg Kujawski
   - e. Okręg Barycki
8. Kraina: Mazowiecka
   - a. Okręg Rawski
   - b. Okręg Warszawski
   - c. Okręg Północnomazowiecki
9. Kraina: Podlaska
   - a. Okręg Łukowsko-Siedlecki
   - b. Okręg Północnopodlaski
10. Kraina: Polesie Lubelskie

A₃ Poddział: Pas Kotlin Podgórskich

11. Kraina: Kotlina Śląska
    - a. Okręg Borów Dolnośląskich
    - b. Okręg Nadodrzański
    - c. Okręg Przedgórza Sudeckiego
12. Kraina: Kotlina Sandomierska
    - a. Okręg Oświęcimski
    - b. Okręg Puszczy Niepołomickiej
    - c. Okręg Radomyski
    - d. Okręg Puszczy Sandomierskiej
    - e. Okręg Biłgorajski
    - f. Okręg Lubaczowski

A₄ Poddział: Pas Wyżyn Środkowych

13. Kraina: Wzgórza Trzebnicko-Ostrzeszowskie
    - a. Okręg Zachodni
    - b. Okręg Wschodni
14. Kraina: Wyżyna Śląska
    - a. Okręg Zachodni
    - b. Okręg Wschodni
    - c. Okręg Północny
15. Kraina: Wyżyna Krakowsko-Wieluńska
    - a. Okręg Południowy
    - b. Okręg Środkowy
    - c. Okręg Północny
16. Kraina: Miechowsko-Sandomierska
    - a. Okręg Miechowsko-Pińczowski
    - b. Okręg Staszowski
    - c. Okręg Sandomiersko-Opatowski
17. Kraina: Świętokrzyska
    - a. Okręg Łysogórski
    - b. Okręg Chęciński
    - c. Okręg Konecki
    - d. Okręg Przejściowy
18. Kraina: Północne Wysoczyzny Brzeżne
    - a. Okręg Kaliski
    - b. Okręg Widawski
    - c. Okręg Łódzko-Piotrkowski
    - d. Okręg Radomsko-Kozienicki
19. Kraina: Wyżyna Lubelska
20. Kraina: Roztocze
    - a. Okręg Roztocze Zachodnie
    - b. Okręg Roztocze Środkowe
    - c. Okręg Roztocze Południowe

B. Dział: Północny

21. Kraina: Mazursko-Kurpiowska
    - a. Okręg Pojezierza Mazurskiego
    - b. Okręg Kurpiowsko-Pisk
22. Kraina: Suwalsko-Augustowska
    - a. Okręg Suwalski
    - b. Okręg Augustowski
23. Kraina: Biebrzańska
24. Kraina: Białowiesko-Knyszyńska
    - a. Okręg Puszczy Białowieskiej
    - b. Okręg Puszczy Knyszyńskiej

Prowincja: Pontyjsko-Pannońska

C. Dział: Stepowo-Leśny

25. Kraina: Wołyń Zachodni
26. Kraina: Opole Zachodnie

Prowincja: Górska, Środkowoeuropejska **

1. Piętro: Pogórza
2. Piętro: Regla Dolnego
3. Piętro: Regla Górnego
4. Piętro: Kosodrzewiny i Alpejskie

Podprowincja: Karpacka

D. Dział: Karpaty Zachodnie

- a. Okręg Tatry
  - a₁ Podokręg Pasmo Siwego Wierchu
  - a₂ Podokręg Tatry Zachodnie
  - a₃ Podokręg Tatry Wysokie
  - a₄ Podokręg Tatry Bielskie
- b. Okręg Pieniny
  - b₁ Podokręg Pas Skałek Spiskich
  - b₂ Podokręg Pieniny Zachodnie
  - b₃ Podokręg Pieniny Właściwe
  - b₄ Podokręg Małe Pieniny
- c. Okręg Beskidy
  - c₁ Podokręg Śląsko-Babiogórski
  - c₂ Podokręg Sądecki
  - c₃ Podokręg Bory Nowotarskie
  - c₄ Podokręg Beskid Niski
  - c₅ Podokręg Pogórze Lessowe
  - c₆ Podokręg Pogórze Wapienne
  - c₇ Podokręg Pogórze Fliszowe

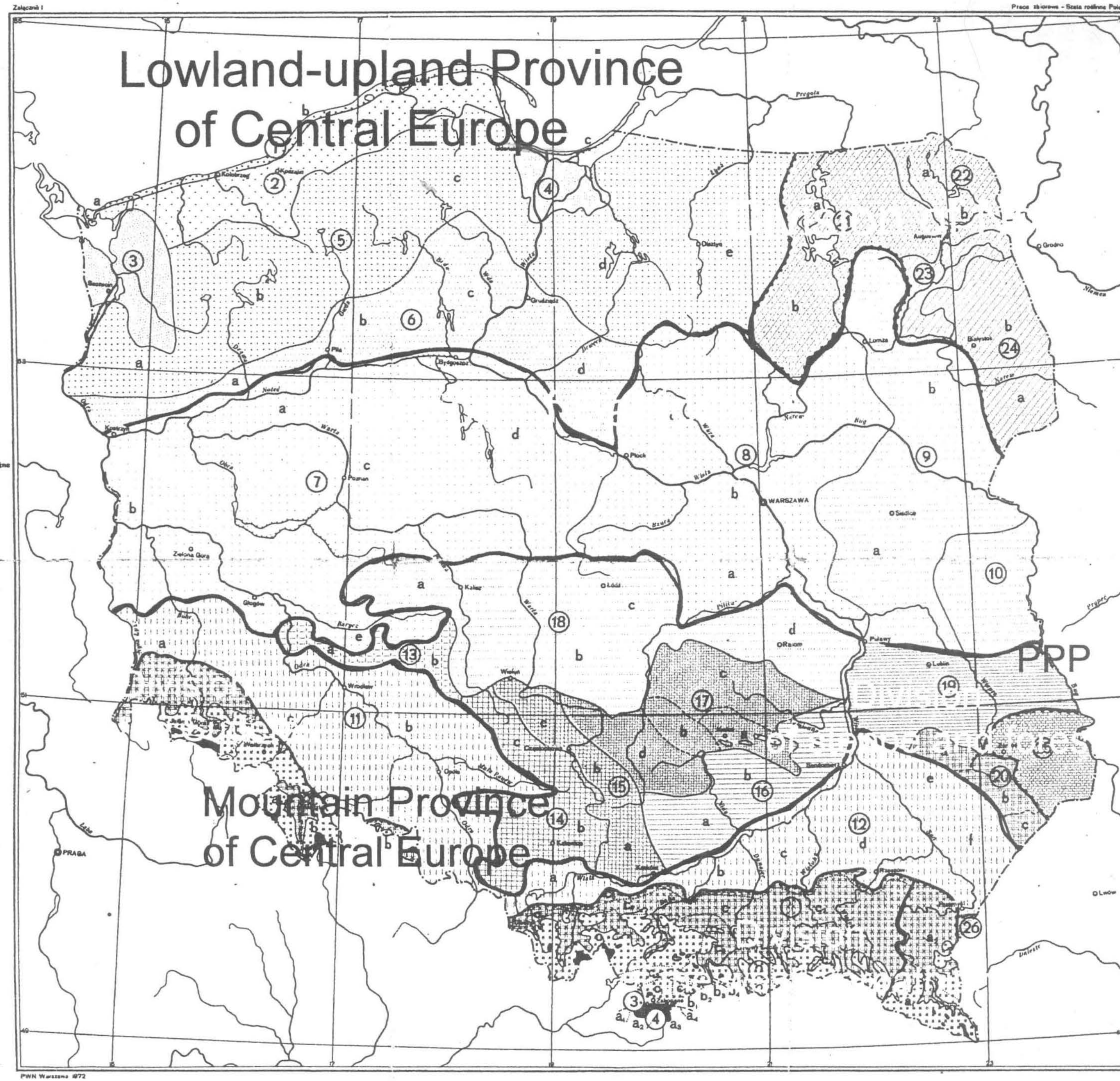
E. Dział: Karpaty Wschodnie

- a. Okręg Karpaty Lesiste
  - a₁ Podokręg Bieszczady
  - a₂ Podokręg Pogórze Przemyskie

Podprowincja: Hercyńsko-Sudecka

F. Dział: Sudety

- a. Okręg Sudety Zachodnie
  - a₁ Podokręg Izersko-Karkonoski
  - a₂ Podokręg Sudety Środkowe
- b. Okręg Sudety Wschodnie

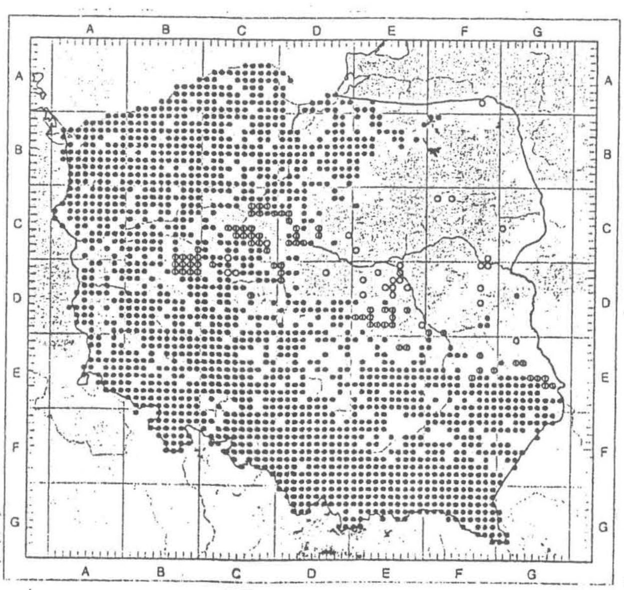


Flora and vegetation of NE Poland

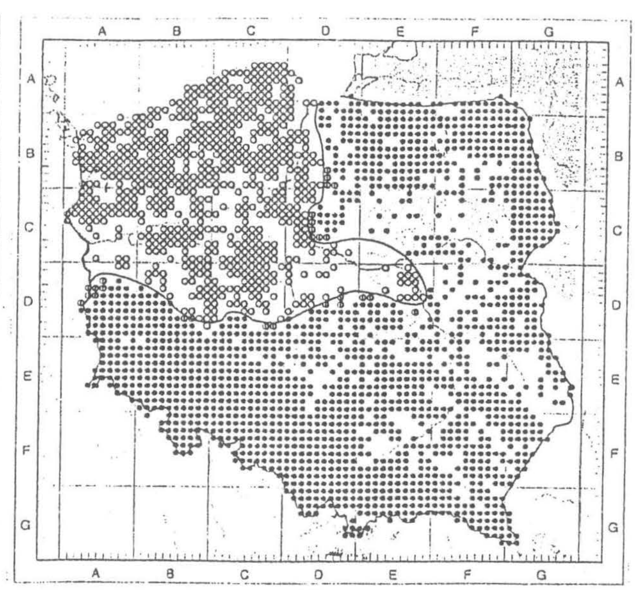
Wołkowycki D. 2010. Zróżnicowanie szaty roślinnej pogranicza Europy Środkowej i Wschodniej. (Main features of vegetation cover of border area of Central and Eastern Europe). In: A. Obidziński (ed.) Z Mazowsza na Polesie i Wileńszczyznę. Zróżnicowanie I ochrona szaty roślinnej pogranicza Europy Środkowej i Północno-Wschodniej. PTB, Warsaw.

Main features:
- location within nemoral zone of deciduous forest
- strong influence of boreal climate
- lack or gradual disappearance of Central European species (like *Fagus sylvatica*)
- occurring of boreal elements (like *Picea abies*)
- occurring of continental elements

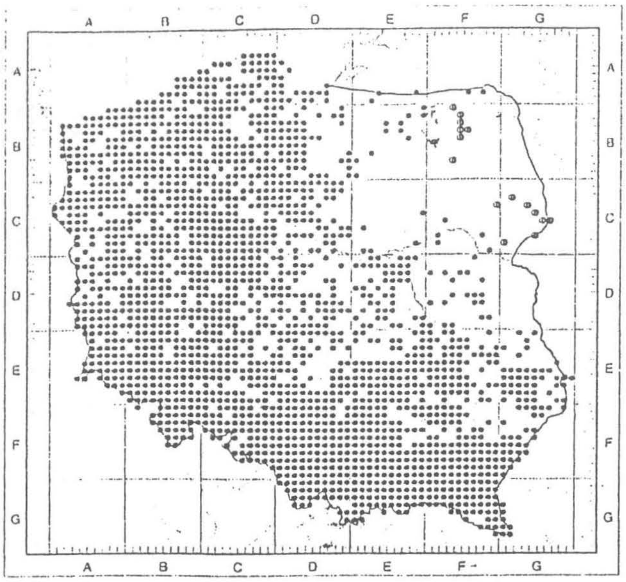
Lack or disappearance of some Central European species:
- *Fagus sylvatica*
- *Taxus baccata,*
- *Acer pseudoplatanus, A. campestre*
- *Quercus petrea*
- *Tilia platyphyllos*
- *Populus alba*
- *Verbascum phoeniceum, V. densiflorum*
- *Ceratophyllum submersum*
- *Drosera intermedia*
- *Salvinia natans*
- *Hydrocotyle vulgaris*



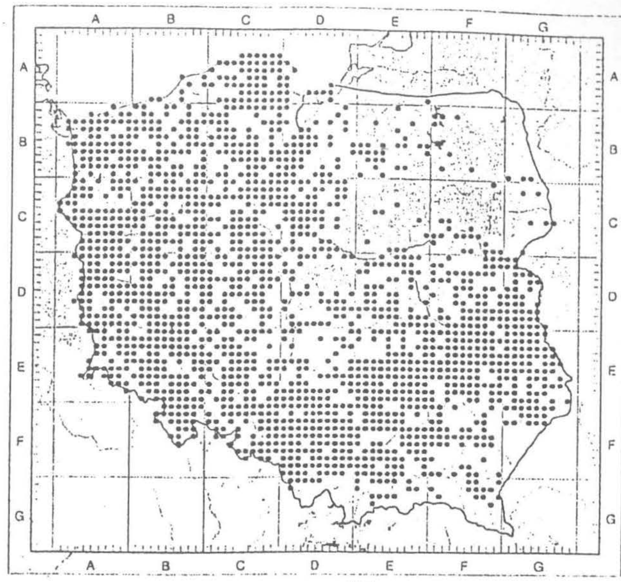
Fagus sylvatica L.[387]
Buk zwyczajny



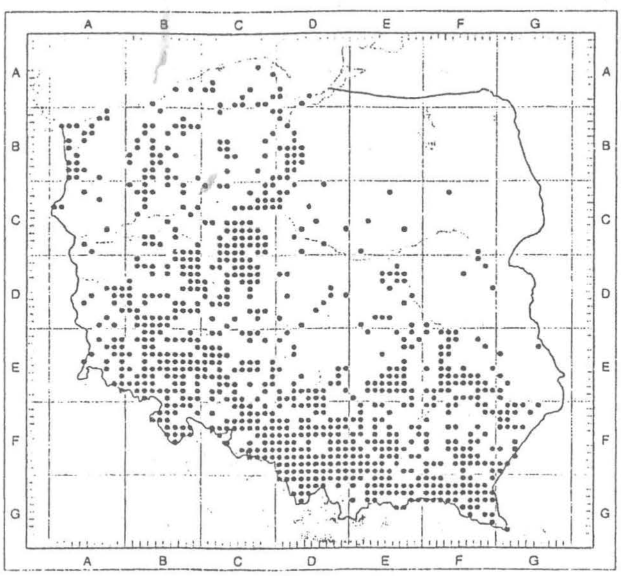
Picea abies (L.) H. Karst.[686]
[P. excelsa (Lam.) Link]
Swierk pospolity



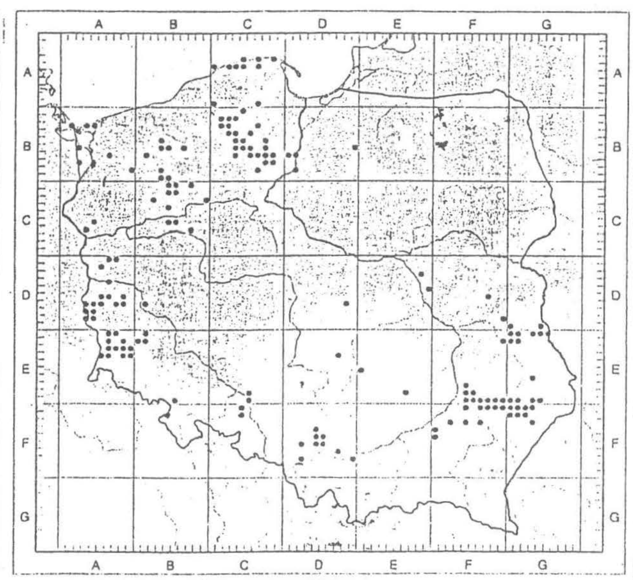
Acer pseudoplatanus L.[4]
Klon jawor



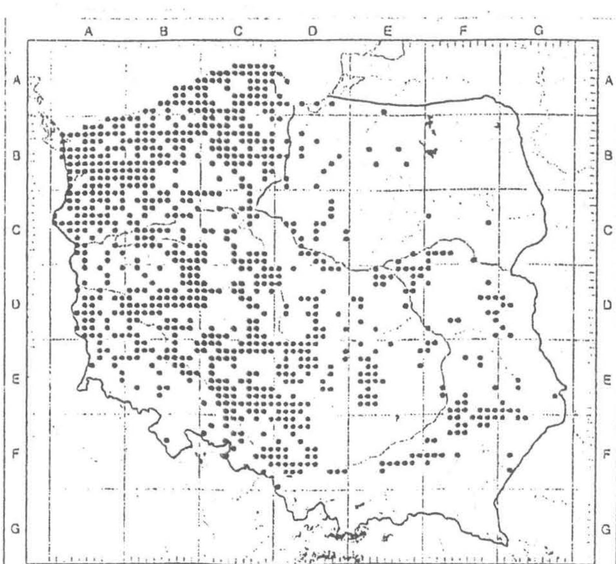
Quercus petraea (Matt.) Liebl. [754]
[Q. sessilis Ehrh.]
Dąb bezszypułkowy



Tilia platyphyllos Scop.[922]
Lipa szerokolistna

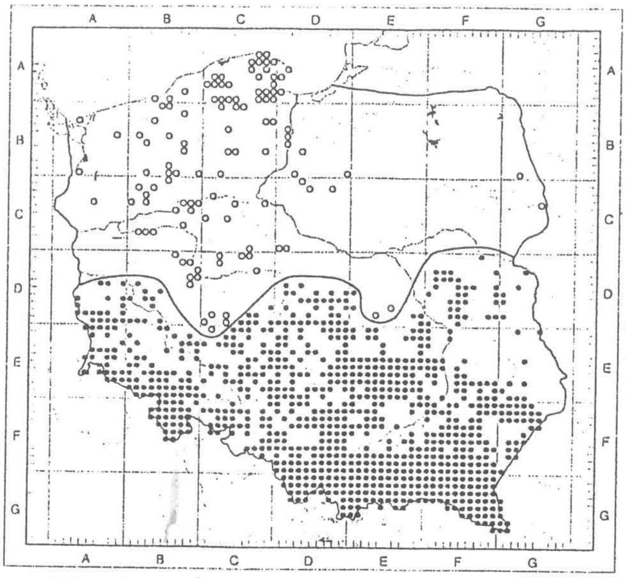


Drosera intermedia Hayne[333]
Rosiczka pośrednia

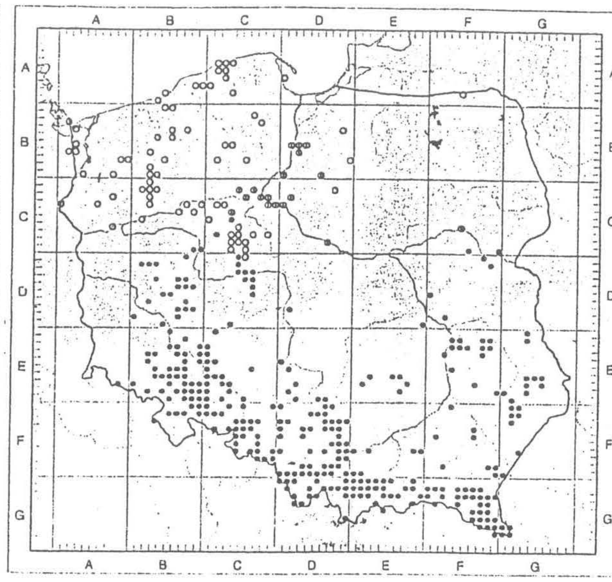


Hydrocotyle vulgaris L.
Wąkrota zwyczajna

Northern limit of distribution:
- Abies alba
- Eleocharis opata
- Juncus atratus
- Galanthus nivalis
- Carex umbrosa

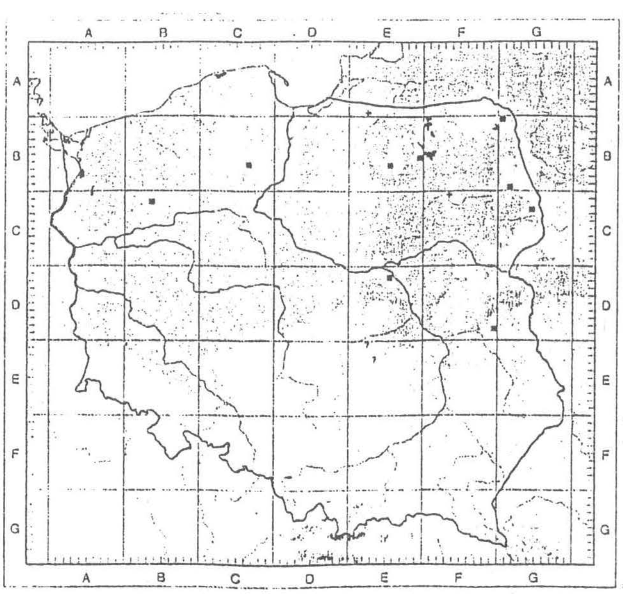


Abies alba Mill.[1]
Jodła pospolita

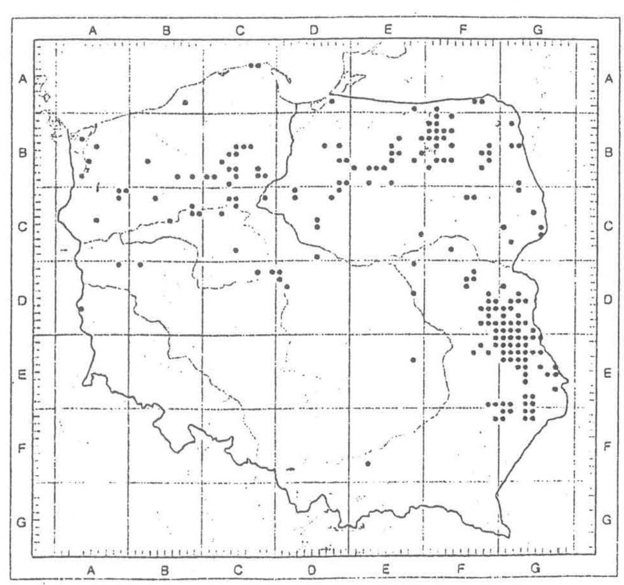


Galanthus nivalis L.[418]
Sniežyczka przebiśnieg

Boreal species (glacial relics):
- Viola epipsila
- Salix myrtilloides
- Chamedaphne calyculata
- Trisetum sibiricum
- Carex disperma, C. loliacea
- Polemonium coeruleum



Chamaedaphne calyculata (L.) Moench [231]
Chamedafne północna



Betula humilis Schrank [117]
Brzoza niska

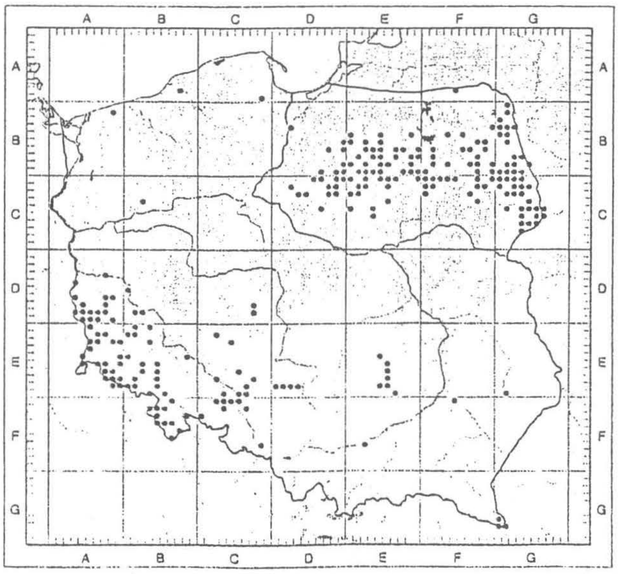
South-western limit of distribution
- Betula humilis
- Chamedaphne calyculata
- Trisetum sibiricum
- Dactylorhiza baltica
- Carex globularis, C. vaginata, C. loliacea
- Polemonium coeruleum

Continental species :
- Succisella inflexa
- Lathyrus laevigatus
- Dactylorhiza incarnata ssp. ochroleuca
- Silene lithuanica
- Salix lapponum

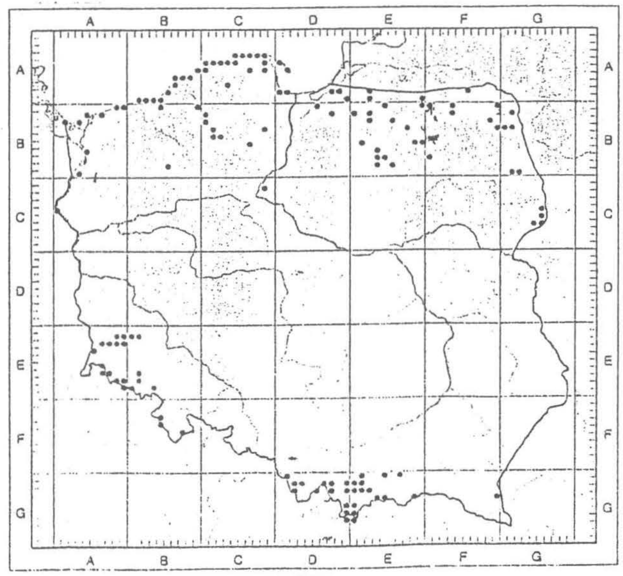
Southern limit of distribution :
- Nuphar pumila
- Nymphaea candida
- Empetrum nigrum
- Saxifraga hirculus

Eastern limit of distribution
- Taxus baccata
- Craetegus laevigata
- Valeriana dioica
- Carex arenaria
- Asplenium ruta-muraria

Montaneous species :
- Arnica montana
- Allium ursinum
- Listera cordata



Arnica montana L.[76]
Arnika górska



Listera cordata (L.) R. Br.[562]
Listera sercowata

Archeophytes and kenophytes are not numerous because of large areas of forests and wetlands, low degree of synathropic changes of vegetation, cold climate, weak urbanization, industry and communication network. At the area of NE Poland was stopped an expansion of such synanthropic species like:

- Geranium columbinum, G. molle
- Lathyrus tuberosus
- Ranunculus arvensis
- Chenopodium murale
- Atriplex nitens, A. tatarica
- Verbena officinalis
- Euphorbia exigua

However there are still growing some archeophytes disappearing in the rest of Polish territory like: Agrostemma githago, Ballota nigra, Leonurus cardiaca and Conium maculatum

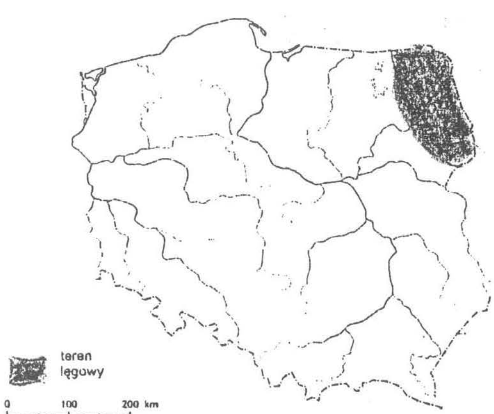
Boreal species of fauna

Lepus timidus – (zając bielak) mountain hare (tundra hare, white hare)

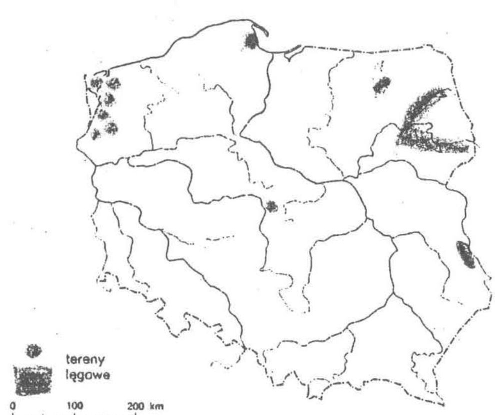
Sorex caecutiens – (ryjówka średnia) Laxmann's Shrew

Eremophila alpestris – (górniczek) horned lark

Loxia pytyopsittacus – (Krzyżodziób sosnowy) parrot crossbill



Turdus iliacus – (droździk) redwing



Acrocephalus paludicola – (wodniczka)
aquatic warbler

Picea abies (L.) H. Karst. – **Spruce**

ANDRZEJ OBIDOWICZ, MAGDALENA RALSKA-JASIEWICZOWA, MIROSŁAWA KUPRYJANOWICZ, KAZIMIERZ SZCZEPANEK, MAŁGORZATA LATAŁOWA, AND DOROTA NALEPKA

PRESENT DISTRIBUTION IN EUROPE

Spruce (*Picea*) is distributed exclusively in the Northern Hemisphere and according to Gaussen (1966) is differentiated into 48 species. According to Flora Europaea (Tutin et al. 1964) in the European continent it is represented by two species: Serbian spruce (*Picea omorika* (Pančić) Purkyné) and common spruce (*Picea abies* (L.) H. Karst.) as well as by several planted species. Two subspecies belong to *Picea abies*: subsp. *abies* (common spruce) and subsp. *obovata* (Ledeb.) Hultén (Siberian spruce). Serbian spruce is limited to a small area of the Balkan Peninsula. Siberian spruce growing in the Boreal-montane zone of Eurasia (Fig. 56) extends west of the Ural Mountains across western Russia and into northern Scandinavia, whereas common spruce grows in the Dinaric Alps, the Alps, the Sudetes and the Carpathians and almost throughout Scandinavia as well as in the lowlands of north-eastern Europe, where its range intermingles with the range of Siberian spruce (Jalas & Suominen 1973, 1988a).

Within this wide geographical range *Picea abies* is characterised by great individual and regional variability,

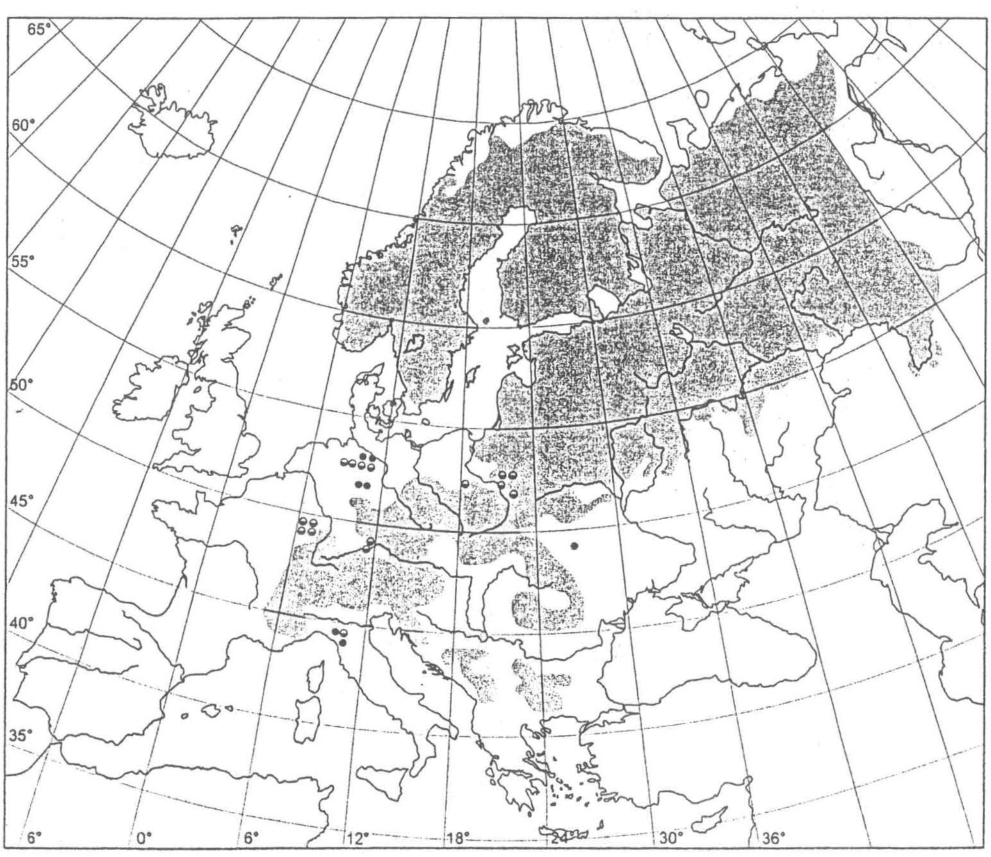
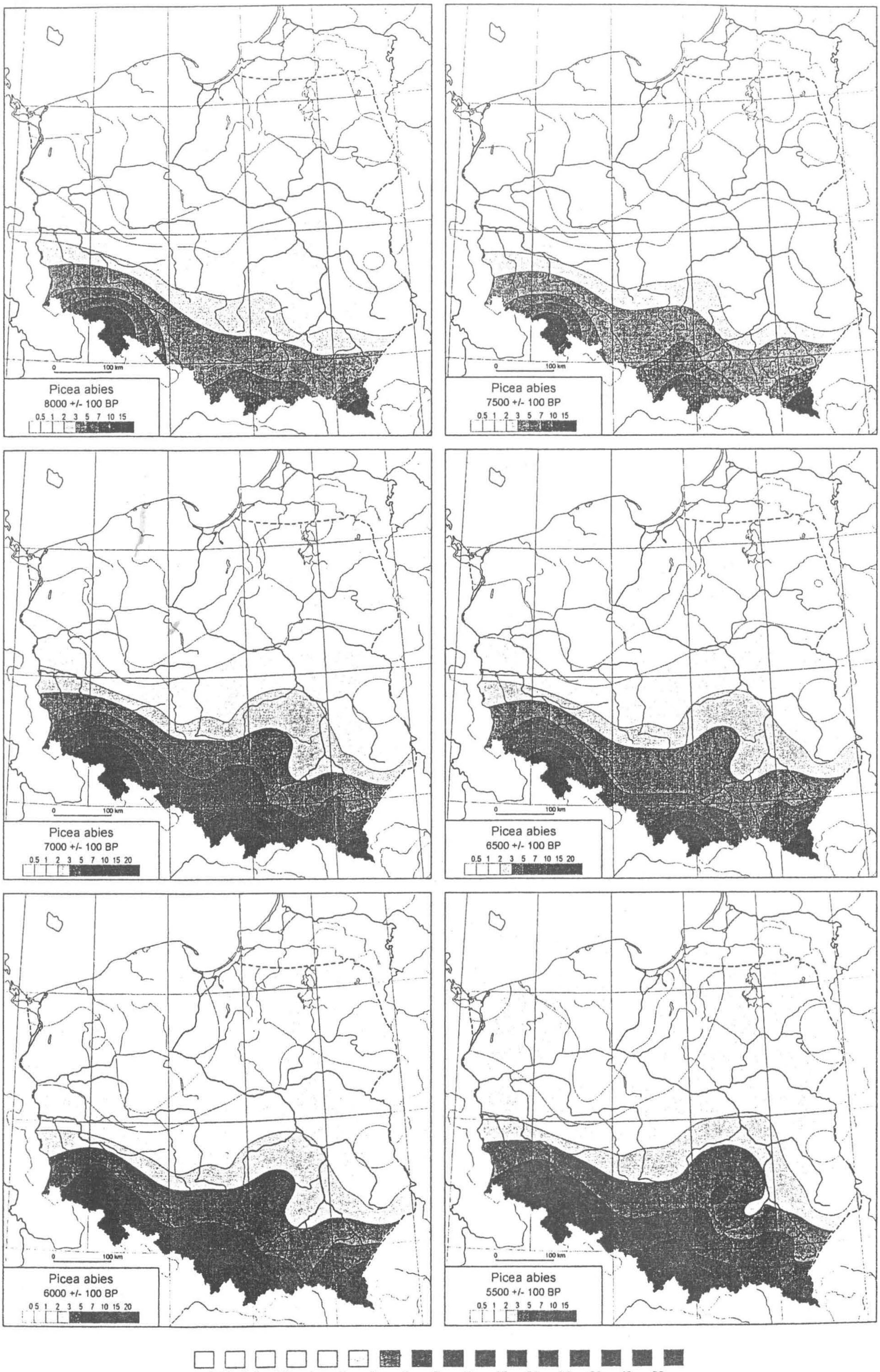
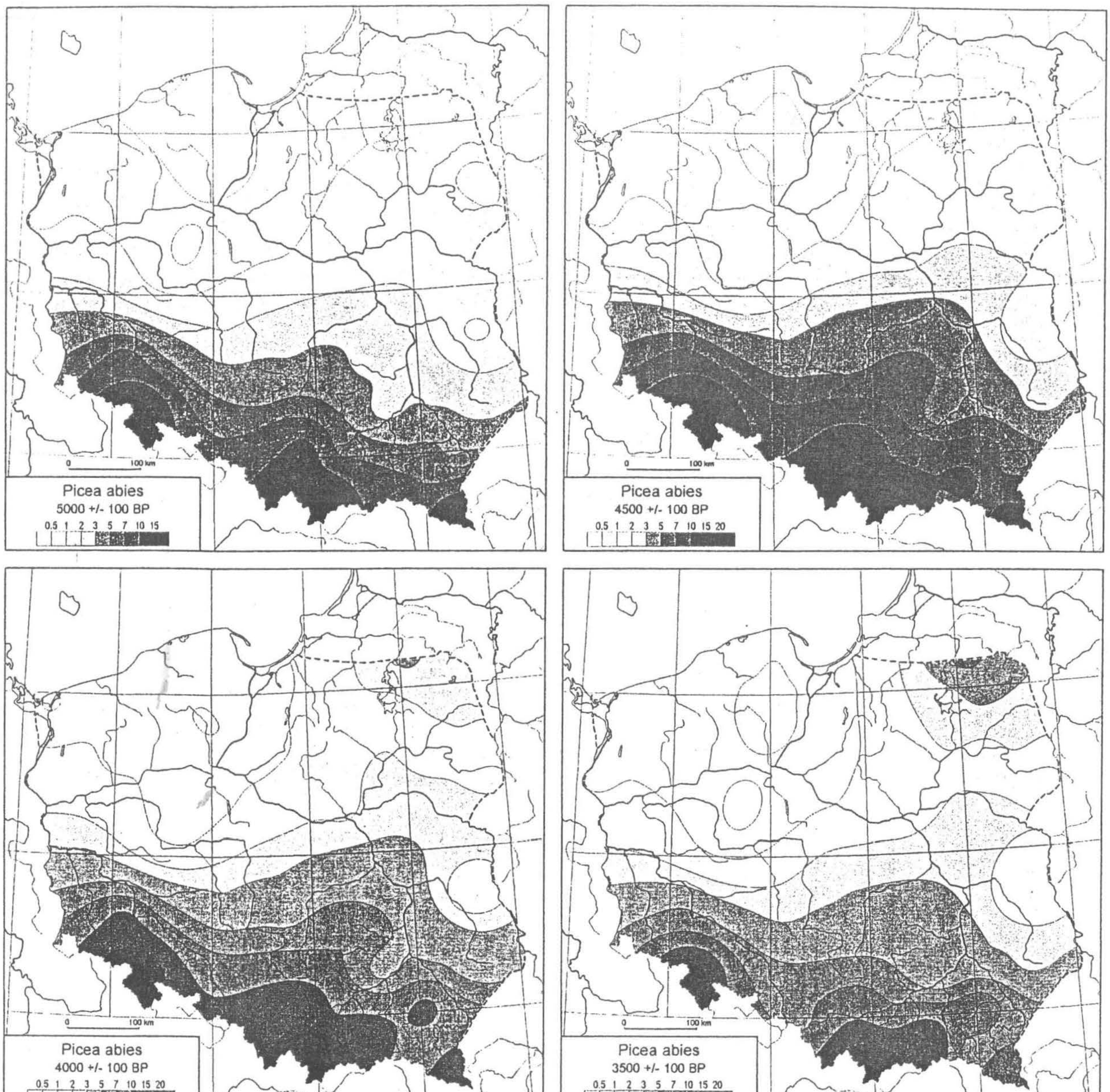
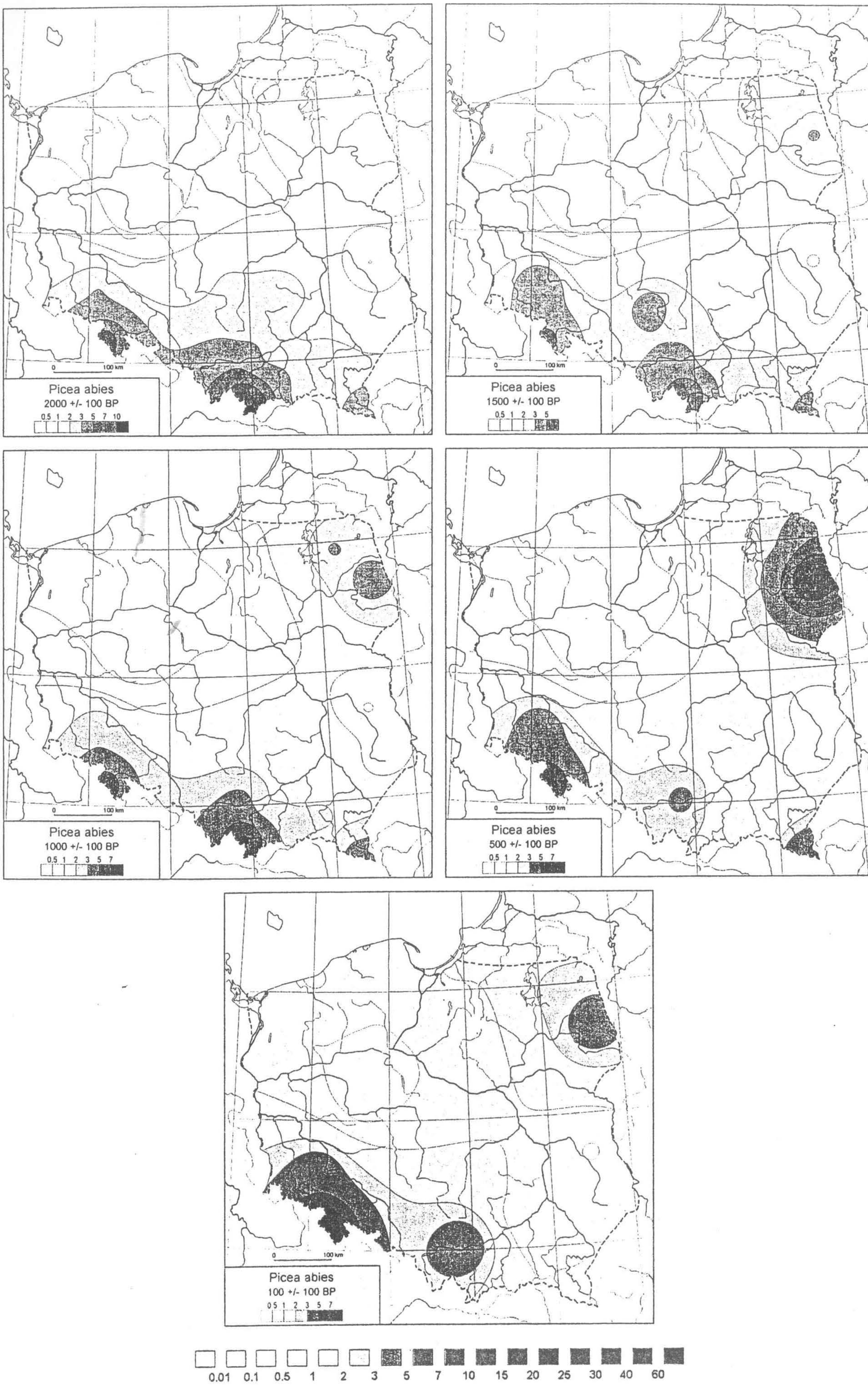


Fig. 56. *Picea abies* – map of present-day distribution in Europe: ● – native isolated occurrence, ◒ – status of site unknown or uncertain (after Jalas & Suominen 1973)



Picea abies
8000 +/- 100 BP
0.5 1 2 3 5 7 10 15
Picea abies
7500 +/- 100 BP
0.5 1 2 3 5 7 10 15
Picea abies
7000 +/- 100 BP
0.5 1 2 3 5 7 10 15 20
Picea abies
6500 +/- 100 BP
0.5 1 2 3 5 7 10 15 20
Picea abies
6000 +/- 100 BP
0.5 1 2 3 5 7 10 15 20
Picea abies
5500 +/- 100 BP
0.5 1 2 3 5 7 10 15
0.01 0.1 0.5 1 2 3 5 7 10 15 20 25 30 40 60


Picea abies
5000 +/- 100 BP
0.5 1 2 3 5 7 10 15
Picea abies
4500 +/- 100 BP
0.5 1 2 3 5 7 10 15 20
Picea abies
4000 +/- 100 BP
0.5 1 2 3 5 7 10 15 20
Picea abies
3500 +/- 100 BP
0.5 1 2 3 5 7 10 15 20
Picea abies
3000 +/- 100 BP
0.5 1 2 3 5 7 10 15 20
Picea abies
2500 +/- 100 BP
0.5 1 2 3 5 7 10 15 20
0.01 0.1 0.5 1 2 3 5 7 10 15 20 25 30 40 60


Picea abies
2000 +/- 100 BP
0.5 1 2 3 5 7 10
Picea abies
1500 +/- 100 BP
0.5 1 2 3 5
Picea abies
1000 +/- 100 BP
0.5 1 2 3 5 7
Picea abies
500 +/- 100 BP
0.5 1 2 3 5 7
Picea abies
100 +/- 100 BP
0.5 1 2 3 5 7
0.01 0.1 0.5 1 2 3 5 7 10 15 20 25 30 40 60

Fagus sylvatica L. – Beech

MAŁGORZATA LATAŁOWA, MAGDALENA RALSKA-JASIEWICZOWA, GRAŻYNA MIOTK-SZPIGANOWICZ, JOANNA ZACHOWICZ, AND DOROTA NALEPKA

There are two well defined species of genus *Fagus* occurring recently in Europe: *Fagus sylvatica* L. and *F. orientalis* Lipsky, the latter growing only in south-eastern part of Europe. The third species *F. taurica* Popl. is regarded as a variant of *F. sylvatica* and occurs sporadically in the areas when the two species meet (Tutin et al. 1964).

PRESENT DISTRIBUTION IN EUROPE

The only representative of the genus *Fagus* in Poland is *F. sylvatica* L. Beech is a Subatlantic species, avoiding areas of continental climate. Its range covers southern, central and western Europe, reaching the southern part of the British Islands, and southern Scandinavia (Fig. 40). In the south it is found in the northern and some central areas of the Iberian Peninsula, almost throughout Italy, including Sicily, and the Balkan Peninsula, except for the Peloponnese. To the east, it barely occurs beyond Poland, and in the south-east just extends to the Ukraine, with an outlying population in the Crimean Peninsula. Within its main area of distribution, it is, however, absent from the more continental areas of the Great Hungarian Plain and also the lower Danube valley (Meusel et al. 1965).

