stantly high input of detrital minerals led to the maximum content of biogenic silica in the sediments. Through the whole YD the water level was high, and the basins of all lakes connected now by the Ruda stream (i.e. Wierzchoń, Brzózka, Gościąż and Mielec) were probably joined together in one great lake.

Younger Dryas/Holocene transition (11,510 cal BP)

The most essential environmental changes occurred at the transition between Younger Dryas and Holocene (dated to 11,510 cal BP). According to the $\delta^{18}O$ curve, the rise of annual mean temperature by more than $5^{o}C$ was completed within 70 years. Abrupt increase of summer water temperature is confirmed by the bloom of *Tetraedron minimum*. In terrestrial vegetation the beginning of the Holocene is marked by reduction of heliophyte herb/shrub vegetation and the spread of *Populus* and tall herbs with *Filipendula*, followed by expansion of *Betula* woods. The warming and expansion of forests enhanced microbial activity in soils and led to their oxygen depletion (indicated by temporary drop of $\delta^{13}C$ values and rapid decline of Fe/Mn ratio in the sediments). Development of forests inhibited also input of detrital material to the lake (decrease of varve thickness and definitive disappearance of aluminium from the sediments). Enhanced evaporation and evapotranspiration due to increase of temperature and development of more abundant vegetation cover, coincident perhaps with increase of soil permeability (shorter season of frozen ground), resulted in temporary shallowing of the lake. It is documented by the development of littoral Cladocera species and short-lasting expansion of reedswamps and Nymphaeaceae, especially in the northern bay. The general lowering of water table was evidenced by the end of gyttja formation as well as peat development in depressions around the lake.

7.9. A COMPARATIVE STUDY ON THE LATE-GLACIAL/EARLY HOLOCENE CLIMATIC CHANGES RECORDED IN LAMINATED SEDIMENTS OF LAKE PERESPILNO – INTRODUCTORY DATA

Krystyna Bałaga, Tomasz Goslar & Tadeusz Kuc

Characteristics of the region

Lake Perespilno (other name: Pereszpa) is one of 67 lakes of the Polesie Lubelskie region within the Łęczna-Włodawa Lake District. This complex of lakes is situated ca. 300 km to the south of the extent of the Vistulian Glaciation (Fig. 7.52). The region is characterized by great variation of climatic parameters. Continentality of climate is well expressed by a high annual amplitude of air temperatures, reaching 22–$23^{o}C$. The mean annual temperatures range between 7^{o} and $8^{o}C$. The mean annual rainfall does not exceed 600 mm (Zinkiewicz & Zinkiewicz 1975, Michna & Paczos 1978).

The study area of the Łęczna-Włodawa Lake District is characterized by relief less than a dozen metres. It lies in the depression between Włodawa Hump in the north and Uhrusk Elevation in the south. Low relief and very small slopes impede the surface runoff and cause the formation of extensive wet and swampy areas. Lakes and mires are the most common elements of the landscape in this region.

The sub-Quaternary surface relief had great significance both for the water conditions and the origin of lake complex. The sub-Quaternary bedrock consists of marl and chalk with a relief of 30–50 m. Chalk and marl are very susceptible to karst processes in rock outcrops as well as on surfaces covered by the Quaternary deposits. These deposits (up to several dozen metres thick) consist of clays, sands, fluvioglacial gravels of older glaciations, and of lacustrine silt (Maruszczak 1966a). The role of karst and thermokarst processes in the origin of the lakes is still under debate (Wilgat 1954, 1991, 1994, Maruszczak 1966b, Buraczyński & Wojtanowicz 1974, 1983, Wojtanowicz 1994).