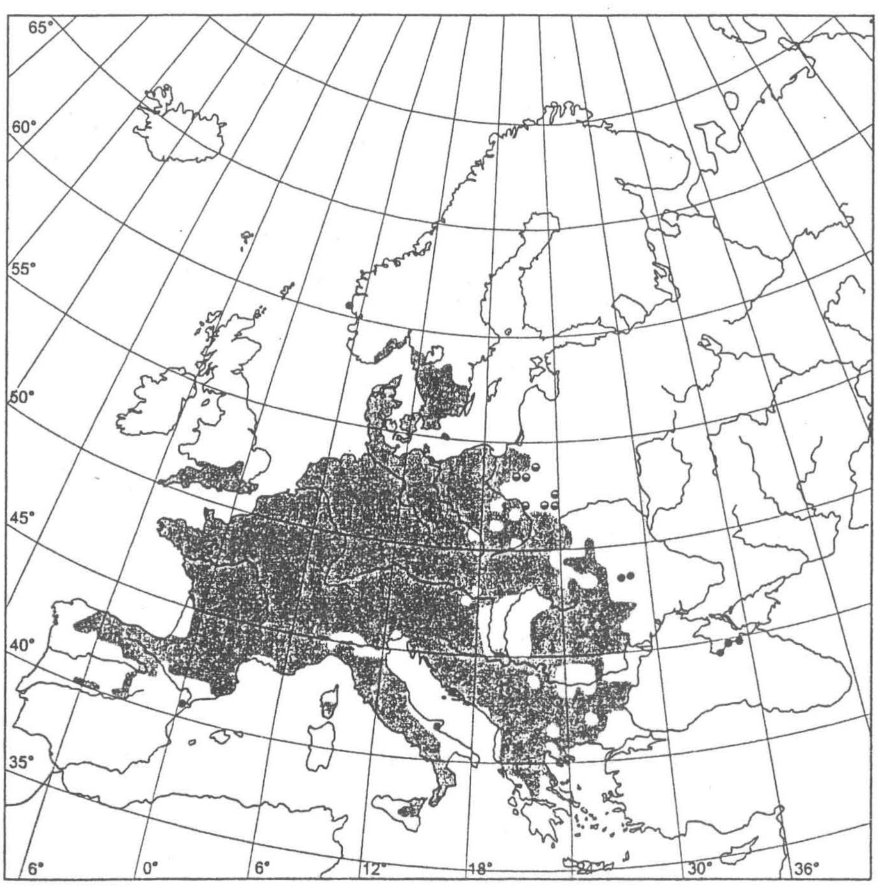
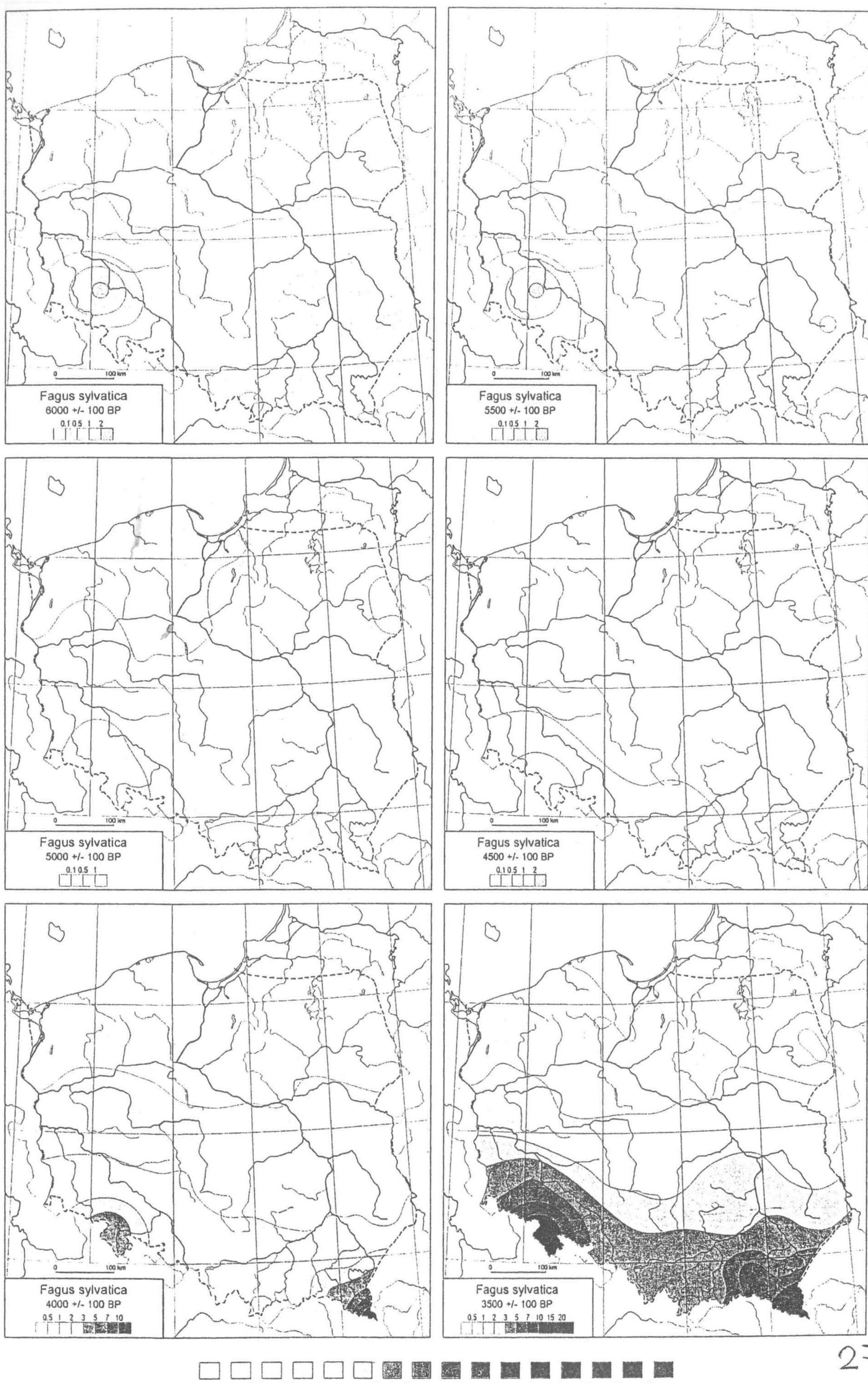
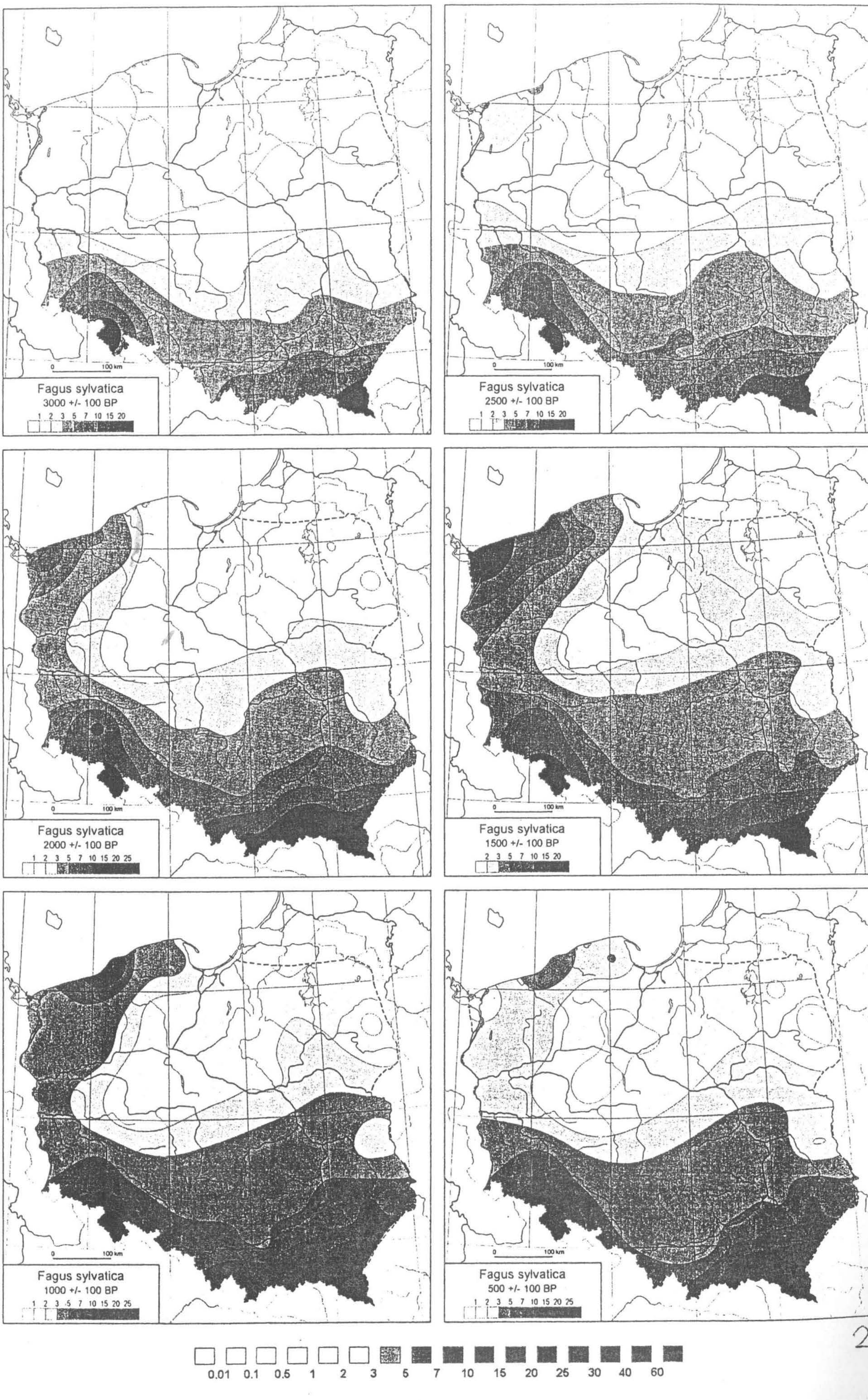


Fig. 40. *Fagus sylvatica* – map of present-day distribution in Europe: ● – native isolated occurrence, ⊖ – status of site unknown or uncertain (after Jalas & Suominen 1976, Boratyńska & Boratyński 1990, and Podbielkowski 1991)


Fagus sylvatica
6000 +/- 100 BP
Fagus sylvatica
5500 +/- 100 BP
Fagus sylvatica
5000 +/- 100 BP
Fagus sylvatica
4500 +/- 100 BP
Fagus sylvatica
4000 +/- 100 BP
Fagus sylvatica
3500 +/- 100 BP
0.01 0.1 0.5 1 2 3 5 7 10 15 20 25 30 40 60

27



Fagus sylvatica
3000 +/- 100 BP
Fagus sylvatica
2500 +/- 100 BP
Fagus sylvatica
2000 +/- 100 BP
Fagus sylvatica
1500 +/- 100 BP
Fagus sylvatica
1000 +/- 100 BP
Fagus sylvatica
500 +/- 100 BP
0 100 km
0.01 0.1 0.5 1 2 3 5 7 10 15 20 25 30 40 60

28

Carpinus betulus L. – Hornbeam

MAGDALENA RALSKA-JASIEWICZOWA, GRAŻYNA MIOTK-SZPIGANOWICZ, JOANNA ZACHOWICZ, MAŁGORZATA LATAŁOWA, AND DOROTA NALEPKA

PRESENT DISTRIBUTION IN EUROPE

Only two species of hornbeam occur in Europe: *Carpinus betulus* L. and *C. orientalis* Mill. The range of *C. orientalis* comprises south-eastern Europe, and to the west it extends as far as Sicily. *C. betulus* is a species common over the greater part of central southern and western Europe (Fig. 34). In the west it reaches the coasts of the North Atlantic Ocean. In the north its boundary runs across southern England and Jutland, and in southern Sweden it extends to beyond latitude 57°N (its most northern site). Its southern boundary runs along the margin of the Pyrenees, across parts of the Apennine and Balkan Peninsulas and along the southern coast of the Black Sea, to the southern Caucasus as far as Iran. In the east its distribution boundary runs south-east from the Baltic coast of Lithuania to the regions of Vilnius, and Minsk in Belarus, down to the valley of the middle Dniestr river and the mouth of the Danube. However, it excludes the Black Sea lowland (Boratyńska 1993).

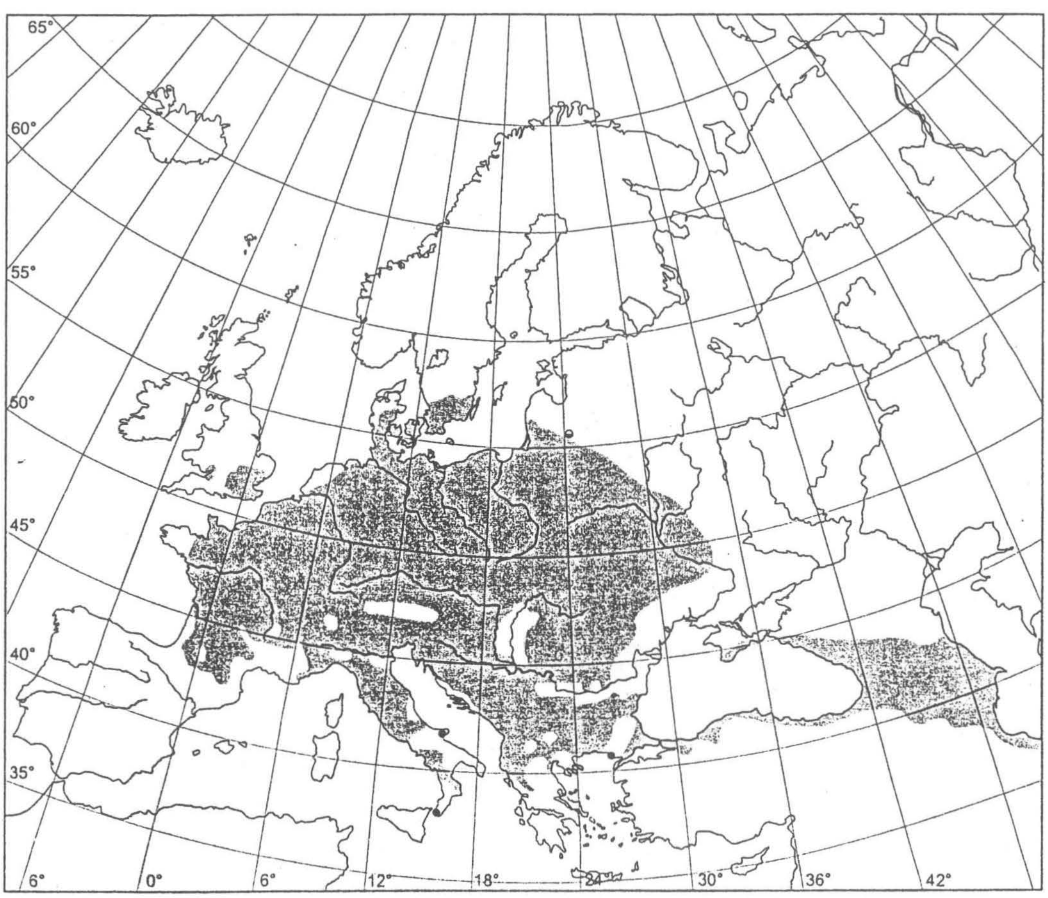
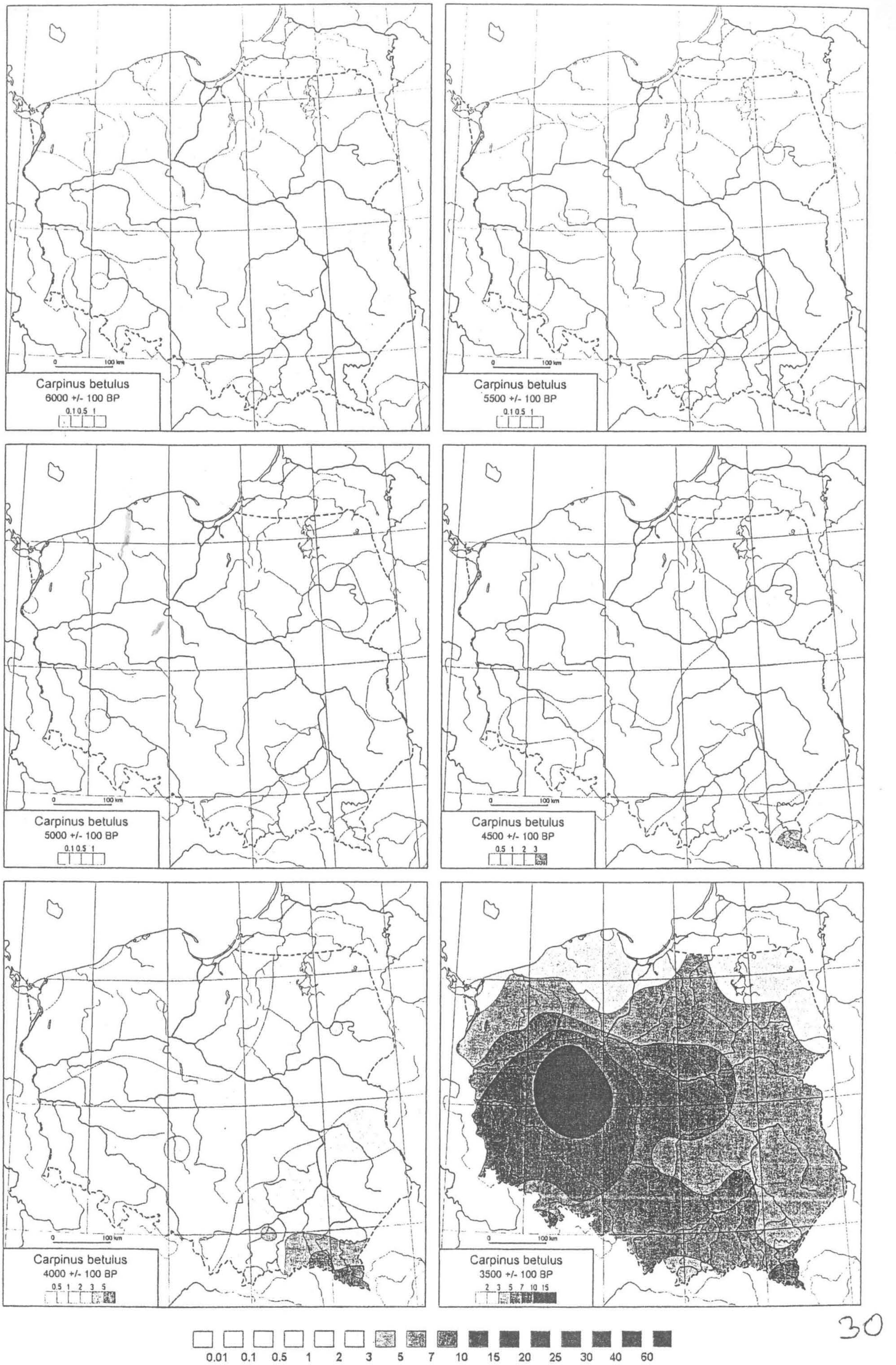
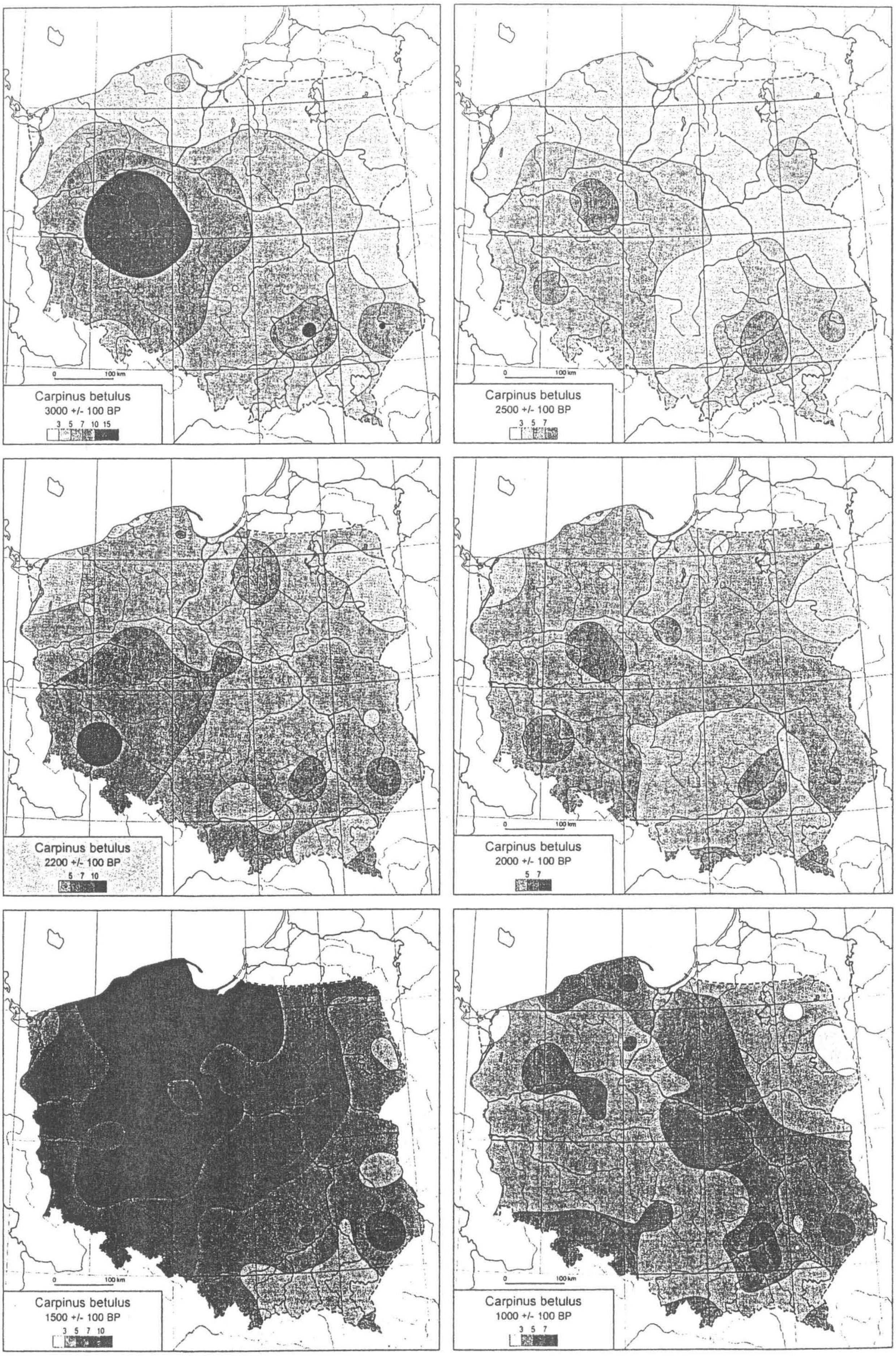
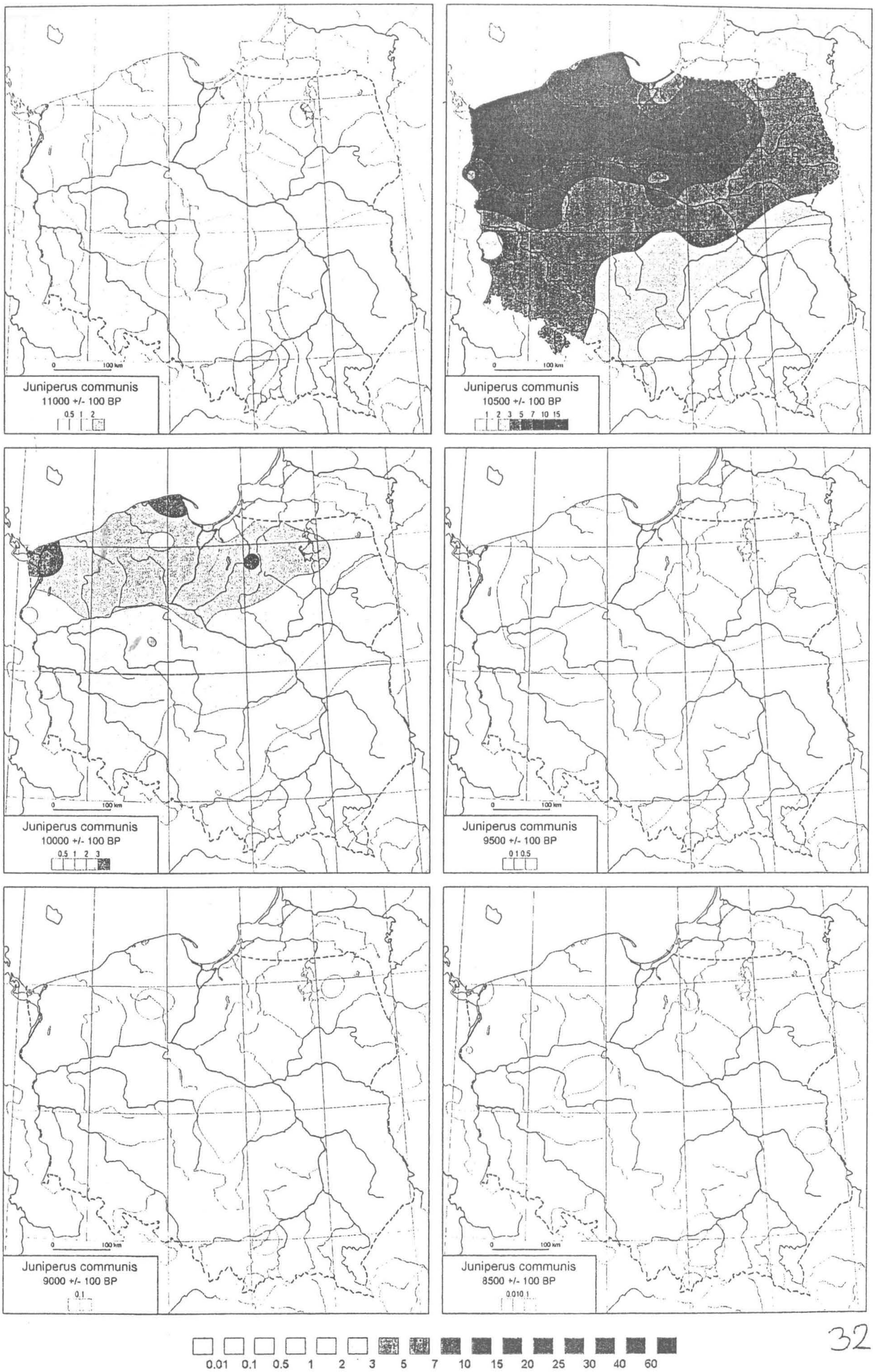


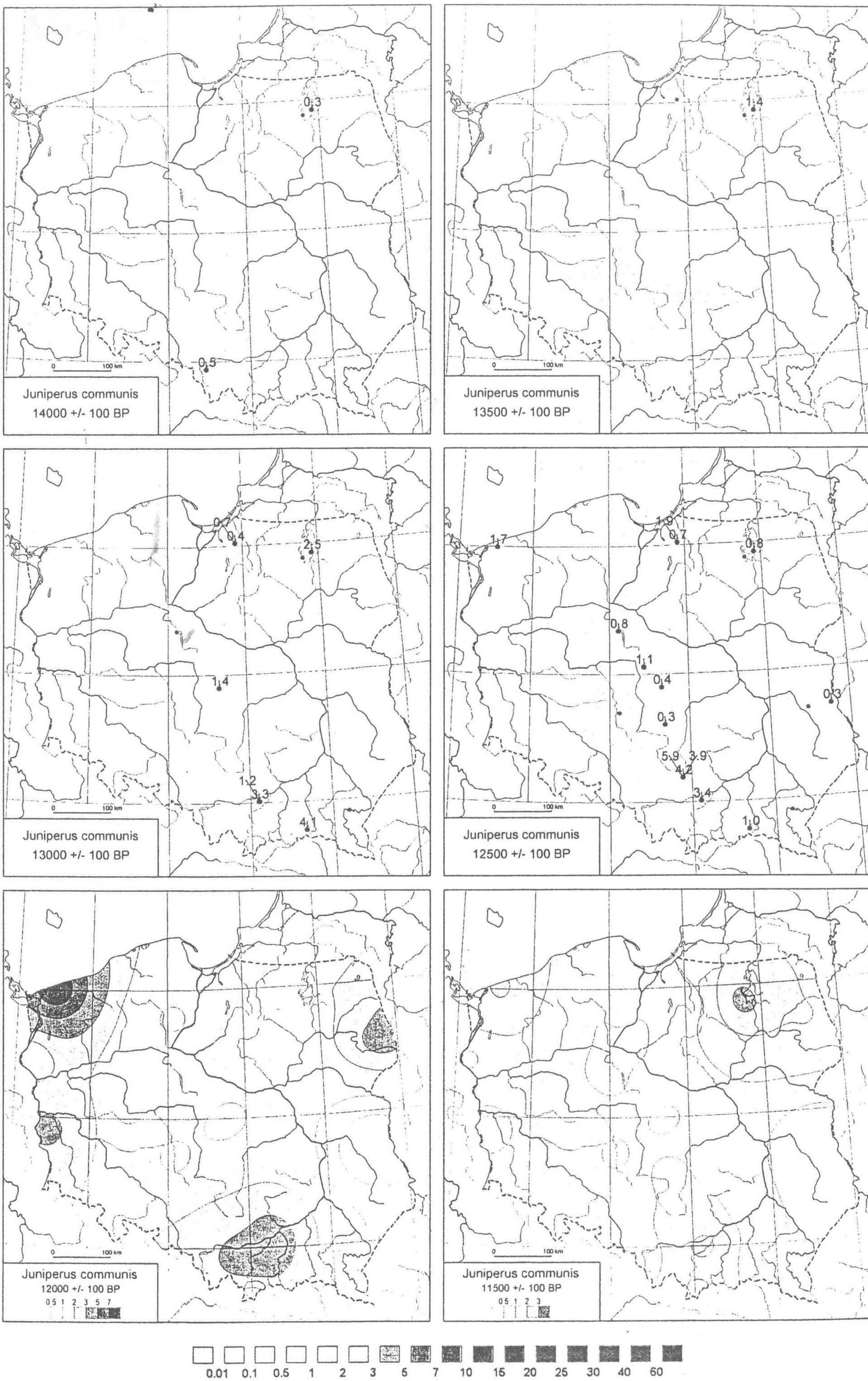
Fig. 34. *Carpinus betulus* – map of present-day distribution in Europe: ● – native isolated occurrence, ◒ – status of site unknown or uncertain (after Jalas & Suominen 1976 and Boratyńska 1993)


0 100 km
Carpinus betulus
6000 +/- 100 BP
0.1 0.5 1
Carpinus betulus
5500 +/- 100 BP
0.1 0.5 1
Carpinus betulus
5000 +/- 100 BP
0.1 0.5 1
Carpinus betulus
4500 +/- 100 BP
0.5 1 2 3
Carpinus betulus
4000 +/- 100 BP
0.5 1 2 3 5
Carpinus betulus
3500 +/- 100 BP
2 3 5 7 10 15
0.01 0.1 0.5 1 2 3 5 7 10 15 20 25 30 40 60



Carpinus betulus
3000 +/- 100 BP
3 5 7 10 15
Carpinus betulus
2500 +/- 100 BP
3 5 7
Carpinus betulus
2200 +/- 100 BP
5 7 10
Carpinus betulus
2000 +/- 100 BP
5 7
Carpinus betulus
1500 +/- 100 BP
3 5 7 10
Carpinus betulus
1000 +/- 100 BP
3 5 7
0 100 km
0.01 0.1 0.5 1 2 3 5 7 10 15 20 25 30 40 60


Juniperus communis
11000 +/- 100 BP
0.5 1 2
Juniperus communis
10500 +/- 100 BP
1 2 3 5 7 10 15
Juniperus communis
10000 +/- 100 BP
0.5 1 2 3
Juniperus communis
9500 +/- 100 BP
0.1 0.5
Juniperus communis
9000 +/- 100 BP
0.1
Juniperus communis
8500 +/- 100 BP
0.01 0.1
0.01 0.1 0.5 1 2 3 5 7 10 15 20 25 30 40 60


Juniperus communis
14000 +/- 100 BP
Juniperus communis
13500 +/- 100 BP
Juniperus communis
13000 +/- 100 BP
Juniperus communis
12500 +/- 100 BP
Juniperus communis
12000 +/- 100 BP
Juniperus communis
11500 +/- 100 BP
0 100 km
0.01 0.1 0.5 1 2 3 5 7 10 15 20 25 30 40 60

33

Monday, 22 August 2011 (day 1st)

Lake Gościąż

Lake Gościąż situated in central Poland contains one of the longest and best preserved requences of annually laminated sediments known form central Europe. It forms a unique archive of environmental history during the last 15,000 years recorded on the calendar timescale. The nearest localities of varved lacustrine sediments of similar quality and time span are known from the crater lakes in the Eifel area, Germany (Zolitschka1989 and others).
Lake Gościąż belongs to a complex of four connected lakes (Na Jazach lake system) located in a small Gostynińskie Lake District formed in the marginal part of last Scandinavian ice sheet.
The full scope of investigations on recent environmental conditions of the lake system and of the surrounding region has been completed; the archeological survey of area around the lake was done and supported with excavations at selected sites. The calendar chronology of annually laminated lake sediments has been established and confirmed with the representative series of AMS ^{14}C datings. Based on this chronology the sequence of various environmental changes has been reconstructed with the average time resolution of 50 yr.
Paleoecological analyses of cores were done using following methods: pollen analysis, Cladocera, diatoms, geochemistry and isotopes.

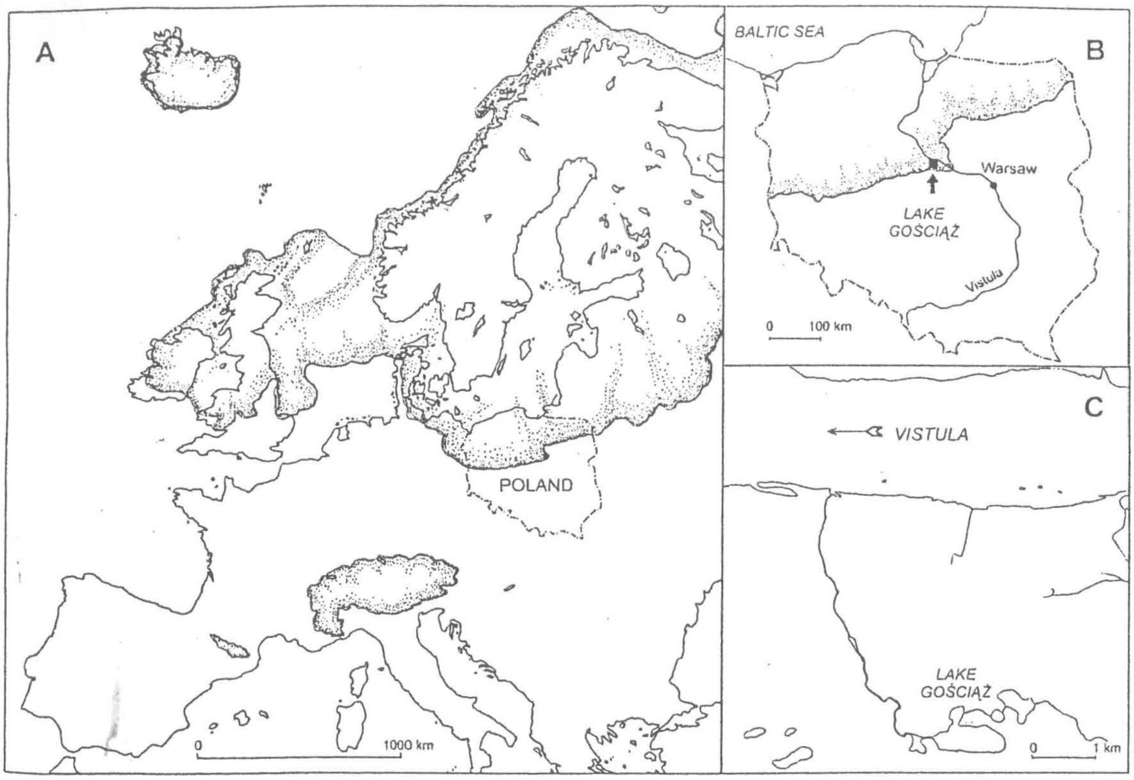


Fig. 1.2. Maps showing geographical situation of Lake Gościąż, central Poland. A – position of Poland with regard to the general extent of the last glaciation in Europe, B – situation of Lake Gościąż towards the maximum glacier lobe in the region of Vistula River valley, C – position of Lake Gościąż within the Na Jazach lakes system including its connection with Vistula River.

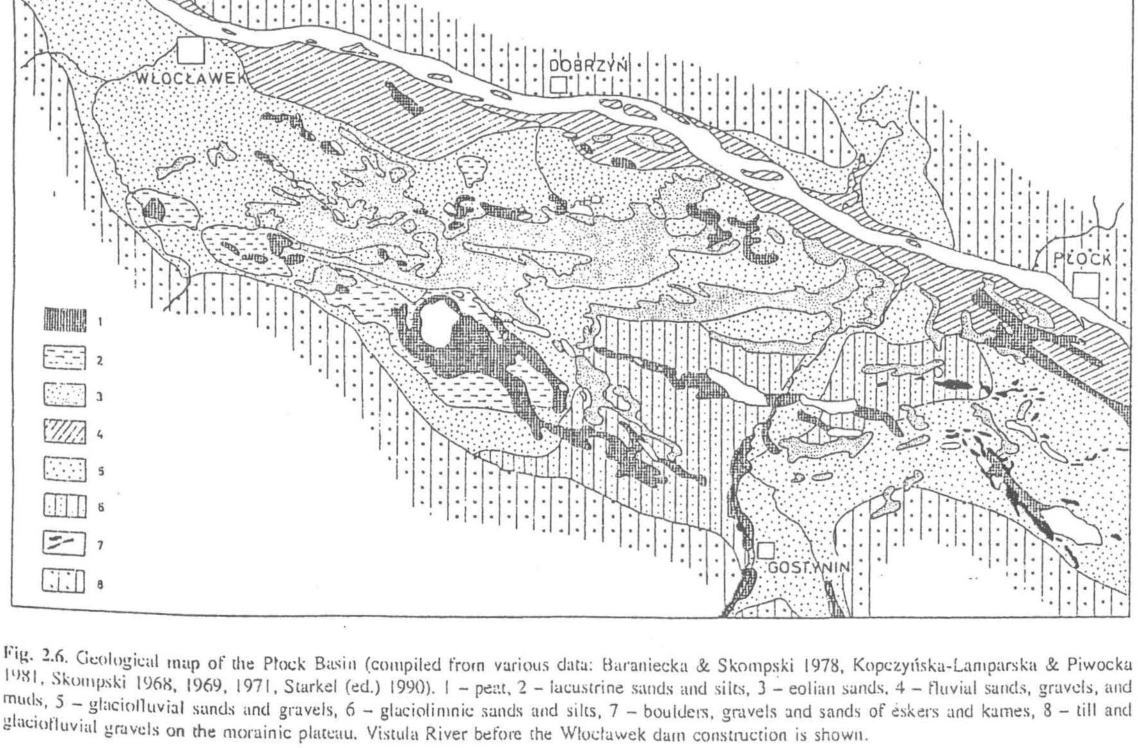


Fig. 2.6. Geological map of the Płock Basin (compiled from various data: Baraniecka & Skompski 1978, Kopczyńska-Lamparska & Piwocka 1981, Skompski 1968, 1969, 1971, Starkel (ed.) 1990). 1 – peat, 2 – lacustrine sands and silts, 3 – eolian sands, 4 – fluvial sands, gravels, and muds, 5 – glaciofluvial sands and gravels, 6 – glaciolimnic sands and silts, 7 – boulders, gravels and sands of eskers and kames, 8 – till and glaciofluvial gravels on the morainic plateau. Vistula River before the Włocławek dam construction is shown.

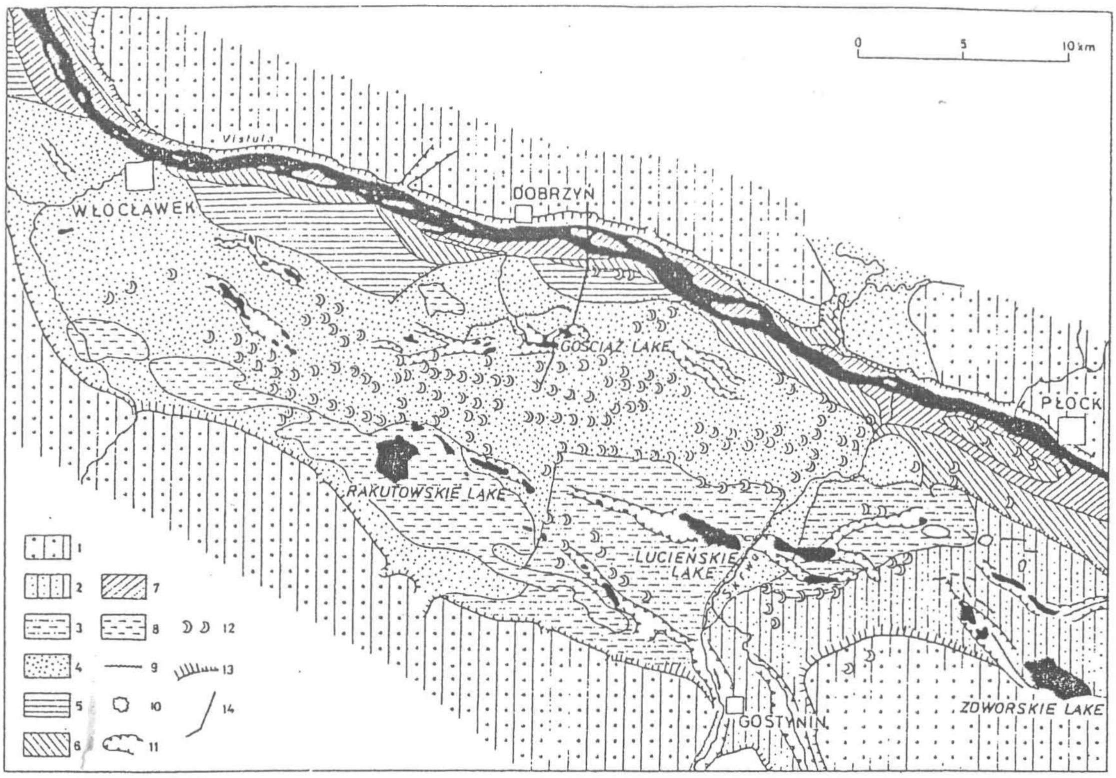


Fig. 2.7. Geomorphological map of the Płock Basin (compiled from: Baraniecka & Skompski 1978, Kopczyńska-Lamparska & Piwocka 1981, Skompski 1968, 1969, 1971, Starkel 1990, Wiśniewski 1976, 1987). 1 – morainic plateau, 2 – Ciechomice level originated due to deglaciation processes, 3 – glaciolimnic and glaciofluvial level 80–82 m a.s.l., 4 – glaciofluvial levels 62–77 m a.s.l., 5 – fluvial terrace III dated to the end of the Pomeranian phase, 6 – Late-Glacial fluvial terrace II, 7 – Holocene flood-plain (terrace I), 8 – lacustrine and swampy plains, 9 – eskers, 10 – kames, 11 – glacial channels, 12 – dunes, 13 – erosional edges, 14 – profile – see Fig. 2.5. Vistula river before the Włocławek dam construction is shown.

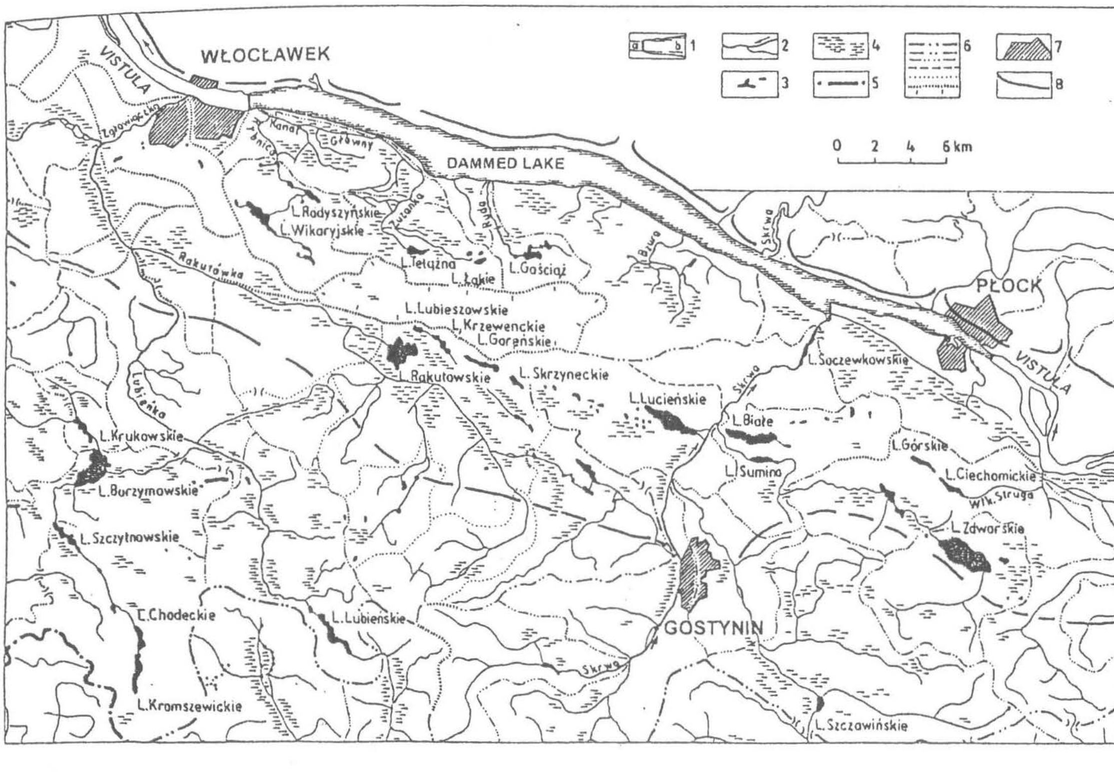


Fig. 2.11. Hydrological map of the Płock Basin. 1 – (a) Vistula River, (b) reservoir, 2 – streams, 3 – lakes, 4 – bogs, 5 – Vistula – Odra watershed, 6 – watersheds of lower order, 7 – towns, 8 – scarp of morainic plateau.

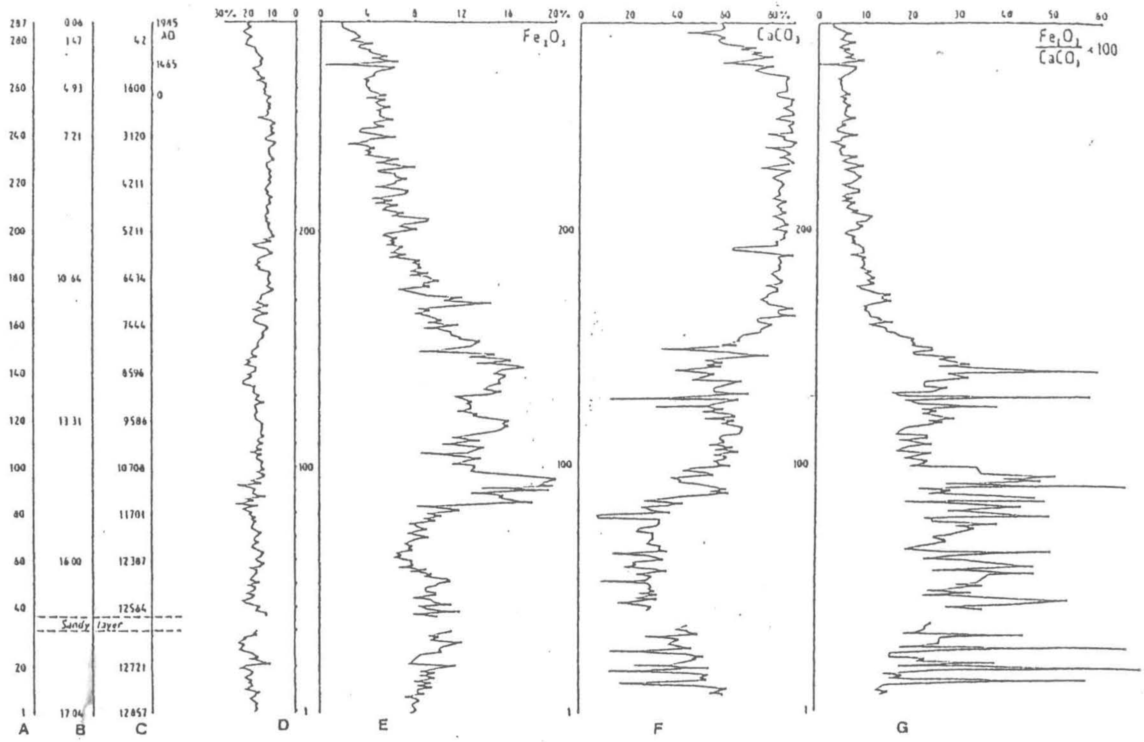


Fig. 5.12. Main sediment components of the Lake Gościąż profile G1/87. A – No. of sample, B – depth in meters, C – age in calendar years BP (after Goslar 1993), D – loss on ignition, E – Fe_2O_3 content in ash, F – $CaCO_3$ content in ash, G – Fe/Ca content ratio.

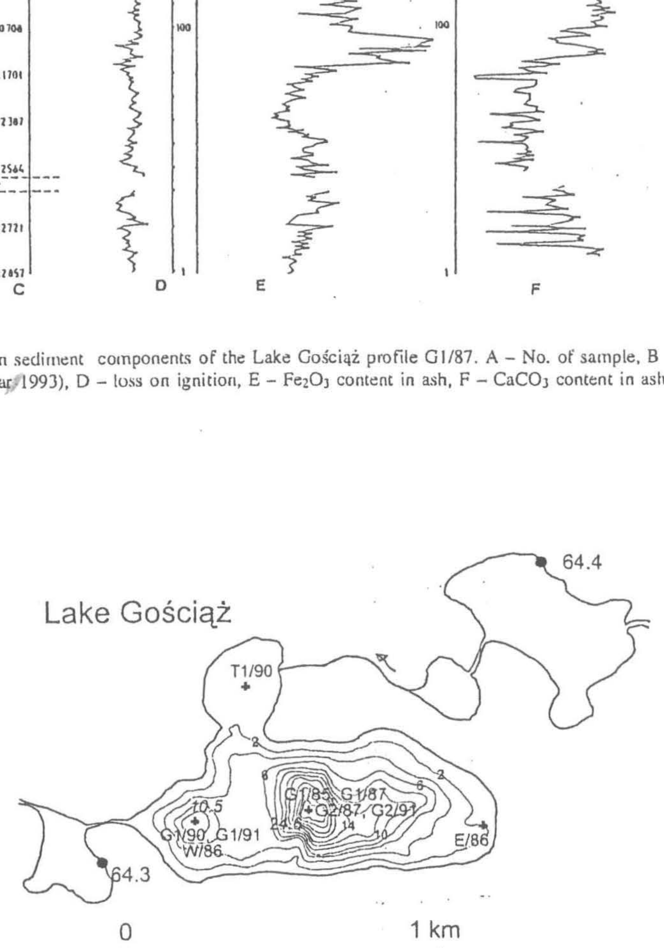


Fig. 6.1. Bathymetric map of Lake Gościąż with the coring sites (+) described in the text. The elevations of water table of adjacent lakes are also shown.

38

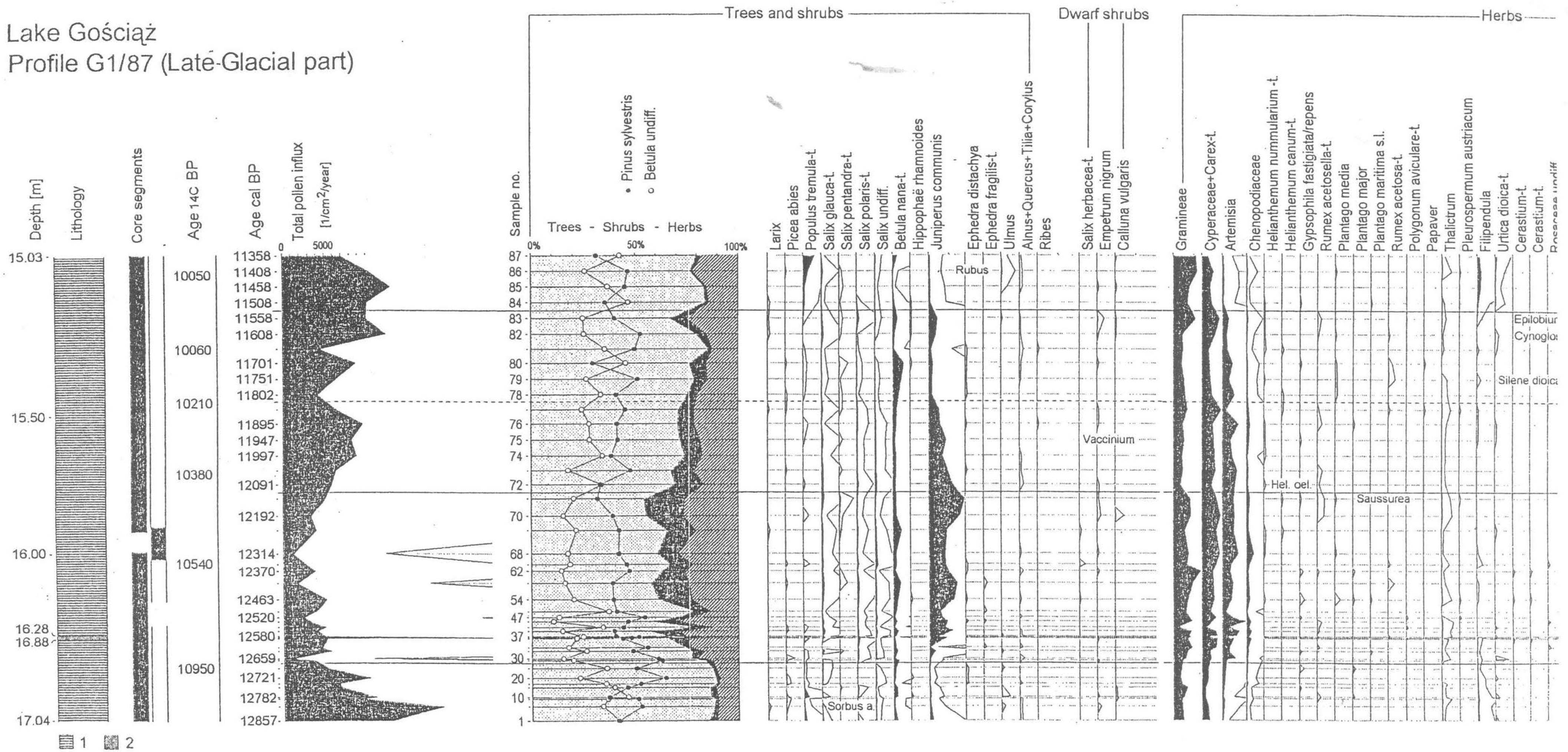
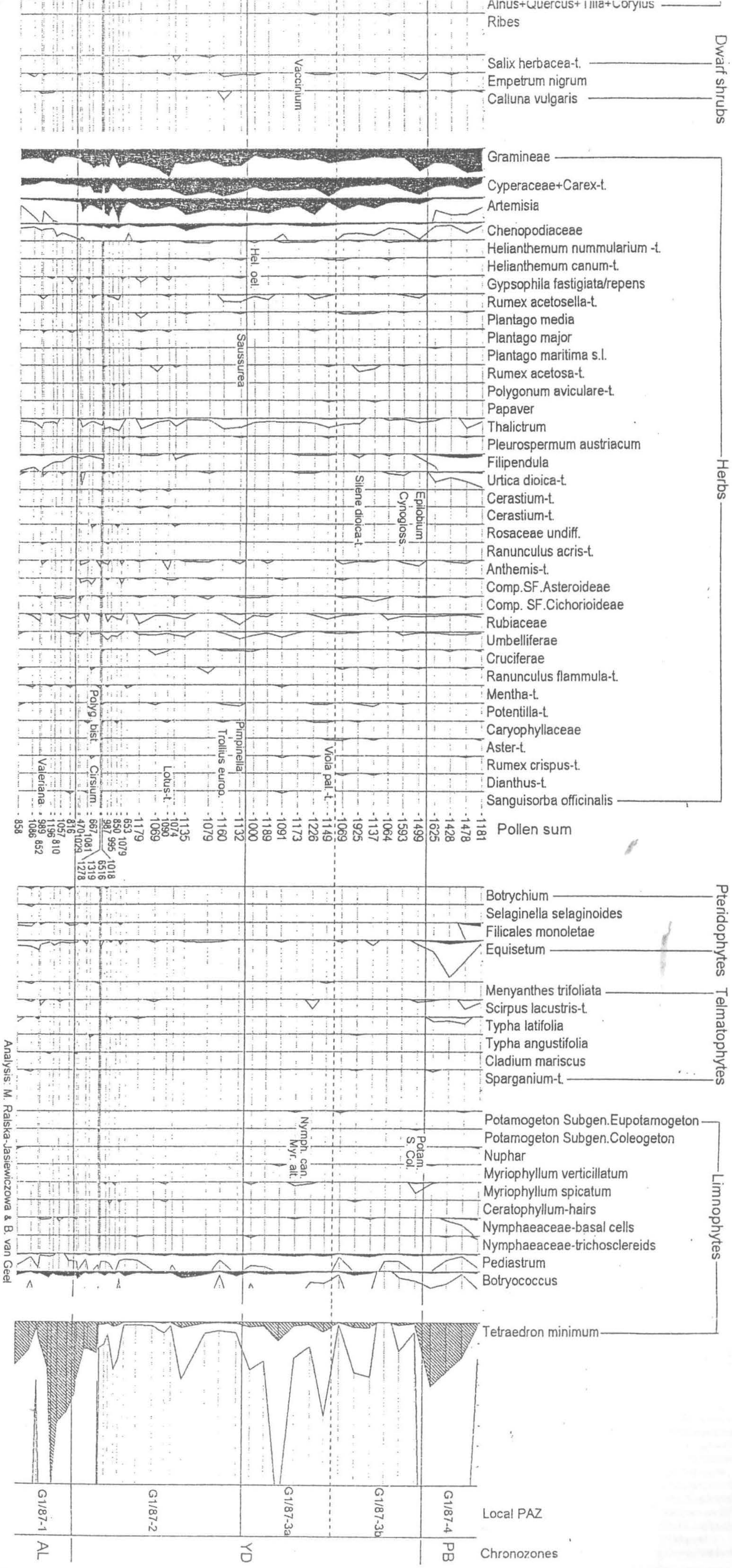


Fig. 7.20. Lake Gościąż, profile G1/87 from the central lake deep, Late-Glacial part – complete percentage pollen diagram. 1 – calcareous-ferruginous gyttja, regularly laminated, 2 – sand. Parts of core segments indicated in black were sampled for pollen analysis.

39

ts indicated in black were sampled for pollen analysis.



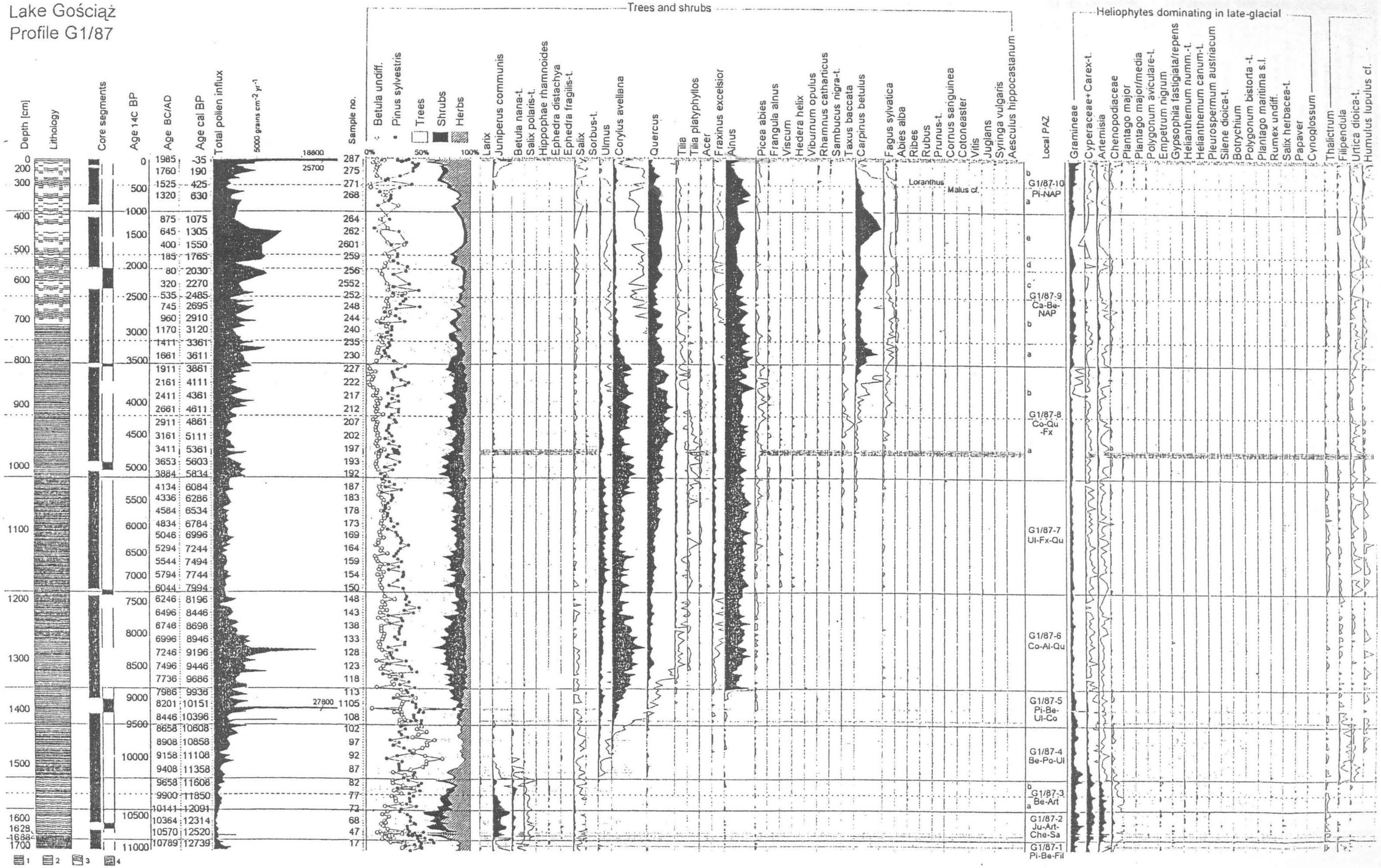
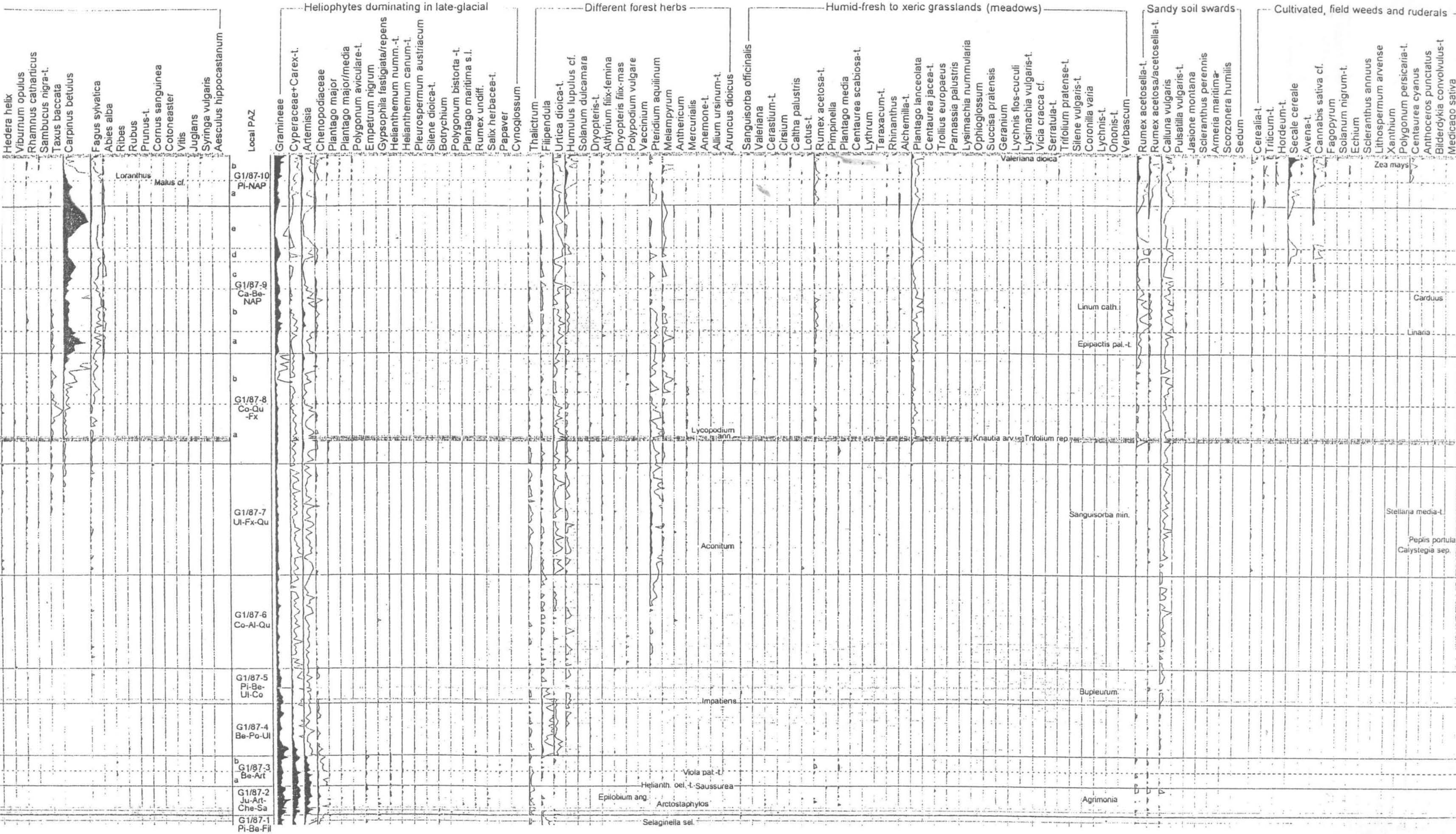
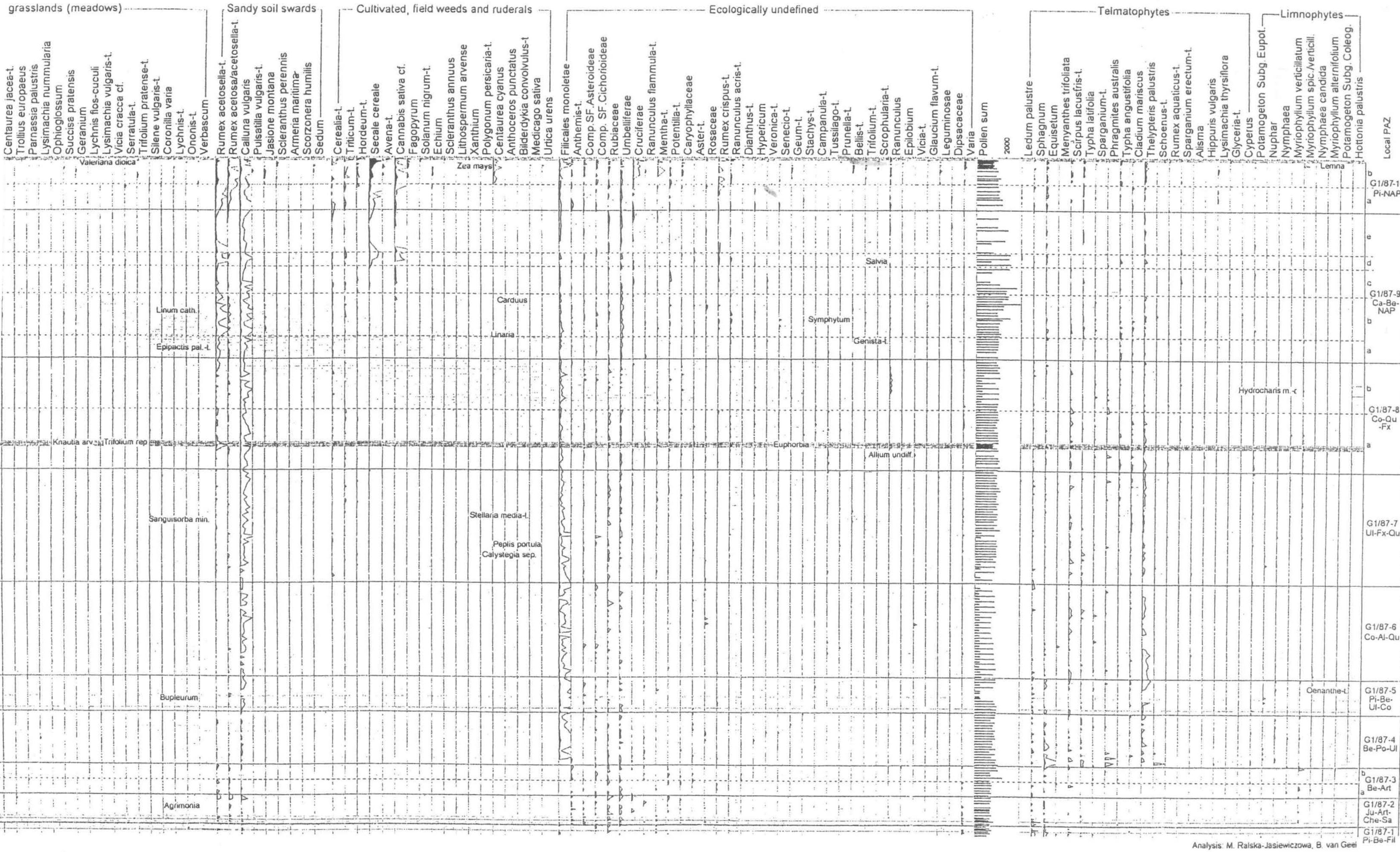


Fig. 8.22. Lake Gościąż, profile G1/87, completed with the core sections from profile G2/87, both cores from the central lake deep – complete percentage pollen diagram. Parts of core segments indicated in black were sampled for pollen analysis. 1 – calcareous gyttja regularly laminated, 2 – calcareous gyttja,



of core segments indicated in black were sampled for pollen analysis. 1 – calcareous gyttja regularly laminated, 2 – calcareous gyttja, wavy laminae, 3 – calcareous gyttja, irregularly laminated, 4 – sand. Because of some differences in pollen identification between both pollen analysts there are a few inconsistences in taxa nomenclature, c



of some differences in pollen identification between both pollen analysts there are a few inconsistences in taxa nomenclature, e.g. *Tilia* = *Tilia* undiff., *Ranunculus* = *Ranunculus flammula* -t. + *R. acris* -t.

42

KRYSTYNA SZEROCZYŃSKA

LATE-GLACIAL AND HOLOCENE ENVIRONMENT OF LAKE GOŚCIĄŻ (CENTRAL POLAND) RECORDED IN CLADOCERA (CRUSTACEA)

An analysis of subfossil Cladocera was conducted on three sediment cores taken from Lake Gościąż. The potential of Cladocera for climate inferences and Late-Glacial and Holocene reconstruction of development of Lake Gościąż was presumed.

Within the frame work of the complex studies on the Late-Glacial history of Lake Gościąż, the analysis of cladoceran remains in sediments of the profiles G1/87, G1/90 and T1/90 were subjected to this analysis. Profiles: G1/87 – central zone, G1/90 – near littoral zone and T1/90 from Tobyłka Bay.

Each sample consisted of sediments deposited during a period of 6-10 years over an area of 1 cm^2 (G1/87, G1/90), or of sediments with a 1 cm^3 volume (T1/90).

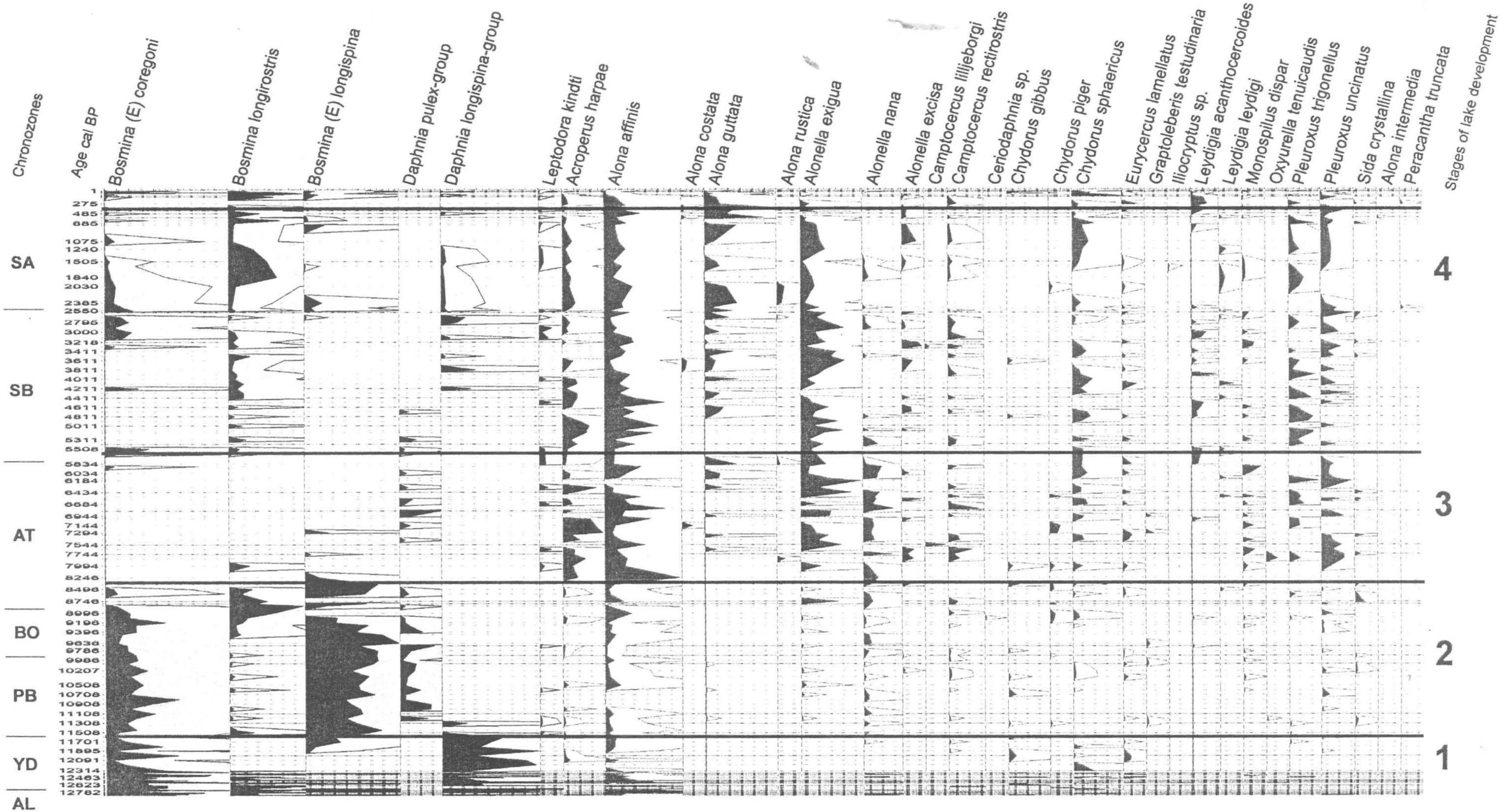
In the sediments the abundance of cladoceran remains was low, and only in profile T1/90 it exceeded 1000 specimens in 1 cm^3 . In Late-Glacial sediments 30 Cladocera species were found. The sediments contain remains of planktonic anf littoral forms of Cladocera. The planktonic forms are represented by species from the families Bosminidae, Daphniidae and Leptodoridae, the littoral forms are represented by the Chydoridae family. In the profile T1/90, a higher number of species was found than in the profile G1/87 and G1/90. During the Younger Dryas *Daphnia* pulex-group was absent in the sediments of profile from Tobyłka Bay, as in the whole profile G1/87. The difference of the sediment record in profile G1/87 in relation to profiles G1/90 and T1/90 concerns a much bigger percentage of *Bosmina longirostris* in profiles G1/90 and T1/90 during the Younger Dryas. The obtained results are presented in diagrams showing the total number of individuals or percent share of all species.

Within the frame work of the complex studies on the Holocene history of Lake Gościąż, the analysis of cladoceran remains only in sediments of the profile G1/87 was subjected.

The Holocene sediments contain remains of 6 planktonic species and 26 of littoral forms. Species composition and quantity of fossil remains in the sediments of lake Gościaż present a slightly different composition from that in other sites in Poland and the quantity of remains is much smaller.

On the basis of the concentration diagram and percentage curves and on the knowledge about climatic and ecologic preferences of Cladocera, VII Cladocera zones and 4 stages of lake development were distinguished. Zones III – VII correspond to the Holocene (I and II to Late-Glacial). The species composition of Cladocera in the Holocene sediments of Lake

Gościąż generally shows a rather oligo- or mesotrophic character of the lake. Changes towards eutrophy was observed during periods of the supposed influence of human activity.
The data of the Cladocera analysis were compared to the abundance of some plants reflecting human activity. It is observed that usually during the periods when these plants occurred in high abundance, the Cladocera species preferring the high trophy water were also much more present than during other times.
According to the comparative palynological and archeological studies, in the Polish lakes, these phases correlated with periods of settlers group's activity from the Neolithic times already. In all lakes, the most visible changes in the species composition of Cladocera were noted in the sediments from the Medieval Period. They were brought on the agricultural revolution, which lasts uninterruptedly up to now. There was observed, that the expression of the abundance of index species in sediments depends on the site (area, depth) of the lake. The smaller the lake is, the greater the changes in species composition of zooplankton, since the smaller water bodies react faster to an excessive supply of compounds and therefore the clear the records in the sediment. As in lake Gościąż, a considerable lower influence of these changes was noted in other large lakes (Lake Lednickie or Vrana lake).



Percentage diagram of subfossil Cladocera species in sediments of profile G1/87

Tuesday, 23 August 2011 (day 2^{nd})

Białowieża Forest

Studia Quaternaria, vol. 26: 25–39.

HISTORY OF THE BIAŁOWIEŻA PRIMEVAL FOREST, NE POLAND

Krystyna Milecka[1], Agnieszka M. Noryśkiewicz[2], Grzegorz Kowalewski[1]

[1] *Department of Biogeography and Palaeoecology, A. Mickiewicz University, Dzięgielowa 27, 61-680 Poznań, Poland; e-mail: milecka@amu.edu.pl; ichtys@amu.edu.pl*

[2] *Institute of Archaeology, Nicolaus Copernicus University, Szosa Bydgoska 44/48, 87-100 Toruń, Poland; e-mail: anorys@uni.torun.pl*

Abstract

Białowieża in Poland is a very famous region in Europe (because of its primeval forest and bison population), but its environmental history is poorly known. This article shows the results of palynological analysis, macrofossil analysis and geological settings of two mires in the Białowieża Forest. The pollen diagrams show changes of the vegetation cover from the younger part of the Late Glacial until the present time. The relative time scale is based on palynostratigraphy and comparison to published results of other sites from the adjacent regions. During the Late Glacial two stages of the vegetation succession were revealed: steppe and forest during the Alleröd period and tundra-like vegetation during the Younger Dryas. The Holocene history consists of five stages of plant cover development. The special features of the Białowieża Forest are conditioned by two main factors: low degree of anthropogenic impact and influences of continental climate and boreal zone, stronger than in the other regions of Poland.

Key words: pollen and macrofossil analysis, Białowieża Primeval Forest, NE Poland, peatland, Late Glacial, Holocene

INTRODUCTION

The Białowieża Primeval Forest (N 52°42' E 23°52') has been a very attractive area for man for many centuries. Natural features of this region, big area of forest and abundance of fauna were appreciated by Polish and Lithuanian kings and princes, who restricted the possibility of hunting there. After the First World War, law protection of the forest started and developed successfully and a nature reserve was installed in 1920. In 1977 Białowieża National Park was included to the World Biosphere Reserves of the UNESCO. The trial to recover the population of European bisons was successful in the twenties of the 20th century. Thanks to that, bison has become the symbol of Białowieża Forest, well known for all Polish people. Protection was one of the reasons for the low degree of anthropogenic changes in the forest communities, building probably the one of a few forest complexes in Europe, which can be called primeval forests. Three-leveled canopy of mixed deciduous forest with *Quercus*, *Ulmus*, *Tilia*, *Acer* and *Picea* is the main feature of this forest complex (Faliński 1986), a precious natural, scientific and touristic object, worth of many-directional studies substantiating the present state and directions of the development of the ecosystems. The most extensive research, made by Prof. J.B. Faliński and other scientists of the Geobotanical Station of Warsaw University provides scientific description of contemporary changes in the Białowieża Forest. This knowledge should be completed by palaeoecological research giving information about plant cover succession and climatic changes in the Late Vistulian (the last glaciation) and the Holocene.

Palaeoecological research at the Białowieża region was initiated in the 30-ties of the 20^{th} century (Paszewski, Poznański 1936; Paszewski 1937) and continued after the Second World War (Dąbrowski 1959; Borowik-Dąbrowska, Dąbrowski 1972). Unfortunately detailed palynological analyses have not been made for a long time in the area of NE Poland. Therefore chronological interpretation of events and their correlation between sites in this region was impossible. In the 80-ties and 90-ties of 20^{th} century new publications concerning some sites in Knyszyńska Forest (Kupryjanowicz 1991, 2000), Podlasie (Balwierz, Żurek 1987) and Polesie (Bałaga 1982, 1990) did appear. A considerable part of the research is still not published, *e.g.* of some sites in the Białowieża Forest and its surrounding (Kupryjanowicz 2003) and on the Late Vistulian (Weichselian) and Holocene vegetation history of the lake near Ełk (Milecka unpubl.).

The need for detailed description of the Białowieża Forest ecosystem history was the main reason for taking up the research in cooperation between the Geobotanical Station of Warsaw University and the Department of Biogeography and Palaeoecology AMU in Poznań. In summer 2000 two cores for sediment description and pollen and macrofossil analyses were taken. The cores were collected in the SE part of Białowieża National Park in the spring area of the Orłówka stream (left tributary of Narewka) in forestry section 373 (Fig. 1). The first core is located in the central part of Dziedzinka mire, the second one was a repetition of Dąbrowski's research (1959) at Kletno, but unfortunately the spot with the largest thickness of sediments could not be found.

Fig. 1. Location of the cores Kletno and Dziedzinka in the Białowieża Forest, NE Poland.

This article documents the results of pollen analysis of the Kletno and Dziedzinka peatbog (preliminary results also in Noryśkiewicz, Milecka 2002), the results of macrofossil analysis of the Kletno peatbog (results of macrofossil analysis of Dziedzinka peatbog in Noryśkiewicz, Kowalewski 2002, 2003) and presents the palaeoecological interpretation of the results and their comparison with other published diagrams of NE Polish sites.

MATERIALS AND METHODS

A geological survey was conducted on the Dziedzinka peatbog. Two coring transects (NS and WE) crossing the center were made (Fig. 2). Core S-20 (0–124 cm), located in the central part of the peatbog was taken for palynological and macrofossil analyses.

In Kletno one core (315 cm lengh) was taken in the central part of the peatbog using an Instorf corer with a diameter of 45 mm. The sediments were described following the Troels-Smith system (Troels-Smith 1955; Tobolski 2000) (Fig. 2).

The samples for pollen analysis were taken every 5 or 10 cm along the core, 1 cm^3 from the limnic part and 3 cm^3 from the peat. A standard preparation procedure and then acetolysis (3 min) was applied (Berglund, Ralska-Jasiewiczowa 1986) and the samples were mounted in glycerine and just before making a microscope preparation, stained with safranine or basic fuchsine for easier examination of pollen grains sculpture. The total of 1000 sporomorphs was counted (trees, shrubs, herbs, telmatophytes, aquatics and *Pediastrum*). In some parts of the cores, especially in the Late Glacial and early Holocene, the frequency was too low, and the counted sums were lower.

Percentage diagrams (Figs 3, 4) were prepared in Tilia and Tilia-Graph programmes (Grimm 1990), based on AP+NAP=100% (aquatic and wetland species excluded). The pollen types were divided into ecological groups and the zonation into local pollen assemblage zones (L PAZ) made on the basis of trees and NAP percentage curves, was confirmed by CONISS (Grimm 1987). Charcoal values are given in percentages of the total pollen sum.

Parts of 1–5 cm thickness (*ca.* 10–50 cm^3) were washed with running water through sieves of mesh diameter 250 and 120 μm. Some compacted samples were heated for 5 minutes in 10% potassium hydroxide (KOH). The remains were examined under a stereo-microscope Stemi 200-C Zeiss under 10–100× magnification and some selected remains in light microscope using 400× magnification. For determinations, keys and the reference collection of the Department of Biogeography and Palaeoecology were used (Bertsch 1941; Aalto 1970; Katz *et al.* 1965, 1977; Grosse-Brauckmann 1972, 1974, 1992; Tobolski 2000).

The macrofossil diagram was prepared with the programme C2 ver 1.4 (Juggins 2003). On the basis of the dominating plant components four local macro assemblage zones (L MAZ I-IV) were defined.

RESULTS

Stratigraphy

Kletno

Limnic sediments such as detritus gyttja mixed with macrofossils of Bryales (mainly *Drepanocladus* sp.) and *Sphagnum* peat are dominant in the Kletno mire (Fig. 2). Detritus gyttja was recorded at the bottom part (315–295 cm). It contains some roots of sedges (Cyperaceae) growing later at this place. Gyttja was accumulated in relatively shallow (*ca* 2 m) and stagnant water, whereas the overlying layer (295–235 cm) was deposited in a more shallow water body forming poorly decomposed peat characteristic for telmatic part of the lake (cf. Tobolski 2000). It contained some wood remains probably floating in water. The upper part of the core consists of normal peat. Poorly decomposed peat consisting of remains of *Carex* radicells and wood was recorded at 235–150 cm depth. More decomposed herbaceous peat dominated the next layer (150–50 cm). In the bottom part of this layer, poorly decomposed peat was recorded with dominating *Eriophorum* and *Sphagnum* remains. Description of sediment components according to Troels-Smith formula is shown below (Ld *Limus detrituosus*; Dh *Detritus herbosus*; Th *Turfa herbacea*; Dl *Detritus lignosus*; Tl *Turfa lignosa*; Sh *Substantia humosa*; Tb *Turfa bryophytica*):

315–295 cm – Ld2, Dh2; detritus gyttja;
295–235 cm – Th3, Dh1, Dl+; herbal peat;
235–150 cm – Th3, Tl1, Sh+; herbal peat with pieces of wood;
150–50 cm – Th2, Sh2; moderately decomposed herbal peat;
50–27 cm – Th3, Sh1; poorly decomposed herbal peat;
27–0 cm – Tb3, Sh1; poorly decomposed moss peat.

Dziedzinka

The coring transect shows the extent of the basin with a flat mineral bottom (Fig. 2). N–S extent of the basin is 280 m and in W–E direction 320 m, depth rarely exceeds 130 cm. A

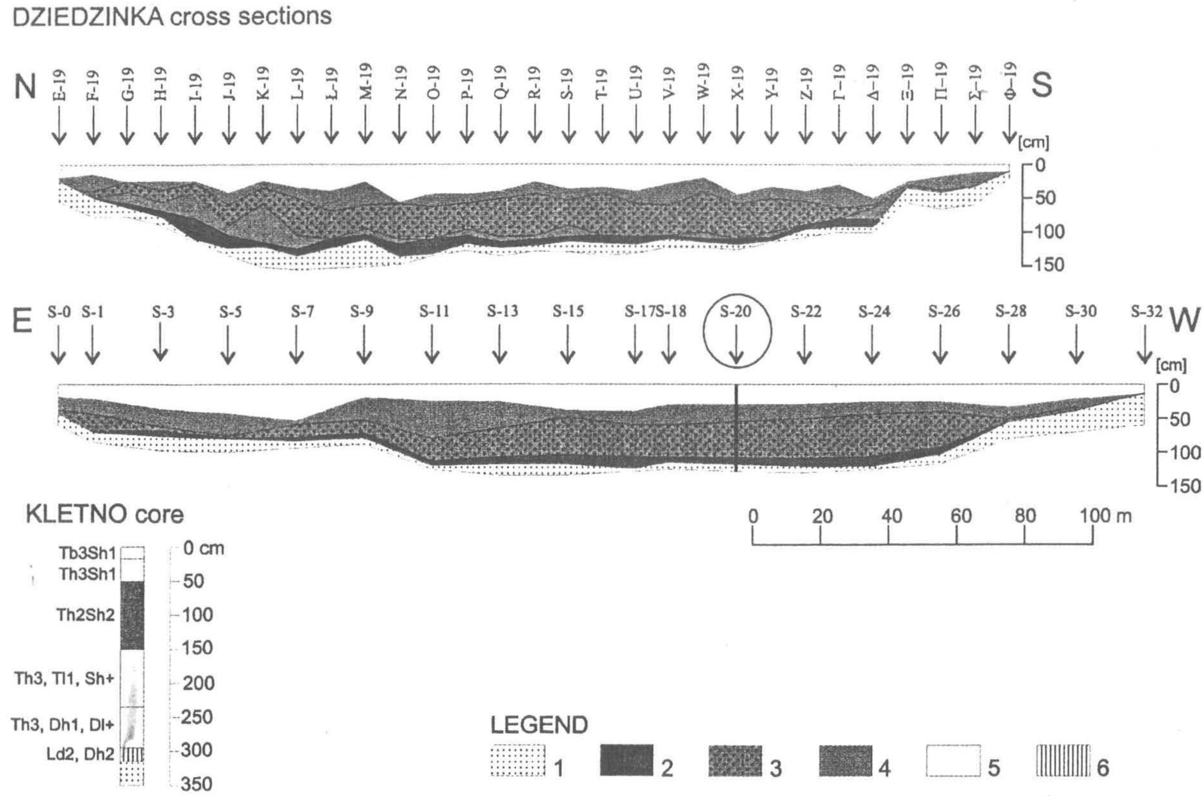


Fig. 2. Stratigraphy of sediment in the accumulation basins Kletno and Dziedzinka. *1* – mineral bedding, *2* – strongly decomposed organic matter, *3* – medium decomposed peat with charcoals, *4* – medium decomposed peat (mainly *Eriophorum* in Dziedzinka), *5* – slightly decomposed peat (mainly *Sphagnum-Pinus* in Dziedzinka, *Eriophorum* peat in Kletno), *6* – detritus gyttja.

similar pattern of layers was found in the entire peatbog. Strongly decomposed organic sediments with a significant content of mineral material (20–50% well rounded sand grains) occur at the bottom. In the core S-20 this layer is about 30 cm thick (124–94 cm), and contains quite a large amount of water and marsh plant macrofossils. The layer of moderately humified peat is overlying. It contains charcoals in addition to mineral material (94–60 cm). Numerous parts of vascular plants, with *Eriophorum angustifolium* roots in them, were the main components of this peat. Fruits and seeds were lacking, only single stems of *Sphagnum* sect. *Cuspidata* were found (80–75 cm). *Eriophorum vaginatum* dominated at the bottom as well as *Sphagnum* and *Pinus sylvestris* at the top (60–0 cm). Detailed description of sediments is given below (Gmin *Grana minora*; Dg *Detritus granosus*; anth *anthrax*; cort *cortex*):

- 124–119 cm – Gmin4, Dg+, Dh+; inflow wood, roots from the upper (younger) layers, endocarps of *Potamogeton* spp., proportion of mineral material up to 90%;
- 119–100 cm – Sh2, Th1, Dg+, Gmin1; rhizoderms, mostly determined as Cyperaceae, endocarps of *Potamogeton*, nuts and utricles of Cyperaceae *e.g. Carex* spp. 2- and 3-stigmata, proportion of mineral material up to 25%;
- 100–95 cm – Sh2, Th2, Dg+, Gmin+; rhizoderms, mostly determined as Cyperaceae, frequent endocarps of *Potamogeton natans* and *P. obtusifolius*, fruits of *Sparganium minimum*, seeds of *Menyanthes*, very frequent nuts of *Carex nigra* and *C. vesicaria*;
- 95–80 cm – Sh2, Th2, Dg+, Gmin+, anth.+; medium decomposed peat with traces of charcoals, mineral part up to 10%, frequent nuts of *Carex* cf. *vesicaria*, seeds of *Menyanthes*;
- 80–60 cm – Sh3, Th1, cort.+, anth.+; highly decomposed peat (the most in the bottom), undetermined rhizoderms dominate, charcoal, single parts of epiderms (with stomata), single parts of dicotyledonous leaves, *Pinus* bark, single branches of *Bryales*, single grains of sand;
- 60–55 cm – Th2, Sh2, Dg+, cort.+, anth.+; dominance of leaf vaginae of *Eriophorum vaginatum*, a seed of *Menyanthes*, traces of *Pinus* bark, a lot of charcoal, single covers of *Sphagnum* capsules, single leaves of *Sphagnum*;
- 55–50 cm – Th2, Sh2, Dg+, Dl+, cort.+; *Eriophorum* peat: epiderms of leaf vaginae of *Eriophorum* (60%), single leaves of *Calliergonella cuspidata*, pieces of wood, frequent seed testae of *Andromeda*, *Pinus* bark;
- 50–45 cm – Tb2, Sh2, Th+, anth.+; *Sphagnum* peat dark brown (60%), *Pinus* remains (40%), seed testae of *Andromeda*, single fibres of *Eriophorum*, single stems of *Aulacomnium palustre*, charcoal;
- 45–40 cm – Th2, Sh1, cort.1, Tb+, Dg+; herbal peat, dark brown, 70% epiderms of leaf vaginae of *Eriophorum vaginatum*, *Pinus* bark 25%, single leaves and stems of *Sphagnum*, single seed testae of *Andromeda*;
- 40–32 cm – Th2, Tb1, Sh1, Dg+, cort.+; *Eriophorum* peat (50%) dark brown, *Sphagnum* 10% (sect. *Cuspidata*, unfrequent stems, dominance of leaves), *Pinus* remains;

Table 1

Names, boundaries and short description of Kletno LPAZ (Fig. 3)

Depth [cm]	Number of LPAZ	Name of LPAZ	Description
45-0	Kl 9	*Carpinus-Picea*	High content of *Carpinus betulus* and *Picea abies* pollen; low curves of deciduous trees; NAP reaches 12%; Chenopodiaceae, *Rumex a/a* type, *Secale cereale* and cereals are present
65-45	Kl 8	*Quercus*	Low content of *Betula* and *Pinus* pollen; *Quercus* and *Corylus avellana* are the most numerous species in the deciduous trees group; *Alnus* curve exceeds 20%; single pollen grains of pasture indicators, *Cannabis* type and cereals
95-65	Kl 7	*Corylus-Betula*	The last increase of *Betula* curve, low content of *Pinus* grains; *Ulmus*, *Tilia* and *Fraxinus* declined; *Carpinus betulus* curve is low, but stable; continuous curve of *Picea abies*; presence of Ericaceae (*Calluna*, *Ledum palustre* and *Vaccinium* type) and *Secale cereale*
125-95	Kl 6	*Ulmus-Tilia-NAP*	*Pinus* curve stable, *ca.* 40%. *Betula* low; pollen grains of deciduous trees are dominant; *Fagus sylvatica* and *Carpinus betulus* appeared; *Pteridium aquilinum* spores are recorded; *Sphagnum* spores are abundant
155-125	Kl 5	*Alnus-Corylus*	Lowering of *Pinus* pollen grains; higher proportion of *Quercus*, *Ulmus*, *Tilia* and *Fraxinus*; *Corylus avellana* exceeding 5%; single pollen of *Viscum*; stable presence of *Pteridium aquilinum*, absence of aquatics and *Pediastrum*
195-155	Kl 4	*Pinus-Corylus*	High percentage of *Pinus* pollen grains; *Corylus avellana* curve reaches 5%; low and uncontinuous curves of *Quercus*, *Tilia* and *Fraxinus* excelsior are present; low, stable content of *Ulmus* grains; beginning of stable content of *Sphagnum* spores
273-195	Kl 3	*Pinus*	Dominant presence of *Pinus*, *Betula* curve decreases; beginning of presence of mesophilous trees like *Quercus*, *Tilia* and *Fraxinus* excelsior; stable, but low content of *Alnus* pollen grains; low NAP curve; presence of sporomorphs of *Typha latifolia*, *Utricularia* and *Menyanthes trifoliata*
294-273	Kl 2	*Betula-Pinus*	A lot of *Betula* pollen grains (max. 60%); *Pinus ca.* 35%; at 287 cm a continuous curve of *Ulmus* appears; decrease in NAP, especially heliophytes like *Artemisia* and Poaceae; increase in concentration of pollen grains
315-294	Kl 1	*Salix-Juniperus*	High percentage of herbaceous plants, *ca.* 30%; stable curves of *Pinus* and *Betula*; presence of *Dryas octopetala*, *Scleranthus perennis*, *Linnaea borealis* and *Selaginella selaginoides*

Table 2

Names, boundaries and short description of Dziedzinka L PAZ (Fig. 4)

Depth [cm]	Number of LPAZ	Name of LPAZ	Description
35-0	DZIE 8	*Carpinus-Picea*	There are absolute maxima of *Carpinus betulus* (20.4%) and *Picea abies* (10.1%); local peaks of *Tilia* and *Quercus*; *Alnus* and *Ulmus* decrease; increasing proportion of anthropogenic indicators: *Rumex*, *Plantago lanceolata*, *Secale* and cereals
62-35	DZIE 7	*Carpinus-Corylus-Betula*	Peak of *Carpinus betulus* (3.1%); single pollen grains of *Fagus sylvatica*; continuous curve of *Picea abies*; decrease of proportion of deciduous trees pollen; single grains of cereals and *Plantago lanceolata*
70-62	DZIE 6	*Corylus-Ulmus-Tilia*	Low proportion of pine; peaks of *Corylus*, *Alnus*, *Ulmus* and *Tilia*; pollen grains of *Viscum* appear; NAP doesn't exceed 4%, *Pteridium aquilinum* spores are still present; increasing content of *Carpinus betulus* pollen in the upper part
75-70	DZIE 5	*Corylus-Ulmus*	Peaks of *Corylus avellana* (8%) and Alnus (19%); increasing proportion of *Ulmus*, *Tilia*, *Quercus* and *Fraxinus* pollen; NAP declines; single spores of *Pteridium aquilinum*; decrease of *Sphagnum* spores
82-75	DZIE 4	*Pinus-Betula II*	Dominance of *Pinus* (26–49%) and *Betula* (31–55%); continuous curves of *Corylus avellana* and *Alnus*; *Sphagnum* average 22%, *Menyanthes trifoliata* and *Comarum palustre* are present
102-82	DZIE 3	*Pinus*	*Pinus* pollen grains are dominant (ca 50%); continuous curve of *Ulmus* appears; Poaceae and *Filipendula* are the most abundant herbs; *Typha latifolia*, *Menyanthes trifoliata*, *Sphagnum* and *Equisetum* are permanently present
115-102	DZIE 2	*Salix-Juniperus-NAP*	High proportion of *Pinus* (up to 61%) and *Betula* (up to 37%); maximum of *Juniperus* and *Salix*; there are heliophytes like: *Artemisia*, Poaceae, Chenopodiaceae; *Helianthemum*, *Linnaea borealis* and *Selaginella selaginoides*; increasing proportion of aquatics: *Alisma*, *Myriophyllum*, Nymphaea and *Pediastrum*
124-115	DZIE 1	*Pinus-Betula I*	*Pinus* pollen grains are dominant (61–75%), *Betula ca.* 20%; continuous curve of *Salix*; single grains of *Juniperus*, *Hippophaë*, *Betula nana* type, *Linnaea borealis* and *Helianthemum*; low curve of *Pediastrum*

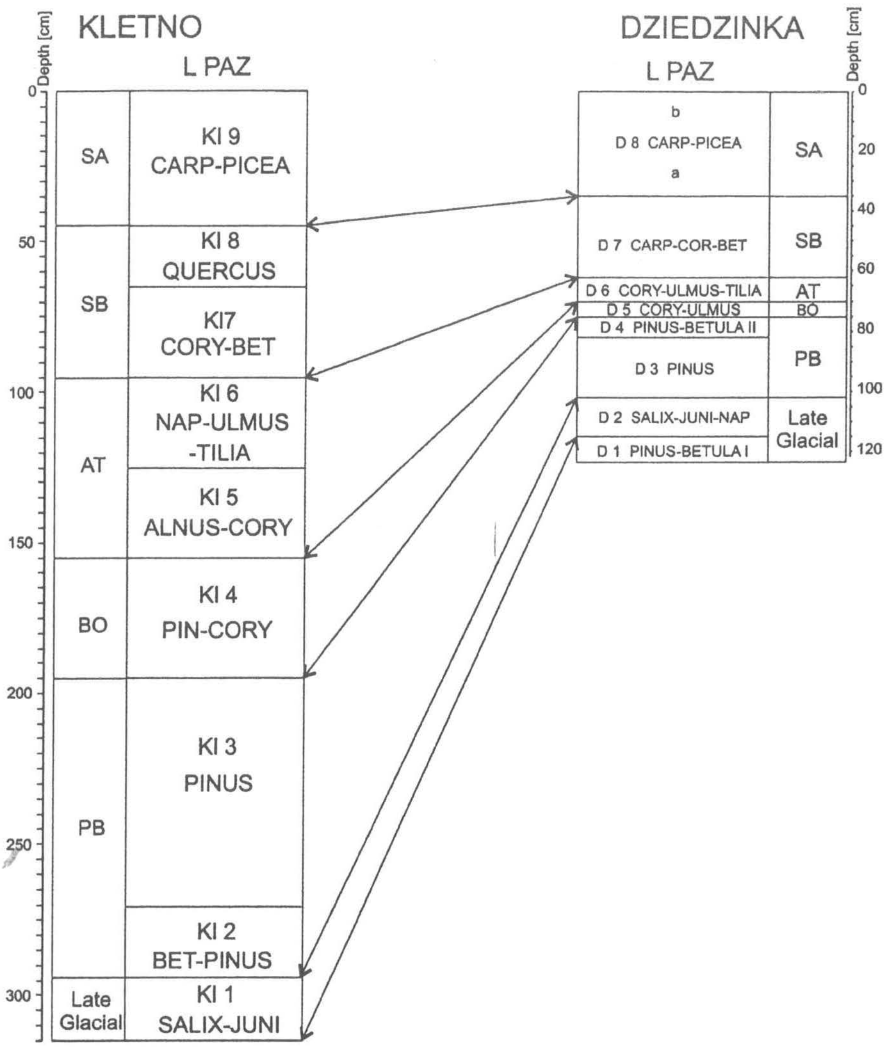


Fig. 5. Correlation of Local Pollen Assemblage Zones (LPAZ) of the Kletno and Dziedzinka S-20 cores. Positions of chronostratigraphical boundaries are uncertain because of lack of independent, absolute dating.

32–28 cm – Tb3, Sh1, Dg+, cort.+; *Sphagnum* peat (90%), *Pinus* remains;
28–25 cm – Tb3, Th+, Sh1, cort.+; *Sphagnum* peat (80%), *Pinus* bark, small roots of conifers;
25–20 cm – Tb1, Dg2, cort.1, Sh+; *Pinus* peat (70%): many pieces of bark;
20–0 cm – Tb4; *Sphagnum* peat.

Results of pollen analysis

On the basis of the main trees and NAP curves, pollen diagrams have been differentiated into nine (Kletno) or eight (Dziedzinka) local pollen assemblage zones (Tables 1, 2). Correlation of Kletno and Dziedzinka LPAZes is shown in Fig. 5.

Results of plant macrofossil analysis

Kletno

Macrofossil remains analysis was made for the bottom part of the sediment core (315–200 cm). It allowed to describe the succession of telmatophyte and aquatic plant communities and to specify the time of the lake overgrowing and mire formation. Four local macro assemblage zones (LMAZ) were defined (Fig. 6). They are correlated with the pollen zones Kl 1–Kl 3 (Fig. 7).

Kletno LMAZ I, *Chara-Scorpidium*, 315–295 cm

Chara is dominant in the sediments of this MAZ, 516 oospores/50 cm^3 were found at the depth of 305–300 cm. There was also *Potamogeton* identified mainly as epiderms of the leaf stalks. In the bottom sample of this layer endocarps of *Potamogeton filiformis* and *P. praelongus* were recorded. There were also fruits of *Ranunculus* sect. *Batrachium* and *Myriophyllum*. Since the beginning of the sedimentation process *Nymphaea* remains were present as seed testae. *Drepanocladus* and *Scorpidium scorpioides* (some leafless stems) represent the Bryales group. Animal remains were identified as well. Cladocera (ephippia), Bryozoa (statoblasts), Chironomidae (head capsules) and Oribatida have been present since the beginning of the accumulation process.

51

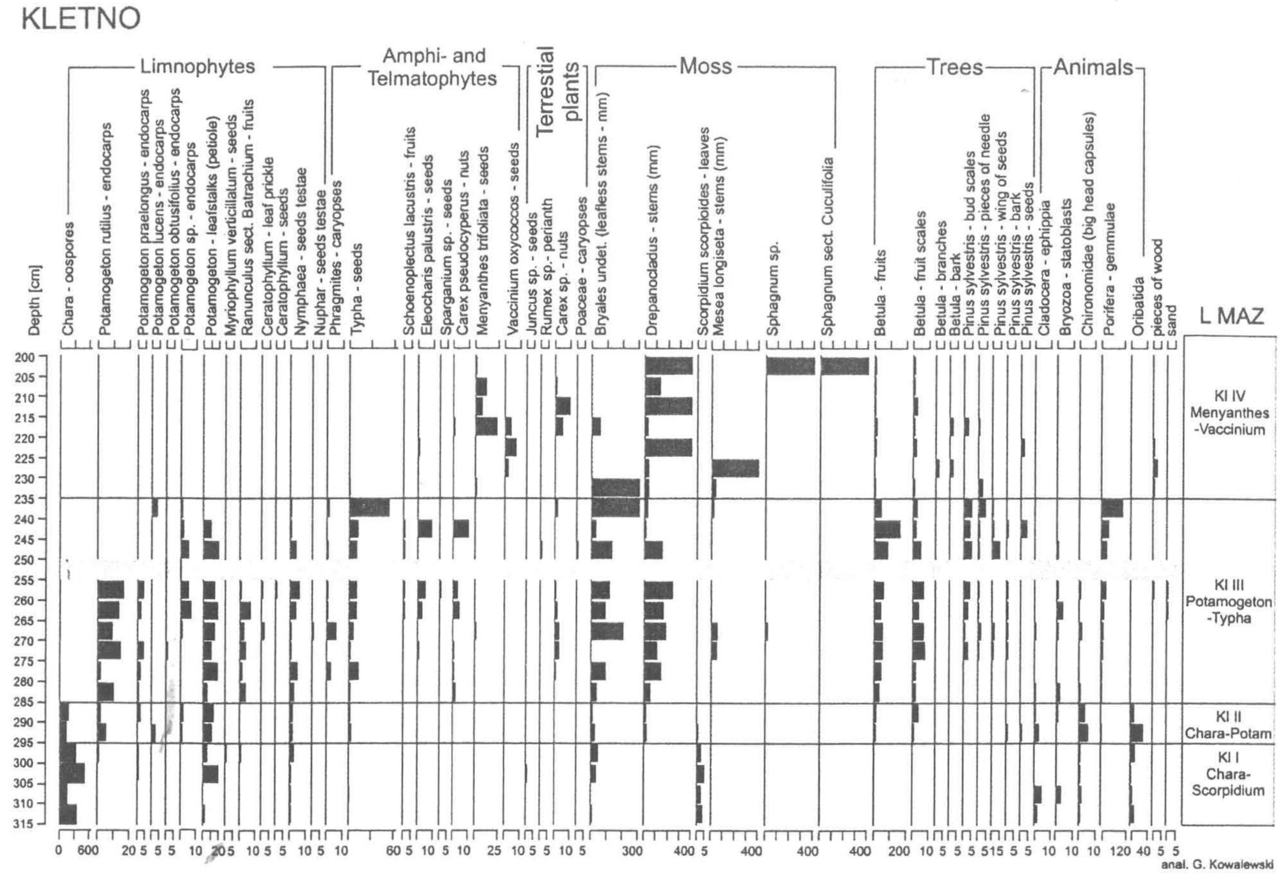


Fig. 6. Macrofossil diagram of a deeper part of the Kletno core. Numbers are given per 50 cm^3 of sediments.