Description of the lake

Lake Perespilno is located in the western part of the Łęczna-Włodawa Lake District in the area of the Sobibór Landscape Park and is one of three lakes situated within a swampy plain in relief not exceeding several metres (Fig. 7.52). The plain is covered by fine river sands and locally small dunes. Fluvioglacial deposits building strongly denuded hills are exposed in places (Zgorzelski 1987). Marls and chalk occur probably at a depth of about 20 m (Projekt, unpubl.). Apart from lakes the depressions are filled by peat or peat underlain by gyttja several metres thick.

Lake Perespilno (165 m a.s.l.) is 24.3 ha in area and consists of two depressions. The deeper depression in the northern part (6.2 m water depth) is separated from the shallower one (4.5 m in depth) by a distinct shallows of 2.7 m. Pine forest grows on the high, sandy shores, especially on the east side of the lake. On the west side only remnants of forest remained as shrubs and single old trees. Alderwood communities are situated mainly on the SE and N sides. In some places the lake shores are swampy and overgrown by reedswamp vegetation. Carpets of floating plants also occur, mainly with *Nymphaea alba* (Fijałkowski 1960).

Description of laminated sediment sequence

Coring was carried out by K. Więckowski in March 1991. Two cores 16.7 m long were taken from organogenic deposits in the north part of the lake 6.0 m deep. Sand occurred in the bottom of cores at a depth of 22.7 m