Kletno LMAZ II, *Chara-Potamogeton*, 295–285 cm

Chara proportion decreased (max. 187 oospors/50 cm^3) and *Potamogeton* remains increased; continued occurrence of *Nymphaea*; *Typha* has been found in all the samples. Among mosses *Drepanocladus* was identified. At the first time macrofossils of *Betula* (nutlets and fruit scales) and *Pinus* (bark and seed testae) were determined. Among the animal remains, Chironomidae (only big head capsules were calculated) and Oribatida had their maxima and Porifera gemmules were observed.

Kletno LMAZ III, *Potamogeton-Typha*, 285–235 cm

Seeds (mostly *Potamogeton rutilus*) and vegetative remains of *Potamogeton* sp. were dominant in the middle part of this LMAZ. Underlying layer contained a lot of *Ranunculus* sect. *Batrachium* and *Nymphaea* seeds. *Ceratophyllum* and *Nuphar* appeared as well. In the whole layer remains of rush components were found: *Phragmites* caryopses, fruits of *Typha*, *Schoenoplectus*, *Eleocharis* and *Sparganium*. Their proportion increased upwards. *Typha* had its maximum in the upper sample of this MAZ – 54 seeds/50 cm^3. *Carex pseudocyperus* increased upwards as well.

Among the Bryales, *Drepanocladus* was dominant. *Meesia longiseta* and *Sphagnum* were identified in low abundance. In the bottom sample of this layer stems with leaves were absent. Frequencies of *Betula* and *Pinus* remains increased upwards and in the uppermost sample they had their maxima. Bryozoa statoblasts, a few Cladocera ephippia and Chironomidae remains represented the animal fossils. Spongiae gemmulas quantity increased and reached 112 items per 50 cm^3 in the uppermost sample.

Kletno LMAZ IV, *Menyanthes-Vaccinium*, 235–200 cm

Rush plants and aquatics dissappeared almost completely. *Vaccinium oxycoccos*, *Rynchospora fusca*, *Carex limosa*, *C.* cf *rostrata* and *Menyanthes trifoliata* were recorded. The latter was the most abundant in the layer 220–215 cm, where 22 seeds/50 cm^3 were found. Variety of Bryales remains in the bottom part of this layer was as poor as in the upper part of the previous MAZ. *Meesia longiseta* was a dominant component in the layer at the depth of 230–225 cm, *Drepanocladus* was the most numerous in the overlying layer. Among tree remnants only pieces of wood occurred frequently. There were no remains of aquatic fauna.

DISCUSSION

History of Białowieża Forest in the light of palynological research of Dziedzinka and Kletno mires

The pollen diagrams (Figs 3, 4 and 7) show changes of the vegetation cover from the younger part of the late glacial until the present time (Noryśkiewicz, Milecka 2002; Noryś-

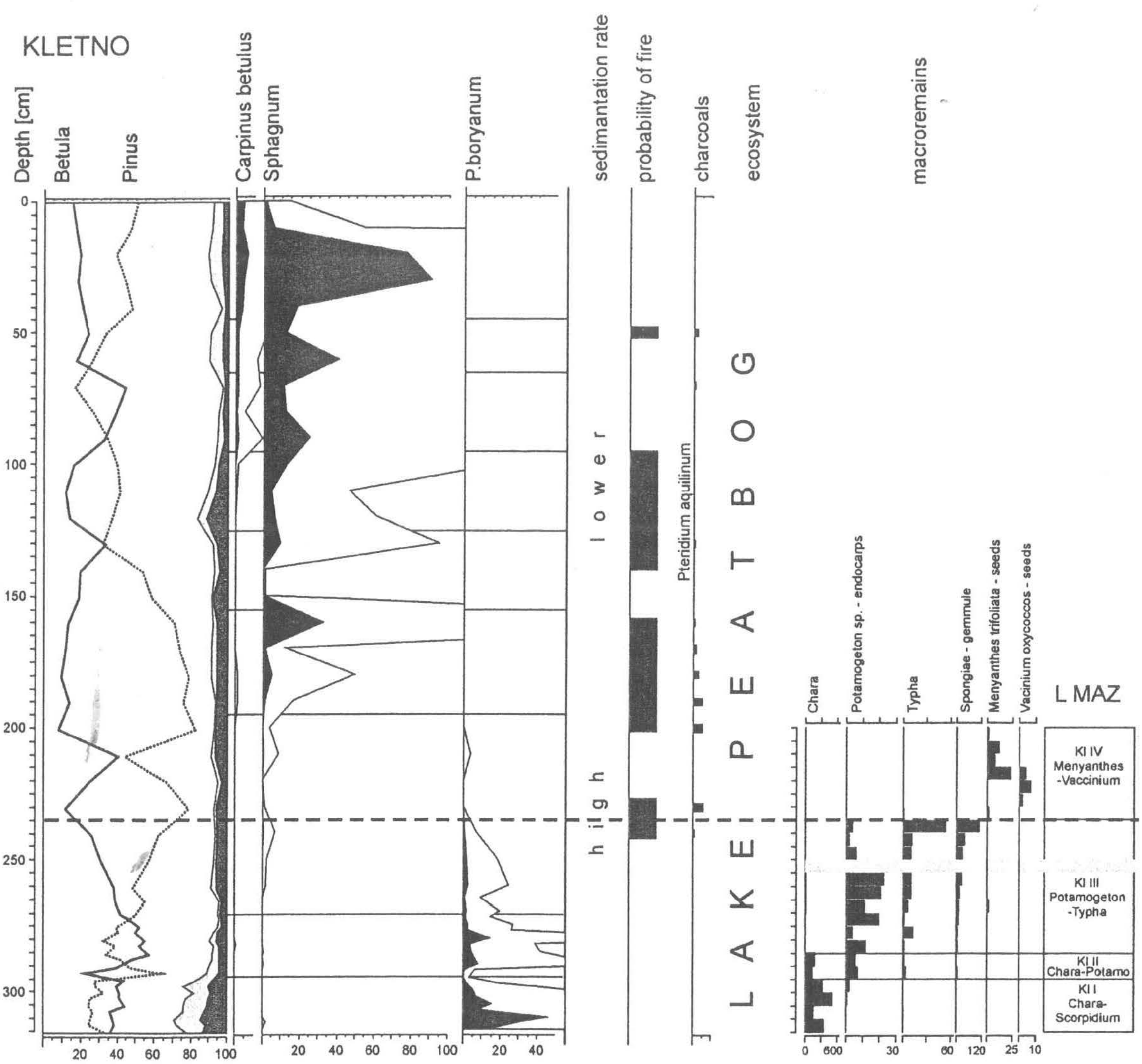


Fig. 7. Selected pollen curves, local pollen assemblage zones of the Kletno diagram, local macrofossil assemblage zones and stages of the basin development. The possibility of fires and the changes of accumulation rate are also marked.

kiewicz, Kowalewski 2002, 2003; Milecka, Noryśkiewicz 2003). It seemed that the Dziedzinka mire formed earlier, in the Alleröd period, but the interpretation of the bottom part of the diagram is ambiguous. An absolute chronology of the sediments was not established, the relative time scale is based on palynostratigraphy and comparison to the published studies made in adjacent regions (Kupryjanowicz 1991, 2000; Bałaga 1998, 2003; Ralska-Jasiewiczowa 1966).

Vegetation history

Late Glacial (Kl 1; Dzie 1, Dzie 2)

The bottommost part in the Dziedzinka profile (D1 L PAZ *Pinus-Betula*, four bottom samples 124–118 cm) shows the presence of forest in the region. *Pinus* was dominant and accompanied by a good amount of *Betula*. Pollen grains of *Juniperus* and *Hippophaë rhamnoides* indicate the development of juniper and sea-buckthorn bush in dry areas. Presence of heliophytes like *Artemisia* and Chenopodiaceae reveals not a very dense canopy and good light conditions at the ground. As shown by pollen analysis accumulation process started during the late Alleröd period, in agreement with the older estimate of Dąbrowski (1959). This is also confirmed by other sites (Kupryjanowicz 2003; Bałaga 1998, 2003).

Cooling of climate during the Younger Dryas caused changes in vegetation of the Białowieża region reflected both in the Dziedzinka and Kletno sediments: D2 L PAZ, *Salix-Juniperus*-NAP; Kl 1 L PAZ, *Salix-Juniperus* (Fig. 5). Pollen spectra indicate that the forest was more open and showed a mosaic pattern of park tundra, herb tundra with bush, steppe, and forest-tundra. Steppe communities with *Artemisia*, Chenopodiaceae, *Hippophaë rhamnoides* and *Juniperus* dominated at the poorest and driest areas. On better ones with more water, Poaceae and Cyperaceae were the most important. Higher proportion of *Salix* and *Betula nana* type show the development of patches with bush-tundra. The Kletno diagram shows higher proportion of NAP than that of Dziedzinka. Probably this is the result of more open character of the plant cover and local conditions reflected around the Kletno peatbog.

Early Holocene (Preboreal and Boreal Periods) (Kl 2, 3, 4; Dzie 3, 4, 5)

The beginning of the Holocene was marked with a lower proportion of open plant communities and a development of forest, which since then has been dominant in the Białowieża region up to the present. However at particular periods the main species and structure of the forest underwent distinct changes. *Betula-Pinus* forest was the main plant community at the beginning of the Holocene with a marked presence of Late Glacial elements like juniper, the latter being important at the beginning only (in Kl 1).

Then *Pinus* became the dominant species, but *Corylus avellana* and *Ulmus* were the next immigrating elements and they quickly grew in meaning. Then, one more mediocratic species – *Quercus* appeared. Much worse light conditions caused decreasing proportion of birch, continued since the beginning of the Holocene. There were only some open plant communities with heliophytes like *Artemisia* and Chenopodiaceae. *Juniperus* disappeared completely. Herbal elements occurred at wet places, as indicated by pollen grains of *Heracleum* type, *Potentilla* type and *Filipendula*. In the end of this period a quick expansion of *Alnus* took place dominating along the rivers and streams up to the present time.

Middle Holocene (Atlantic Period) (Kl 5, 6; Dzie 6)

Gradually the proportion of *Pinus* decreased in the forest. *Corylus avellana* and then *Ulmus*, *Quercus* and *Tilia* became the most important components of the more and more dense forest communities. *Betula* played a greater role, as it benefited probably locally better light conditions. A continued development of communities on wet areas took place and *Alnus glutinosa* was the most important element there.

The next stage shows full development of mixed, deciduous forest. *Quercus*, *Ulmus* and *Tilia* dominated the tree canopy and *Corylus avellana* the brushwood. *Pinus sylvestris* was still present probably on mesotrophic soils. The importance of deciduous tree species suggests dense canopy of the forest but the Kletno diagrams display higher NAP curves, because of more Poaceae which could exist in open communities and in some kinds of forests as well. *Pteridium aquilinum* in the understorey suggests fires (Behre 1981; Latałowa 1992). *Pteridium* likes a lot of mineral elements in the soil and often appears after fire. *Pteridium aquilinum* could also indicate clearing by fire (slash-and-burn) (Göransson 1986).

Late Holocene, older part (Subboreal Period) (Kl 7, 8; Dzie 7)

The mixed deciduous forest changed at the beginning of this period. All deciduous elements decreased, except *Corylus avellana*. This species grew in the brushwood or it produced more pollen grains due to less density of the forest. Better transport and spreading of pollen caused higher proportion of *Corylus avellana* in the pollen spectra. An increasing amount of *Betula* indicates better light conditions in the forest. NAP taxa are not numerous and they mostly occur in communities of the understorey: *Calluna vulgaris*, *Ledum palustre*, Ericaceae and *Pteridium aquilinum*. The latter species was still present at the beginning of this period but then it dissappeared.

Then *Quercus* forest developed with increasing proportion of *Pinus* and *Carpinus betulus*. Pollen grains of hornbeam occurred at the beginning of this period, but *Carpinus* trees were present already four thousand years ago (Ralska-Jasiewiczowa *et al.* 2004). The forest at the "*Quercus*" phase (Kl 8, Fig. 3) was gradually enriched with hornbeam. *Ulmus* and *Tilia* were still present, but *Fraxinus excelsior* decreased, probably replaced by *Alnus* on wet areas.

Rare pollen grains of *Fagus sylvatica* do not show the occurrence of this tree in the forest (see below).

Late Holocene, younger part (Subatlantic Period) (Kl 9; Dzie 8)

At the beginning of this period another change in species proportion in the forest communities occurred. *Quercus* and *Carpinus betulus* decreased clearly, and a second *Ulmus* fall appeared. *Tilia* was not very frequent but stable in amount. These elements were taken over by *Carpinus betulus* and *Picea abies*. A considerable variety of forest communities developed, that are still present in the Białowieża region depending on local soil and hydrological conditions. Proportion of herbs was low, dominated be Ericaceae dwarfshrubs.

In the youngest part of the diagram, human impact in the Białowieża forest is revealed. *Artemisia*, Chenopodiaceae, *Plantago lanceolata* and *Rumex* represent ruderal and pasture land. In the Białowieża National Park there was no cultivation. A few pollen grains of *Secale cereale* do not indicate cereal fields, but have been long distance transported. Pollen grains of other cultivated plants (except cereals) were not found.

Presence and proportion of some tree species

The proportion of *Carpinus betulus* is relatively low in the Białowieża Forest during the late Holocene; 5% in Kletno and 15% in Dziedzinka, are the maximum amounts reached only in the youngest phase of the forest development. Also other sites of NE Poland do not show a large abundance of hornbeam. Its proportion does not exceed 10% (Balwierz, Żurek 1987) or, as a rule, even 5% (Bałaga 1982; Kupryjanowicz 2000; Milecka, unpubl.). *Carpinus betulus* is a species well-growing under the influence of continental climate in middle east Europe, but pollen analyses of many sites show the development of forest with hornbeam also in Great-Poland and West Pomerania during the Subboreal Period (Ralska-Jasiewiczowa 1964, 1983; Tobolski 1987, 1991; Filbrandt-Czaja 1998, Milecka 1998; Makohonienko 2000). All these sites and isopollen maps for Poland (Ralska-Jasiewiczowa *et al.* 2004) show up to 30–50% of *Carpinus betulus* in the pollen sum. Hornbeam-oak forest was suggested to be unlike any kind of presently existing community (Tobolski 1991). In the eastern part of Poland such a community has never developed and isopollen maps show a lower proportion of *Carpinus betulus*. This indicates a balanced meaning of several deciduous forest components instead of a dominant role of *Carpinus betulus* as it was observed in Great-Poland.

Single pollen grains of *Fagus sylvatica* were recorded during the Atlantic at Kletno and Dziedzinka as well. In the Subboreal the beech curves are continuous, but very low. A

54

similar picture can be observed on the isopollen maps for north-eastern Poland. *Fagus* grains appeared 4000 BP (up to 0.5%), and according to the maps came from distant sites located probably on the south. The maps 3500–2000 BP show *ca.* 1–2% for NE Poland. Concurrently forests with high proportions of *Fagus* developed in NW and S Poland. It was the beginning of formation of the modern range of this species and its plant communities. The highest beech pollen content in the Białowieża region is found at 2000 BP, however it does not exceed 2% suggesting that *Fagus* has never reached the Białowieża Forest (Huntley, Birks 1983; Latałowa *et al.* 2004). The maps for the younger periods show lower percentages ranging between 1–2%. More studied sites are needed in the region to solve the problem of *Fagus* presence.

Is Białowieża different from other sites in NE Poland?

Pollen analyses reflect a succession of regional plant communities on mineral soils showing all successive stages in an adjacent area. However to compare the results of many sites in a reliable way, some points have to be kept in mind: a) only complete profiles are a good basis for palaeoecological research (*i.e.* with no hiatus); b) to get reliable results big and deep basins (lakes) should be analysed; c) in each site the basis for calculation of percentages (sum AP+NAP) should be the same; d) peat sediments give a lot of information concerning local environment *e.g.* hydrology and plant communities on wetlands but high proportions of local pollen types can distort the picture of regional changes; e) location of a site in a traditional settlement area, strongly influenced by human activity for thousands of years, gives results different from a site lying in areas forested up to the present time. We must say that the studies of the sites of NE Poland often do not fulfill these points. Some of them are incomplete, the time scales are not reliable, which make their comparison difficult. The Kletno and Dziedzinka cores have these disadvantages too, so very detailed descriptions and conclusions are not thought to be the final ones. Further research of the region is therefore needed.

There were some, climatically different stages during the Late Glacial with initial type of soils as well as a pioneer plant communities. Climate warming resulted in spreading of forest communities. Alternatively, cooling of climate caused recession of forest and development of steppe and tundra. At the beginning of sediment accumulation in the Kletno and Dziedzinka basins, (during the Alleröd period) Central Europe was covered with *Pinus* and *Betula* forest. Preserved trunks of *Pinus* from the area adjacent to Lake Kruklin (Stasiak 1964) are a direct proof of forest presence in NE Poland during Alleröd period. All the pollen diagrams from the eastern part of Poland show relatively high amounts of arboreal pollen, however stable presence of heliophytes indicates not very dense forests (Bałaga 1990; Kupryjanowicz 1991, 2000). Changing curves of *Pinus* and *Betula* recorded at many neighbouring sites (Moszne, Karaśne, Durne Bagno, Krowie Bagno, Bałaga 1990; Kupryjanowicz 1991) suggest a relation to local and soil rather than climatic conditions. During the Younger Dryas climatic cooling steppe and tundra plant communities developed. High values of *Juniperus* are a "marker" for the Younger Dryas in North Poland, exceeding, e.g. at Stare Biele site 7% (Kupryjanowicz 2000) but proportion of *Juniperus* at Kletno and Dziedzinka sites (0.6%) is surprisingly low (Fig. 8). It seems that the differences are caused by a complicated soil–environment system. *Juniperus communis* is a heliophyte species of dry, sandy soils. Lack of appropriate local conditions could be the reason of its rare occurrence in the Białowieża Forest.

Attention has to be paid to the occurrence of *Quercus*, that seems to appear rather late in the early Holocene. The *Quercus* curve starts at Kl 4 and D 4 (Boreal) (Figs 3 and 4), but the content of oak pollen grains is very low, suggesting their transport from distant sites. The real, local presence of *Quercus* in the plant cover started in the middle Holocene. According to the isopollen maps (Milecka *et al.* 2004) late immigration of oak is characteristic for NE Poland. Many diagrams of this area (Balwierz, Żurek 1987; Kupryjanowicz 1991, 2000; Milecka, unpubl.) confirm that. During the late Holocene *Quercus* has a low proportion in the forest vegetation. Isopollen maps of *Quercus* sp. show percentages of 10–15% at almost all regions of Poland. NE Poland is an exception and *Quercus* values at all the sites mentioned above do not exceed 10%. Lower proportion of oak is a feature of this area up to the present time.

Fraxinus excelsior does not exceed 1%. The sediments of Stare Biele mire in Knyszyńska Forest (Kupryjanowicz 2000) and Machnacz peatbog near Białystok (Kupryjanowicz 1991) show similar values of *Fraxinus excelsior*. Ash appeared rather late and its local occurrence and development in plant communities should be connected with the climatic optimum and middle stage of the Atlantic period (cf. Tobolski 1995). Clearly higher values of *Fraxinus* are observed at Wizna site, Podlasie (Balwierz, Żurek 1987) and in the Miluki diagram at the site near Ełk (Milecka, unpubl.). It is hard to explain these differences and low proportion of ash in forest communities, especially in light of "multilateral specialisation" in life strategy of this species and its good ability to use many ways of reaching the reproductive success (Faliński, Pawlaczyk 1995). Local hydrographic conditions, that influence development of *Fraxinus excelsior* are the most probable reason of differences in its proportion. Activity of some animals (*e.g.* European bison, deer or beaver) can change the occurrence of ash in plant communities to some (low) degree (Faliński, Pawlaczyk 1995), but this phenomenon has not significant meaning. Frequency of *Fraxinus* at sites of the other regions in Poland is usually higher (more than 1%), but seldom exceeding 2% (Latałowa 1992; Noryśkiewicz 2002; Obremska, Lamentowicz 2002; Milecka, Szeroczyńska 2005).

After the climatic optimum *Ulmus* fall took place in Białowieża Forests. This phenomenon has been described at many sites of Central Europe (Troels-Smith 1953; Iversen 1973; Aaby 1986; Göransson 1986; Latałowa 1992; Miotk-Szpiganowicz 1992; Makohonienko 2000) and it is thought to be the final stage of the Atlantic Period and of the existence of mixed, deciduous forest. Usually however, in pollen diagrams *Ulmus* is the only declining species and the other mesophilous components stay at the stable level. In Kletno the difference is that *Tilia*, *Quercus* and *Fraxinus* fall concur-

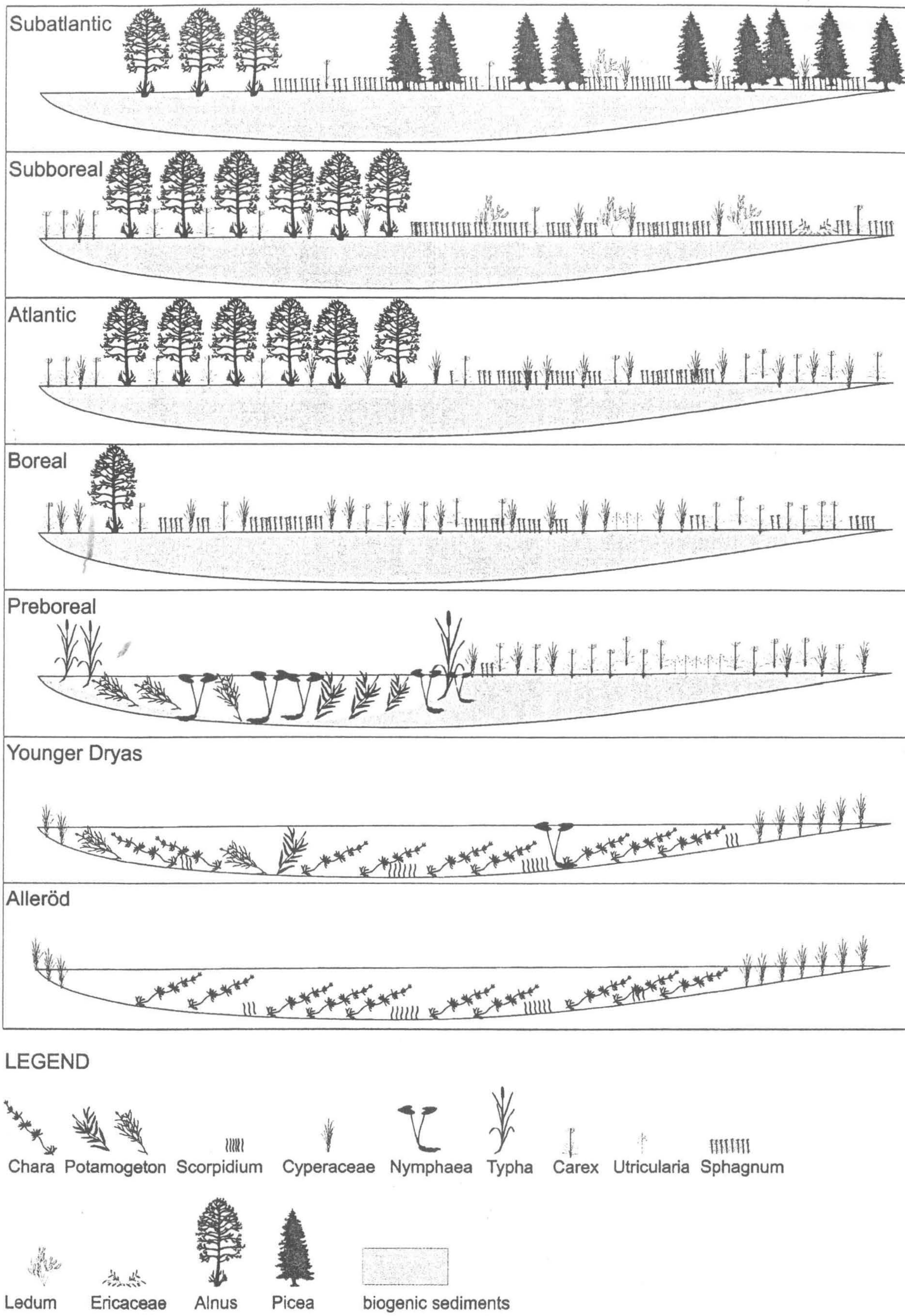


Fig. 8. Dominant components of the local plant communities in the accumulation basins in the different chronozones of the Late Glacial and the Holocene.

55

rently or almost concurrently with *Ulmus*. We can not say that definitely because of poor time resolution of the diagram. In Dziedzinka *Ulmus* and *Fraxinus* declines preceded the oak and *Tilia* falls. Then *Quercus* renewed to develop *Quercus-Corylus* forest, but *Ulmus* and *Fraxinus* stayed of no importance up to the present. Diminishing of *Tilia* and *Fraxinus* is seen at the sites in Knyszyńska Forest as well (Kupryjanowicz 2000). Proportion of *Fraxinus excelsior* in the surrounding of Lake Łukcze at Polesie has been low, but more or less stable in the Atlantic, Subboreal and Subatlantic Periods (Bałaga 1982, 1990). *Fraxinus*, just like *Tilia* belongs to the stable components of the forest at the area adjacent to Lake Łukcze. Their proportion was the highest during the climatic optimum and then they diminished until the present, but the lowering has been very slow and insignificant. It seems that the NE Polish sites give a different picture of the vegetation changes: increasing meaning of *Carpinus betulus* and then *Picea abies* caused lower proportions of mesophilous trees like *Ulmus*, *Tilia* and *Fraxinus*, but in the middle-east part of Poland, beyond the geographical range of *Picea*, proportions of trees were different.

During the youngest part of the Holocene the plant communities that exist in Białowieża Forest today, were developed. There are rich deciduous forests and mixed forests with high proportion of *Picea*. Pollen analyses in Knyszyńska Forest (Kupryjanowicz 2000) give a different picture. Proportions of deciduous trees are clearly lower. Curves of *Quercus*, *Corylus*, *Ulmus* and *Fraxinus* diminished and ceased, *Carpinus* presence has been slightly marked. It means that forest communities developing at that area were poorer in deciduous elements and conifers have been dominating. Next to *Picea*, high proportion of *Pinus* was remarkable too, probably as the result of pine plantations going on since the 19th century. Similar results are obtained at Podlasie site (Balwierz, Żurek 1987). Absence of pollen grains of deciduous trees in the uppermost samples of the diagrams suggests lack of deciduous elements of the mixed forest, or that they have been rare and dominated by *Picea*. Miluki site near Ełk (Milecka, unpubl.) shows low amount of deciduous trees as well. However, human impact caused changes in vegetation there. Consequently, *Pinus*, herbs and human indicators have been dominating. The plant communities differ also south of the Białowieża Forest, in Łęczna-Włodawa Lake District, where absence of *Picea abies*, high proportion of *Quercus* and *Carpinus betulus*, and lower proportions of *Ulmus*, *Tilia* and *Fraxinus* are observed. This phenomenon is due to the natural geographical range of spruce and its limited occurrence south of Białowieża.

The special features of Białowieża Forest are conditioned by two main factors: a) continuous occurrence of forest throughout the Holocene and weak human impact; b) influences of continental climate and boreal zone which are stronger than in the other regions of Poland. These conditions resulted in low values of the *Fagus* curves in the Kletno and Dziedzinka diagrams. *Fagus sylvatica*, as subatlantic species was possibly absent in Białowieża. That's also why the proportion of mesophilous trees has decreased in the youngest part of the Holocene and *Picea abies*, an important component of boreal, coniferous forest has increased in significance and co-created many plant communities.

Mire development based on macrofossil and pollen analysis

Kletno

The development of a peatbog ecosystem was preceded by the existence of a shallow lake (Figs 6, 7 and 8). The same took place at Dziedzinka peatbog in the adjacent area. Pollen analysis unambiguously indicates the beginning of the accumulation process during the Late Glacial. Results of macrofossils analysis are less clear. The oldest stage of the sedimentation is documented only by remains of aquatic plants living in undisturbed, shallow lakes. Absence of tree macrofossils, *Pinus* and *Betula* in L MAZ Kl I provides an indirect proof of tundra existence during the Younger Dryas. The spectra of macro remains indicate the end of limnic accumulation at the same level as evidenced by the pollen diagram (disappearance of *Nymphaea* and *Pediastrum* curves, Fig. 6).

L MAZ Kl I is correlated with L PAZ Kl 1, represented by fine, detrituous gyttja with parts of rush roots, that are thought to be secondary in this layer. Since the beginning of the lake existence there have been communities of vascular macrophytes growing in shallow water together with some *Chara* species. *Scorpidium scorpioides* and *Chara* indicate the presence of calcium carbonate in the lake ecosystem. Surprisingly there was a small amount of identified plant remains, but a lot of animal remnants, especially undetermined chitinous parts of beetles. Oribatida disappeared together with *Chara* suggesting their relationship to Characeae. Continuous presence of *Nymphaea* indicates, that the lake depth has never exceeded 1.5–2 m (Podbielkowski, Tomaszewicz 1979).

Warming of climate at the beginning of the Holocene caused clear changes in the local plant communities. Abundance of *Chara* diminished and vascular plants played a more important role. *Scorpidium scorpioides* decreased as a result of declining calcium carbonate in the water. This rapid change is marked by development of *Pediastrum*, occuring at the turn of the late glacial to the Holocene. *Potamogeton rutilus* and *P. praelongus* as the main species among pondweeds suggest rather eutrophic environmental conditions. Appearance of *Typha* is an indicator of lake shallowing, as it grows at the shore and dissappears as late as after the lake extinction.

At the beginning of the Holocene (L MAZ III) proportion of pondweeds increased but Characeae disappeared completely. Increasing trophy of the basin could be one reason of these phenomena. It is also confirmed by a big amount of *Nymphaea* seed testae and continuous presence of seeds of *Ranunculus* sect. *Batrachium*. *Typha* increased a little next to *Phragmites* rushes. These events reflect the continuous process of lake shallowing and getting the bottom more boggy. Such conditions made a suitable ground for *Carex pseudocyperus* and *Eleocharis palustris*, eutrophic species entering the rushes at boggy, not stable bottom (Podbielkowski, Tomaszewicz 1979). The last stage of shallowing of the lake was dominated by *Typha* rushes. Disappearance of water invertebrates was a consequence of decreasing open water area and volume of water. There was the only dynamic increase of Porifera quantity in the upper part of the sediments and it confirms quick decrease of the water volume. Continuous

56

presence and high proportion of *Drepanocladus* indicates meso-and/or eutrophic water conditions. *Drepanocladus* grew together with *Meesia longiseta*. The remains of this species (leafless stems) were hardly found at this level (L MAZ III/IV turn) but they were identified more often in the lower and upper layers of the sediments. During the last stage of the lake existence, some water level changes could take place, which probably caused good conditions for higher microorganisms activity.

The rushes were overtaken by terrestrial species. Occurrences of *Vaccinium oxycoccos*, *Menyanthes trifoliata*, *Carex limosa* and *Carex rostrata* are especially important because they indicate development of plant communities in mesotrophic, peatland conditions, the first stage of peat-forming terrestrial communities. They have developed a dense vegetation cover as a basis for trees and shrubs growth. Existence of local trees is documented by an increasing amount of remains of bark, branches and pieces of wood. Presence of *Menyanthes trifoliata* pollen grains correlates well with its seeds in the sediments. Clear decrease in *Menyanthes* remains is concurrent to dynamic increasing abundance of *Sphagnum* spores, which suggests intensive development of *Sphagnum* peat during the early Holocene (probably Boreal period) (Figs 7 and 8). At the same time some charcoals were found. They probably document fires in the Białowieża Forest.

Dziedzinka

The Dziedzinka basin was not deep enough to develop a typical lacustrine sedimentation leading to gyttja. During the initial stage (in the Late Glacial) *Chara* communities did not develop, either. At the beginning the basin looked like a telmatic zone and existed as an extent boggy area overgrown with shallow lake and rush plants (*Potamogeton*, *Carex* spp., *Sparganium* spp.). The layer of biogenic sediments containing remains of aquatic organisms is not thicker than 30 cm. Appearance of *Menyanthes* fruits marks the level of shallowing of the basin (95–100 cm) which is confirmed by clear decrease in planktonic organisms as *Pediastrum*. According to pollen analysis, terrestrialization of the area took place at the beginning of the Holocene, earlier than at the Kletno site. The next stage of sediment accumulation took place in stable hydrological conditions of high groundwater level. Cyperaceae were the main element of the peat-forming community and sedentation process of organic material was dominant. Charcoals appeared for the first time.

In the middle of the early Holocene a peat layer (80–60 cm) was formed. Differentiated degree of decomposition indicates water level changes. Such unstable conditions probably prevailed through several thousands of years, up to the end of the climatic optimum.

There is a high proportion of *Eriophorum* remains with charcoals above 60 cm. There are also traces of *Sphagnum* and *Pinus* remains. That kind of sedentation process is dated by pollen analysis to the late Holocene (probably the Subboreal period). Presence of *Eriophorum* and *Sphagnum* peat suggest oligotrophic conditions in the basin.

Eriophorum was the main component of the sediment up to 32 cm and then *Sphagnum* was dominating. However, *Sphagnum* spores were present since the Preboreal, so it appeared earlier in Dziedzinka than at the Kletno site. Probably *Sphagnum* appeared at the margins of the basin at first and then it spread into the center (to the location of S-20 core) following oligotrophication. An intensive terrestric accumulation was possible as late as in the Subboreal when the climate was wetter. This fact confirms the conclusion of Żurek (1993) about the time of development of bogs and transitional peatbogs in the accumulation basins without run-off at the beginning of the Subboreal.

Water level changes and sediments accumulation rate

Clear discrepancy was revealed between the accumulation rates of the older and younger sections of the sediment (Fig. 7). The thickest section accumulated at the beginning of the Holocene despite limnic character of the environment. The thinnest layer of sediment represents the climatic optimum. This layer was accumulated after the shallowing of the lake, in rather terrestrial environment. We did not found indicators of hiatus in the sequence of sediments, however we cannot exclude that some layers of sediments could be destroyed *e.g.* by the forest fires. A significant lowering of water level at the mire was the other reason for a break in the accumulation process. So we can suppose, that the thin layer of peat of the middle Holocene was the result of an extremely low accumulation rate, but loss of sediment layers was possible as well. Kupryjanowicz (2003) draw similar conclusions concerning the sites in Knyszyńska Forest (Machnacz and Stare Biele) and Biebrza Valley (Żurawisko). Deep layers of sediments (gyttja) accumulated during the oldest part of the Holocene were found at Maliszewo peatbog in Biebrza Valley (Balwierz, Żurek 1987). According to these authors during the Boreal period the rate of accumulation was 1.13 mm/year. All these data may suggest that the phenomenon found at some sites had a regional meaning and was a result of hydrological changes in NE Poland. However it was connected with mires as ecosystems sensitive to water level changes and limnic sediments directly underlying the peat *i.e.* accumulated in shallow lake in the final stage of its overgrowing. Accumulation rate found in the lakes existing up to the present is not so differentiated and does not show clear changes (cf. Bałaga 1990; Milecka, unpubl.).

Indication of fires in the Białowieża Forest

Content of charcoals identified during the pollen analysis is an indicator of fires in plant communities. Some greater charcoal particles have been found in macrofossil analysis as well. However, the research has not shown the levels with clear content of charred parts of organic origin. In the pollen diagram of Kletno a small proportion of charcoals was observed at the depths of 230, 200–170 and 50 cm, and macrofossil analysis noted presence of charcoals in 205–200 cm (the younger layers were not analysed). The highest probability of fires can be determined for the younger phase of the Preboreal and during the Boreal. Indirectly, probability of fires (Fig. 7) is also indicated by *Pteridium aquilinum* spores in the pollen diagram. Continuous curve of *Pteridium* during the Atlantic Period suggests possibility of natural or anthropogenic fires caused by Neolithic man.

GENERAL CONCLUSIONS

Palaeoecological analyses revealed some trends in the development of the Białowieża region ecosystems. Possible hiatus in the investigated sections causes some doubts, whether our results are complete or not. For that point more research is needed. On the basis of the results available, it can be concluded that:

1. Process of organic sediment accumulation started during the Late Glacial in the Alleröd period (Dziedzinka) or in the Younger Dryas (Kletno). It was the initiation of shallowing of the lakes. Then the hydroserial succession ceased limnic sedimentation and open water table disappeared at the beginning of the Holocene during the Preboreal.

2. Both limnic sediments and overlying peat allowed the description of regional and local plant communities succession by the content of identified sporomorphs and macro remains. During the Late Glacial two stages of the succession were revealed, steppe and open forest during the Alleröd period and tundra-like vegetation during the Younger Dryas.

3. The Holocene history contains five stages of plant cover development: *Betula-Pinus* forest at the beginning, *Pinus-Betula* forest with increasing proportion of *Corylus avellana* in the Boreal, mixed deciduous forest in climatic optimum, *Quercus-Carpinus* forest in the Subboreal and at last, development of various types of plant communities which are existing in the Białowieża Forest up to the present.

4. There was a relatively low content of *Carpinus betulus* during the Subboreal and Subatlantic periods. Pollen analysis and isopollen maps for Poland show the main centres of hornbeam forest development to have been in Great Poland and Pomerania, whereas the NE part of Poland shows rather constant frequency of *Carpinus* pollen.

5. A low content of pollen grains of *Fagus sylvatica* indicates, that the Białowieża Forest has possibly never been inhabited by this species.

6. There are only weak indications of fires in the Białowieża Forest. Presence of charcoals in pollen and macrofossil samples and occurrence of *Pteridium aquilinum* spores show the probability of fires during a short period of the Preboreal and in the Boreal and Atlantic Periods. Also some charcoals were recorded in the youngest phase of the Subboreal Period.

REFERENCES

Aaby B. 1986. Trees as anthropogenic indicators in regional pollen diagrams from Eastern Danmark. In Behre K.E. (ed.) *Anthropogenic indicators in pollen diagrams*, 73–94. Balkema, Rotterdam, Berlin.

Aalto M. 1970. Potamogetonaceae fruits. I. Recent and subfossil endocarps of the Fennoscandian species. *Acta Botanica Fennica* 88, 1–85.

Balwierz Z., Żurek S. 1987. The Late Glacial and Holocene vegetational history and paleohydrological changes at the Wizna site (Podlasie Lowland). *Acta Palaeobotanica* 27, 121–136.

Bałaga K. 1982. Vegetational history of the Lake Łukcze environment (Lublin Polesie, E. Poland) during the Late-Glacial and Holocene. *Acta Palaeobotanica* 22, 7–22.

Bałaga K. 1990. The development of Lake Łukcze and changes in the plant cover of the south-western part of the Łęczna- Włodawa Lake District in the last 13 000 years. *Acta Palaeobotanica* 30, 77–146.

Bałaga K. 1998. Post-glacial vegetational changes in the middle Roztocze (E Poland). *Acta Palaeobotanica* 38, 175–192.

Bałaga K. 2003. Hydrological changes in the Lublin Polesie during the late glacial and Holocene as reflected in the sequences of lacustrine and mire sediments. *Studia Quaternaria* 19, 37–53.

Behre K.E. 1981. The interpretation of anthropogenic indicators in pollen diagrams. *Pollen et Spores* 23, 225–245.

Berglund B.E. Ralska-Jasiewiczowa M. 1986. Pollen analysis. In Berglund. B.E. (ed.) *Handbook of Holocene Palaeoecology and Palaeohydrology*, 455–484, John Wiley & Sons, Chichester – New York – Brisbane – Toronto – Singapore.

Bertsch K.H. 1941. Früchte und Samen. Ein Bestimmungsbuch zur Pflanzenkunde der vorgeschichtlichen Zeit, 1–247. Stuttgart.

Borowik-Dąbrowska M., Dąbrowski M.J. 1972. Natural and anthropogenic vegetation changes in Białowieża National Park (original: Naturalne i antropogeniczne zmiany roślinności Białowieskiego Parku Narodowego). *Archeologia Polska* XVIII, 181–200 (in Polish).

Dąbrowski M.J. 1959. Late Glacial and Holocene vegetation history of Białowieża Primeval Forest (original: Późnoglacjalna i holoceńska historia lasów Puszczy Białowieskiej). *Acta Societatis Botanicorum Poloniae* 28, 197–248 (in Polish).

Faliński J.B. 1986. Vegetation dynamics in temperature lowland primeval forests. Dr W. Junk Publishers, Dordrecht-Boston-Lancaster.

Faliński J.B., Pawlaczyk P. 1995. An outline of ecology (original: Zarys ekologii). In Bugała W. (ed.) *European Ash Fraxinus excelsior L. Our forest trees.* (orginal: *Jesion wyniosły Fraxinus excelsior L. Nasze drzewa leśne*) 17, 217–305. Sorus, Poznań – Kórnik (in Polish).

Filbrandt-Czaja A. 1998. Vegetation history of the northern part of Lednicki Landscape Park highlighting of anthropogenic factor (original: Historia roślinności północnej części Lednickiego Parku Krajobrazowego ze szczególnym uwzględnieniem czynnika antropogenicznego). *Biblioteka Studiów Lednickich* III, 9–41 (in Polish).

Göransson H. 1986. Man and the Forest of Nemoral Broad – Leafed Trees During the Stone Age. In Königsson L.K. (ed.) *Nordic Late Quaternary, Biology and Ecology. Striae* 24, 143–152.

Grimm E. C. 1987. CONISS: A fortran 77 program for stratigraphically constrained cluster analysis by the method of incremental sum of squares. *Computers & Geosciences* 13, 13–35.

Grimm E.C. 1990. Tilia and Tilia_graph: PC spreadsheet and graphics software for pollen data. *INQUA Working Group on Data-Handling Methods*, Newsletter 4.

Grosse-Brauckmann G. 1972. Über pflanzliche Makrofossilien mitteleuropäischer Torfe. I. Gewebereste krautiger Pflanzen und ihre Merkmale. *Telma* 2, 19–55.

Grosse-Brauckmann G. 1974. Über pflanzliche Makrofossilien mitteleuropäischer Torfe. II. Weitere Reste (Früchte und Samen, Moose u. a.) und ihre Bestimmungsmöglichkeiten. *Telma* 4, 51–117.

Grosse-Brauckmann G. 1992. Über pflanzliche Makrofossilien mitteleuropäischer Torfe. III. Früchte, Samen und einige Gewebe (Fotos von fossilen Pflanzenresten). *Telma* 22, 53–102.

Huntley B., Birks H.J.B. 1983. An atlas of past and present pollen maps for Europe: 0–13000 years ago. Cambridge University Press.

Iversen J. 1973. The Development of Danmark's Nature since the Last Glacial. *Geology of Denmark Survey Bulletin* V, 7-C, 1–126.

Juggins S. 2003. C2 User guide. Software for ecological and palaeoecological data analysis and visualisation. Newcastle upon Tyne, UK, University of Newcastle.

58

Katz N.J., Katz S.W., Kipiani M.G. 1965. Atlas and keys of fruits and seeds occurring in the Quaternary deposits of the USSR (original: Atlas i opredelitel płodow i semian wstreczajuszczychsia w czetwerticznych otłożeniach SSSR). Izdatielstwo Nauka, Moskwa (in Russian).

Katz N.J., Katz S.W., Skobiejewa E.I. 1977. Atlas of plant fossils in peat (original: Atlas rastitielnych ostatkow w torfach). Izdatielstwo Nauka, Moskwa (in Russian).

Kupryjanowicz M. 1991. Eemian, Early and Late Vistulian, and Holocene vegetation in the region of Machnacz peat-bog near Białystok (NE Poland) – preliminary results. *Acta Palaeobotanica* 31, 215–225.

Kupryjanowicz M. 2000. Habitat and vegetation changes of Stare Biele mire in Knyszyńska Forest (original: Przemiany siedlisk i roślinności torfowisk uroczyska Stare Biele w Puszczy Knyszyńskiej). Politechnika Białostocka, *Rozprawy naukowe* 70, 78–97 (in Polish).

Kupryjanowicz M. 2003. Palynological investigation in northern Podlasie Region. History, present state and main problems (original: Badania palinologiczne na północnym Podlasiu, historia, stan obecny, główne problemy). *I Polska Konferencja Paleobotaniki Czwartorzędu, conference abstract.* Białowieża 22-24 V 2003, 15–18.

Latałowa M. 1992. Man and vegetation in the pollen diagrams from Wolin Island (NW Poland). *Acta Palaeobotanica* 32, 123–149.

Latałowa M., Ralska-Jasiewiczowa M., Miotk-Szpiganowicz G., Zachowicz J., Nalepka D. 2004. Fagus sylvatica L. – Beech. In Ralska-Jasiewiczowa M., Latałowa M., Wasylikowa K., Tobolski K., Madeyska E., Wright H.E. Jr. & Turner Ch. (eds) *Late Glacial and Holocene history of vegetation in Poland based on isopollen maps*, 95–105. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.

Makohonienko M. 2000. Natural history of Gniezno (original: Przyrodnicza historia Gniezna). Homini, Bydgoszcz-Poznań (in Polish).

Milecka K. 1998. History of human activity in Giecz and Wagowo areas based on pollen analysis (original: Historia działalności człowieka w okolicach Giecza i Wagowa w świetle analizy pyłkowej). *Biblioteka Studiów Lednickich* III, 43–95 (in Polish with English summary).

Milecka K. The results of pollen analysis of Miłuki site (original: Wyniki analizy pyłkowej na stanowisku Miłuki) (in Polish, unpubl).

Milecka K., Noryśkiewicz A.M. 2003. The development of Kletno mire based on pollen analysis from Białowieża Primeval Forest (original: Rozwój torfowiska Kletno w świetle analiz paleoekologicznych na terenie Puszczy Białowieskiej). *I Polska Konferencja Paleobotaniki Czwartorzędu, conference abstract* Białowieża 22-24 V 2003, 29–30 (in Polish).

Milecka K., Szeroczyńska K. 2005. Changes in macrophytic flora and planktonic organisms in Lake Ostrowite, Poland as a response of climatic and trophy fluctuations. *The Holocene* 15, 74–84.

Milecka K., Kupryjanowicz M., Makohonienko M., Okuniewska-Nowaczyk I., Nalepka D. 2004. *Quercus* L. – Oak. In Ralska-Jasiewiczowa M., Latałowa M., Wasylikowa K., Tobolski K., Madeyska E., Wright H.E. Jr., Turner Ch. (eds) *Late Glacial and Holocene history of vegetation in Poland based on isopollen maps*, W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków, 189–199.

Miotk-Szpiganowicz G. 1992. The history of the vegetation of Bory Tucholskie and the role of man in the light of palynological investigations. *Acta Palaeobotanica* 32, 39–122.

Noryśkiewicz A. M. 2002. The Holocene history of the forest near Wierzchlas on the basis of palynological investigation from Lake Mukrz (original: Holoceńska historia lasów okolic Wierzchlasu na podstawie analizy pyłkowej osadów z jeziora Mukrz). In Banaszak J., Tobolski K. (eds) *Bory Tucholskie National Park on the background of the projected Biosphere Reserve* (original: *Park Narodowy Bory Tucholskie na tle projektowanego rezerwatu biosfery*), 195–204. Homini, Bydgoszcz-Charzykowy (in Polish).

Noryśkiewicz A.M., Kowalewski G. 2002. Development of the Dziedzinka raised bog (the Białowieski National Park) on the basis of palynological and plant macrofossils analysis. *Acta Agrophysica* 67, 197–206.

Noryśkiewicz A.M., Kowalewski G. 2003. Postglacial history of Dziedzinka mire (original: Postglacjalna historia roślinności torfowiska Dziedzinka). *I Polska Konferencja Paleobotaniki Czwartorzędu, conference abstract* Białowieża 22-24 V 2003, 32–34 (in Polish).

Noryśkiewicz A.M., Milecka K. 2002. Development of the Kletno peat-bog and postglacial and Holocene transformation of the Białowieża primeval forest vegetation in the light of pollen analysis. *Acta Agrophysica* 67, 207–216.

Obremska M., Lamentowicz M. 2002. Geology and history of kettle-hole bog on Brda Outwash plain on the base of pallen and testate amoebae (Protozoa) analyses (original: Geologia i historia torfowiska kotłowego na sandrze Brdy koło Tucholi na podstawie analizy palinologicznej i korzenionóżek *Testacea*). In Banaszak J., Tobolski K. (eds) *Bory Tucholskie National Park on the background of the projected Biosphere Reserve* (original: *Park Narodowy Bory Tucholskie na tle projektowanego rezerwatu biosfery*), 205–218. Homini, Bydgoszcz-Charzykowy (in Polish).

Paszewski A., Poznański F. 1936. Contribution to the history of the Białowieża Primeval Forests I (original: Materiały do historji lasów Puszczy Białowieskiej). *Roczniki Naukowe Rolnictwa i Leśnictwa* 36, 58–67 (in Polish).

Paszewski A. 1937. Contribution to the history of the Białowieża Primeval Forests II (original: Dalsze badania nad historią lasów Puszczy Białowieskiej na podstawie analizy pyłkowej torfowisk. *Roczniki Naukowe Rolnictwa i Leśnictwa* 36, 183–187 (in Polish).

Podbielkowski Z., Tomaszewicz H. 1979. An outline of hydro- botany (original: Zarys hydrobotaniki). Warszawa, PWN (in Polish).

Ralska-Jasiewiczowa M. 1964. Correlation between the Holocene history of the *Carpinus betulus* and prehistoric settlement in North Poland. *Acta Societatis Botanicorum Poloniae* 33, 463–468.

Ralska-Jasiewiczowa M. 1966. Bottom deposits of Lake Mikołajskie (Masurian Lakeland) in the light of paleobotanical investigation (original: Osady denne Jeziora Mikołajskiego na Pojezierzu Mazurskim w świetle badań paleobotanicznych). *Acta Palaeobotanica* 7, 1–118 (in Polish).

Ralska-Jasiewiczowa M. 1983. Isopollen maps for Poland: 0–11000 years B.P. *New Phytologist* 94, 133–175.

Ralska-Jasiewiczowa M., Miotk-Szpiganowicz G., Zachowicz J., Latałowa M., Nalepka D. 2004. *Carpinus betulus* L. – hornbeam. In Ralska-Jasiewiczowa M., Latałowa M., Wasylikowa K., Tobolski K., Madeyska E., Wright H.E. Jr., Turner Ch. (eds) *Late Glacial and Holocene history of vegetation in Poland based on isopollen maps*, W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków, 69–79.

Stasiak J. 1964. History of Kruklin Lake as revealed by the deposits of its littoral zone (original: Historia Jeziora Kruklin w świetle osadów strefy litoralnej). *Prace Geograficzne IG PAN* 42, 1–94. Warszawa.

Tobolski K. 1987. Holocene vegetational development based on the Kluki reference site in the Gardno-Łeba plain. *Acta Palaeobotanica* 22, 179–222.