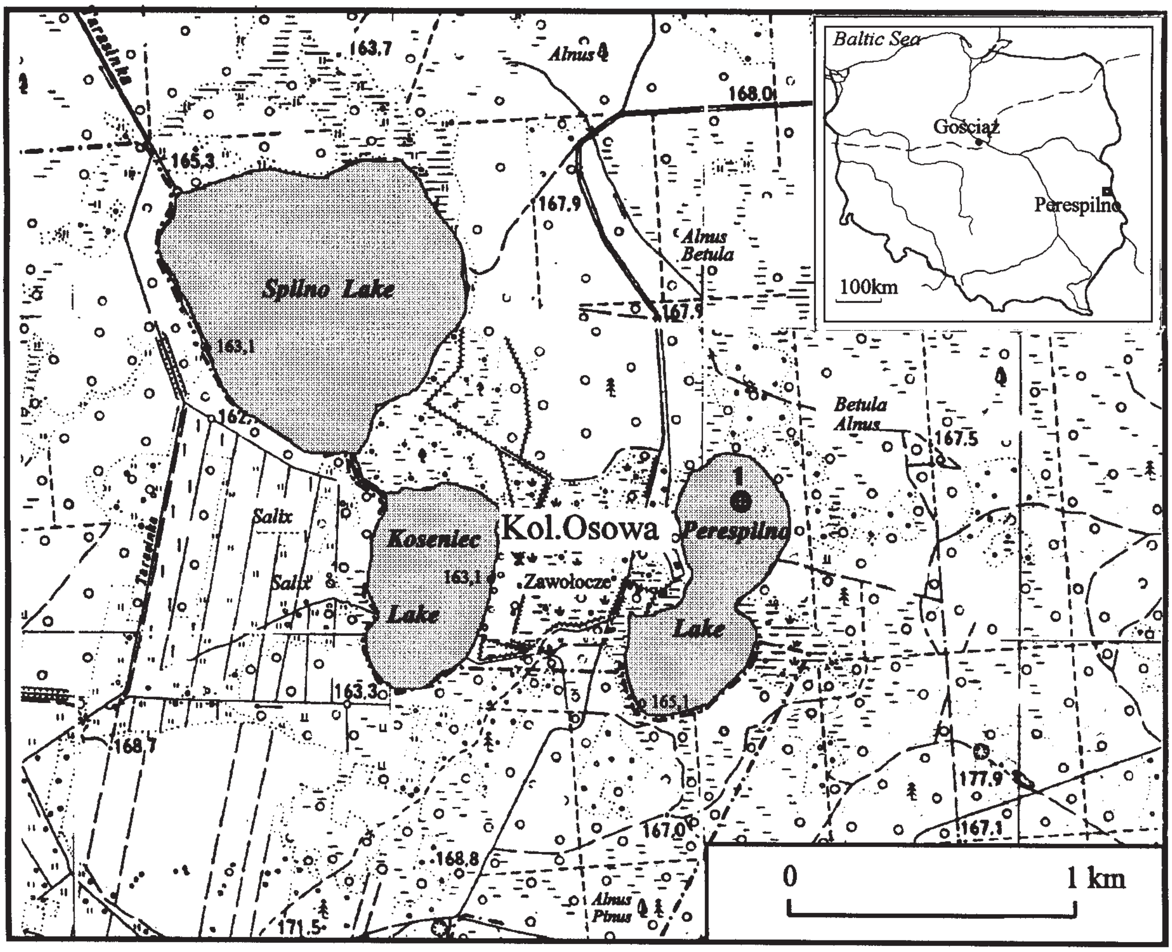


Fig. 7.52. Map showing the location of Lake Perespilno. The maximum extent of Vistulian Glaciation is denoted by dashed line in the inset.

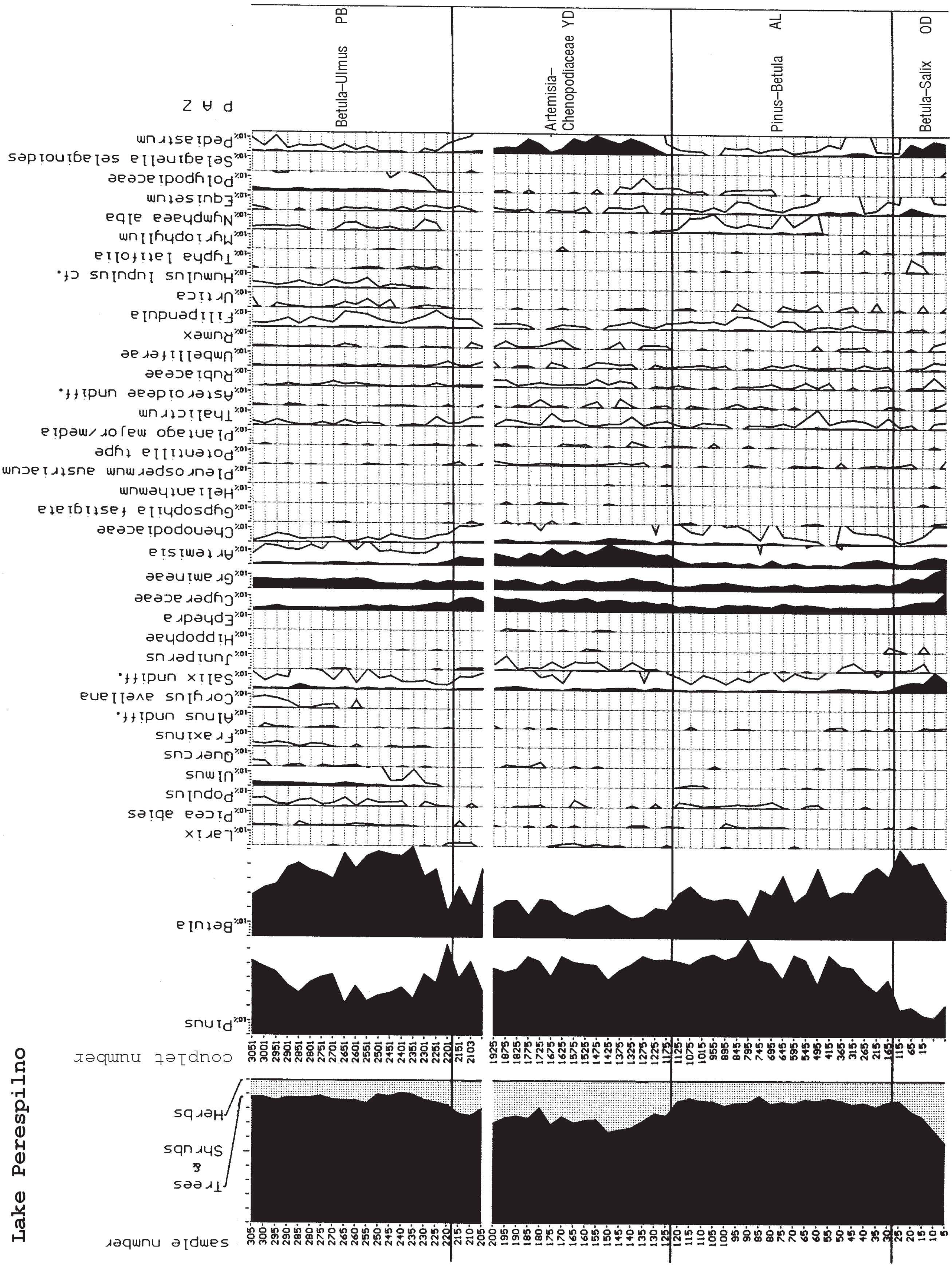
below the water surface. The basal 3 m were laminated (Więckowski 1993). In order to construct continuous laminated sequence, the individual segments of the two cores were correlated by the same methods as used for the Lake Gościąż sediments (Goslar, Chapters 6.1 and 7.2). However, two serious discontinuities could not be overcome. In the basal continuous sequence 925±15 couplets were counted. The older discontinuity is caused by a non-laminated section in both cores ca. 10.8 cm thick. The duration of its deposition was estimated as 145±20 years, assuming the same sedimentation rate as in the adjacent laminated sections. The younger discontinuity, 886±5 couplets higher up, is a gap between core segments, corresponding to the same laminae in both cores. Relying on the field-noted coring depths, the number of couplets lacking due to that gap was estimated to be 60±100. Hence, it is possible that the two cores overlap, but if so, the overlap is too short to be confirmed by direct comparison of laminae. The upper continuous sequence has 1053±150 couplets. The total number of counted couplets together with those estimated for the gaps is 3068±250. Because of gaps, this estimate must be treated as tentative. Comparison of the pollen diagram and δ^{18}O curve with corresponding data from Lake Gościąż suggests that the number of couplets in the upper gap was underestimated. However, this requires to be confirmed by further cores.

Since the annual cyclicity in sediment composition has not been studied, the couplets cannot be called varves. The close correspondence of the pollen diagram with that from Lake Gościąż, however, allows us to believe that the regular couplets counted in Perespilno sediments are annual laminae.

Laboratory procedures

For the laminated part of core 1 samples were collected for pollen analysis and treated in the same way as

Fig. 7.53. Pollen diagram from Lake Perespilno, including selected pollen taxa. The gap in the diagram represents discontinuity in the laminated sequence.


Lake Perespilno
Betula–Ulmus PB
Artemisia–Chenopodiaceae YD
Pinus–Betula AL
Betula–Salix OD
P A Z
couplet number
sample number
Trees & Shrubs
Herbs
Pinus
Betula

applied to Lake Gościąż cores – Chapter 4 (1 cm^2 per 10 laminae couplets: HCl, Erdtman acetolysis with hydrofluoric acid pretreatment and addition of *Lycopodium* tablets (Stockmarr 1971)). Every fifth sample was analyzed. The percentages of all taxa were calculated on the basic sum of trees, shrubs, and herbs pollen, excluding aquatic and swamp taxa and spores. Data are presented in the form of a simplified diagram (Fig. 7.53).

For selected samples near the boundaries of pollen-assemblage zones, the analysis of oxygen and carbon stable isotopes was carried out. The standard laboratory preparation and measurement technique is described elsewhere (Kuc et al., Chapter 4.4).