59

Tobolski K. 1991. Gegenwärtiger Stand der paleobotanischen und biostratigraphischen Forschungen in Lednicer Landschaftspark (original: Dotychczasowy stan badań paleobotanicznych i biostratygraficznych Lednickiego Parku Krajobrazowego). In Tobolski K. (ed.) *Introduction to paleoecology of Lednicki National Park* (orignal: *Wstęp do Paleoekologii Lednickiego Parku Krajobrazowego*), 11–34. Wydawnictwo Naukowe UAM. Poznań (in Polish).

Tobolski K. 1995. Ash in past landscapes (original: Jesion w minionych krajobrazach). In Bugała W. (ed.) *European Ash Fraxinus excelsior L. Our forest trees.* (orginal: *Jesion wyniosły, Fraxinus excelsior L. Nasze drzewa leśne*), 17, 7–17. Sorus. Poznań – Kórnik (in Polish).

Tobolski K. 2000. Guidebook to identification of peat and lake sediments (original: Przewodnik do oznaczania torfów i osadów jeziornych). PWN, Warszawa.

Troels-Smith J. 1953. Ertebølle Culture – Farmer Culture. Results of the post ten years excavations in Aamosen Bod, West Zealand (original: Ertebøllekultur – Bodenkultur. Resultater af de sidste 10 Aars Undersogelser i Aamosen, Vestsjaelland). *Aarbøger for nordisk Oldkyndighed og Historie* 1953, 5–62 (in Danish).

Troels-Smith J. 1955. Characterization of unconsolidated sediments (original: Karakterisering af lose jordarter). *Danmarks Geologiske Undersogelse* IV,3,10, 1–73 (in Danish).

Żurek S. 1993. Paleohydrological changes in wetlands (original: Zmiany paleohydrologiczne w mokradłach). *Przegląd Geograficzny* 64, 75–95 (in Polish).

60

Wednesday, 24 August 2011 (day 3rd)

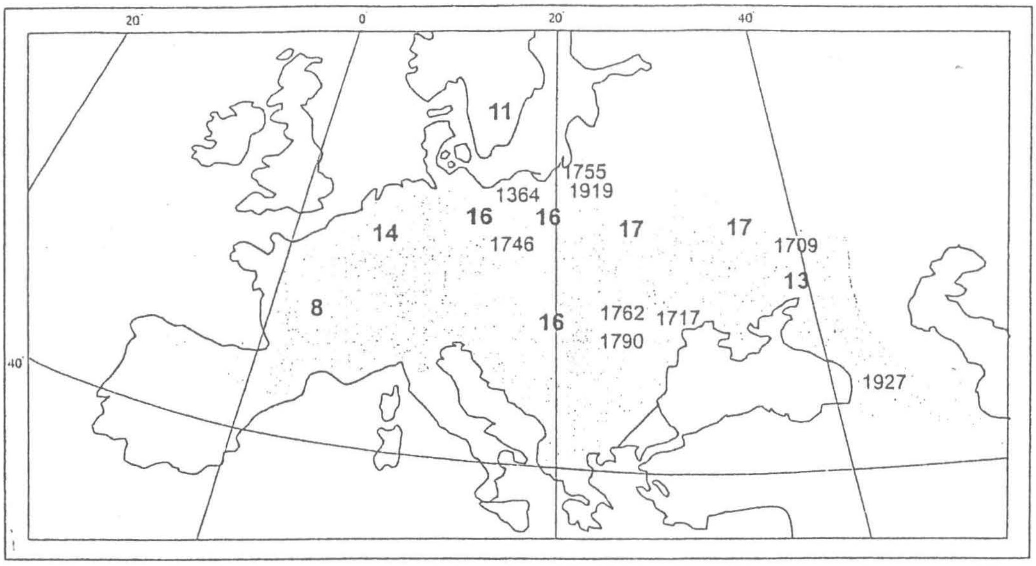
European bison and Eurasian lynx conservation: threats to the endangered species

Rafał Kowalczyk

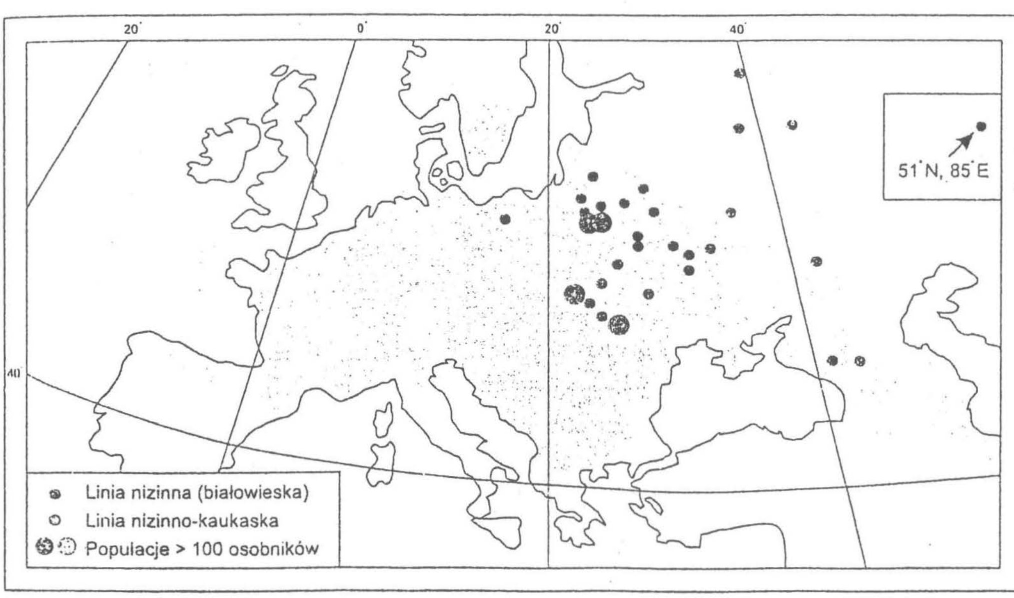
Mammal Research Institute, Polish Academy of Sciences, 17-230 Białowieża, Email:rkowal@zbs.bialowieza.pl

The European bison (*Bison bonasus*) is the largest terrestrial mammal in Europe and a flagship species for nature conservation. Only 10 years after the extinction of the last primeval population of bison in Białowieża Forest in 1919, the restoration of the species began, which resulted in release of the first bison back into the wild in 1952. Despite its successful restoration and the increase in population numbers, the European bison still remains an endangered species - it is listed in Red Data Books and is on the list of priority protected species the UE. There is a number of actual and potential threats to the bison, such as: (1) fragmented and limited distribution range and isolation of herds; (2) low genetic variation and lack of gene exchange among bison populations; (3) inappropriate forms of management and low naturalisation of the species and (4) diseases and parasites. Among other threats recently recognized are as follows: environmental changes and road infrastructure development, inadequate legal protection and low public acceptance of the species, and a lack of science-based guidelines for management and conservation of bison populations. Further conservation of the species should ensure the survival of bison and should counteract the threats listed above. This may be achieved by the continuation of the bison reintroduction programme and a wide scope of actions supported by modern science-based management and conservation strategies. These actions should lead to more widespread naturalisation of the species and should become an established, long–term programme of bison conservation.

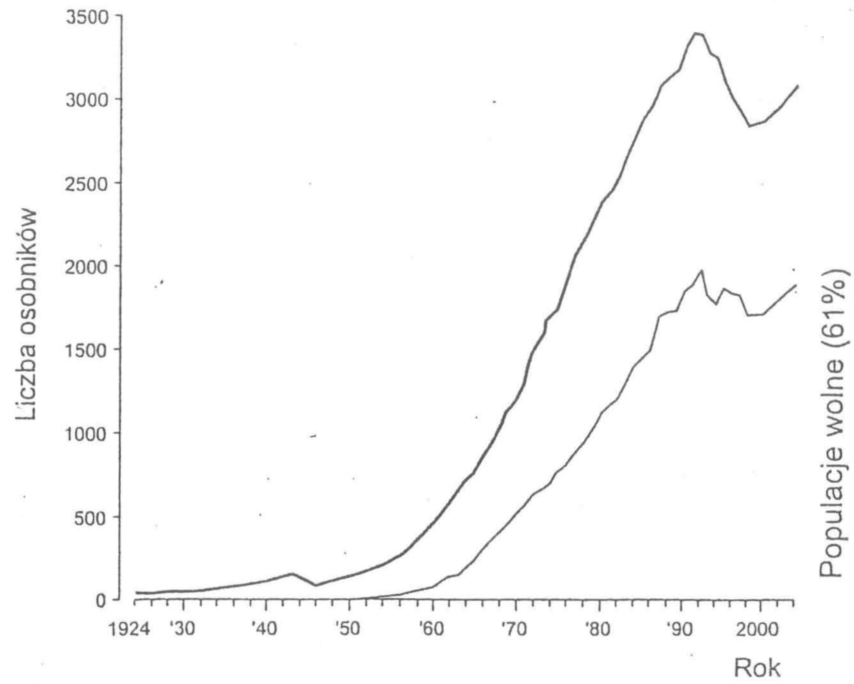
The status of Eurasian lynx (*Lynx lynx*) population in Europe is dramatically variable. Whereas it expands despite of hunting harvest in some areas, it shrinks despite of protection in the other. Studies have revealed a number of aspects contributing to the observed variability in the population state. Prey depletion had an immediate effect on lynx spatial organization and movements resulting from increased foraging efforts, particularly in females. The populations differ also by the level of genetic variability with low variation recorded in its most severely fragmented parts. The habitat characteristics (structure of the forest) have been shown to be a key factor for lynx hunting efficiency and resting site selection. Diversity and complexity of the habitat structure may thus determine carrying capacity of the habitat for lynx, which in concert with environmental discontinuity and the prey scarcity can result in lowering the viability of the population. The studies showed that local lynx populations in Europe can be threatened despite of currently secure global situation of the species.



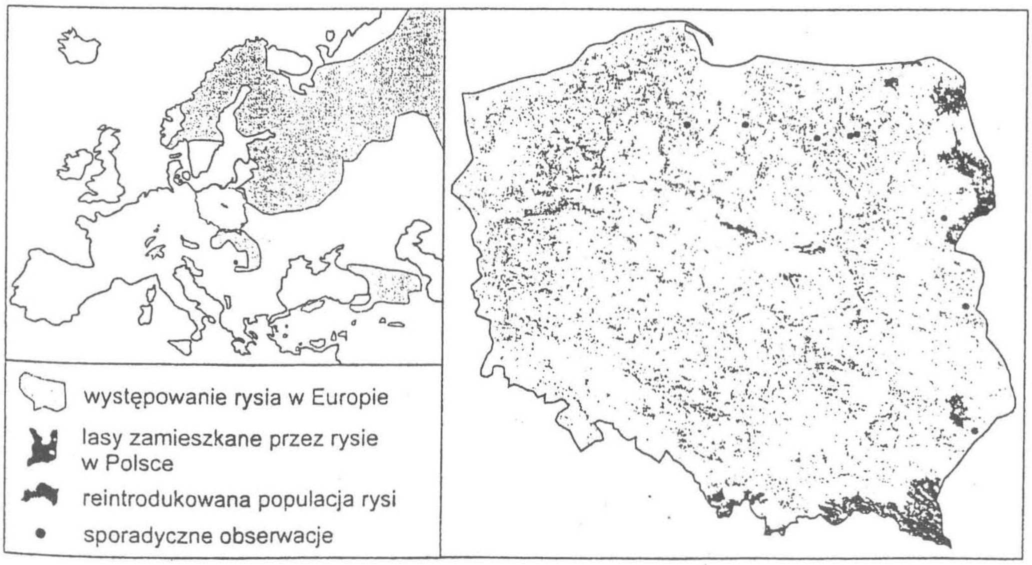
Reconstructed range of European bison during the Holocene and early historical times. Centuries and years of the last observation.



Appearance of European Bison in 2002. Big dots – population of more than 100 individuals.



Population of European bison in number of individuals. Grey part – free populations.



Appearance of European lynx in Europe and in Poland.

Thursday, 25 August 2011 (day 4th)

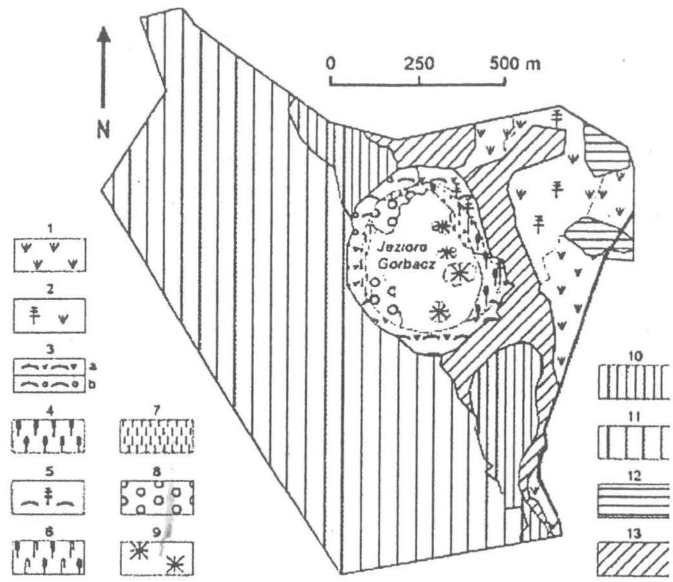
Characteristic of the Puszcza Knyszyńska Forest

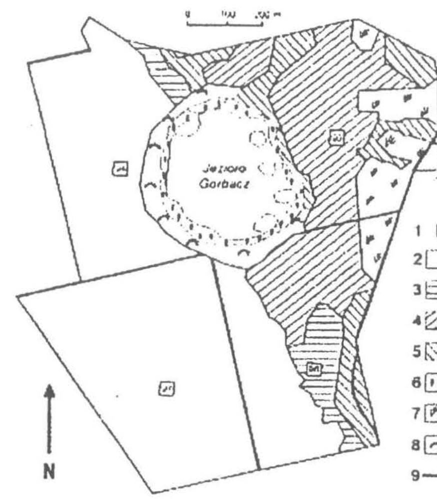
The Puszcza Knyszyńska Forest is located in the North-Podlasie Lowland and it is assigned to two mezoregions – a larger one belonging to the Białystok Upland and a smaller one (north-eastern fragment) to the Sokólskie Hills (Kondracki 1994). The geological structure and some climatic features relate the Puszcza Knyszyńska Forest region to East European territory (Kondracki & Pietkiewicz 1967). Thickness of Quaternary cover varies from 130 to 220 m. Relief of the area was formed by the Warta glaciation (Musiał 1992) that produced an number of fluvioglacial features that include kames, kame terraces and numerous melt water forms. The Puszcza Knyszyńska Forest region is located in an immediate neighbourhood of the Vistula glaciation landscape (Pawłowska & Miodek 1993). Holocene sediments (sands, loams, fluvial gravels, and peat) fill in the river valleys and melt depressions.

Location of the Puszcza Knyszyńska Forest causes a mesothermal transitional climate. The mean annual temperature is relatively low, +7°C, but annual amplitude is very high, up to 22°C, and mean annual precipitation oscillates around 570 mm. The growing season is about 200 days and snow cover lasts 85–90 days, i. e., longer than in the middle and western regions of Poland (Sasinowski 1995). Polar-maritime air masses are dominant for approximately 145 days of the year. In this region brown soils predominate where they account for 60% of the forest area (Czerwiński 1995).

The Puszcza Knyszyńska Forest is located in the vicinity of the Vistula and Niemen rivers watershed in the Supraśl river basin. Specific for this area are numerous springs in the short lateral valleys passing for the Supraśl river valley.

According to the geobotanical division of Poland, the Puszcza Knyszyńska Forest belongs to the Northern Division, the Białowieża-Knyszyn Region (Szafer 1977). The characteristic feature of vegetation in this area is the distinct participation of *Picea abies* in nearly all forest associations and an absence of *Fagus sylvatica.* Except for spruce, other boreal species also occur, including *Betula humilis* or *Vaccinium oxycoccos*. Forests cover about 80% of the area of the Puszcza Knyszyńska Forest. The main tree species are *Pinus sylvestris* and *Picea abies. Quercus robur*, *Betula verrucosa*, *Carpinus betulus*, *Tilia cordata*,





Ryc. 3. Roślinność rezerwatu „Gorbacz" w 1968 roku (CZERWIŃSKI 1974): 1 – *Caricetum gracilis* (Graebn. et Hueck 1931) R. Tx. 1937, 2 – *Caricetum gracilis* (Graebn. et Hueck 1931) R. Tx. 1937 z *Pinus sylvestris*, 3 – *Caricetum limosae* Br.-Bl. 1921 (a – facja z *Carex*, b – facja z *Oxycoccus*), 4 – szuwar z *Typha*, 5 – *Caricetum lasiocarpae* Koch 1926 z *Pinus* i *Betula*, 6 – szuwar z *Typha* i *Phragmites*, 7 – szuwar z *Equisetum*, 8 – roślinność pływająca, 9 – roślinność denna, 10 – *Vaccinium uliginosi-Pinetum* Kleist 1929 facja typowa, 11 – *Vaccinium uliginosi-Pinetum* Kleist 1929 facja po pożarze, 12 – *Fraxino-Ulmetum* (Tx. 1952) Oberd. 1953, 13 – *Thelypteridi-Betuletum pubescentis* Czerw. 1972

Ryc. 4. Roślinność rezerwatu „Gorbacz" w 1992 roku (CZERWIŃSKI 1992): 1 – numer oddziału, 2 – *Vaccinium uliginosi-Pinetum* Kleist 1929 facja po pożarze, 3 – *Vaccinium uliginosi-Pinetum* Kleist 1929 facja typowa, 4 – zbiorowisko zastępcze *Viola palustris-Pinus sylvestris* Czerw. 1992, 5 – *Carici elongatae-Alnetum* Koch. 1926, 6 – *Typhetum latifoliae* Soó 1927, 7 – łąki uprawne z klasy *Molinietalia* W. Koch 1926, 8 – *Caricetum limosae* Br.-Bl. 1921, 9 – linia oddziałowa

Populus tremula, *Fraxinus excelsior*, *Alnus glutinosa*, and *Acer platanoides* are the most important deciduous species (Żarska 1993).

Characteristics of the studied mires

Three mires under study are located within the territory of the Puszcza Knyszyńska Forest Landscape Park: Taboły and Kładkowe Bagno – in its northern part and the Borki mire – in its eastern (Fig. 1).

Taboły and Kładkowe Bagno

Taboły mire is situated in a melt water-basin. The forest nature reserve is 307 ha. The Kładkowe Bagno peat bog is located in close proximity to this mire. It is 40 ha and consists of two depressions connected by a distinct isthmus with shallow peat of ca. 0.3 m. Both mires are surrounded by numerous kames. According to Żarska (1993) and Czerwiński (pers. com), the Taboły mire is overgrown by *Thelypteri-Betuletum typicum* in the north part and by *Sphagno girgensohnii-Piceetum* (3 subassociations: *Sphagno girgensohnii-Piceetum typicum*, *Sphagno girgensohnii-Piceetum caespitosae* and *Sphagno girgensohnii-Piceetum alnetosum*) in the middle part. At the periphery, there are narrow fragments of *Carici elongatae-Alnetum* sensu lato. The south part of the mire is overgrown by *Salici-Betuletum polytrichetosum strictae*.

According to Czerwiński (pers. com.), there are different hydrological patters that influence the Taboły mire. Presence of alder can be a result of surface flow from kame terraces. High river stages in the Sokołda river also can impact irrigation, especially in the northern part of the mire.

Both depressions in the Kładkowe Bagno peat bog are overgrown by *Vaccinio uliginosi-Pinetum* in the final phase of succession (Czerwiński, personal information). According to J. M. Matuszkiewicz (2001), this community can be defined as the *Vaccinio uliginosi-Pinetum typicum* subassociation, inland variety, subboreal subvariety. Kładkowe Bagno is a raised bog, receiving water from the atmosphere. Areas surrounding both mires are overgrown by *Tilio-Carpinetum*, *Melitti-Carpinetum*, *Serratulo-Piceetum*, and *Myceli-Piceetum*.

Borki

Borki mire is situated in a large melt water-basin within the Bahno Reserve in Borki and is approximately 286 ha in area. From the east, it borders with a plateau enclosed by kame terraces. At the western margin of the mire the Sokołda river occurs, separated from the mire by 300 m wide zone of mud and alluvium (Dembek 1989). The central part of the deposit is covered by *Carici chordorrhizae-Pinetum* and *Thelypteri-Betuletum* with *Betula humilis* occurring in the underwood. *Sphagno girgensohnii-Piceetum* and a narrow zone of alder appear marginally, and *Serratulo-Piceetum* and *Melitti-Carpinetum* grow in the surrounding area (Żarska 1993, Czerwiński, pers. com.). The mire is constantly and profusely irrigated by waters from deeper water-bearing horizons, lying under a clay layer (Dembek 1989, 1993).

Acta Palaeobotanica 46(2): 255–275, 2006

Subfossil plant communities in deposits from the Taboły, Kładkowe Bagno and Borki mires in the Puszcza Knyszyńska Forest, NE Poland

DANUTA DRZYMULSKA

Department of Botany, Institute of Biology, University in Białystok, 15-950 Białystok, Świerkowa 20B, Poland; e-mail: drzym@uwb.edu.pl

Received 17 January 2006; accepted for publication 16 November 2006

ABSTRACT. This paper presents results from investigations on peat sediments from three mires (Taboły, Kładkowe Bagno and Borki) located in the Puszcza Knyszyńska Forest. Using analysis of plant remains from the peat samples, vegetative and generative finds were identified that include 109 plant taxa of different rank. Compared to syntaxa from the present time, 22 subfossil plant communities have been delimited. They belong to five plant phytosociological classes: *Phragmitetea*, *Scheuchzerio-Caricetea nigrae*, *Alnetea gutinosae*, *Oxycocco-Sphagnetea* and *Vaccinietea uliginosi*. Subfossil communities of uncertain systematic position are also described. Difficulties of phytocoenosis reconstruction are connected with the identification of some macrofossil finds, and either relate to an absence of distinct features in differentiation of some tissues within herbs or bad quality of preserved plant remains in the peat samples.

KEY WORDS: macrofossils, peat analysis, subfossil plant community, Puszcza Knyszyńska Forest, NE Poland

INTRODUCTION

In 1999 palaeobotanical studies started on peat sediments from three mires located in the Puszcza Knyszyńska Forest using plant macrofossil analysis. Radiocarbon dating of the bottom samples of sediments dated the beginning of the peat forming processes back to the Late Glacial in the Taboły and Kładkowe Bagno mires, and to the early Holocene in the Borki mire. The main goal of the present research is to reconstruct the past plant communities that grew in these mires, but development of the mires are not considered in the present contribution.

CHARACTERISTIC OF THE PUSZCZA KNYSZYŃSKA FOREST

The Puszcza Knyszyńska Forest is located in the North-Podlasie Lowland and it is assigned to two mezoregions – a larger one belonging to the Białystok Upland and a smaller one (north-eastern fragment) to the Sokólskie Hills (Kondracki 1994). The geological structure and some climatic features relate the Puszcza Knyszyńska Forest region to East European territory (Kondracki & Pietkiewicz 1967). Thickness of Quaternary cover varies from 130 to 220 m. Relief of the area was formed by the Warta glaciation (Musiał 1992) that produced an number of fluvioglacial features that include kames, kame terraces and numerous melt water forms. The Puszcza Knyszyńska Forest region is located in an immediate neighbourhood of the Vistula glaciation landscape (Pawłowska & Miodek 1993). Holocene sediments (sands, loams, fluvial gravels, and peat) fill in the river valleys and melt depressions.

Location of the Puszcza Knyszyńska Forest causes a mesothermal transitional climate. The mean annual temperature is relatively

68

low, +7°C, but annual amplitude is very high, up to 22°C, and mean annual precipitation oscillates around 570 mm. The growing season is about 200 days and snow cover lasts 85–90 days, i. e., longer than in the middle and western regions of Poland (Sasinowski 1995). Polar-maritime air masses are dominant for approximately 145 days of the year. In this region brown soils predominate where they account for 60% of the forest area (Czerwiński 1995).

The Puszcza Knyszyńska Forest is located in the vicinity of the Vistula and Niemen rivers watershed in the Supraśl river basin. Specific for this area are numerous springs in the short lateral valleys passing for the Supraśl river valley.

According to the geobotanical division of Poland, the Puszcza Knyszyńska Forest belongs to the Northern Division, the Białowieża-Knyszyn Region (Szafer 1977). The characteristic feature of vegetation in this area is the distinct participation of *Picea abies* in nearly all forest associations and an absence of *Fagus sylvatica*. Except for spruce, other boreal species also occur, including *Betula humilis* or *Vaccinium oxycoccos*. Forests cover about 80% of the area of the Puszcza Knyszyńska Forest. The main tree species are *Pinus sylvestris* and *Picea abies*. *Quercus robur*, *Betula verrucosa*, *Carpinus betulus*, *Tilia cordata*, *Populus tremula*, *Fraxinus excelsior*, *Alnus glutinosa*, and *Acer platanoides* are the most important deciduous species (Żarska 1993).

CHARACTERISTICS OF THE STUDIED MIRES

Three mires under study are located within the territory of the Puszcza Knyszyńska Forest Landscape Park: Taboły and Kładkowe Bagno – in its northern part and the Borki mire – in its eastern (Fig. 1).

TABOŁY AND KŁADKOWE BAGNO

Taboły mire is situated in a melt water-basin (Fig. 2). The forest nature reserve is 307 ha. The Kładkowe Bagno peat bog is located in close proximity to this mire. It is 40 ha and consists of two depressions connected by a distinct isthmus with shallow peat of ca. 0.3 m. Both mires are surrounded by numerous kames. According to Żarska (1993) and Czerwiński (pers. com.), the Taboły mire is overgrown by *Thelypteri-Betuletum typicum*

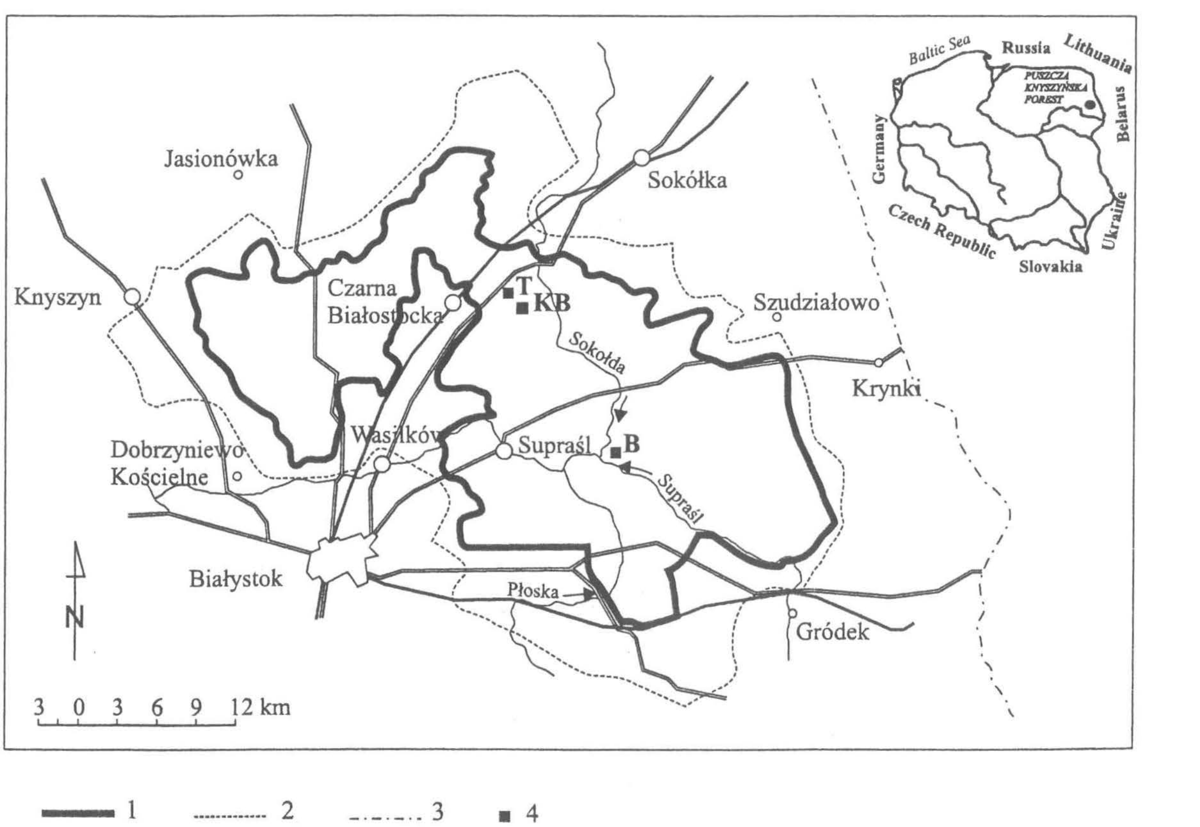


Fig. 1. The Puszcza Knyszyńska Forest Landscape Park (according to Chabros et al. 1993). **1** – border of the landscape park, **2** – border of the protected zone, **3** – state border, **4** – mire under study, **T** – Taboły, **KB** – Kładkowe Bagno, **B** – Borki

Limnological Review 6 (2006): 73-78

The Late Glacial and Holocene water bodies of Taboły and Kładkowe Bagno mires (Puszcza Knyszyńska Forest): genesis and development

Danuta Drzymulska

University in Białystok, Institute of Biology, Department of Botany
Świerkowa 20B, 15-950 Białystok, drzym@uwb.edu.pl

Abstract: This article presents forming and development of water bodies functioning in the Late Glacial and Holocene in two mires of the Puszcza Knyszyńska Forest. Research was based on the results of plant macrofossil remains analyses (carpological mainly), what allowed to make palaeoenvironmental reconstruction in the region of water bodies. Stages of their development were dated by radiocarbon method.

Key words: Puszcza Knyszyńska Forest, Late Glacial, Holocene, lacustrine sediment, carpological findings, ^{14}C dating

Introducing

The Puszcza Knyszyńska Forest is located in North-east Poland, in the territory of old-glacial plains, which genesis is connected with the Warta glaciation. During the Vistula glaciation, this area occurred in an immediate neighbourhood of ice-sheet. However, periglacial denudation was not intensive here, so relief seems to be similar to the young-glacial one. More than 20% of the Puszcza Knyszyńska Forest area is occupied by paludal habitats, therein mires. Degree of peat-cover achieves 10% almost, what is one of the biggest value in Poland (Okruszko 1995). In northern part of the Puszcza Knyszyńska Forest, two mires under study - Taboły and Kładkowe Bagno are located (Fig. 1). A main goal of research was to know history of their vegetation in the Late Glacial and whole Holocene. The plant macrofossil analysis was used. In the development of both mires lacustrine phase was noted, what is a subject of this article.

Characteristic of studied mires

Taboły mire is a site situated in a basin of melting. This forest nature reserve has 307 ha. Kładkowe Bagno peat bog is located in a close neighbourhood of Taboły. It has 40 ha and consists of two depressions connected by a distinct isthmus with shallow peat of ca. 0,3 m. Both mires are surrounded by numerous kames and kame terraces. Taboły is a soligenous mire (Okruszko 1995) and Kładkowe Bagno is a peat bog, receiving water only from the atmosphere.

Materials and methods

Spots of drillings were marked, forming long and cross transects (Fig. 2a, b). Drillings were made with an "Instorf" type drill. Altogether 3 cores contained lacustrine sediments. Their classification was based on Tobolski (2000):

1. Lacustrine chalk (TVII 490 - 460 cm and TIX 600-590 cm, Fig. 3)
2. Calcareous gyttja (T VII 460 - 440 cm and TIX 590-570 cm, Fig. 3)
3. Detritus-calcareous gyttja (KBVII 490-450 cm, Fig. 4)
4. Medium-detritus gyttja (TIX 570-550 cm, Fig. 3 and KBVII 450-400, Fig. 4)

Development of water bodies was dated by ^{14}C method. Radiocarbon datings, ordered according to Mangerud et al. (1974), presents Table 1. Lacustrine sediments were analysed by plant macrofossil remains method, mainly carpological, what allowed to make palaeoenvironmental reconstruction.

70

Tab. 1. Radiocarbon datings of sediment samples

Taboły			Kładkowe Bagno			Chronostratygraphy acc. to Mangerud et al. (1974)
Core/ depth of sample (cm)	Laboratory number	BP dating	Core depth of sample (cm)	Laboratory number	BP dating	
			KBVII/395	Poz-2878	8120±40	Boreal (BO)
			KBVII/445	Poz-2879	9570±40	Preboreal (PB)
TIX/545	Poz-2972	10710±50	KBVII/485	Poz-2881	10460±40	Younger Dryas (YD)
TVIII/385	Poz-2981	10810±50				
TVII/485	Ki-10401	10940±120				

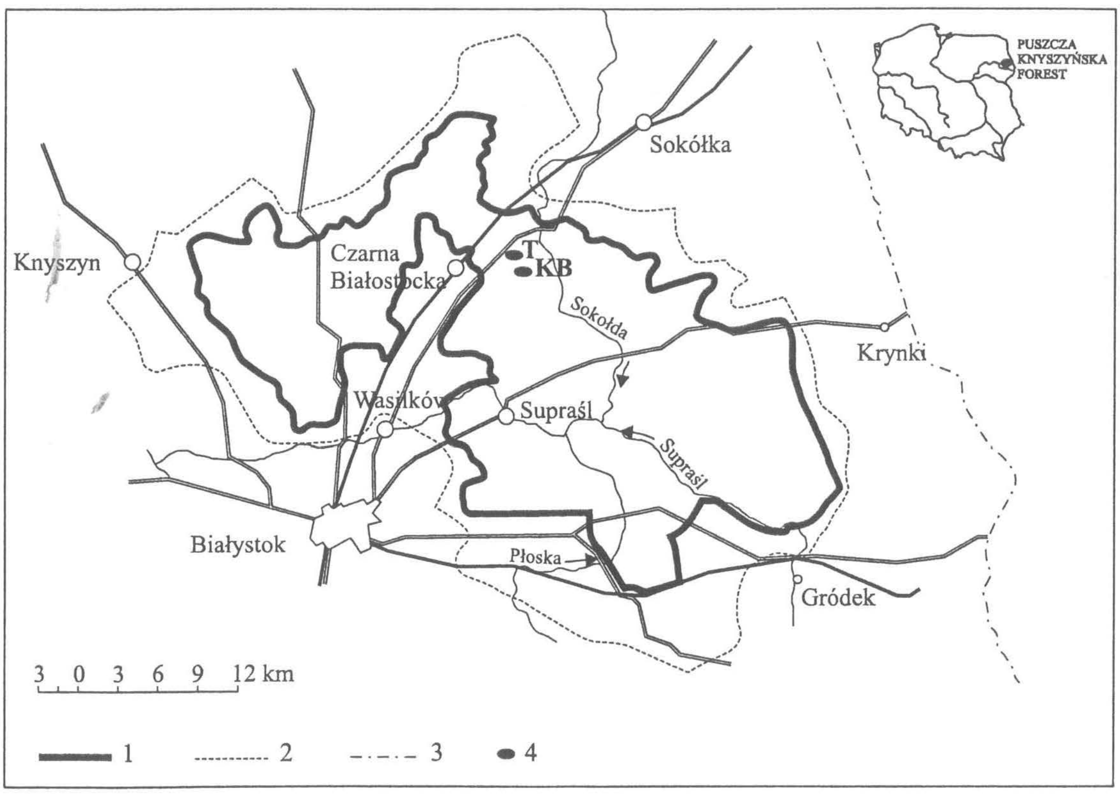


Fig. 1. The Puszcza Knyszyńska Forest. Localization of Taboły and Kładkowe Bang mires. 1 – border of the landscape park, 2 – border of the protected zone, 3 – state border, 4 – mire under study, T – Taboły, KB - Kładkowe Bagno

Results and discussion

Shallow lake functioned in the central part of Taboły mire (in its contemporary form). It consisted of two basins (northern one - TVII and southern one - TIX) connected by a mineral step (TVIII) (Fig. 3). The beginning of organic sediment accumulation in the region of TVII was connected with the first half of Younger Dryas or even with transmission from Younger Dryas to Alleröd (10940±120 BP). Whereas analogous event was not dated in the southern basin but the age of the oldest peat sample was connected with the first half of Younger Dryas (10710 ± 50 BP). Then, southern basin changed into mire (Fig. 3), so lake functioned here probably from Alleröd.

During deliberations about development of lake, except conception of ground ice melting, which blocks filled depressions, the other hypothesis about genesis of lake was proposed. The form of basin of melting was a key-element. The presence of two more distinct depressions in the region of TVII and TIX implied that just there accumulation of organic sediments was initiated (cf. Ivanov 1975). However it was excluded, because the oldest sediments were noted in TIV profile (Older Dryas, 11880±60 BP) (Fig. 3). Different form of basin bottom in the region of TVII and TIX (without hol-

Studia Quaternaria, vol. 25 (2008) 23–32.

DEVELOPMENT OF THE KŁADKOWE BAGNO PEAT-BOG IN THE LATE GLACIAL AND HOLOCENE: DIVERSIFIED HISTORY OF TWO DEPOSIT BASINS STUDIED WITH USE OF MACROFOSSIL REMAINS ANALYSIS

Danuta Drzymulska

University in Białystok, Institute of Biology, Department of Botany, Świerkowa 20B, 15-950 Białystok, Poland;
e-mail: drzym@uwb.edu.pl

Abstract

This paper presents results of investigation on peat and lacustrine sediments from the Kładkowe Bagno peat-bog located in the Puszcza Knyszyńska Forest. Using analysis of plant remains from sediment samples, vegetative and generative finds were identified which allowed describing peat units. Basing on these results, reconstruction of subfossil vegetation and palaeoenvironmental changes in the mire was made. Altogether 4 subassociations of *Sphagnetum magellanici* were described, which delivered information about humidity of the mire surface during peat forming processes. Stages of deposit development were dated by radiocarbon method. Accumulation of the oldest sediments in the southern basin took place in the Late Glacial. Peat of the northern basin started to accumulate in the Atlantic period. The both parts of the mire aggregated probably 400 years ago.

Key words: Late Glacial, Holocene, Puszcza Knyszyńska Forest, peat, analysis of plant remains, subfossil vegetation

INTRODUCTION

The Puszcza Knyszyńska Forest is located in Northeastern Poland (Fig. 1), in the area of old-glacial plains, which genesis is connected with the Warta glaciation. During the Vistula glaciation, the area was situated in an immediate neighbourhood of the ice-sheet. More than 20% of the Puszcza Knyszyńska Forest is now occupied by paludal habitats, therein mires. Degree of peat-cover reaches 10%, which is one of the highest value in Poland (Okruszko 1995).

In 1999 palaeobotanical studies started on sediments of the Kładkowe Bagno peat-bog. Radiocarbon analysis of the bottom sediments dated the beginning of the mire development back to the Late Glacial. The main goal of the present study was to describe process of peat-bog development, with a special attention to the vegetation history.

CHARACTERISTIC OF THE KŁADKOWE BAGNO PEAT-BOG

The Kładkowe Bagno peat-bog is located in the northern part of the Puszcza Knyszyńska Forest (Fig. 1). It covers 40 ha and consists of two depressions connected by a distinct isthmus with shallow peat of ca. 0.3 m. The mire is surrounded by numerous kames. Both depressions are overgrown by *Vaccinio uliginosi-Pinetum* in the final phase of succession (Czerwiński, pers. comm.). Kładkowe Bagno, as a peat-bog, receives water from the atmosphere. According to Żarska (1993) the areas surrounding the mire are overgrown by *Tilio-Carpinetum*, *Melitti-Carpinetum*, *Serratulo-Piceetum*, and *Myceli-Piceetum*.

MATERIALS AND METHODS

Altogether 11 cores of sediments were collected using a Russian sampler of 5 cm diameter. The spots of drillings formed long and cross transects (Fig. 2). The southern depression of the Kładkowe Bagno peat-bog is ca. 5 m deep and the northern depression ca. 2.15 m deep. In total 149 samples of sediments have been prepared for analyses. Peat samples (140) were rinsed with distilled water with an addition of 10% KOH. The aim of that was full dispersion of peat lumps. Next the suspensions were boiled, then washed out on 0.2 mm sieve and peat was placed in Petri dishes. At first, generative finds (fruits, seeds, fruit scales) from every peat sample and from gyttja samples (9, not boiled) were picked out and placed in another dishes with glycerine-thymol mixture (Tobolski 2000). These finds were identified under a stereoscopic binocular. Vegetative plant remains were identified only in peat, with a light microscope. Different kinds of macrofossils were recognized: roots, periderm, epiderm, leaves, stems, wood. For each sample, a proportion of every taxon tissues in the total tissue mass was estimated.

After these analyses peat was classified according to Tołpa *et al.* (1967). Delimitation of subfossil syntaxa was

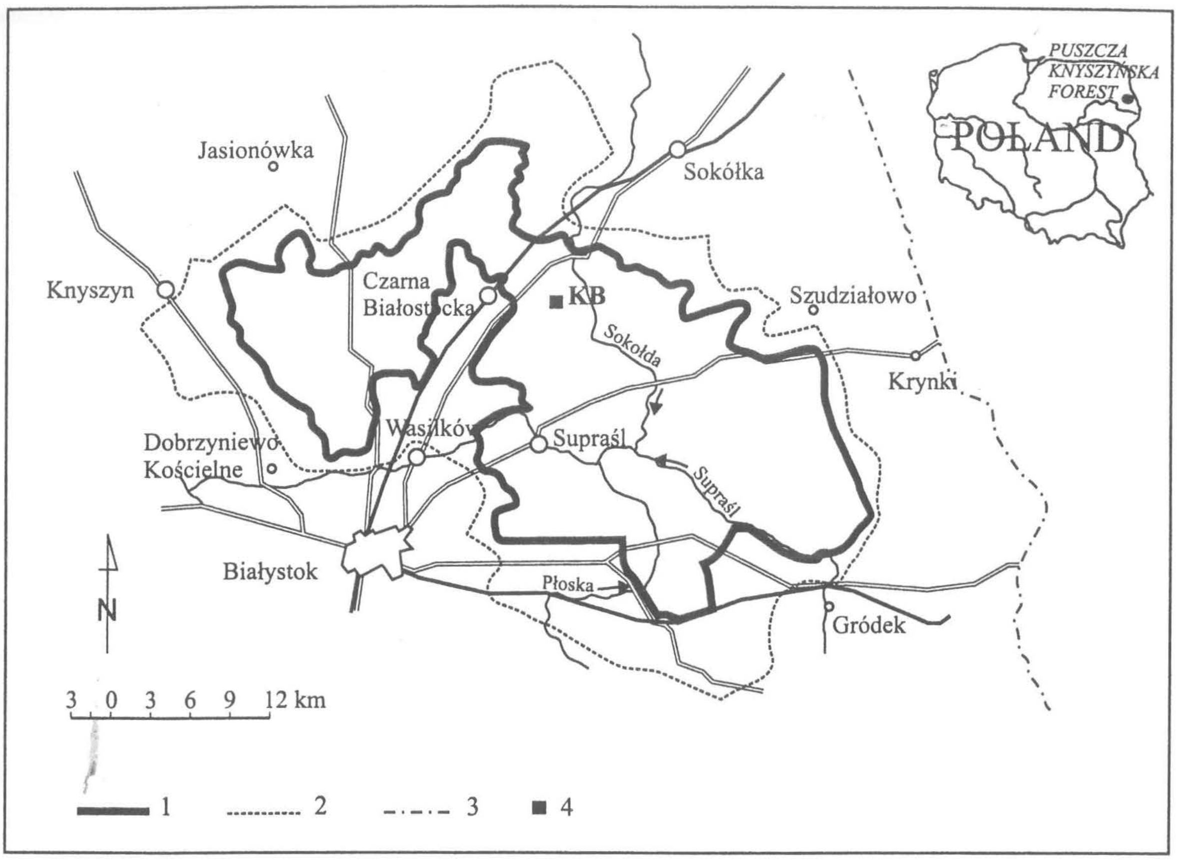


Fig. 1. Territory of the Puszcza Knyszyńska Forest. *1* – border of the landscape park, *2* – border of the buffer zone, *3* – state border, *4* – peat bog under study (KB – Kładkowe Bagno).

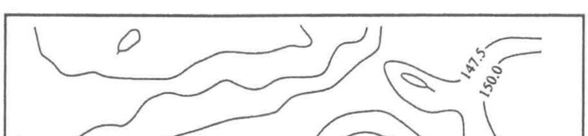


Fig. 2. Kładkowe Bagno peat bog. *1* – location of drillings.

based on the combination of plant remains. Criteria established for contemporary plant phytocoenology were adapted (Oświt 1973, Pałczyński 1975).

Several samples of peat were dated by the radiocarbon method. Chronology of peat profiles was presented in form of chronozones according to Mangerud *et al.* (1974).

RESULTS AND DISCUSSION

Plant remains, peat units and subfossil plant communities

Remains of 52 different plant taxa (species, genus, family) were identified in the investigated sediments. Quantitative representation of major plant types is as follows: trees and shrubs (7 taxa), dwarf shrubs (4), herbs (14), pteridophytes (2), peat-mosses (13), brown mosses (9), and algae (3). Some of the identified taxa are characteristic of seven vegetation classes: *Scheuchzerio-Caricetea nigrae* (11 taxa), *Oxycocco-Sphagnetea* (10), *Phragmitetea* (5), *Alnetea glutinosae* (3), *Vaccinio-Piceetea* (2), *Charetea* (1).

Four of the recognized taxa are not found in the Puszcza Knyszyńska Forest region today:

a) peat-mosses: *Sphagnum platyphyllum, Sphagnum centrale*, and *Sphagnum angustifoilum*

b) brown moss: *Warnstorfia fluitans*

In total 13 peat units and two kinds of gyttja were recognized in the studied deposit (Fig. 3, 4). All peat units (humo-

73

Acta Palaeobotanica 44(2): 175–193, 2004

The vegetation changes recorded in sediments of Kładkowe Bagno peat bog in Puszcza Knyszyńska Forest, north-eastern Poland*

MIROSŁAWA KUPRYJANOWICZ

Department of Botany, Institute of Biology, University of Białystok, 15-950 Białystok, Świerkowa 20b, Poland; e-mail: kuprbot@uwb.edu.pl

Received 24 November 2003; accepted for publication 18 November 2004

ABSTRACT. Material for the palynological study comes from the Kładkowe Bagno peat bog in the north-eastern part of the Puszcza Knyszyńska Forest (Białystok Upland, north-eastern Poland). Nine local pollen assemblage zones (L PAZ) have been distinguished in the pollen diagram produced from this site. The results were used to reconstruct the succession of vegetation during the Late Glacial form the Vistulian and Holocene. It is shown in different aspects: (1) as changes in the surroundings of the studied site, (2) as changes caused by human activity and (3) as changes in a water level and mire plant communities.

KEY WORDS: pollen analysis, pollen assemblage zones, human impact, Late Glacial, Holocene, Puszcza Knyszyńska Forest, Białystok Upland, Poland

INTRODUCTION

Since 1999, palaeobotanical investigations for reconstruction of the late Glacial and Holocene succession of the local peat bog vegetation in various hydrological conditions have been made in the Puszcza Knyszyńska Forest in north-eastern Poland (Drzymulska 2001, 2003). The main study, based on analyses of macroscopic plant remains and of botanical composition of peat, has been prepared by Drzymulska (2001, 2003). It is complementary to pollen analysis of selected investigated profiles, of which main goal has been the description of vegetation changes in the studied peat bogs and their vicinity.

Pollen analysis results from the first of the examined profiles – KBVII profile from the Kładkowe Bagno peat bog – are presented in this paper. Preliminary palynological study of this profile was the subject of a Master of Science Thesis (Brzostowska 2001). In 2002 its results were included to a scientific project "Late Glacial and Holocene history of vegetation in Poland based on isopollen maps" (Ralska-Jasiewiczowa et al. 2004). Obtained pollen data suggested that this pollen profile, in the contrast to other profiles from the Puszcza Knyszyńska Forest (Kupryjanowicz 1991, 1995, 2000), may present the full record of Holocene vegetation history and, after the precise analysis and ^{14}C dating, it will become the stratotype profile for this part of Poland.