Description of pollen assemblage zones

The simplified diagram shows selected pollen taxa and is divided into pollen assemblage zones (PAZ) which may be interpreted in terms of vegetational development under the influence of climate. Climato-biostratigraphical zones in the sense of Blytt-Sernander are also used.

1. *Betula-Salix* PAZ (samples 1–25, couplets 0–140)

Betula and *Salix* are characteristic taxa of this zone, and their pollen occurs in largest amounts. The values of herbs are high, with dominant Cyperaceae, Gramineae, and *Artemisia*. Significant are also Chenopodiaceae, *Rumex*, *Thalictrum*, *Urtica*, and Rubiaceae. Pollen of *Hippophaë* and *Juniperus* is present. Aquatic and swamp plants are represented by *Typha latifolia*, *Myriophyllum* sp., *Sparganium* type, *Equisetum*, and others.

This zone is represented by a gyttja layer 13 cm thick and by ca. 140 couplets.

2. *Pinus-Betula* PAZ (samples 25–120; couplets 141–1150)

Pinus and *Betula* are the most abundant and characteristic taxa of this zone. *Pinus* curve increases as *Betula* gradually decreases. Values of *Salix* and *Juniperus* are significant in the older part of zone. Higher frequencies of *Populus* pollen are pronounced in the younger part of the zone. Cyperaceae, Gramineae and *Artemisia* are still important taxa. Greater proportion of *Thalictrum* and *Rumex* pollen are characteristic for the older part of zone. The rise of *Filipendula* pollen values is significant for the upper part.

This zone is represented by ca. 1010 couplets including 10 cm with disturbed lamination between samples 104 and 114. The disturbed section has an estimated 145±20 couplets.

3. *Artemisia* – Chenopodiaceae PAZ (samples 120–215; couplets 1151–2175)

This zone is characterized by high proportions of *Artemisia*, Gramineae, Cyperaceae, and Chenopodiaceae pollen. *Thalictrum*, *Rumex*, Rubiaceae, and Asteraceae have also relatively high frequencies. Values of *Salix* and *Juniperus* pollen rise. *Ephedra*, *Helianthemum*, *Gypsophila fastigiata*, and *Pleurospermum austriacum* pollen is present.

This zone is represented by ca. 1025 couplets. The section between samples 200 and 205 is estimated to represent 60±100 couplets.

4. *Betula-Ulmus* PAZ (samples 215–305; couplets 2176–3051)

Betula and *Pinus* pollen is dominant. *Ulmus* pollen appears and its proportions increase consistently; values of *Populus* pollen rise. Pollen of other thermophilous species also occur sproradically, especially of *Corylus*. Proportions of herb pollen are considerably reduced, particularly of *Artemisia*, Chenopodiaceae, *Rumex*, *Thalictrum*, and *Potentilla*. The percentages of *Filipendula* and *Urtica* pollen are higher than in preceding zone and *Humulus* pollen appears. *Nymphaea alba* and *Typha latifolia* pollen is present.

This zone is represented by ca. 875 couplets.

Changes of the plant cover

1. *Betula-Salix* PAZ

High proportion of herbs and shrubs indicates the occurrence of open vegetation, mainly as communities of heliophytes with *Artemisia*, Chenopodiaceae, *Thalictrum*, and *Hippophaë* in sandy and dry areas. The abundance of *Salix* and high frequencies of *Betula* indicate that wet places situated near the lake were occupied by willow and birch shrubs. The lake shores were overgrown by reedswamp with *Typha latifolia* and *Equisetum*. Occurrence of fairly thermophilous species *Typha latifolia* and *Myriophyllum* sp. probably suggests improvement in the climatic conditions. This zone corresponds to the end of the Older Dryas.