SHORT CHARACTERISTIC OF THE PRESENT-DAY NATURAL ENVIRONMENT OF THE PUSZCZA KNYSZYŃSKA FOREST

According to the regional division of Poland made for palaeobotanical studies, the Puszcza Knyszyńska Forest belongs to the Białystok Upland and the Biebrza Basin region (P-o),

* The article has been prepared thanks to the financial support by the State Committee for Scientific Research (grant No. 3 P04C 066 24)

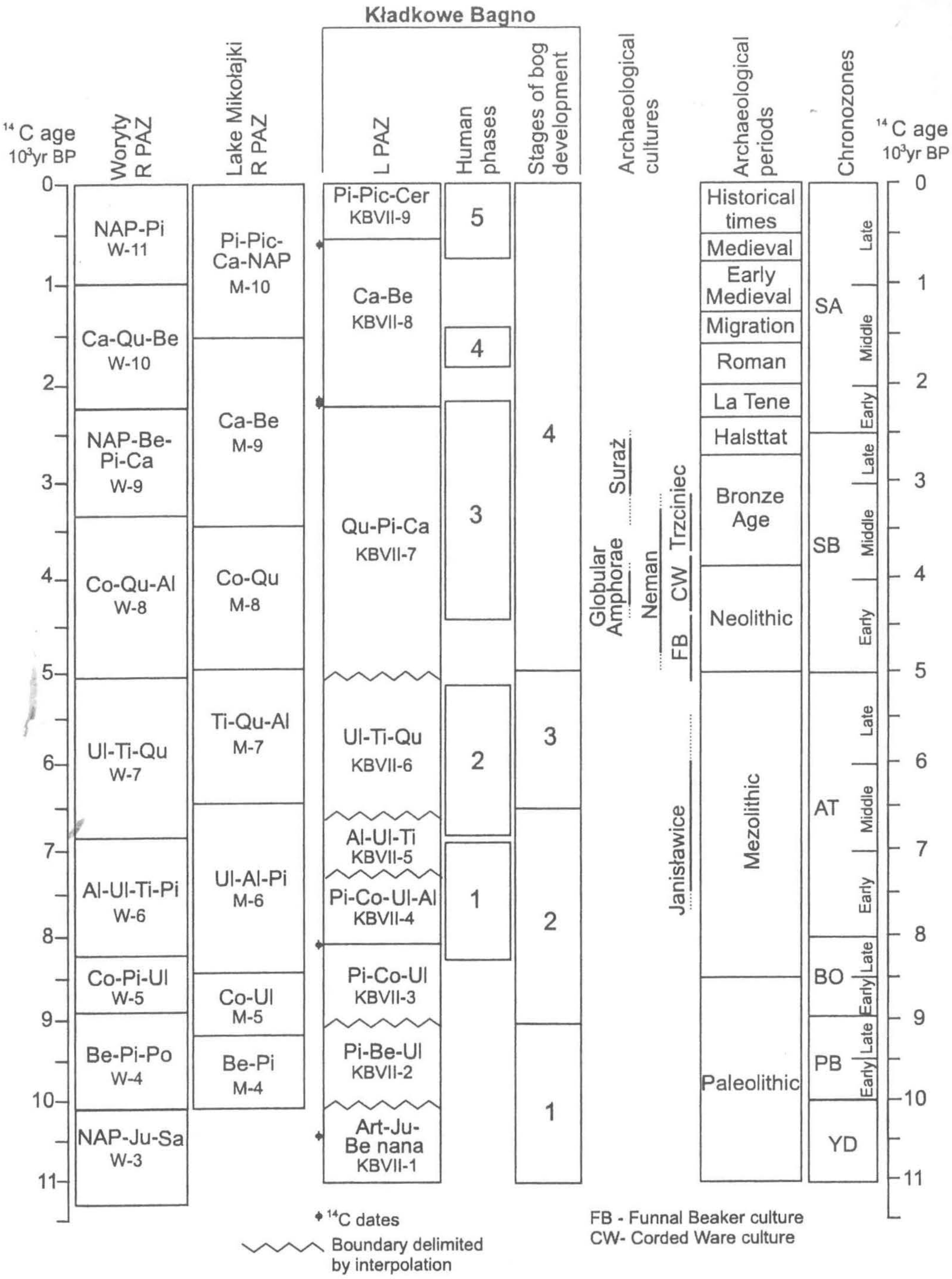


Fig. 3. Comparison of local pollen assemblage zones, anthropogenic phases and stages of development of aquatic-mire vegetation distinguished at the Kładkowe Bagno peat bog. Regional pollen zones from Woryty (Noryśkiewicz & Ralska-Jasiewiczowa 1989) and Lake Mikołajki (Ralska-Jasiewiczowa 1989c), chronozones (Mangerud et al. 1974) and archaeological cultures; the archaeological chronology according to Jażdżewski (1968) modified by Kozłowski (1989) for the Late Paleolithic and Mesolithic, by Dąbrowski (1997) for the Bronze Age and by Kowalski (1991) for Migration period

represents the older part of the Younger Dryas. This was the time of the maximum development of *Juniperus* that expanded on drier and more exposed habitats. However, its participation in plant communities around the Kładkowe Bagno peat bog was in that period distinctly lower than in the majority of other sites from central and northern Poland (e.g. Ralska-Jasiewiczowa 1966, 1989c, Latałowa 1982, 1989a, 1989b, Noryśkiewicz 1982, Pawlikowski et al. 1982, Bińka & Szeroczyńska 1989, Noryśkiewicz & Ralska-Jasiewiczowa 1989, Miotk-Szpiganowicz 1992, Ralska-Jasiewiczowa et al. 2001a). Low values of *Juniperus* pollen are noted only in profiles from the Puszcza Knyszyńska Forest (Kupryjanowicz 1991, 1995, 2000) and Lake Łukcze (Bałaga 1990). According to Bałaga (1990) it seems

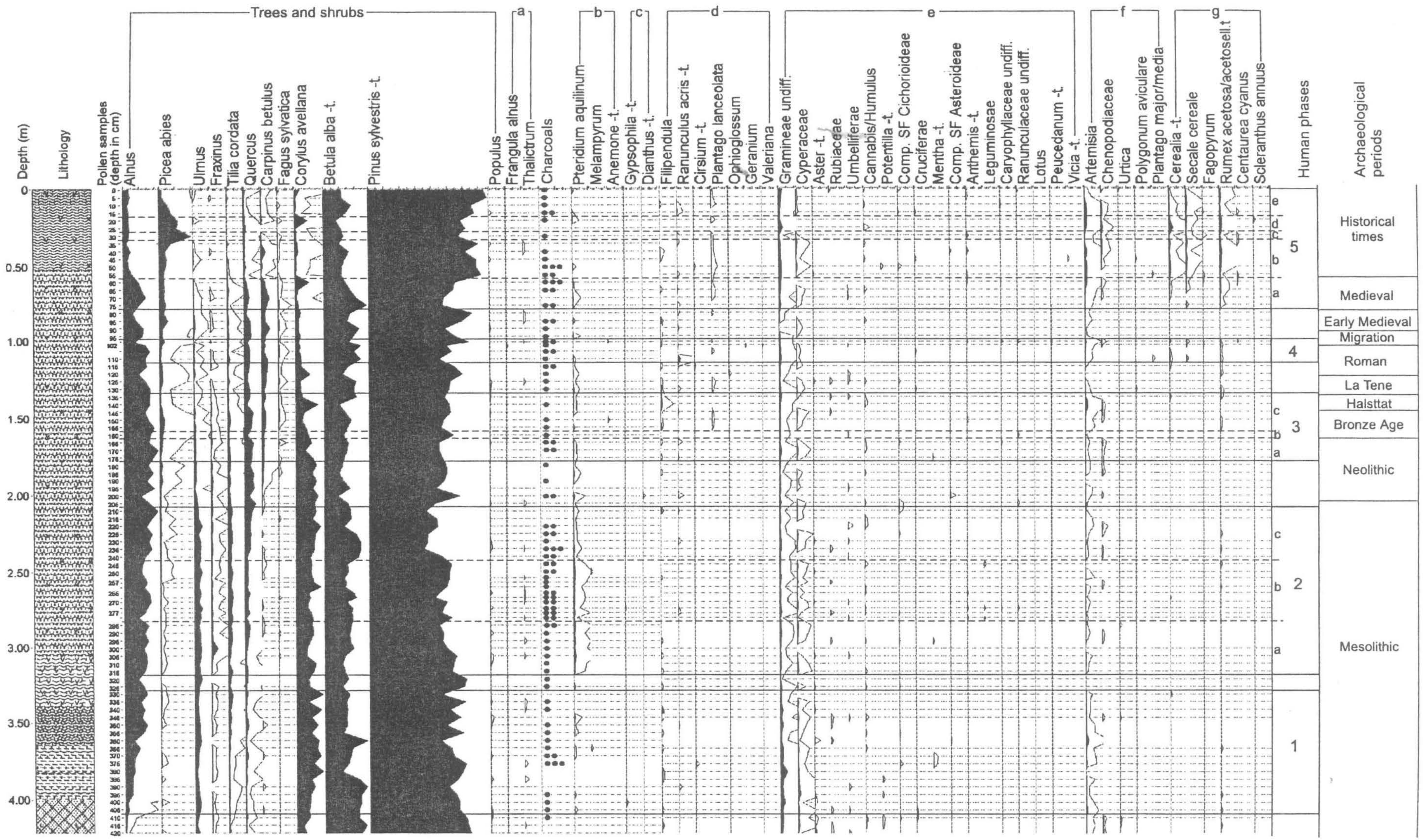


Fig. 4. Kładkowe Bagno. Section of the pollen percentage diagram from the KBVII profile showing the human impact on the landscape; curves of herbs related to the economic activity of man have been grouped according to Behre (1981) modified by Berglund and Ralska-Jasiewiczowa (1986) and Latałowa (1992): **a** – mantle/outskirt shrubs, **b** – grazed woodland, **c** – dry grasslands (pastures), **d** – fresh-wet grasslands (meadows), **e** – taxa ecologically undefined (family or genus type rank mostly), but favoured for human use, **f** – ruderals, **g** – cultivated plants and field weeds; charcoals content (black dots) is estimated according to the 3-grade scale: one dot – present, two dots – frequent, three dots – abundant. For other explanations see Figures 2 and 3

Friday, 26 August 2011 (day 5th)

Lake Wigry

Natalia Piotrowska

Changes of stable carbon and oxygen isotope composition in Lake Wigry (NE Poland) as a source of palaeoclimatic information

The work was focused on isotopic investigations of carbonate sedimentation carried out for the southern part of the Lake Wigry. Since now many interdisciplinary studies have been conducted, especially a 5.26 m long core (called WZS/03), reaching the beginning of lake sedimentation, was recovered from the Slupianska Bay site in 2003 (Fig. 1). The conducted study of the core include lithological (Rutkowski *et al.* 2007) and palaeobiological analyses, namely palynology (Kupryjanowicz 2007), *Cladocera* (Zawisza and Szeroczyńska 2007) and *Ostracoda* analysis (Staniszewska and Namiotko 2007). The results of palaeobiological analysis allowed distinguishing of local assemblage zones and reconstruction of environmental conditions in Lake Wigry and its surroundings from the Late Glacial up to the present time. Radiocarbon dating and statistical tools were used to build a calendar age-depth model for the core (Piotrowska *et al.* 2007, Fig.2).

The study included determination of stable carbon and oxygen ratios ($\delta^{13}C$, $\delta^{18}O$) in the carbonate fraction of WZS/03 core (see Fig. 3 and 4). The results of isotopic composition measurements obtained for various elements of contemporary carbonate sedimentation environment (DIC, carbonates deposited on short-living submerged or semi-submerged plants, shells, Fig. 1), published by Pawlyta *et al.* (2004), Sensuła *et al.* (2006) and Paprocka (2007) have also been included in this chapter.

The isotope record was compared directly to the climate record and phases of Lake Wigry development and show good correlation with other palaeo data. Comparison of $\delta^{18}O$ with isotope record of Greenland ice core (NGRIP) on the calendar timescale shows also the clear Younger Dryas/Holocene boundary in WZS/03 core (Fig. 3).

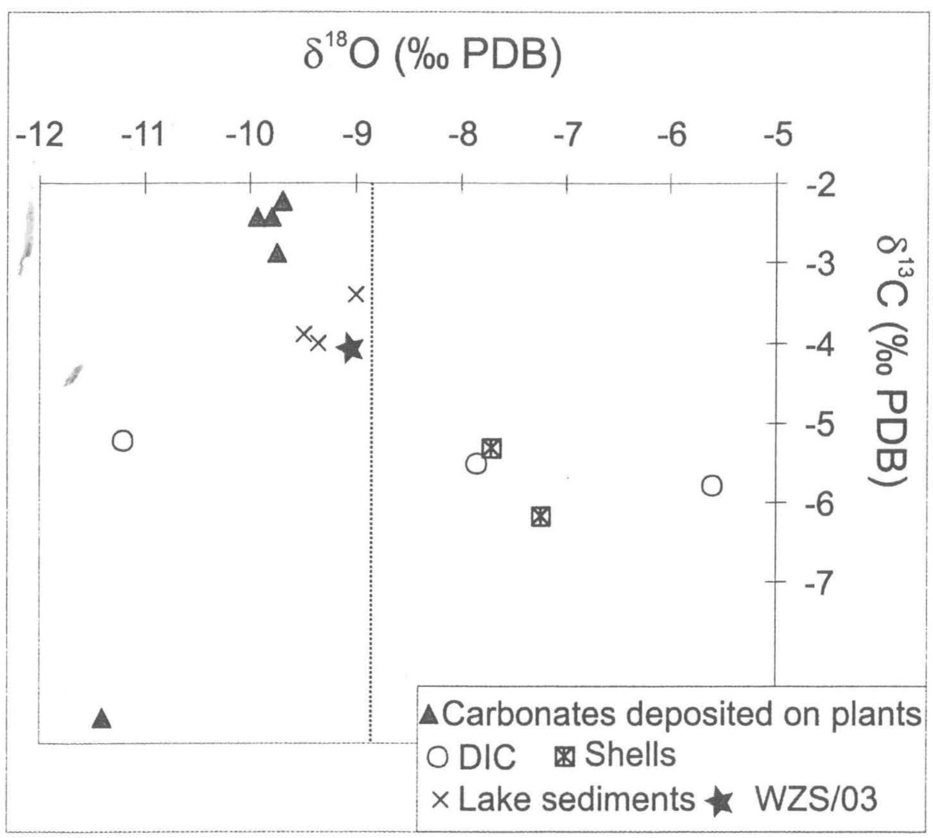


Fig. 1 SW part of the Wigry Lake with marked positions of sampling sites for various samples of contemporary carbonates (upper pat). The results of stable isotope composition measurements for abovementioned samples (lower part).

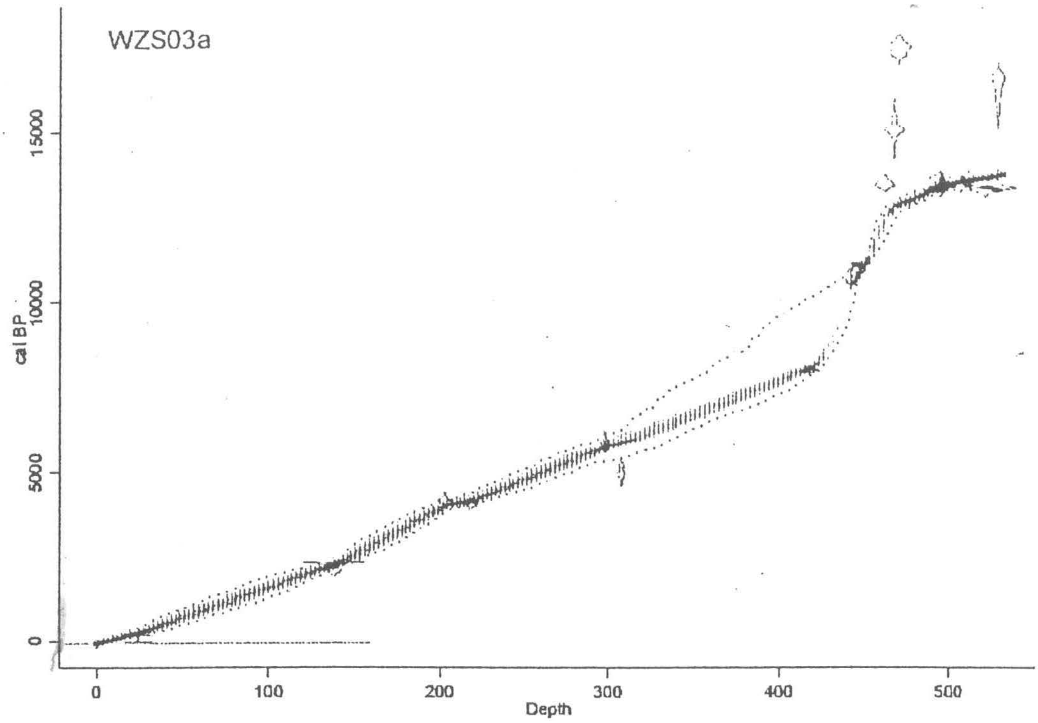


Fig. 2 Age-depth model for the WZS/03 core on the basis of radiocarbon ages, obtained with use of BACON software (Blaauw & Christen 2011).

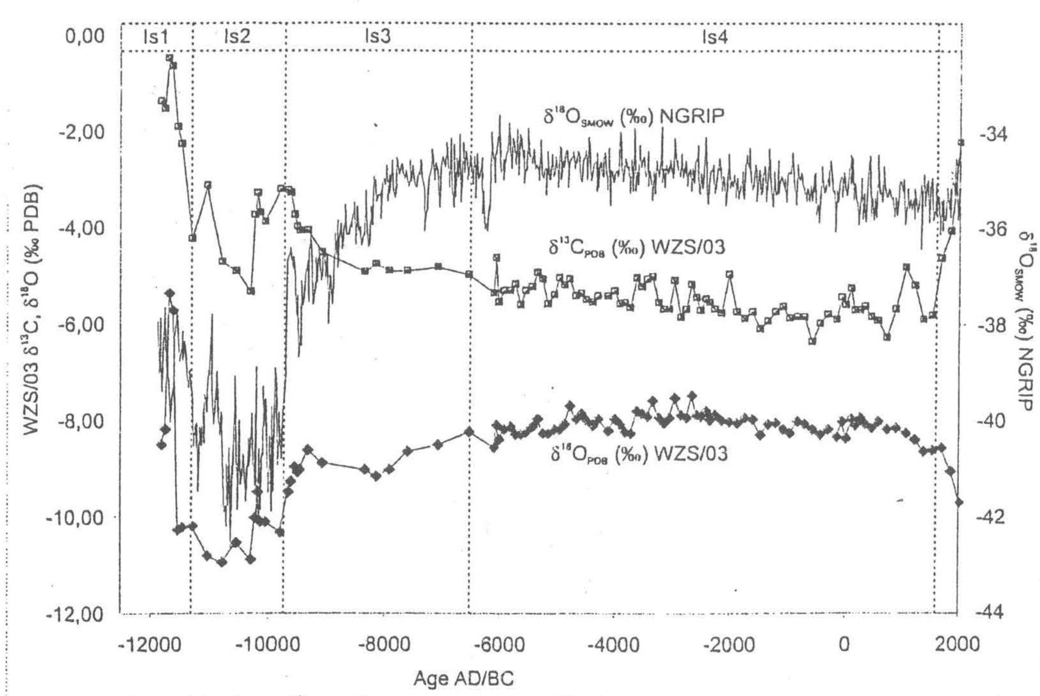


Fig. 3 Changes of stable carbonate composition in carbonate sediments of Wigry Lake and NGRIP ice core isotope record (North Greenland Ice Core Project Members 2004, Vinther *et al.* 2006, Rasmussen *et al.* 2006).

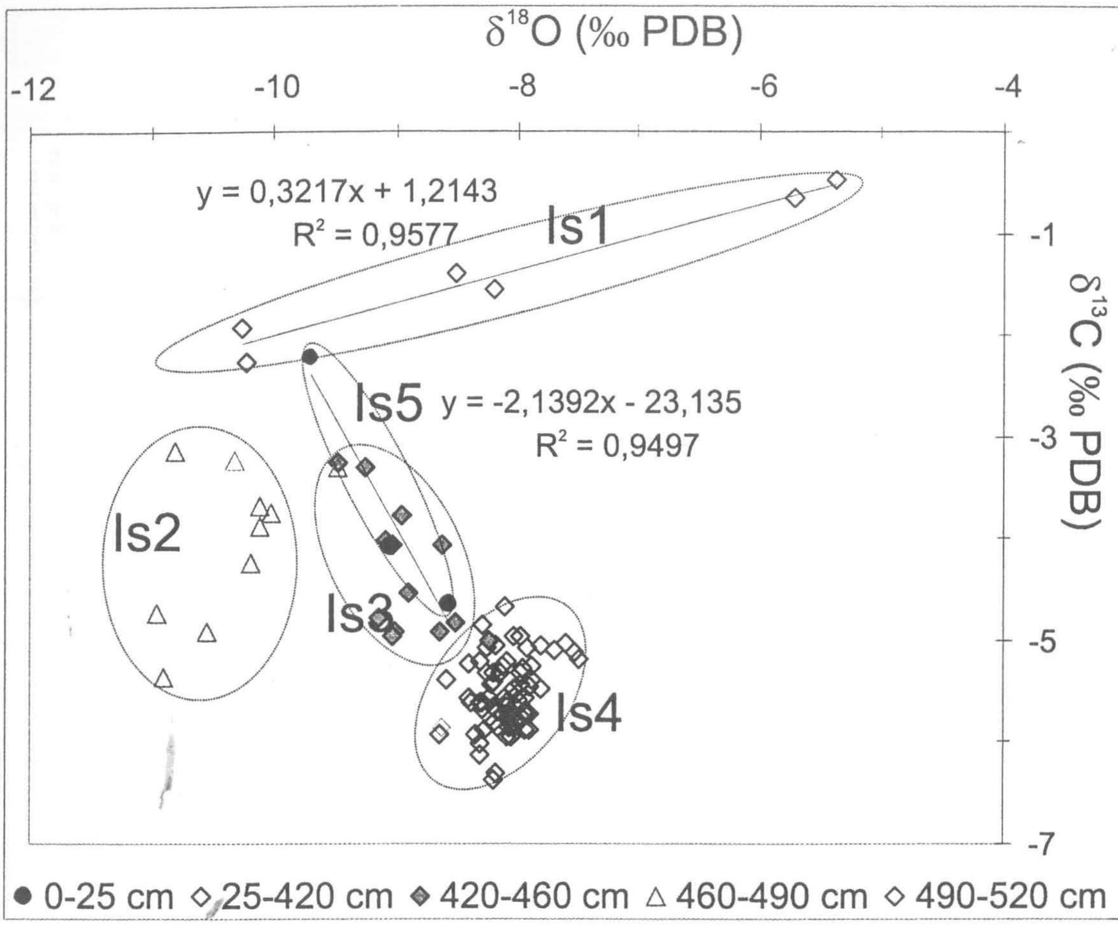


Fig. 4 Plot showing the relations between $\delta^{13}C$ and $\delta^{18}O$ in the WZS/03 core.

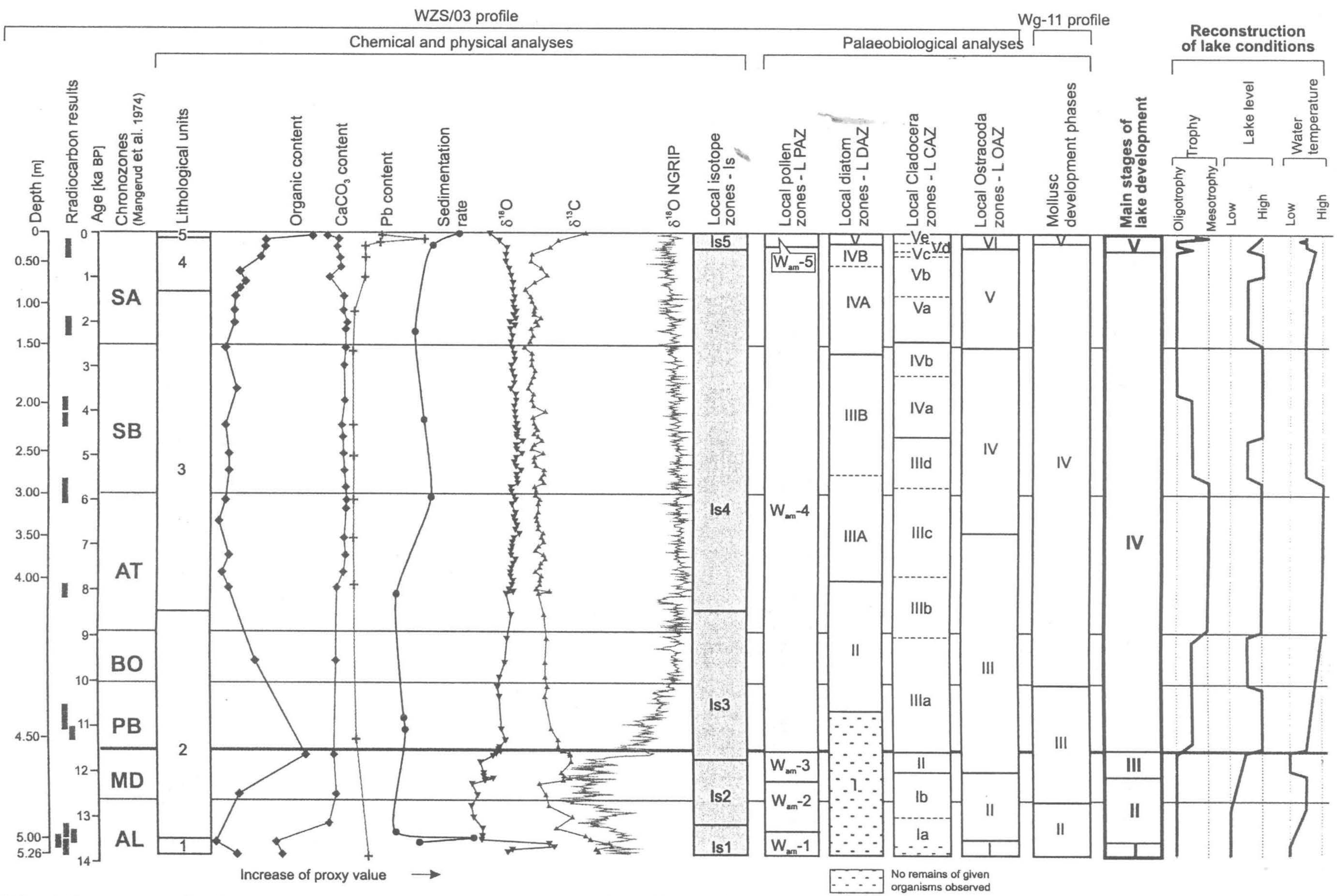


Fig. 5 Summary of paleoenvironmental reconstruction s for Wigry Lake since the Last Glacial.

Kupryjanowicz M. 2007. Postglacial development of vegetation in the vicinity of the Wigry Lake. *Geochronometria*, 29, 53-66.

North Greenland Ice Core Project Members. 2004. High-resolution record of Northern Hemisphere climate extending into the last interglacial period. *Nature*, 431, 147–151.

Paprocka A. 2007. Stable carbon and oxygen isotopes in recent sediments of Lake Wigry, NE Poland: Implications for lake morphometry and environmental changes. (w:) Dawson T.E., Siegwolf T.W. (red.) *Stable isotopes as indicators of ecological change*. Elsevier, 267-281.

Pawlyta J., Pazdur A., Rutkowski J., Król K., Piotrowska N., Poręba G., Szczepanek M., Sikorski J., Hałas S. 2004. Isotopic investigations of uppermost sediments from Lake Wigry (NE Poland) and its environment, *Geochronometria*, 23, 71-78.

Piotrowska N., Hajdas I., Bonani G. 2007. Construction of the calendar timescale for Lake Wigry (NE Poland) sediments on the basis of radiocarbon dating, *Radiocarbon*, 49(2), 1133-1143.

Rasmussen S.O., Andersen K.K., Svensson A.M., Steffensen J.P., Vinther B.M., Clausen H.B., Siggaard-Andersen M.-L., Johnsen S.J., Larsen L.B., Dahl-Jensen D., Bigler M., Röthlisberger R., Fischer H., Goto-Azuma K., Hansson M.E., Ruth U. 2006. A new Greenland ice core chronology for the last glacial termination, *Journal of Geophysical Research*, 111, D06102, doi:10.1029/2005JD006079.

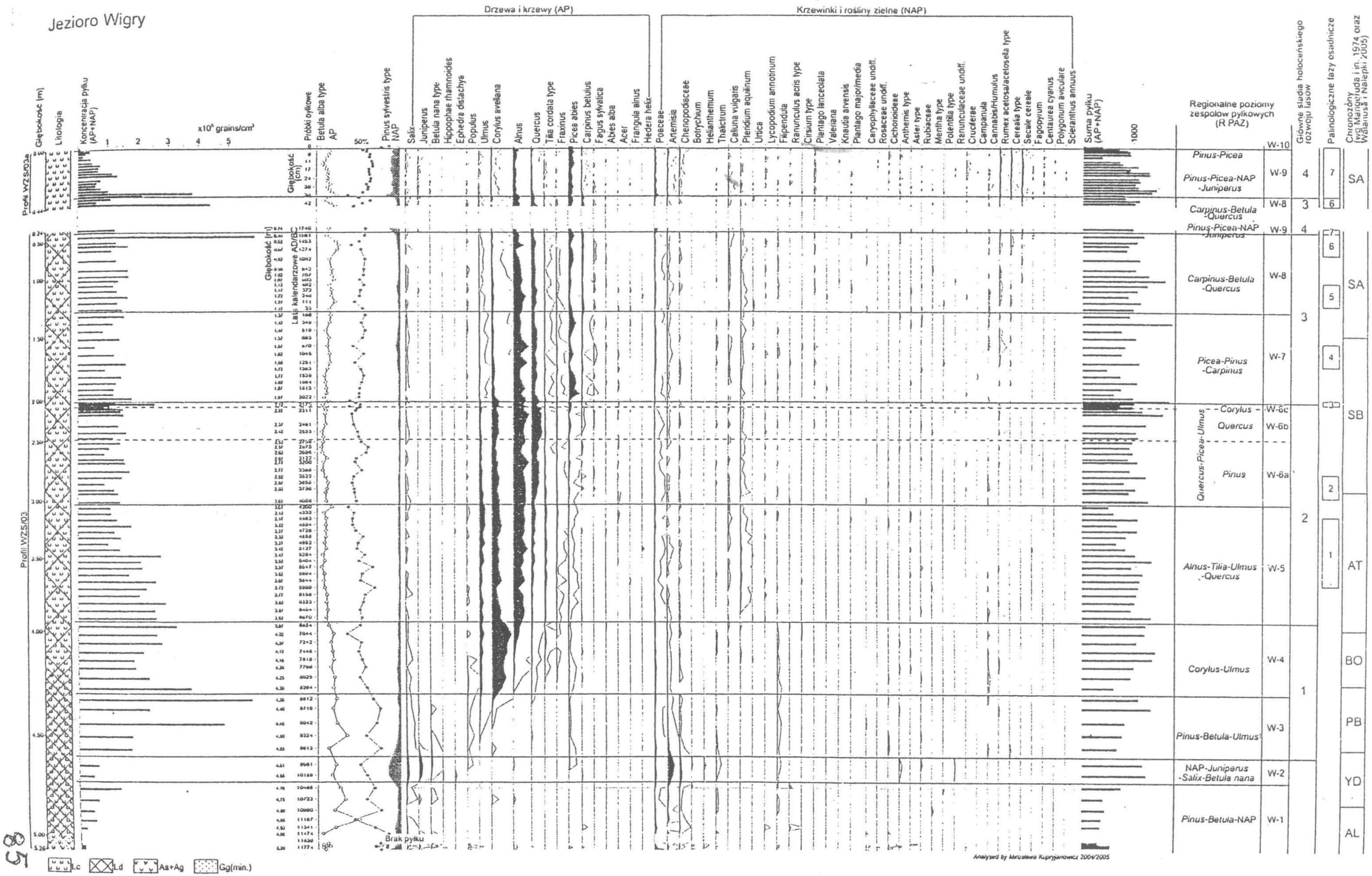
Rutkowski J., Król K., Szczepańska J. 2007. Lithology of the profundal sediments in Słupiańska Bay (Wigry Lake, NE Poland) – introduction to interdisciplinary study. *Geochronometria*, 27, 47-52.

Sensuła B., Böttger T., Pazdur A., Piotrowska N., Wagner R. 2006. Carbon and oxygen isotope composition of organic matter and carbonates in recent lacustrine sediments, *Geochronometria*, 25, 77-94.

Staniszewska W., Namiotko T. 2007. Sukcesja zgrupowań małżoraczków (Ostracoda) w późnoglacjalnych i holoceńskich osadach jeziora Wigry: wstępne wyniki analiz z wiercenia WZS-03 w Zatoce Słupiańskiej. *Prace Komisji Paleogeografii Czwartorzędu PAU*, 5, 95-100.

Vinther B.M., Clausen H.B., Johnsen S.J., Rasmussen S.O., Andersen K.K., Buchardt S.L., Dahl-Jensen D., Seierstad I.K., Siggaard-Andersen M.-L., Steffensen J.P., Svensson A.M., Olsen J., Heinemeier J. 2006. A synchronized dating of three Greenland ice cores throughout the Holocene. *Journal of Geophysical Research*, 111, D13102, doi:10.1029/2005JD006921.

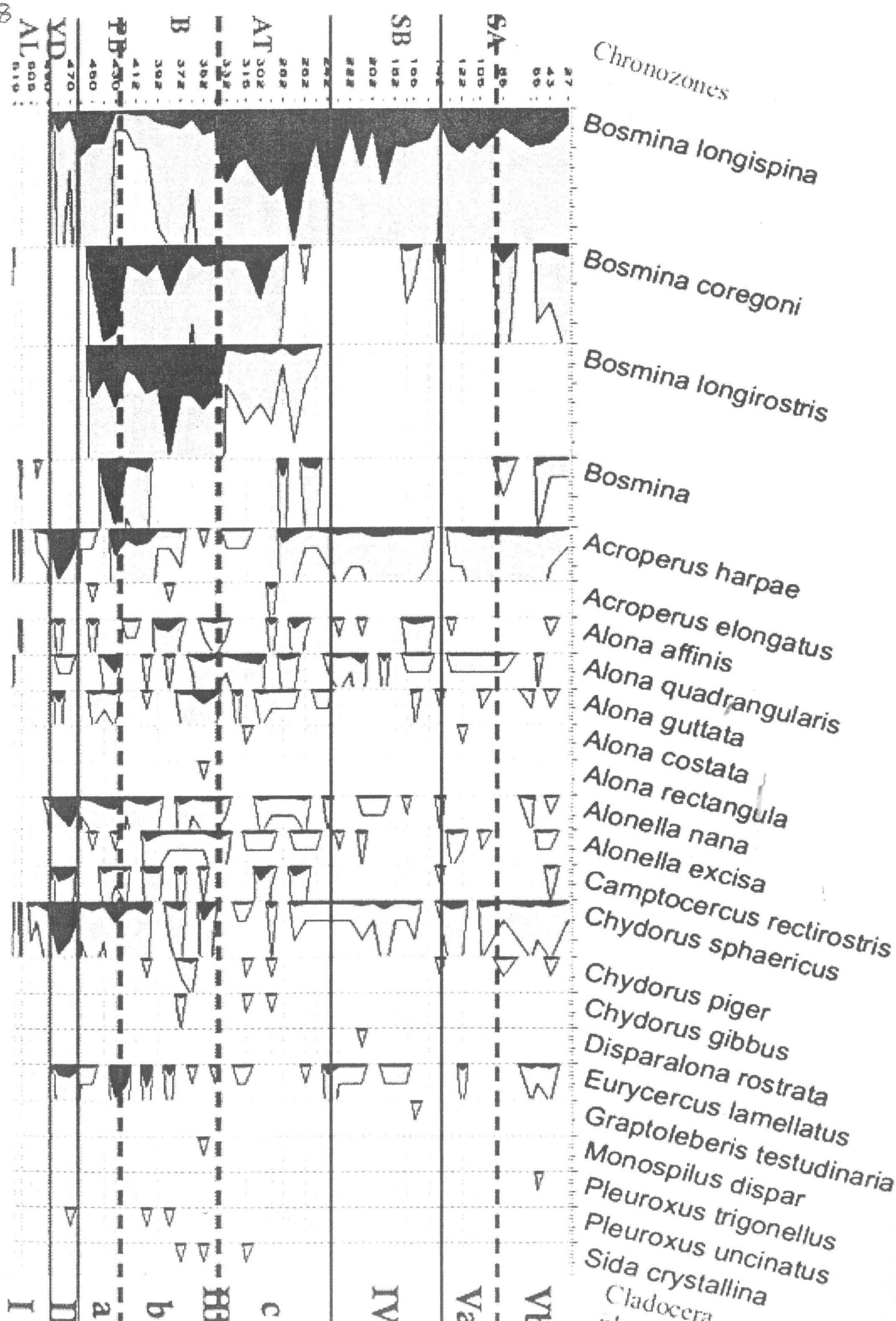
Zawisza E., Szeroczyńska K. 2007. The development history of Wigry lake as shown by subfossil Cladocera. *Geochronometria*, 27, 67-74.



Ryc. 2. Uproszczony diagram procentowy z profili WZS/03 i WZS/03a – wybrane krzywe pyłkowe, bez krzywych roślin wodnych i bagiennych (wg Kupryjanowicz 2007). Składniki osadu wg systemu Troels-Smith'a (Troels-Smith 1955): Lc – *limus calcareus* (węglan wapnia), Ld – *limus detrituosus* (gytia detrytusowa), As+Ag – *argilla steatodes* i *argilla granosa* (iły i mułki), Gg(min.) – *grana glareosa minora* (piasek drobny). Datowanie próbek pyłkowych w profilu WZS/03 wg Piotrowskiej i Hajdas (2005). Chronologia archeologiczna wg Jażdżewskiego (1968), z modyfikacjami Kozłowskiego (1989) dla późnego paleolitu i mezolitu, Dąbrowskiego (1997) dla epoki brązu i Kowalskiego (1991) dla okresu wędrówek ludów

Lake Wigry develompment history recorded in subfossil Cladocera fauna remains.

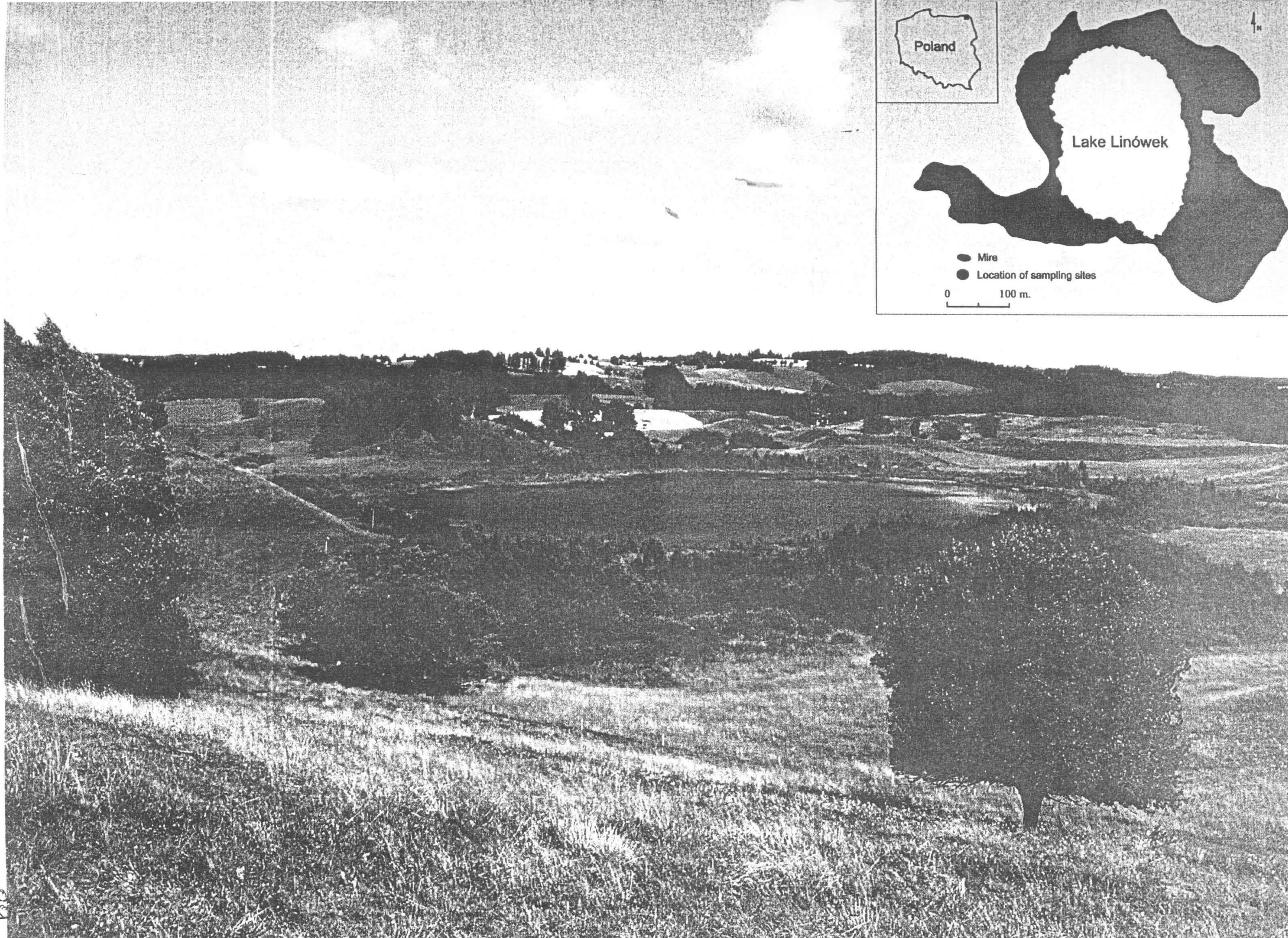
Environmental changes in Wigry Lake during the Late Glacial and Holocene were also studied on the basis of the results of subfossil Cladocera analysis. The two cores of sediments were taken from Słupiańska Bay: long core WZS 03, and short, surface sediments core. The material were prepared according to standard method proposed by Frey and samples were investigated. Sediments contained remains of twenty-seven species belonging to 5 families. Species composition of plankton and variability in the frequency of Cladocera specimens allowed to distinguish five phases of lake Wigry development. They are very well correlated with palynological phases. The correlation proves that the biological development of Wigry Lake was determined mainly by climatic changes. During the history of the lake, planktonic forms were dominant and represented by Bosminidae. It indicates that the lake was (excluding the initial part) deep and oligo- or mesotrophic. The mesotrophic state has been noted during the Atlantic period and in the modern times. Taking into consideration the size and the depth as well as the rare human population around the lake it can be stated that the trophy rise was the result of the warmer climate. It is also possible that during the last 30 years the natural and anthropogenic factors could add. Probably mild winters, warm and long summers, increased tourists number are partly responsible for changes of water status.



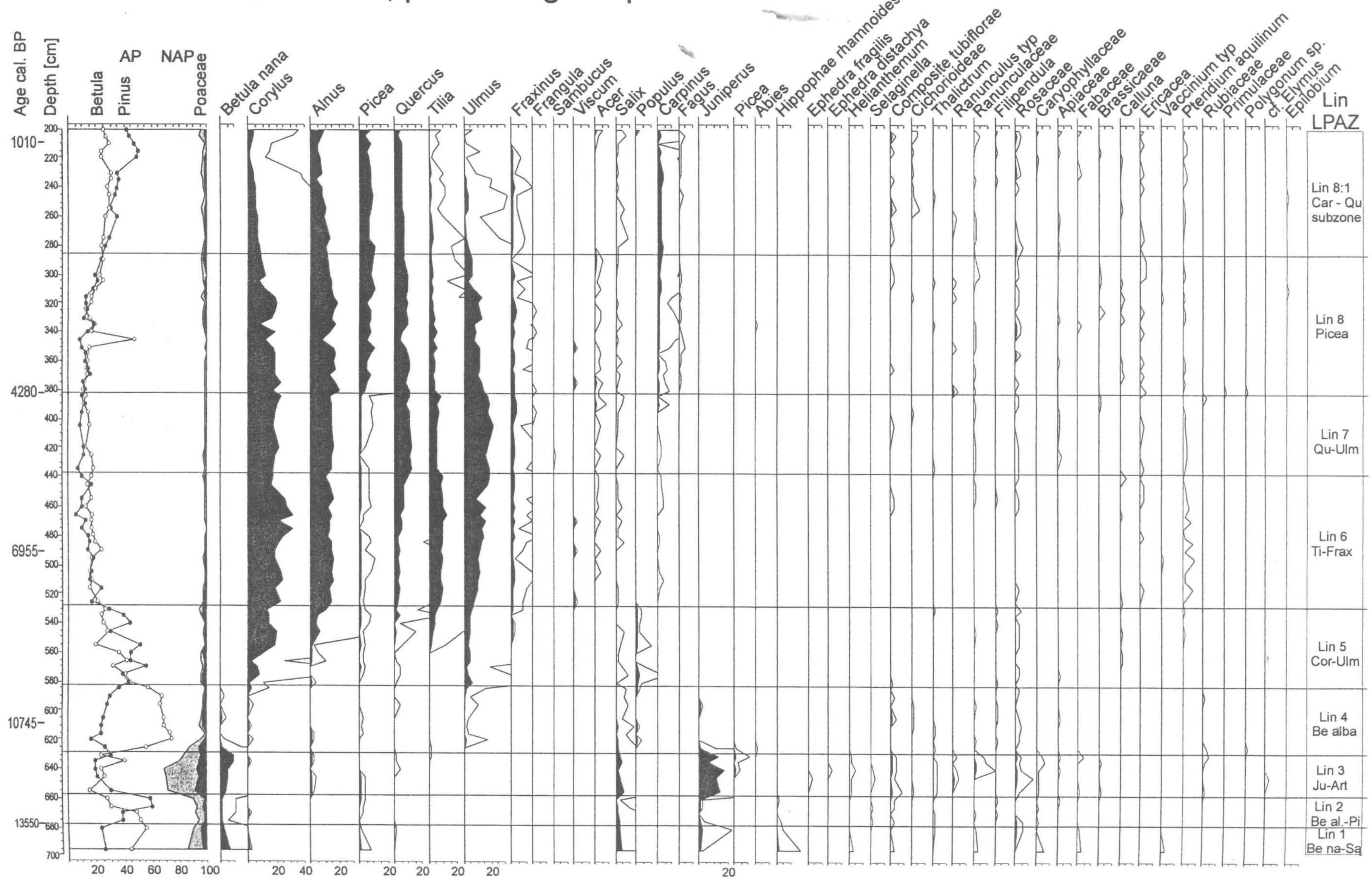
Autor: dr Edyta Zawisza

Saturday, 27 August 2011 (day 6^{th})

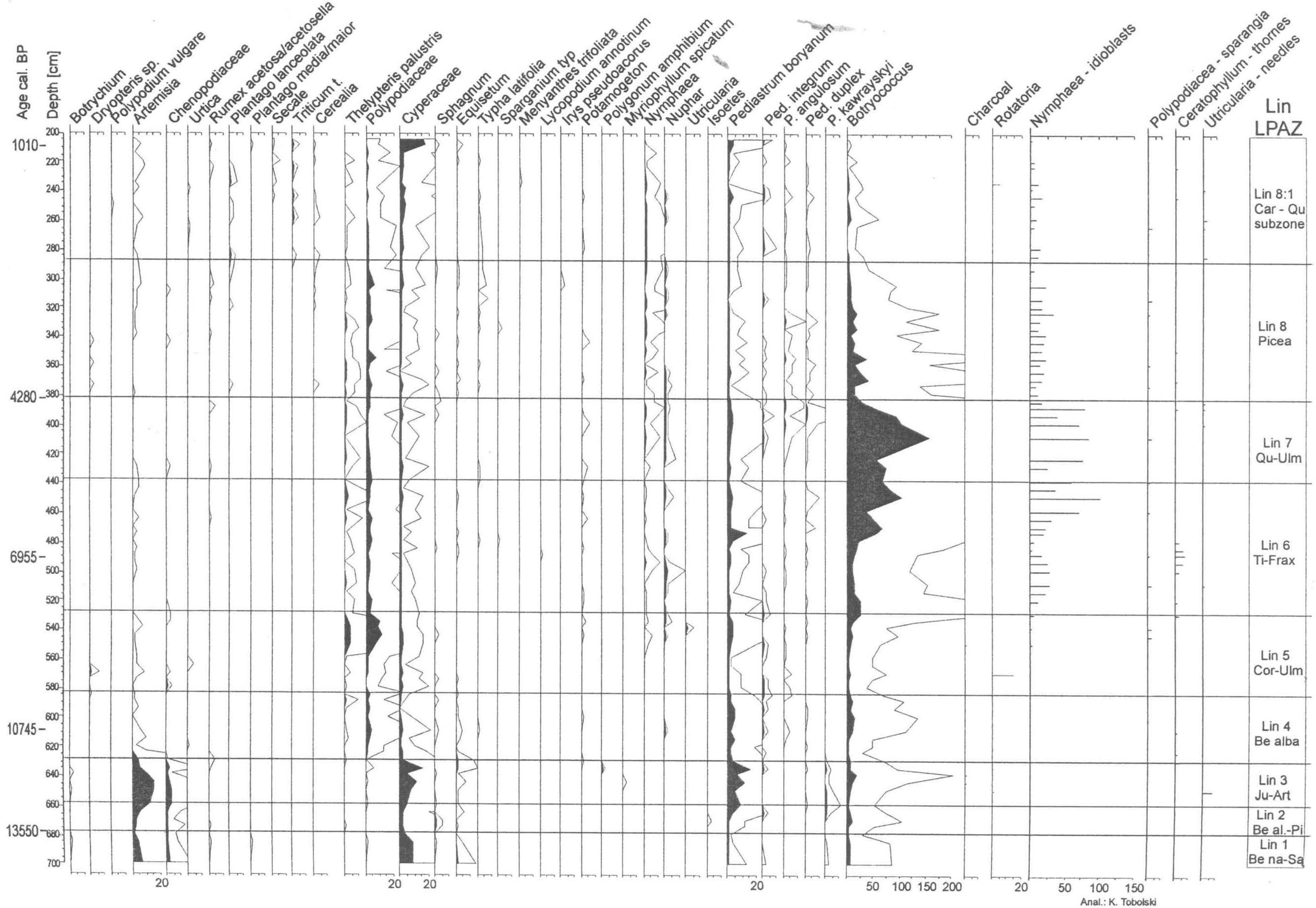
Suwalski Landscape Park


Poland
Lake Linówek
Mire
Location of sampling sites
0
100 m.

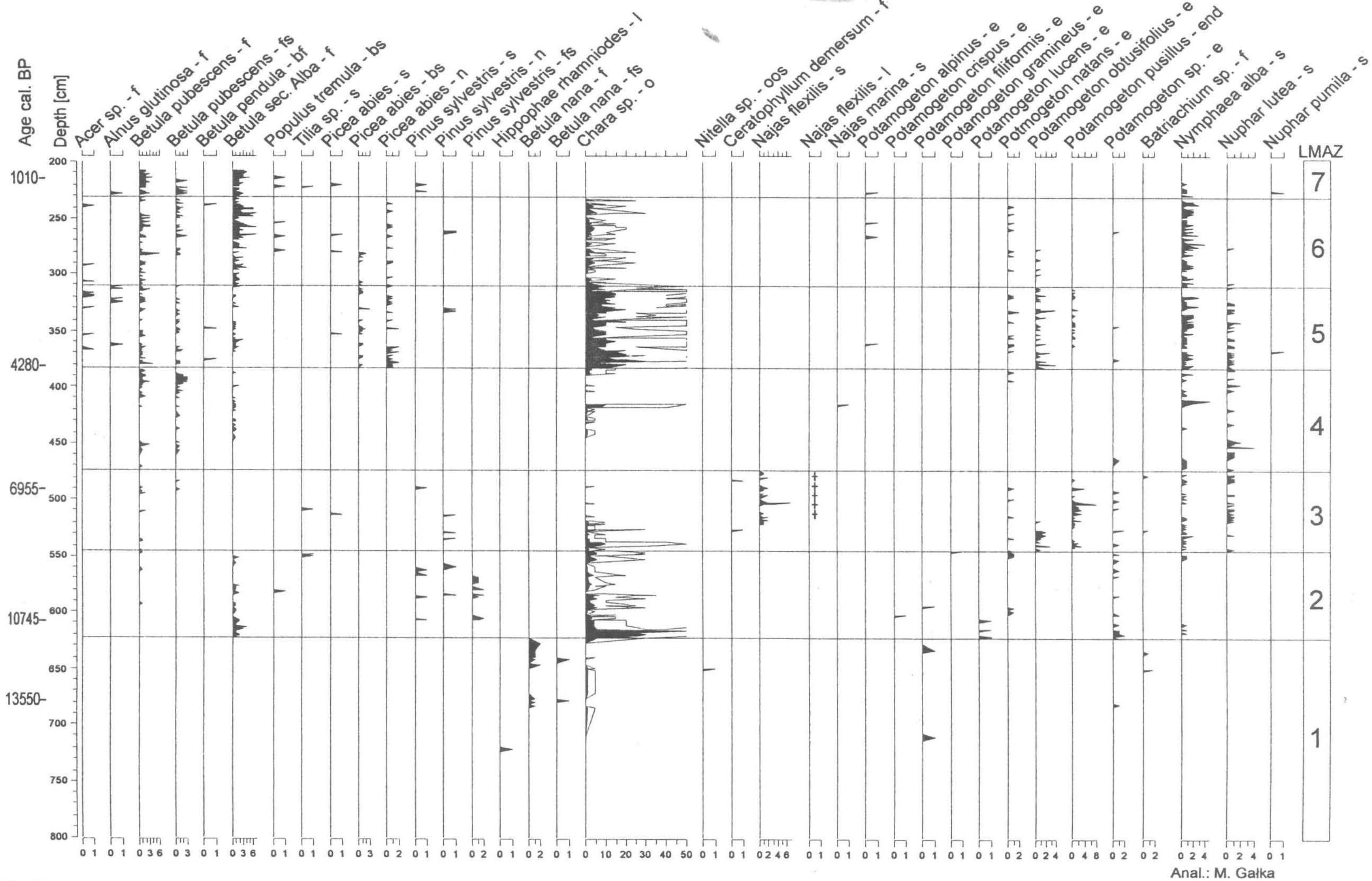
Lake Linówek, pollen diagram part I



Lake Linówek, pollen diagram part II

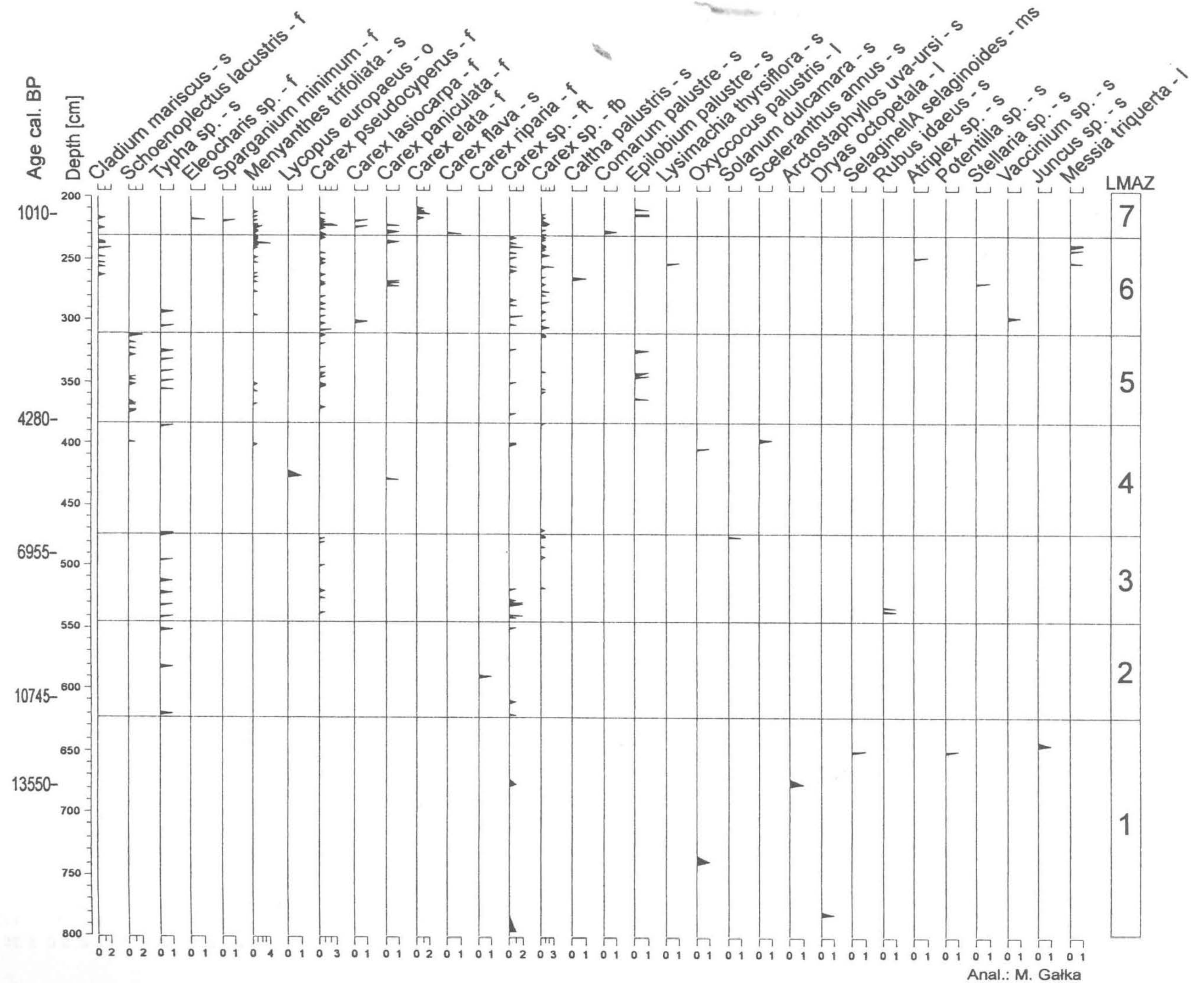


Lake Linówek, plant macrofossil diagram presenting local vegetation changes part I



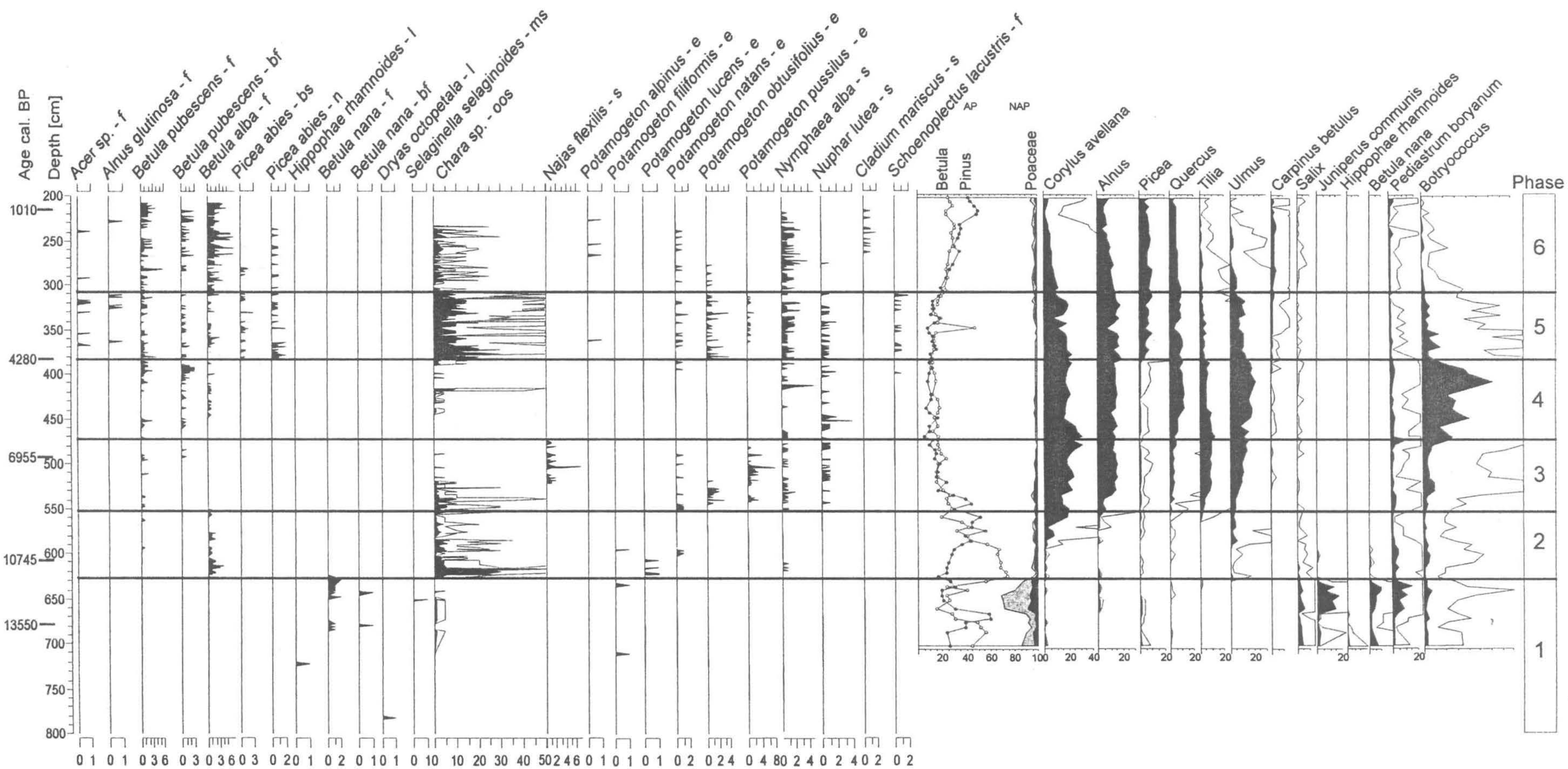
F - fruits, s - seeds, e - endocarps, oo - oospores, fs - fruit scales, bs - bud scales, n - needles, l - leaves, ms - megaspores

Lake Linówek, plant macrofossil diagram presenting local vegetation changes part II

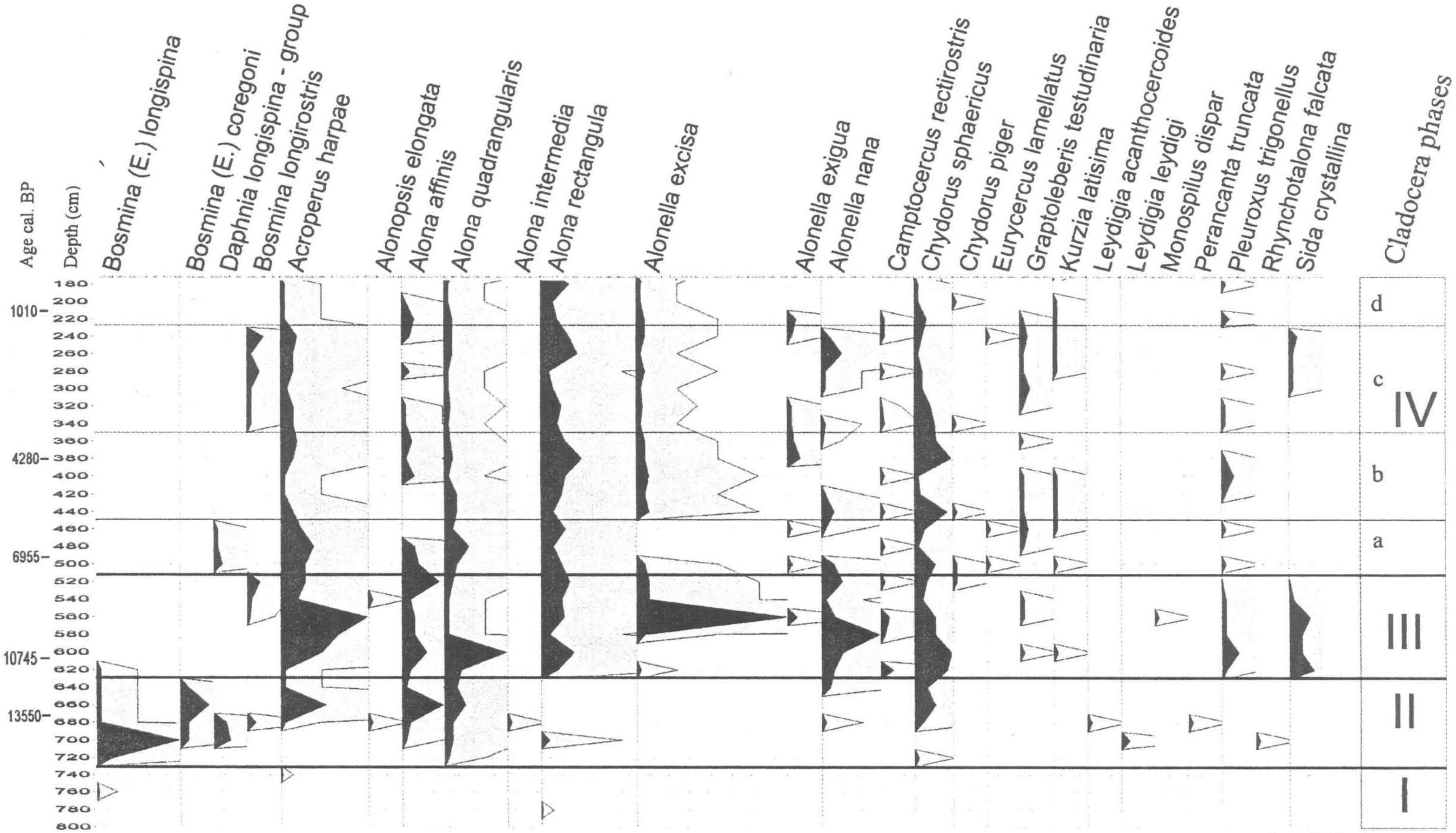


F - fruits, s - seeds, e - endocarps, oo - oospores, fs - fruit scales, bs - bud scales, n - needles, l - leaves, ms - megaspores

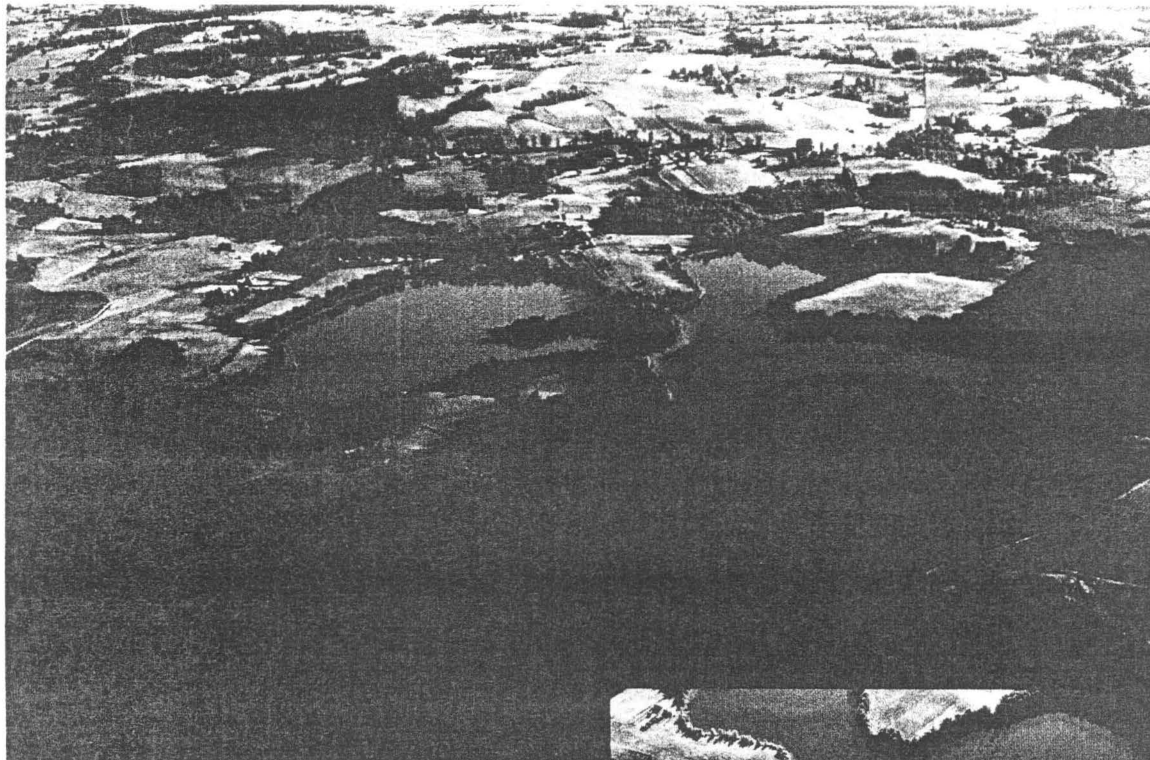
Composite diagram presenting selected indicators of environmental changes

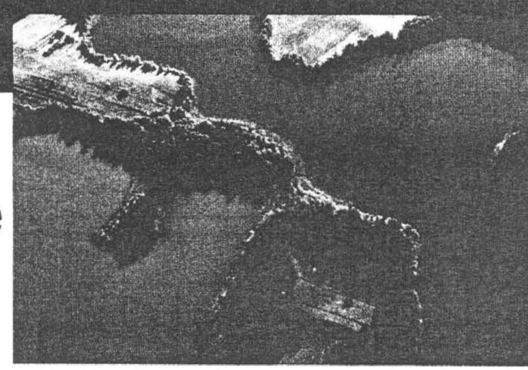


Lake Linówek, percentage diagram of Cladocera

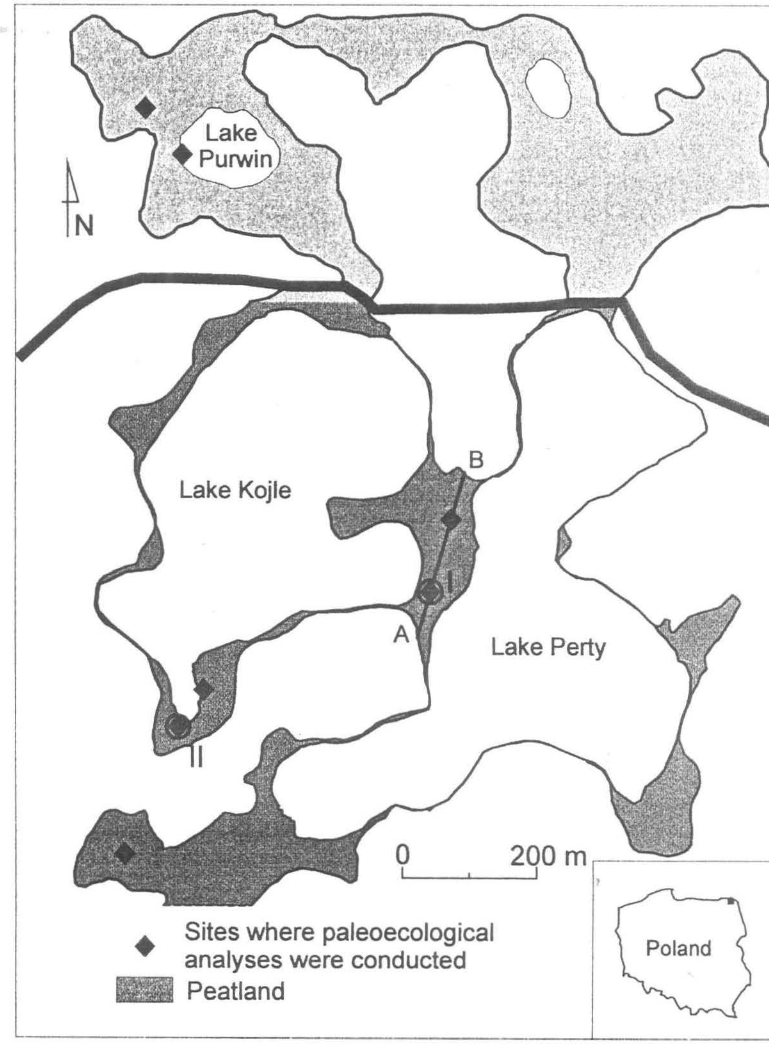


Anal.: E. Zawisza

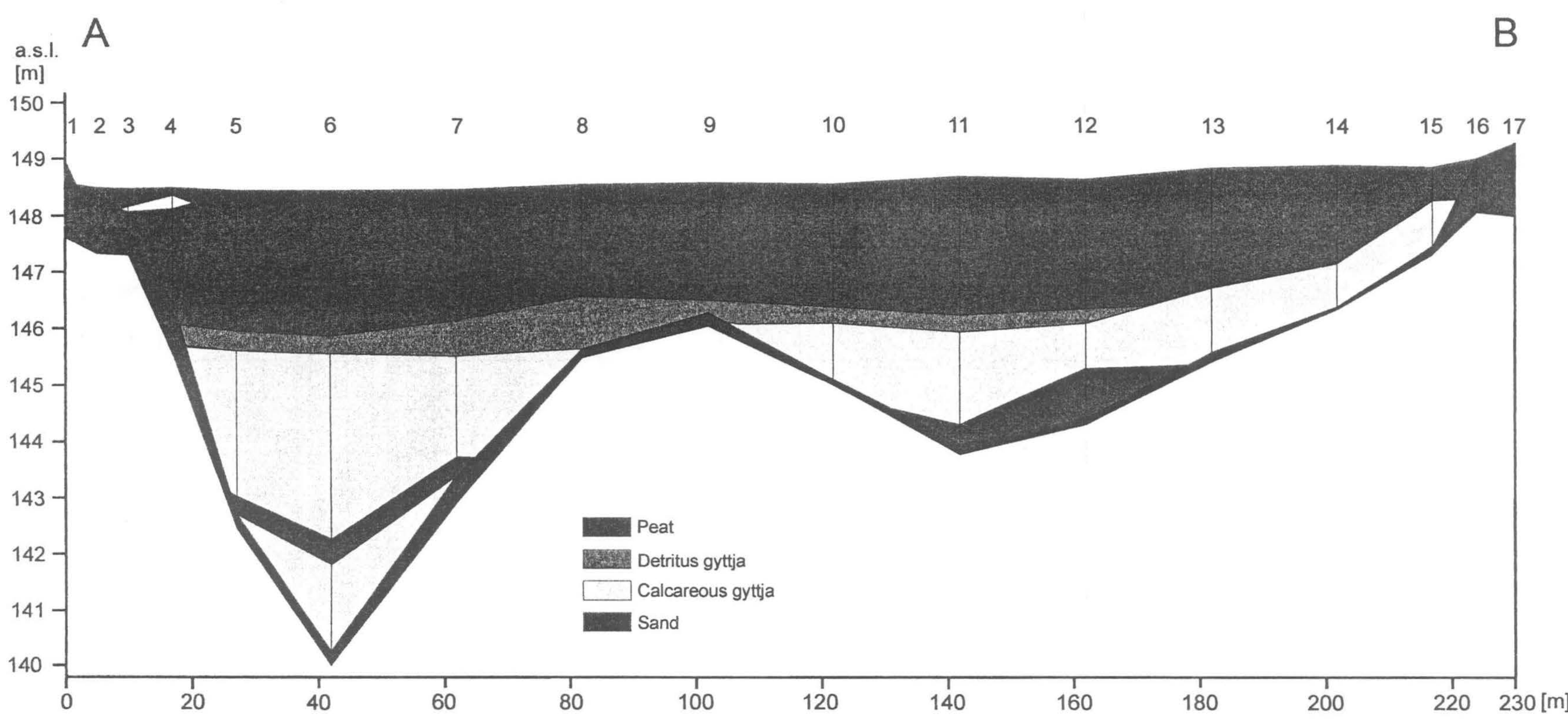




Kojle-Perty study site

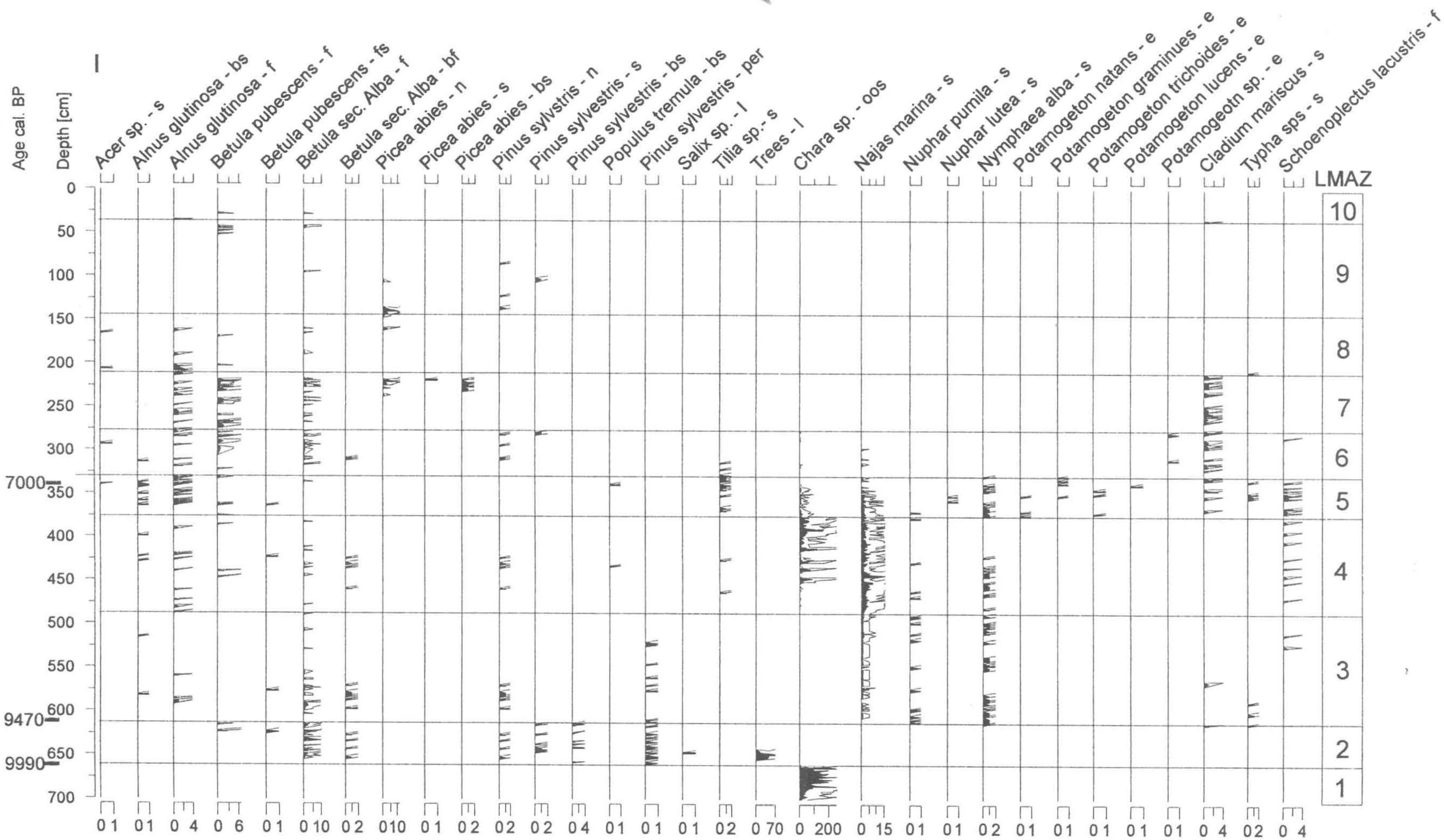


Cross-section of mire between Lake Kojle and Lake Perty



Kojle - Perty site I

Plant macrofossil diagram - local vegetation changes Part I

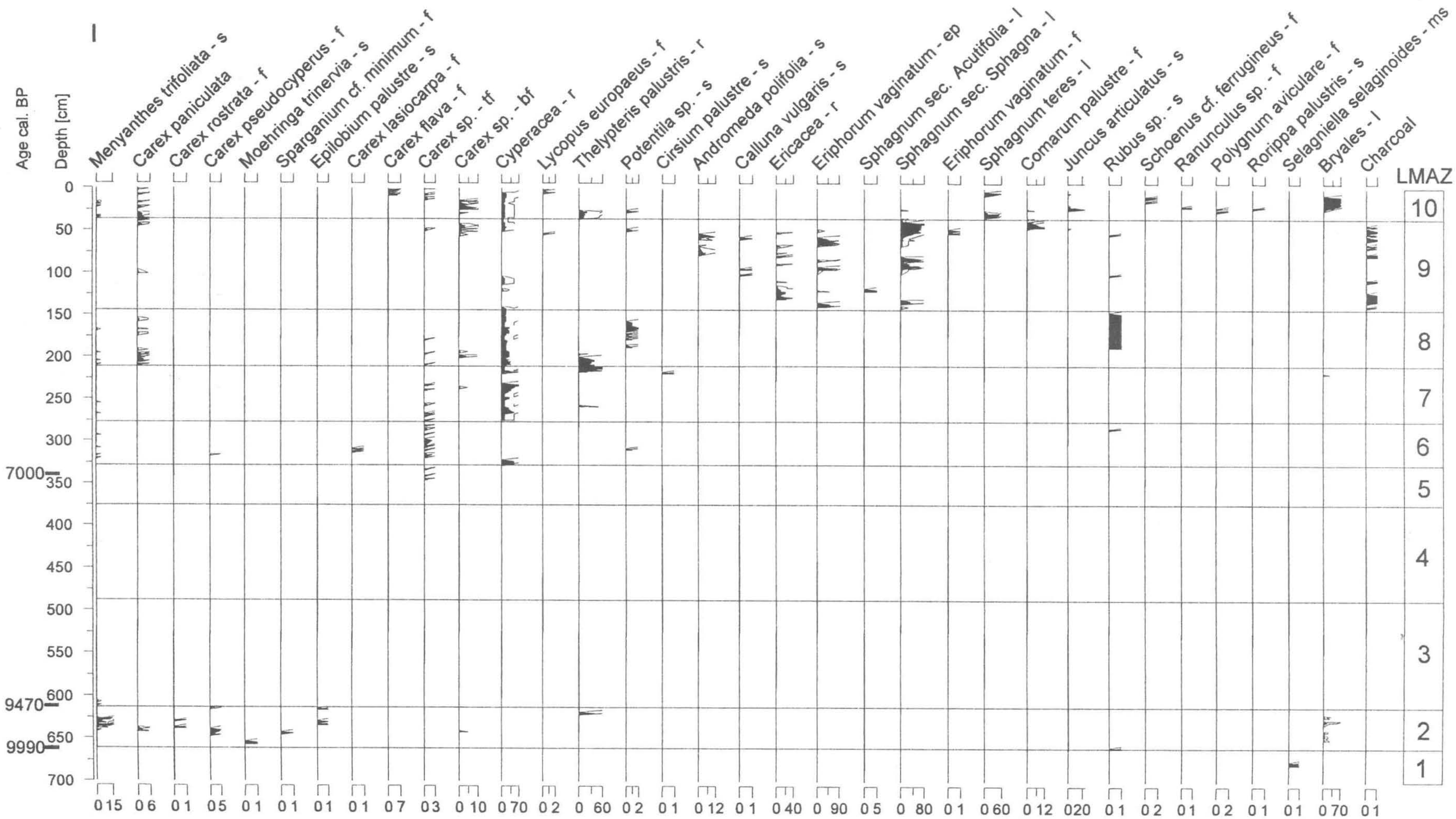


F - fruits, s - seeds, e - endocarp, oo - oospores, fs - fruit scales, bs - bud scales, n - needles, l - leaves, ms - megaspores

Kojle - Perty site I

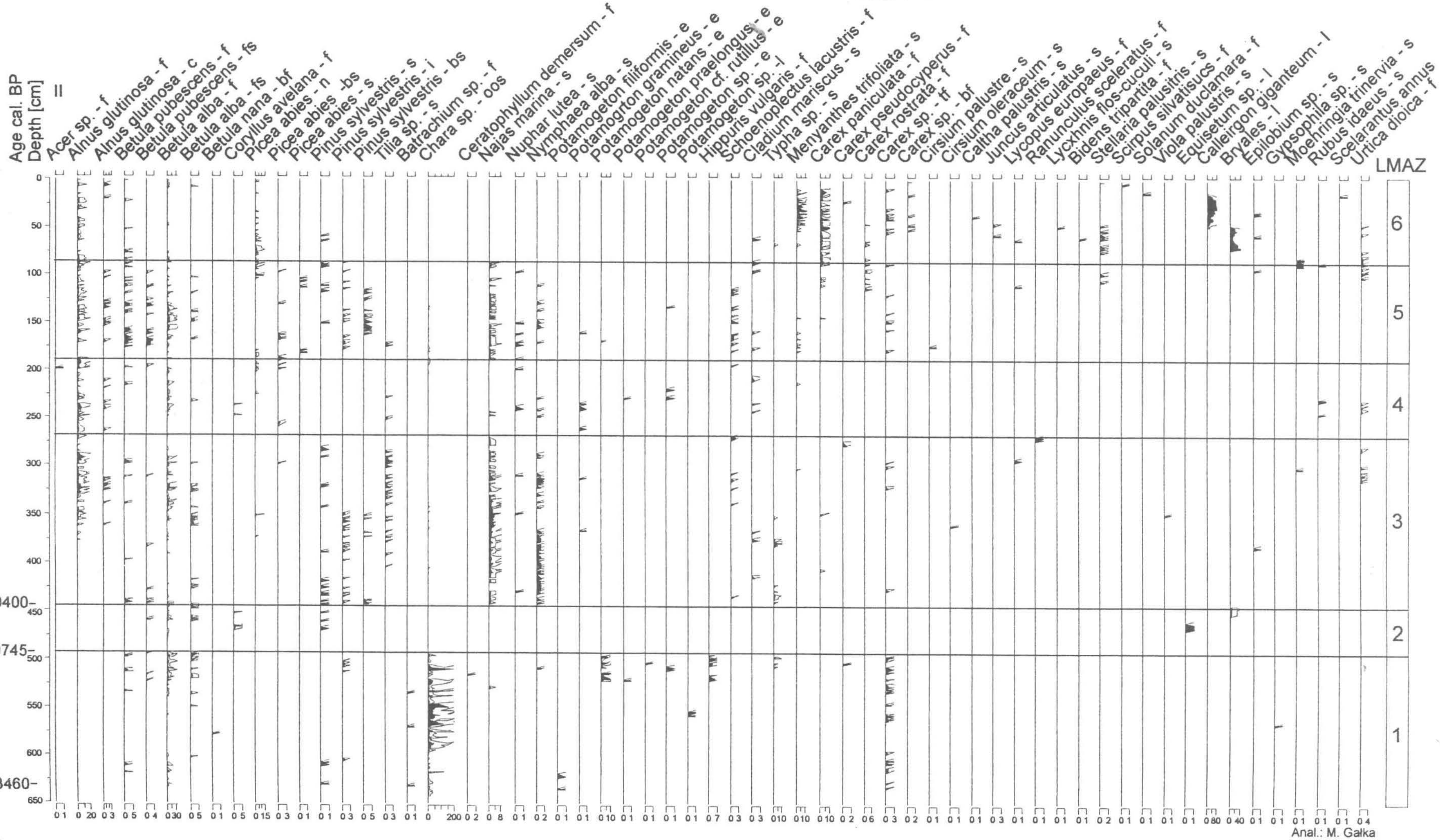
Plant macrofossil diagram - local vegetation changes

Part II



F - fruits, s - seeds, e - endocarp, oo - oospores, fs - fruit scales, bs - bud scales, n - needles, l - leaves, ms - megaspores

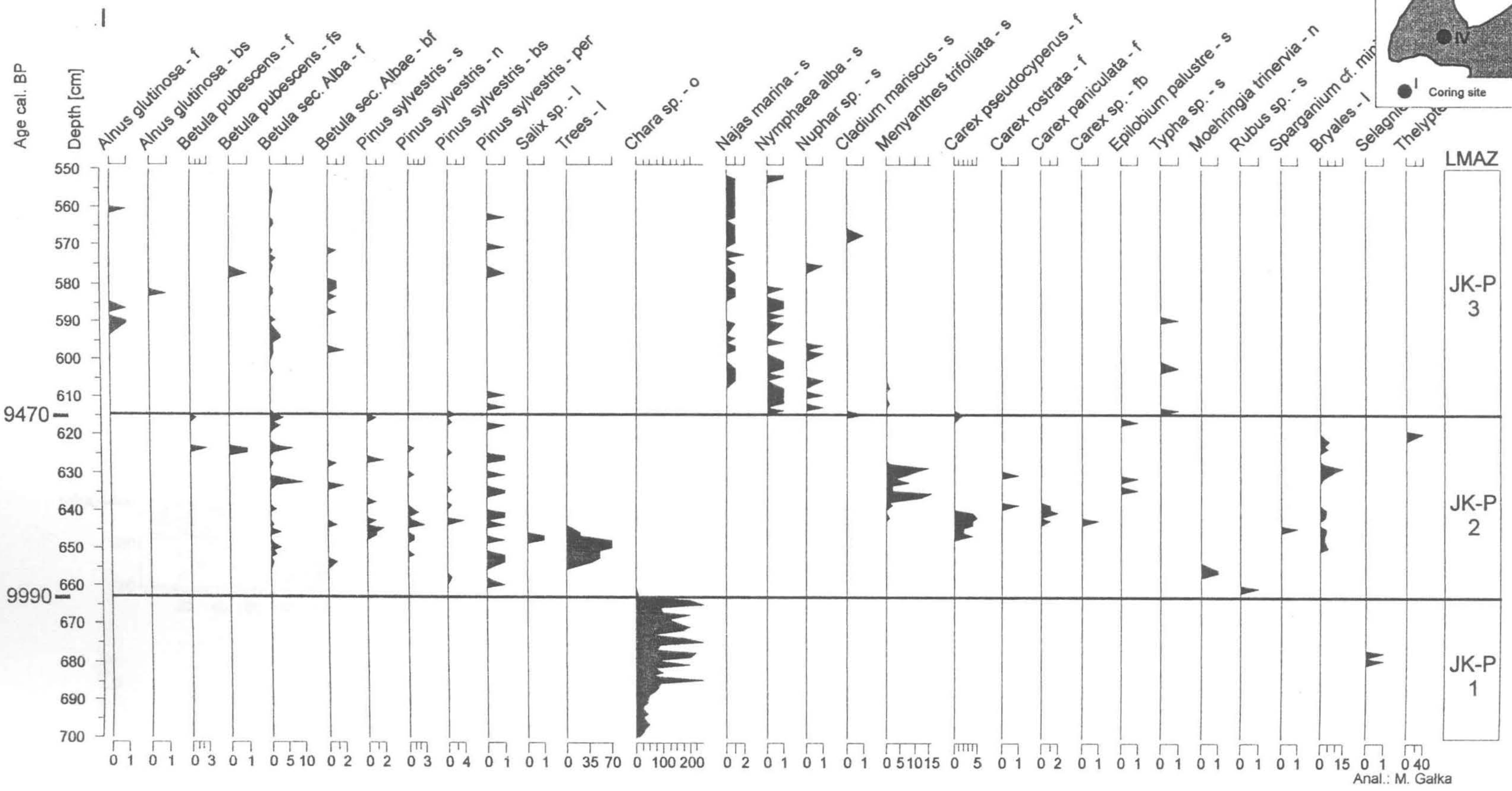
Kojle - Perty site II
Plant macrofossil diagram - local vegetation changes

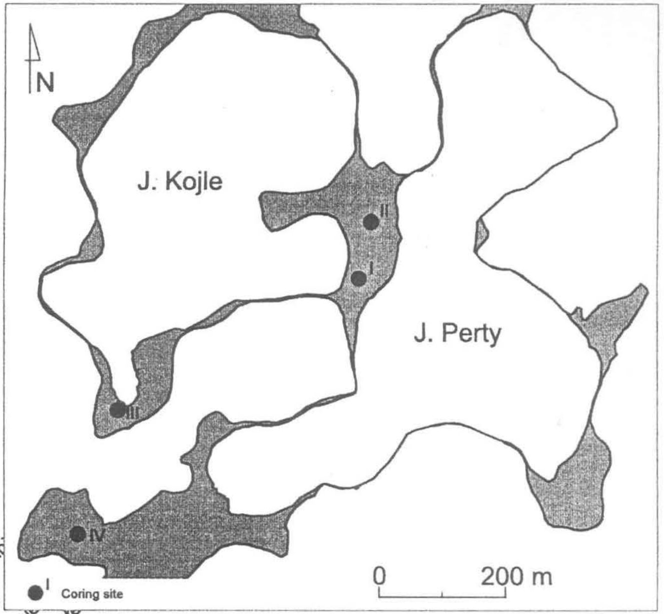


F - fruits, s - seeds, e - endocarp, oo - oospores, fs - fruit scales, bs - bud scales, n - needles, l - leaves, ms - megaspores

Kojle - Perty site I

Plant macrofossil diagram - local vegetation changes

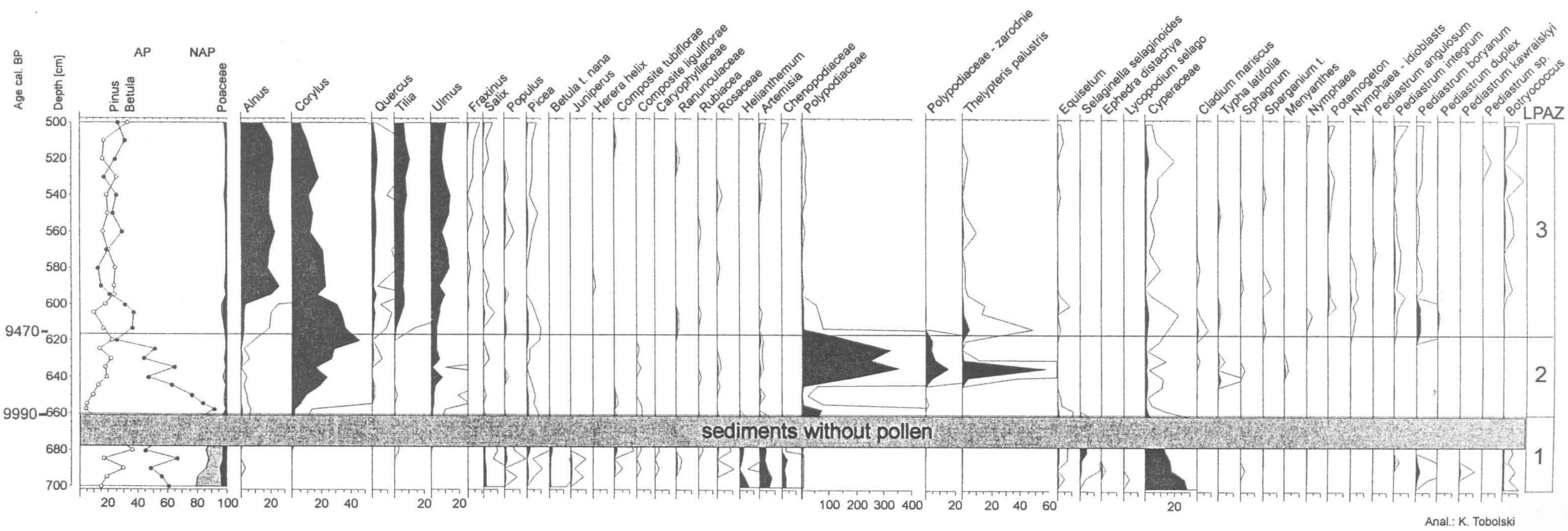




3

Kojle - Perty site I

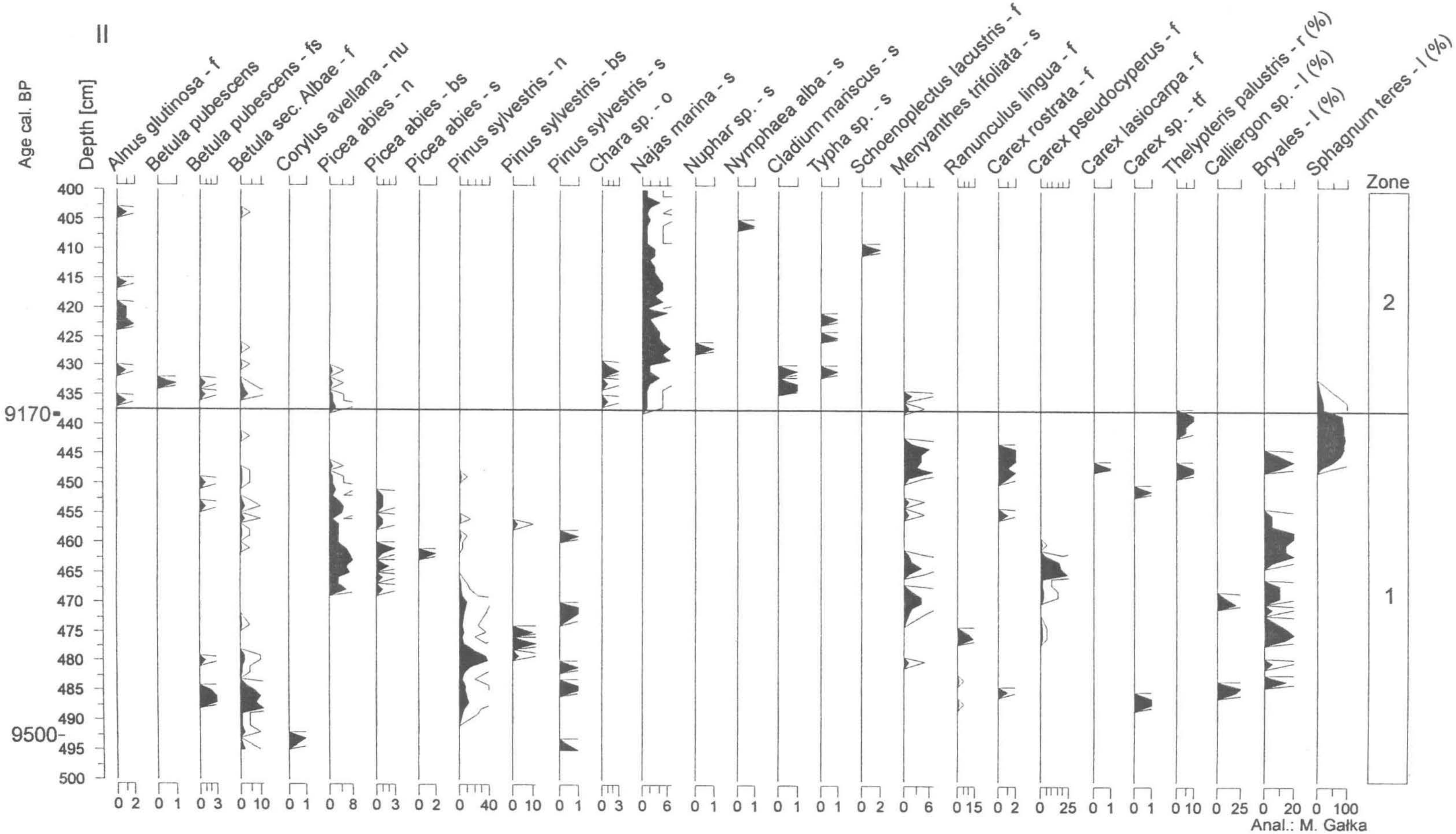
Percentage pollen diagram



102

Kojle - Perty site II

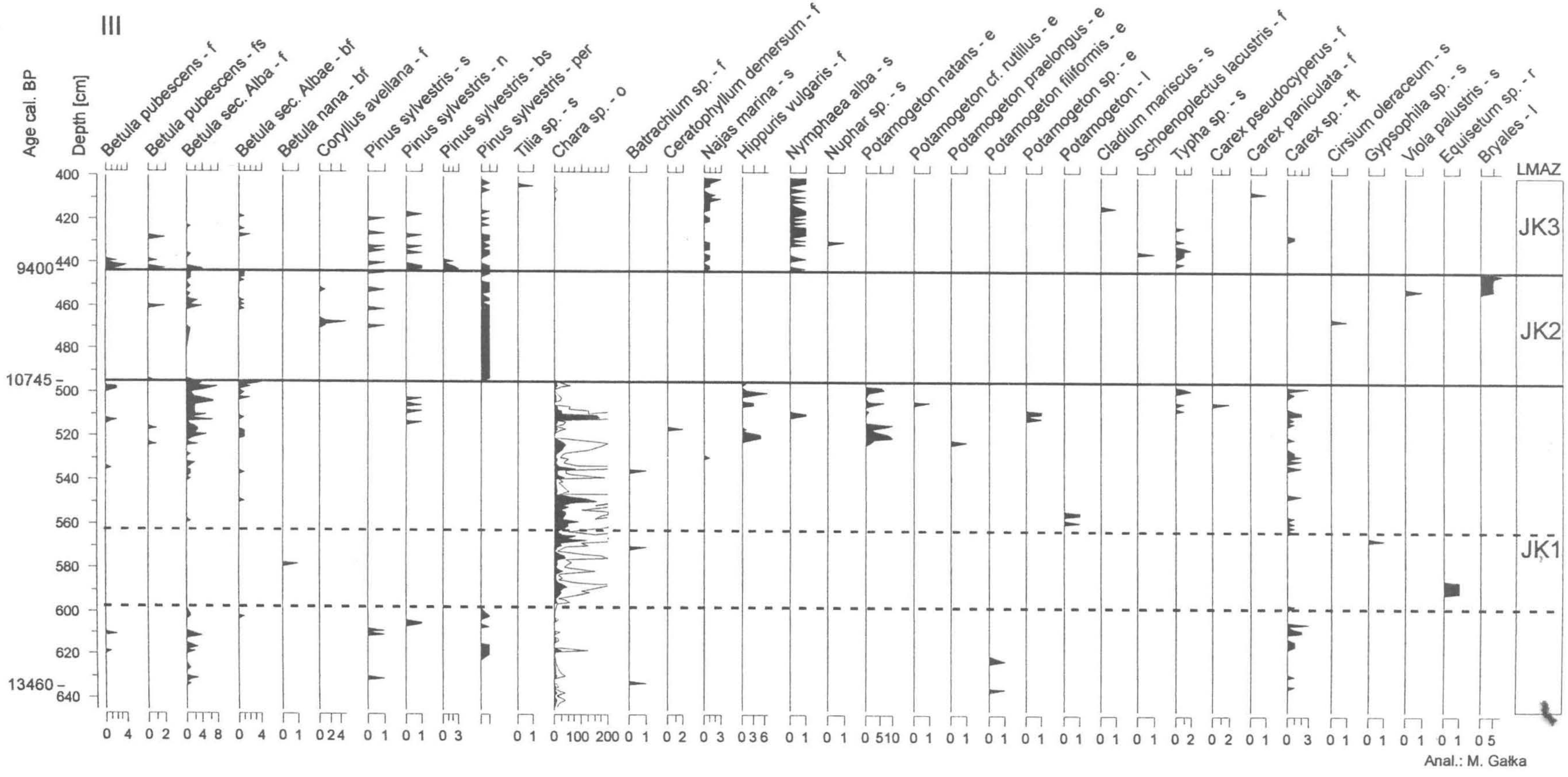
Plant macrofossil diagram - local vegetation changes



F - fruits, s - seeds, e - endocarp, oo - oospores, fs - fruit scales, bs - bud scales, n - needles, l - leaves, ms - megaspores

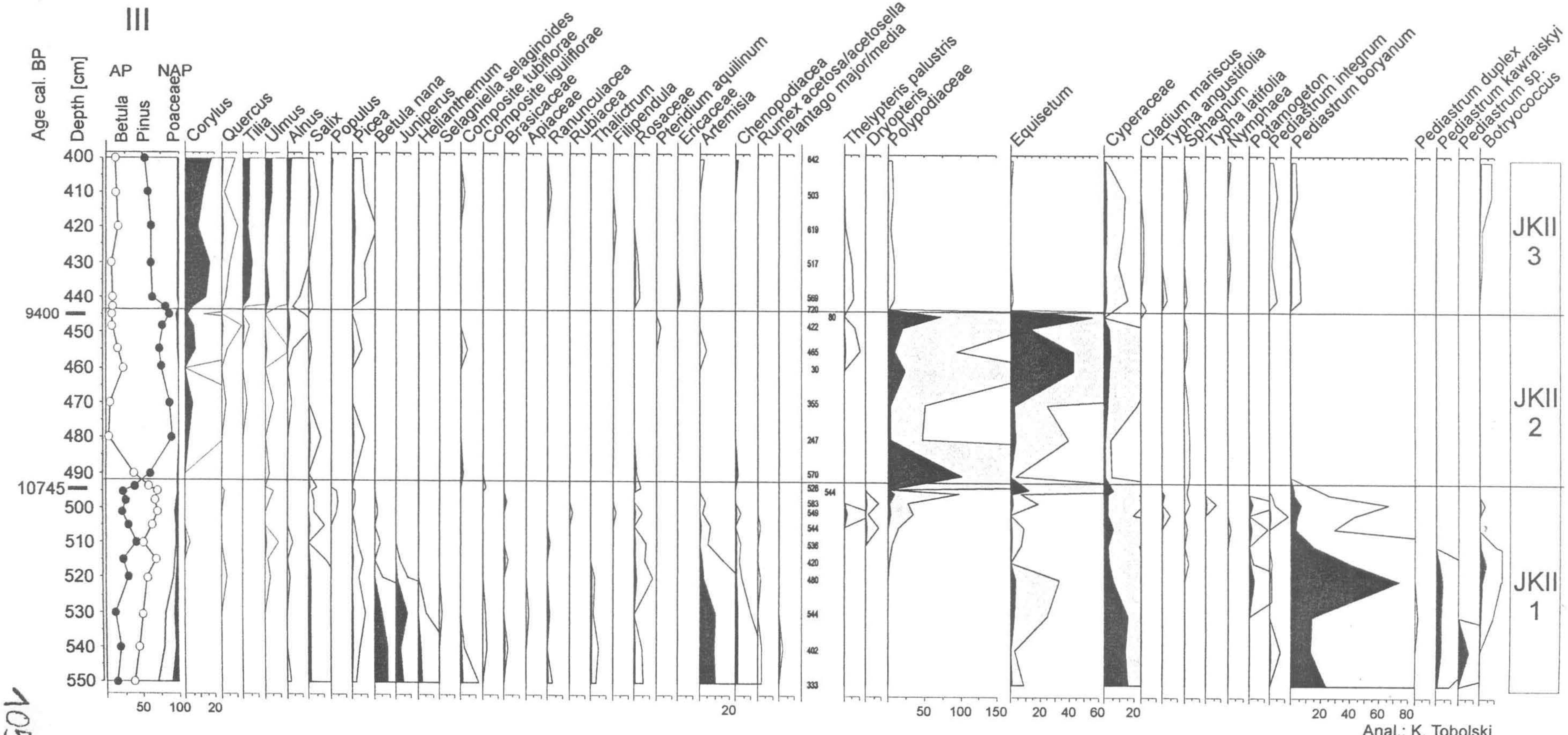
Kojle - Perty site III

Plant macrofossil diagram - local vegetation changes



Kojle - Perty   Site III

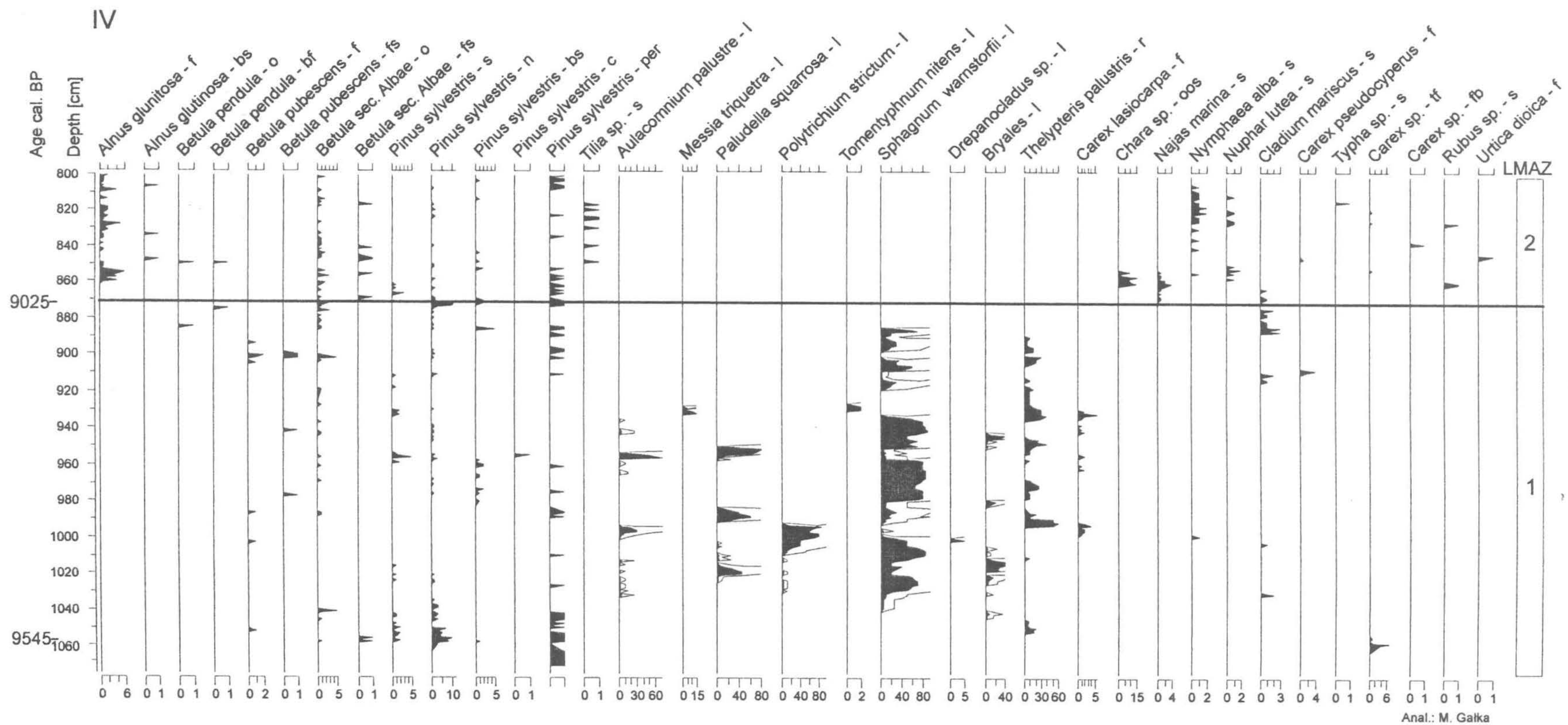
Percentage pollen diagram



7

Kojle - Perty site IV

Plant macrofossil diagram - local vegetation changes



Radiocarbons dates

Site 1

Depth (cm)	Dated material	Lab. No.	Age ^{14}C date	Calibrated range 95%
Rut/07 214-215	Fruits and fruits scales of *Betula* sp.	Poz-35957	1025 ± 30 BP	1051 - 803
Rut07 381-382	Needle and fruits scales *Picea abies*	Poz-39023	3860 ± 50 BP	4420-4102
Rut/07 491-492	Seed of *Pinus sylvestris* and fruits and fruits scales of *Betula* sp.	Poz-35949	6100 ± 70BP	7166 - 6791
Rut/07 607-608	Seed of *Pinus sylvestris* and fruits and fruits scales of *Betula* sp	Poz-35958	9510 ± 60 BP	11090 - 10592
Rut/07 678-679	Seed of *Arctostaphyllos uva-ursi*	Poz-35959	11690 ± 60 BP	13730 -13380

Site 2

Depth (cm)	Dated material	Lab. No.	Age ^{14}C date	Calibrated range 95%
I 340-341	Fruits and fruits scales of *Betula* sp.	Poz-37192	6130 ± 40 BP	7160 - 6910
I 614.5-615.5	Bud scales	Poz-37191	8430 ± 50 BP	9533 - 9308
I 660-662	wood	Poz-38708	8890 ± 50 BP	10191-9781
II/III 444-446	Fruits and fruits scales of *Betula* sp.	Poz-38822	8330 ± 50 BP	9473-9142
II/III 494-495	Fruits and fruits scales of *Betula* sp.	Poz-38823	9510 ± 50 BP	11086-10600
II/III 630-631	Seed of *Pinus sylvestris* and fruits of *Betula* sp.	Poz-39560	11650 ± 70 BP	13706-13326
II/XI 436.5-439	Fruits of Betula sp. and needles of *Pinus sylvestris*	Poz-38709	8230 ± 50 BP	9400-9028
II/XI 492.5	Nut of *Corylus avellana*	Poz-38710	8490 ± 50 BP	9542-9438
IV 10 872-873	Needles and peryderm of *Pinus sylvestris*	Poz-39558	8120 ± 50 BP	9262-8819
IV 10 1057-1058	Needles and seed of *Pinus sylvestris*	Poz-39559	8600 ± 50 BP	9680-9495

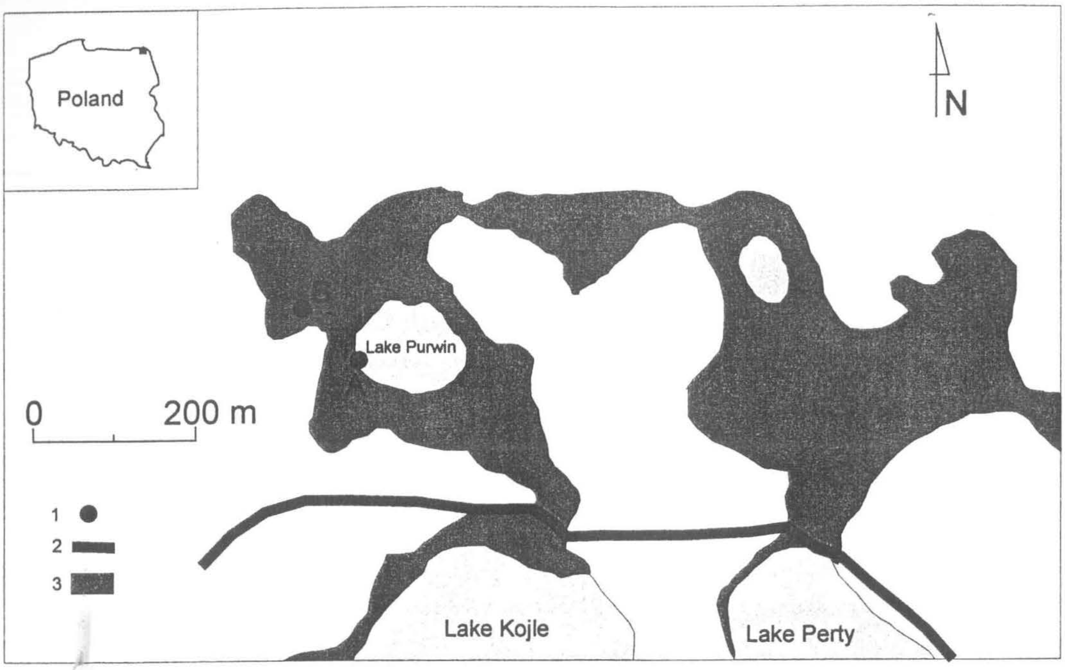
Site 3

Depth (cm)	Dated material	Lab. No.	Age ^{14}C date	Calibrated range 95%
LakeP 453-455	Needles of *Picea abies*	Poz-35960	2940± 35 BP	3214 - 2971
LakeP 781-782	Bud scale of *Alnus glutinosa*	Poz-37193	4260 ± 40 BP	4959 - 4646
LakeP 10.99-11.00	Bud scales	Poz-37190	7760 ± 50 BP	8628 - 8425
Sfen I 243-244	Seeds of *Stachys palustris*	Poz-39091	4470 ± 40 BP	5295-4971
Sfen II 363-364	Fruits of *Alnus glutinosa*	Poz-39093	6270 ± 50 BP	7307-7018
Sfen III 625-627	Bark of *Pinus sylvestris*, fruit scale of *Betula* sp.	Poz-39092	9200 ± 80 BP	10567-10231

The resulting conventional radiocarbon dates were calibrated with OxCal 4.1 software (Bronk Ramsey 2009).

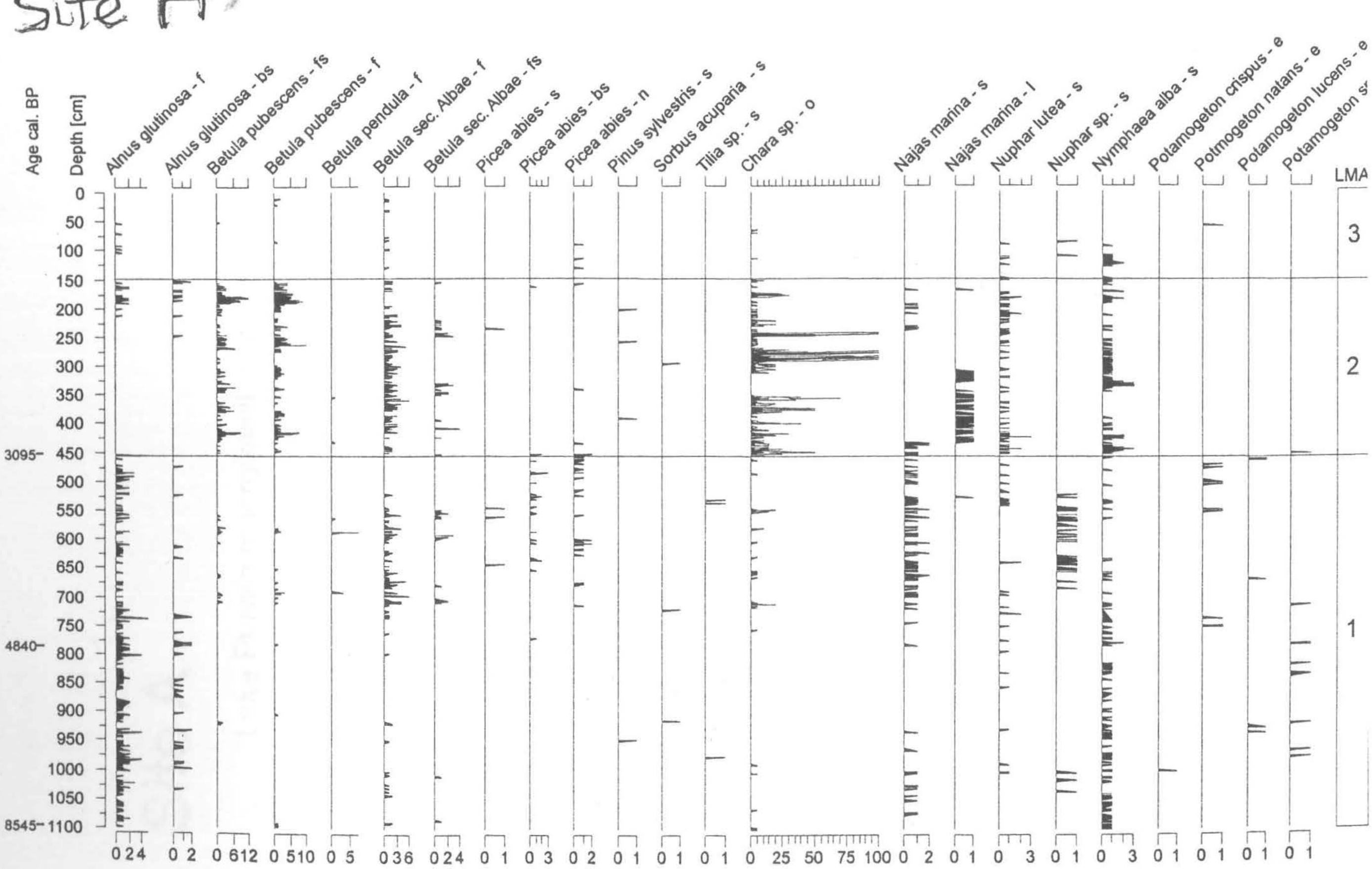
1,2a

Lake Purwin



1 - coring site, 2 - roads, 3 - peatbog

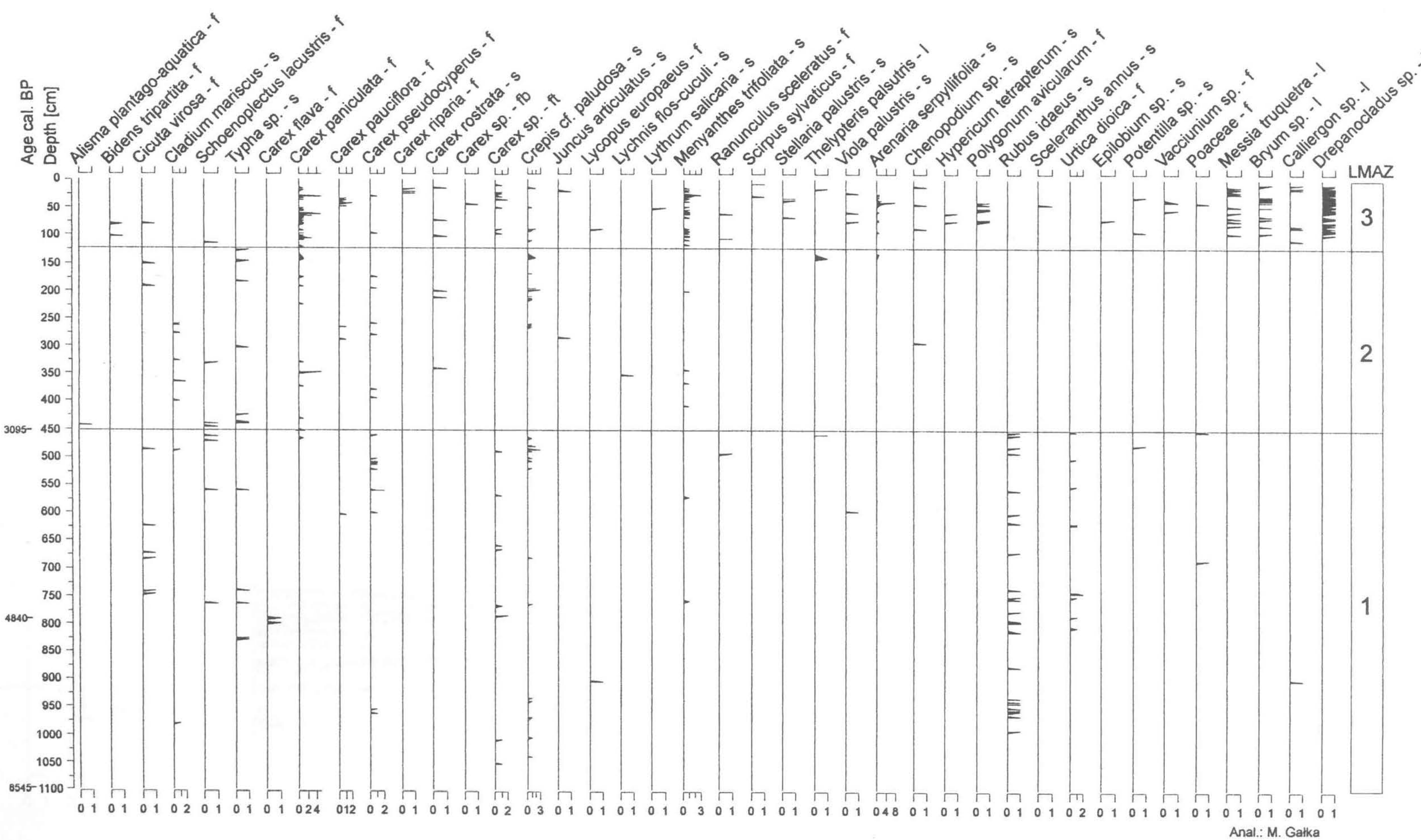
Site A



Plant macrofossil diagram - local vegetation changes

Site A

Lake Purwin macrofossil diagram, part II

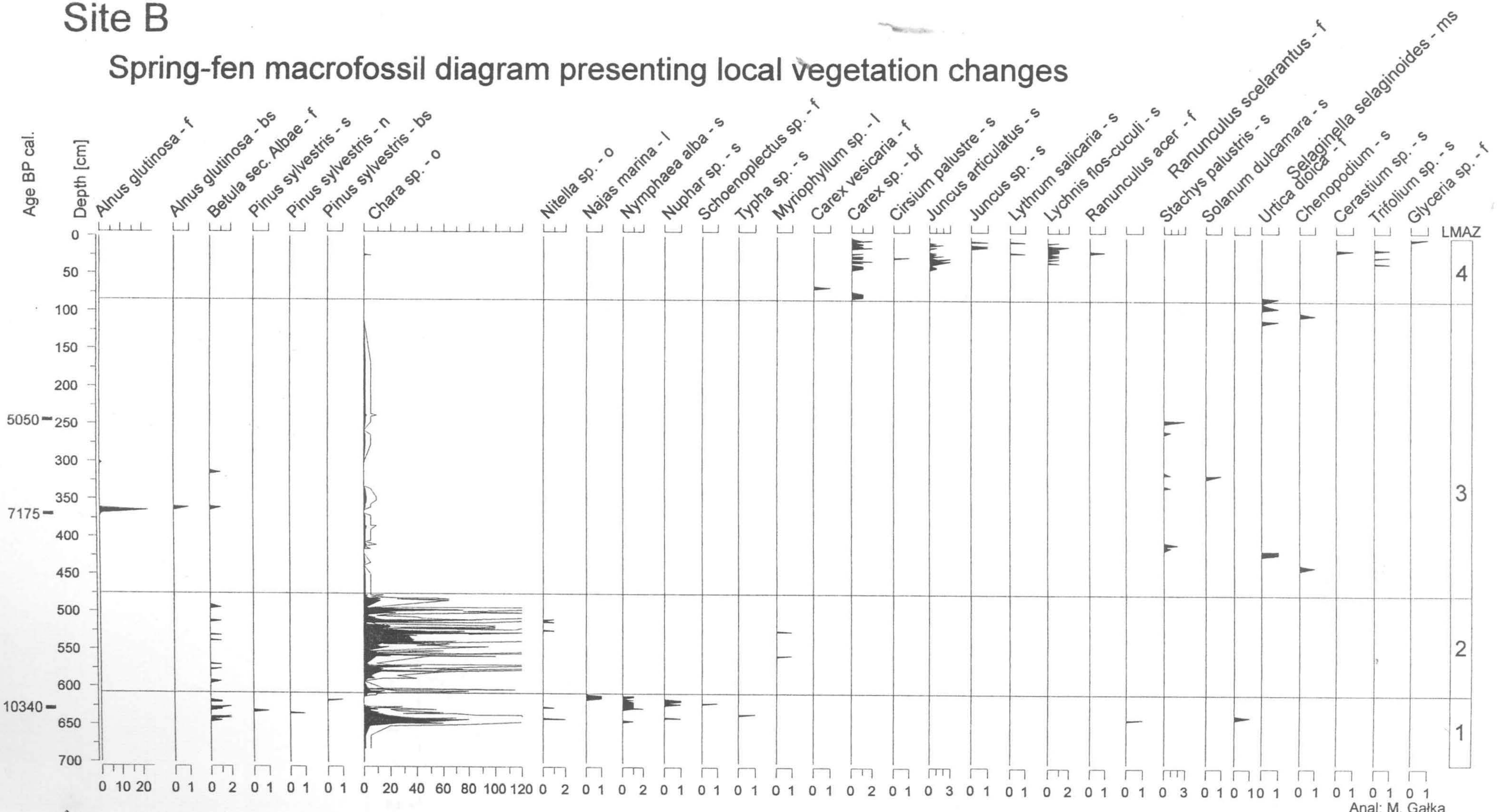


110

3

Site B

Spring-fen macrofossil diagram presenting local vegetation changes



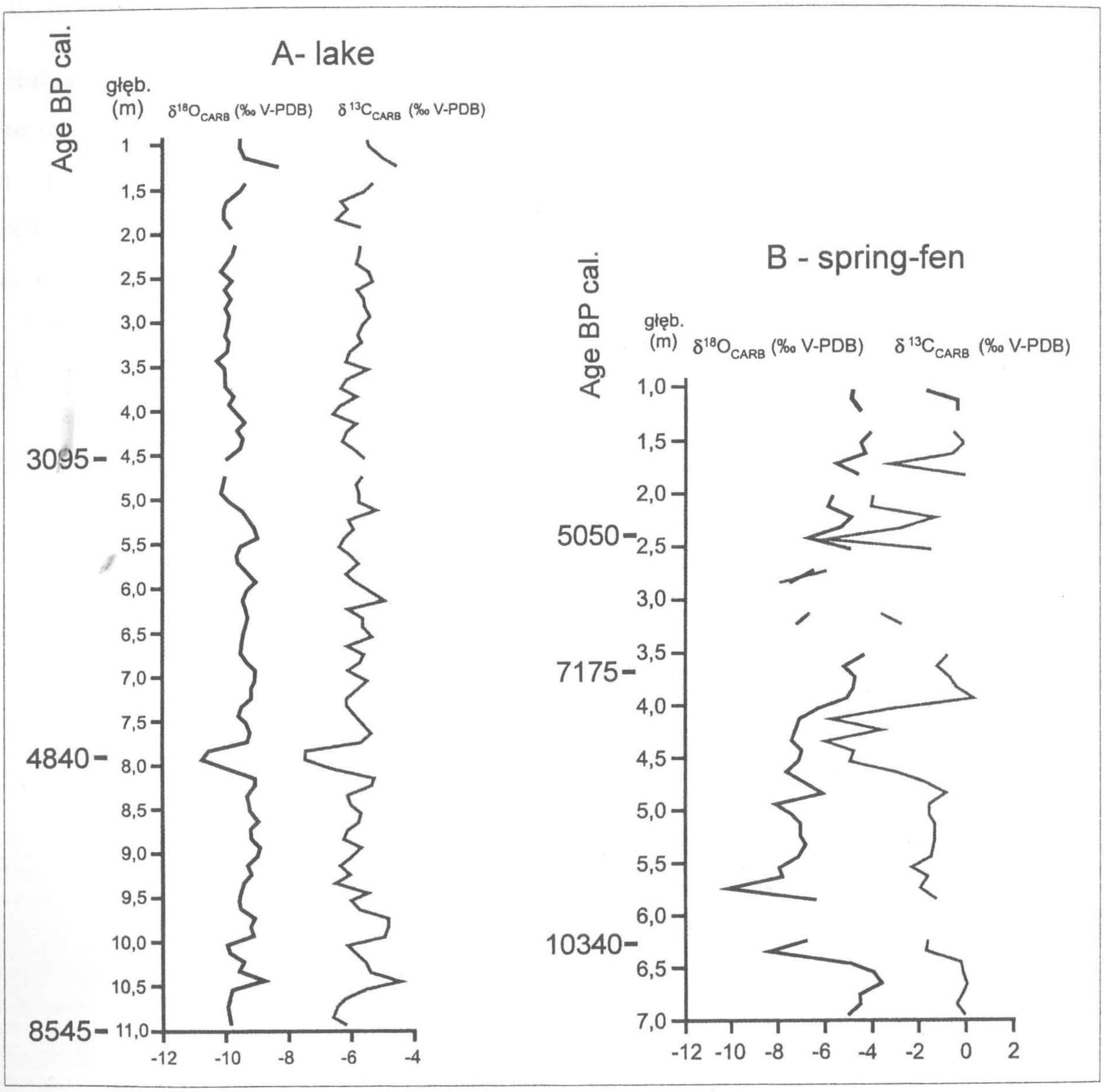
111

F - fruits, s - seeds, e - endocarps, oo - oospores, fs - fruit scales, bs - bud scales, n - needles, l - leaves, ms - megaspores

Stable oxygen and cabon isotopes curves

A - lake Purwin

B - spring fen



Lake Hańcza

54°16'N, 22°49'E,

surface - 3,1 km²,

227 m a.s.l.

Lake Hańcza, is the deepest lake in Poland and Central European Lowland. It is located in moraine upland of north-eastern part of the country, near the Polish – Lituania border and the region is called East Suwałki Lakeland (Kondracki 1994). There are a lot of geomorphological forms: drumlins, eskers, end moraines, kames and deep channels. Together with anthropogenic elements like: fields, meadows, bushes and single small buildings they create differentiated and attractive landscapes. Hańcza belongs to the Baltic Sea catchment through the river Czarna Hańcza, a tributary of Niemen.

BOREAS An international journal of Quaternary research

HAŃCZA

Multi-proxy evidence for early to mid-Holocene environmental and climatic changes in northeastern Poland

STEFAN LAUTERBACH, ACHIM BRAUER, NILS ANDERSEN, DAN L. DANIELOPOL, PETER DULSKI, MATTHIAS HÜLS, KRYSTYNA MILECKA, TADEUSZ NAMIOTKO, BIRGIT PLESSEN, ULRICH VON GRAFENSTEIN AND DECLAKES PARTICIPANTS

BOREAS

Lauterbach, S., Brauer, A., Andersen, N., Danielopol, D. L., Dulski, P., Hüls, M., Milecka, K., Namiotko, T., Plessen, B., von Grafenstein, U. & DecLakes participants 2011 (January): Multi-proxy evidence for early to mid-Holocene environmental and climatic changes in northeastern Poland. *Boreas*, Vol. 40, pp. 57–72. 10.1111/j.1502-3885.2010.00159.x. ISSN 0300-9483.

We investigated the sedimentary record of Lake Hańcza (northeastern Poland) using a multi-proxy approach, focusing on early to mid-Holocene climatic and environmental changes. AMS ^{14}C dating of terrestrial macrofossils and sedimentation rate estimates from occasional varve thickness measurements were used to establish a chronology. The onset of the Holocene at *c.* 11 600 cal. a BP is marked by the decline of Lateglacial shrub vegetation and a shift from clastic-detrital deposition to an autochthonous sedimentation dominated by biochemical calcite precipitation. Between 10 000 and 9000 cal. a BP, a further environmental and climatic improvement is indicated by the spread of deciduous forests, an increase in lake organic matter and a 1.7‰ rise in the oxygen isotope ratios of both endogenic calcite and ostracod valves. Rising $\delta^{18}O$ values were probably caused by a combination of hydrological and climatic factors. The persistence of relatively cold and dry climate conditions in northeastern Poland during the first one and a half millennia of the Holocene could be related to a regional eastern European atmospheric circulation pattern. Prevailing anticyclonic circulation linked to a high-pressure cell above the retreating Scandinavian Ice Sheet might have blocked the influence of warm and moist Westerlies and attenuated the early Holocene climatic amelioration in the Lake Hańcza region until the final decay of the ice sheet.

*Stefan Lauterbach (e-mail: slauter@gfz-potsdam.de), Achim Brauer, Peter Dulski and Birgit Plessen, Deutsches GeoForschungsZentrum GFZ, Section 5.2 – Climate Dynamics and Landscape Evolution, Telegrafenberg, D-14473 Potsdam, Germany; Nils Andersen and Matthias Hüls, Leibniz Laboratory for Radiometric Dating and Stable Isotope Research, University of Kiel, Max-Eyth-Strasse 11–13, D-24118 Kiel, Germany; Dan L. Danielopol, Austrian Academy of Sciences, Institute for Limnology, Mondseestrasse 9, A-5310 Mondsee, Austria, present address: Austrian Academy of Sciences, Commission for the Stratigraphical & Palaeontological Research of Austria, c/o Institute of Earth Sciences, Geology and Palaeontology, University of Graz, Heinrichstrasse 26, A-8010 Graz, Austria; Krystyna Milecka, Adam Mickiewicz University, Faculty of Geographical and Geological Science, Department of Biogeography and Palaeoecology, ul. Dzięgielowa 27, PL-61-680 Poznań, Poland; Tadeusz Namiotko, University of Gdańsk, Department of Genetics, Laboratory of Limnozoology, ul. Kładki 24, PL-80-822 Gdańsk, Poland; Ulrich von Grafenstein, Laboratoire des Sciences du Climat et de l'Environnement, UMR CEA-CNRS, Orme des Merisiers, F-91191 Gif-sur-Yvette, France; DecLakes participants are: Soumaya Belmecheri (LSCE, Gif-sur-Yvette), Marc Desmet (*ACCES-INRP*, Lyon), Helmut Erlenkeuser (Leibniz Laboratory, Kiel), Jérôme Nomade (LGCA, Grenoble)*; *received 2nd April 2009, accepted 8th March 2010.*

Detailed information about the regional characteristics of past climate variability is key for the assessment of possible regional environmental responses to future global climate change. Previous studies have shown that major climate oscillations across the Lateglacial/Holocene transition are synchronous within dating uncertainties in lacustrine (e.g. Björck *et al.* 1996; Gulliksen *et al.* 1998; von Grafenstein *et al.* 1999a; Brauer *et al.* 2000; Brauer & Casanova 2001; Litt *et al.* 2001; Yu 2007), marine (e.g. Koç Karpuz & Jansen 1992; Haflidason *et al.* 1995; Hughen *et al.* 2000; Ebbesen & Hald 2004) and ice-core (Johnsen *et al.* 1992; NGRIP Members 2004; Rasmussen *et al.* 2006) archives in the North Atlantic realm. In contrast, early Holocene warming and the associated environmental response in northeastern Europe have been suggested to be delayed (Subetto *et al.* 2002; Wohlfarth *et al.* 2002, 2007; Stančikaitė *et al.* 2008). However, multi-proxy palaeoclimate studies for the southeastern Baltic region, which could aid in gaining an understanding of the regional climate evolution, are still limited to only a few sites and focus mainly on the Lateglacial (Goslar *et al.* 1993, 1999; Ralska-Jasiewiczowa *et al.* 1998, 2003; Makhnach *et al.* 2004; Kupryjanowicz 2007; Rutkowski *et al.* 2007; Zawisza & Szeroczyńska 2007; Stančikaitė *et al.* 2008; Apolinarska & Hammarlund 2009).

In order to test the hypothesis of a particular eastern European pattern of early Holocene climatic amelioration, we present new high-resolution data from the sediment record of Lake Hańcza in northeastern Poland, the deepest lake in the Central-European Lowland. As part of the ESF project DecLakes (Decadal Holocene and Lateglacial variability of the oxygen isotopic composition in precipitation over Europe reconstructed from deep-lake sediments), this study combines microfacies analysis, µ-XRF geochemistry, pollen and stable isotope analyses to reconstruct the early to mid-Holocene climatic and environmental evolution in northeastern Poland. This is the first in a series of papers, focusing on climatic and environmental changes

DOI 10.1111/j.1502-3885.2010.00159.x

recorded in the Lake Hańcza sediments. Later contributions will address the vegetation development and ostracod assemblage changes in detail.

Study site

Lake Hańcza (54°16'N, 22°49'E, 229 m a.s.l.) is located about 20 km northwest of the town of Suwałki in the Suwałki-Augustów Lake District of northeastern Poland (Fig. 1A–C). The mesotrophic lake (maximum depth 108.5 m, surface area 3.1 km^2, volume 0.12 km^3, catchment area 39.7 km^2), which occupies a former subglacial channel incised into Saalian tills, is fed and drained by the Czarna Hańcza river.

Catchment geology is dominated by Quaternary deposits of up to 280 m thickness, particularly glacial tills and fluvioglacial sands with intercalated interstadial/interglacial silts and clays (Ber 1974, 1987), that cover Cretaceous and Tertiary limestones and sandstones. Carbonate contents of 5–15% have been reported for various Pleistocene tills and glaciofluvial sands in Poland (Bukowska-Jania & Pulina 1999). The Pomeranian Moraine, located about 7 km south of the lake (Ehlers & Gibbard 2004), is evidence for the last advance of the Scandinavian Ice Sheet at the end of the Weichselian glaciation. Age estimates for the moraine are highly variable, ranging between *c.* 18 500 cal. a BP (western Poland, derived from radiocarbon dating; Marks 2002 and references therein) and *c.* 14 600 cal. a BP (northeastern Poland and Lithuania, derived from ^{10}Be exposure dating; Rinterknecht *et al.* 2006).

Today, the study area is characterized by a humid continental climate with warm summers and cold winters. The mean annual air temperature is +6.1 °C, with January and July means of −4.9 °C and +16.9 °C, respectively. Average annual precipitation in the region amounts to about 600 mm (Vose *et al.* 1992) (Fig. 1D), with the highest rainfall during summer. Recent vegetation is dominated by nemoral forest communities with boreal influences. A significant proportion of *Picea abies* and the absence of *Fagus sylvatica* are

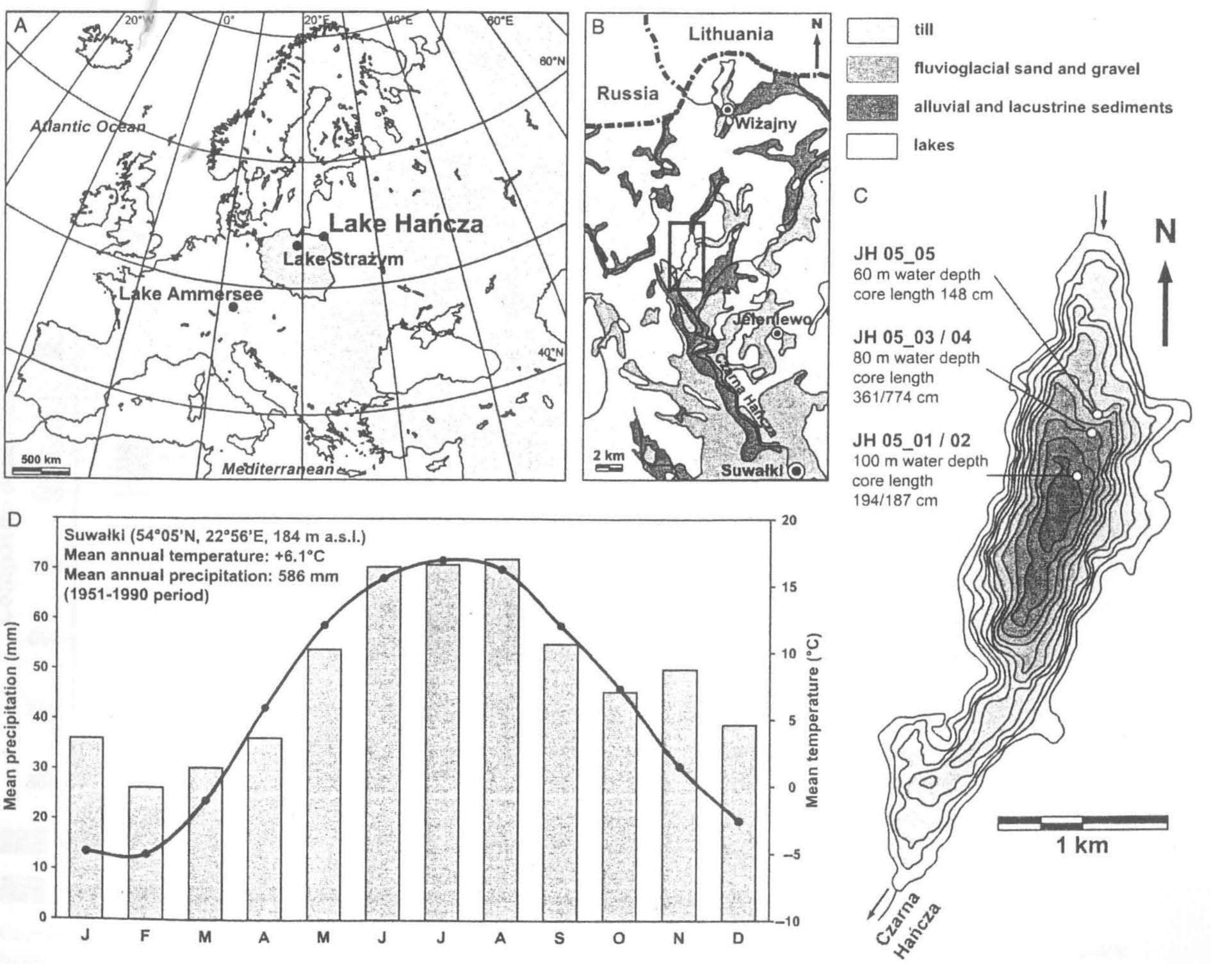


Fig. 1. A. General geographic overview map with locations mentioned in the text. B. Simplified geological map of the area surrounding Lake Hańcza (modified after Ber 1971). C. Bathymetric map of Lake Hańcza with coring locations. Isobaths are given at 10-m intervals. D. Climate diagram for the weather station Suwałki (Vose *et al.* 1992).

115

characteristic differences from the western parts of Poland (Ralska-Jasiewiczowa & Latałowa 1996).

Methods

Fieldwork

Five sediment cores, each consisting of 2-m-long segments, were recovered with a 90-mm-diameter UWITEC piston corer from the deep northern part of the lake (Fig. 1C). The two longest cores, from 80 m water depth (JH 05_03 and JH 05_04; Fig. 2), comprise 361 and 774 cm of lake sediments and were selected as master cores. After photographing and lithostratigraphic description, the overlapping segments of the two cores were visually correlated by using distinct lithological marker layers, resulting in a continuous composite profile of about 820 cm length (Fig. 2). Continuous spectrophotometry measurements at 1-cm intervals were performed with a Minolta CM-2500d spectrophotometer on the fresh sediment surface, covered with a thin transparent polyethylene film (Chapman & Shackleton 1998). The mean of reflectance, measured at 10-nm increments over the 400–700 nm wavelength range, results in the sediment lightness L* (Fig. 2), given on a scale from 0 to 100 (black to white). Subsequently, the composite profile was sampled for all further analyses in the field lab to ensure precisely parallel samples for the multi-proxy approach. Detailed investigation focused on the core interval between 220 and 530 cm, which is characterized by major sedimentological changes.

Sedimentology and geochemistry

Microfacies analysis and final core correlation were carried out under a ZEISS Axiophot polarization microscope at 25–400× magnification on a continuous series of large-scale petrographic thin sections, prepared from 10-cm-long overlapping sediment blocks according to the method described by Brauer *et al.* (1999b).

High-resolution micro X-ray fluorescence (μ-XRF) element scanning was carried out on a vacuum-operating EAGLE III XL μ-XRF spectrometer with a low-power Rh X-ray tube at 40 kV and 300 μA. Measurements were performed on a single scan line with 200-μm step width (250-μm spot size, 60-s counting time) on the

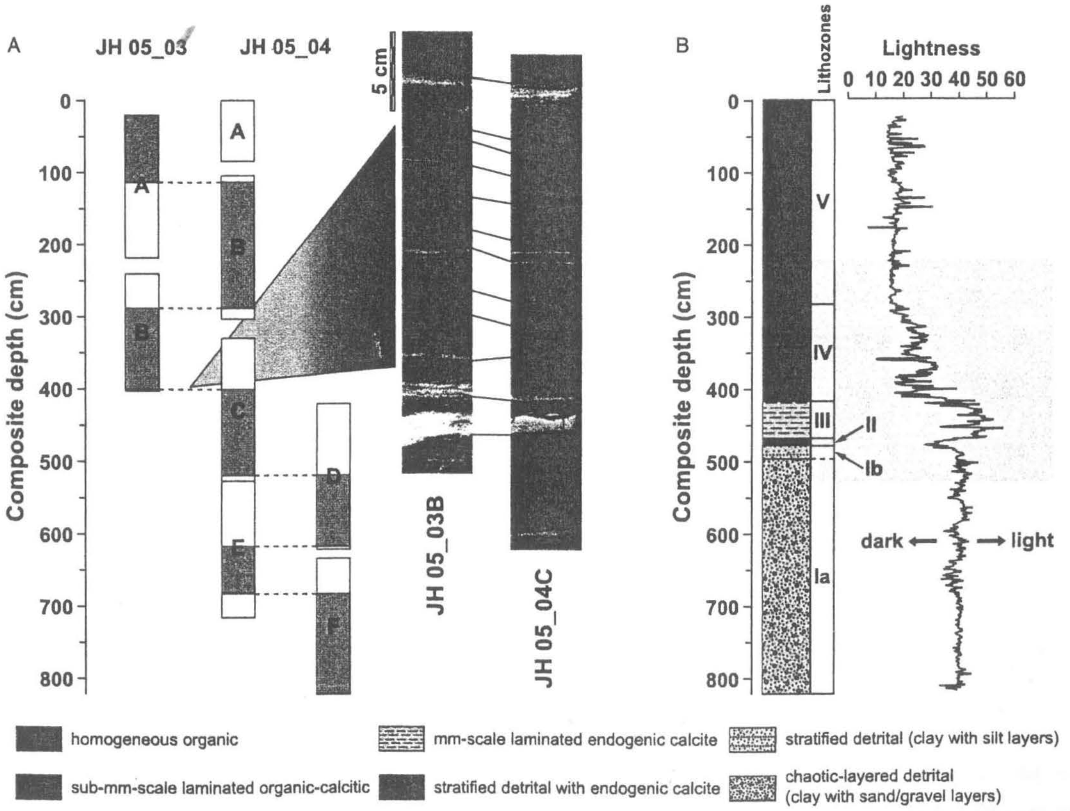


Fig. 2. A. Correlation between the segments of cores JH 05_03 and JH 05_04. Grey-shaded intervals indicate sections included in the composite profile. Detailed photographs of the core segments JH 05_03B and JH 05_04C illustrate the correlation through lithological marker layers. B. Lithological composite profile of the complete Lake Hańcza sediment record. The grey-shaded interval between 220 and 530 cm indicates the sequence investigated in this study. Sediment lightness L* was derived from spectrophotometry measurements (see text for details). This figure is available in colour at http://www.boreas.dk.

layer are intercalated at about 400.0 cm. Lithozone V (above 282.0 cm) consists of an almost black, homogeneous diatom gyttja rich in plant remains and amorphous organic matter. Endogenic calcite is absent and minerogenic components are very rare.

Chronology

Thirteen AMS ^{14}C dates on terrestrial plant macro remains (10 samples of leaf fragments, 3 samples of small pieces of wood) were obtained from the profile (Table 2). Calibrated ages of all samples are in stratigraphical order. Owing to its small size (~0.2 mg C), sample KIA34647 gave a large 2σ error range of *c.* 700 years and is thus statistically indistinguishable from sample KIA34648, which was taken 1.5 cm above. Two dates were omitted from age modelling owing to probable reworking: (1) sample KIA34642 (351.5–352.0 cm), as it contains wood fragments and appears *c.* 200 years too old compared with the neighbouring sample KIA34648 (360.0–360.5 cm); and (2) sample KIA33887 (516.0–517.5 cm), a wood fragment from the clastic high-energy deposits of Lithozone Ia that revealed a *c.* 1000 year older age than sample KIA34650, which was obtained only 5 cm above. Consequently, the upper (younger) of these dates (KIA34650) was accepted, although we are aware that reworking cannot also be fully excluded for this wood sample. Therefore, the date must be considered as a maximum age. The final core chronology is based on 11 calibrated ages (Table 2) and the biostratigraphically determined Younger Dryas/Holocene transition (477.5 cm) as an additional time marker. For the latter, an age of 11 590 calendar years BP was adopted from published varve chronologies (Brauer *et al.* 1999a). The age–depth model (Fig. 3) was developed using Bayesian sequence modelling (*P_Sequence* deposition model, k = 1), implemented in the

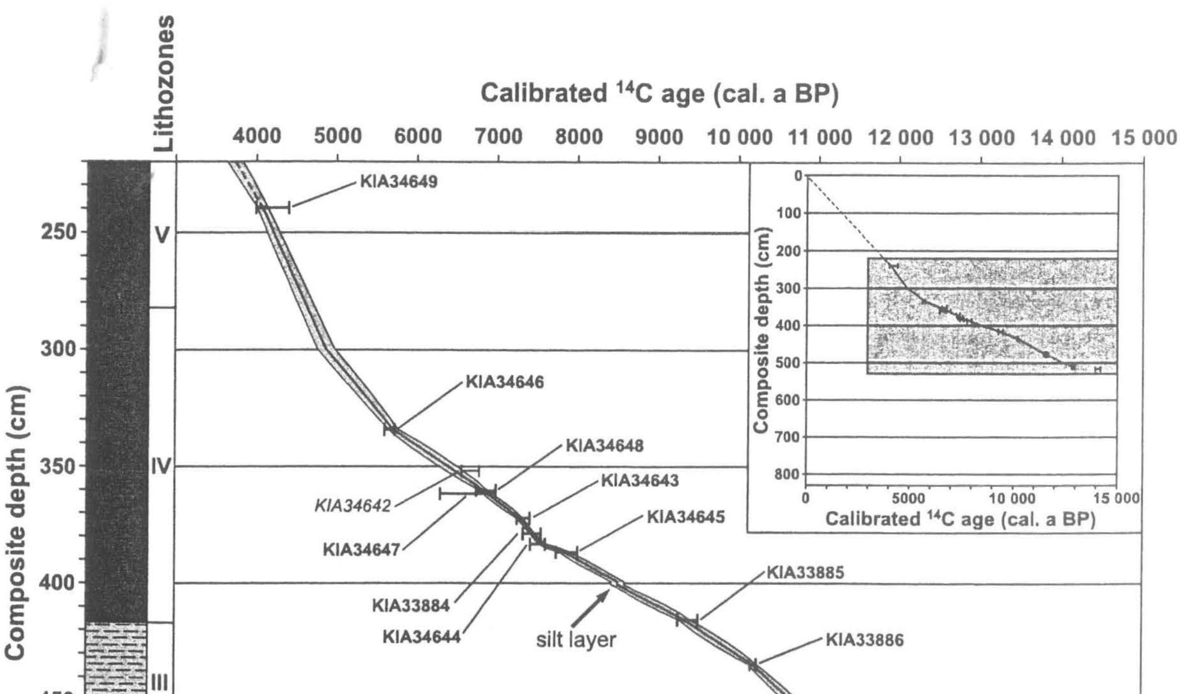
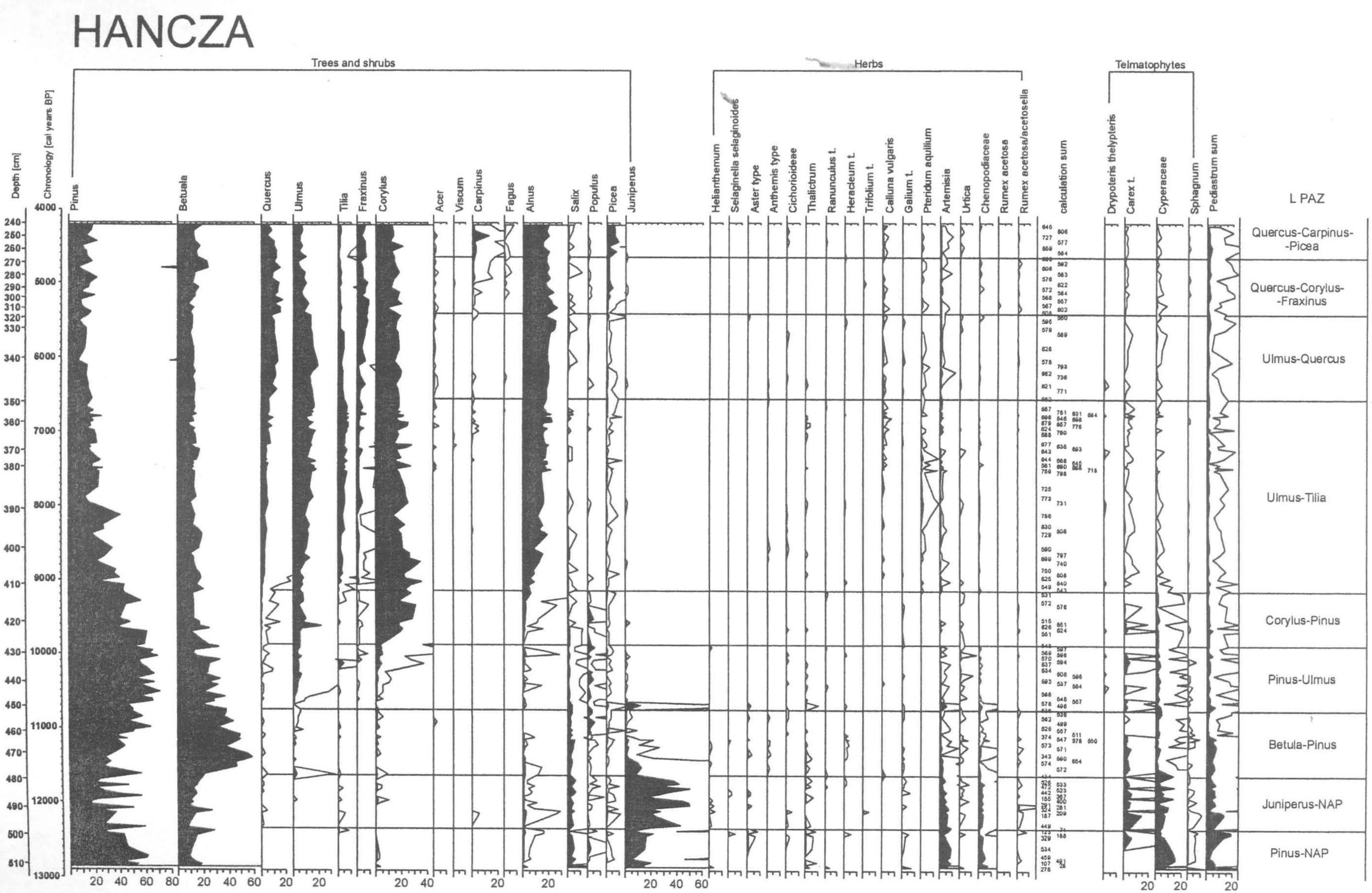


Fig. 3. Radiocarbon-derived age–depth model for the investigated sediment sequence from Lake Hańcza with the inset figure illustrating its position within the composite profile. Error bars for individual AMS ^{14}C dates indicate calibrated 2σ ranges. Italicized samples were omitted from age–depth modelling. The line between individual radiocarbon dates and the Holocene base represents the age–depth model derived from the *P_Sequence* depositional model implemented in the OxCal v4.1 program (Ramsey 2008), with the grey shading representing its 1σ probability range. Dashed lines indicate sections where the chronology is uncertain as a result of probable reworking of the dated material and/or not confirmed by additional dates.


HANCZA
Trees and shrubs
Herbs
Telmatophytes
Depth [cm]
Chronology [cal years BP]
Pinus
Betuala
Quercus
Ulmus
Tilia
Fraxinus
Corylus
Acer
Viscum
Carpinus
Fagus
Alnus
Salix
Populus
Picea
Juniperus
Helianthemum
Selaginella selaginoides
Aster type
Anthemis type
Cichorioideae
Thalictrum
Ranunculus t.
Heracleum t.
Trifolium t.
Calluna vulgaris
Galium t.
Pteridum aquilium
Artemisia
Urtica
Chenopodiaceae
Rumex acetosa
Rumex acetosa/acetosella
calculation sum
Drypoteris thelypteris
Carex t.
Cyperaceae
Sphagnum
Pediastrum sum
L PAZ
Quercus-Carpinus-
-Picea
Quercus-Corylus-
-Fraxinus
Ulmus-Quercus
Ulmus-Tilia
Corylus-Pinus
Pinus-Ulmus
Betula-Pinus
Juniperus-NAP
Pinus-NAP

118