2. *Pinus-Betula* PAZ

This zone corresponds with the Allerød interstadial. *Pinus* and *Betula* are the predominant trees in the arising forests, but in the younger part of the zone *Pinus* began to play a more important role. The forest had a rather open structure. The gradual rise of *Populus* and *Filipendula*, and fall of *Thalictrum*, *Potentilla*, and *Juniperus* pollen indicate that climate of the younger Allerød was probably not only warmer but also more humid. Abundance of *Nymphaea alba* and occurrence of *Typha latifolia* is worth notice because these plants indicate that the July temperatures were not lower than about 16^{o}C.

3. *Artemisia*-Chenopodiaceae PAZ

Increasing proportion of herbs, especially of different species of *Artemisia* and Chenopodiaceae, evidences the occurrence of open communities and very dry and continental climate. This zone corresponds with the Younger Dryas period. Dominant communities were grasslands with *Artemisia* and Chenopodiaceae as well as species

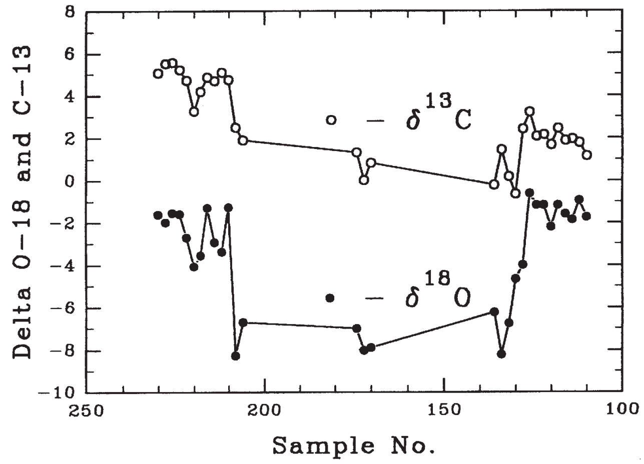


Fig. 7.54. Changes of isotopic composition of carbon and oxygen in the laminated sediments of Lake Perespilno, at the Allerød/Younger Dryas and YD/Preboreal boundaries.

typical for dry and cool climate, such as *Ephedra distachya, Helianthemum, Pleurospermum austriacum, Gypsophila fastigiata.*

4. *Betula-Ulmus* PAZ

This zone reflects successive woodland development during the Preboreal, with increasing contribution of *Betula.* In the younger part of this period the importance of pine in the forests progressively increased. The continuous *Ulmus* curve is characteristic for the occurrence of this tree in situ, connected with its migration from the south-east (Bałaga 1982, 1990, Bałaga et al. 1983, 1992, Ralska-Jasiewiczowa 1983). An important role was played by willow and poplar scrub in wet places at the marginal belt of the lakes, probably with *Humulus, Urtica,* and *Filipendula*. Appearance of pollen of other thermophilous trees and shrubs (*Quercus, Fraxinus, Alnus, Corylus*) indicates their approaching to the studied area. The reappearance of *Nymphaea alba* and *Typha latifolia* in the lake confirms considerable warming.

^{18}O and ^{13}C isotopes in authigenic carbonates

The onset and termination of the Younger Dryas, very well marked in both analysed isotopes ($\delta^{18}O$ and $\delta^{13}C$) as a sharp lowering, and increase of ^{18}O and ^{13}C, is very well correlated with palynological indicators (Fig. 7.54). The relatively constant value of $\delta^{18}O$ in the Allerød part, with fluctuations not exceeding 0.5‰ around average value of ca. 1.2‰, decreases during the AL/YD transition to ca. -7‰ within 80 varve years. A small number of samples measured so far representing the Younger Dryas part indicates generally very low $\delta^{18}O$ values forming a characteristic plateau without any trend. “Isotopic termination” of the YD is marked as an increase of ^{18}O concentration (from -7.7‰ to -3‰), even faster than at the YD onset, and completed in ca. 40 varve years. Rapid changes of isotopic ratio reflecting climatic parameters shown in the Perespilno sediments are in good agreement with other observations for Europe and Greenland (Kuc et al., Chapter 7.6, Goslar et al., Chapter 7.7).

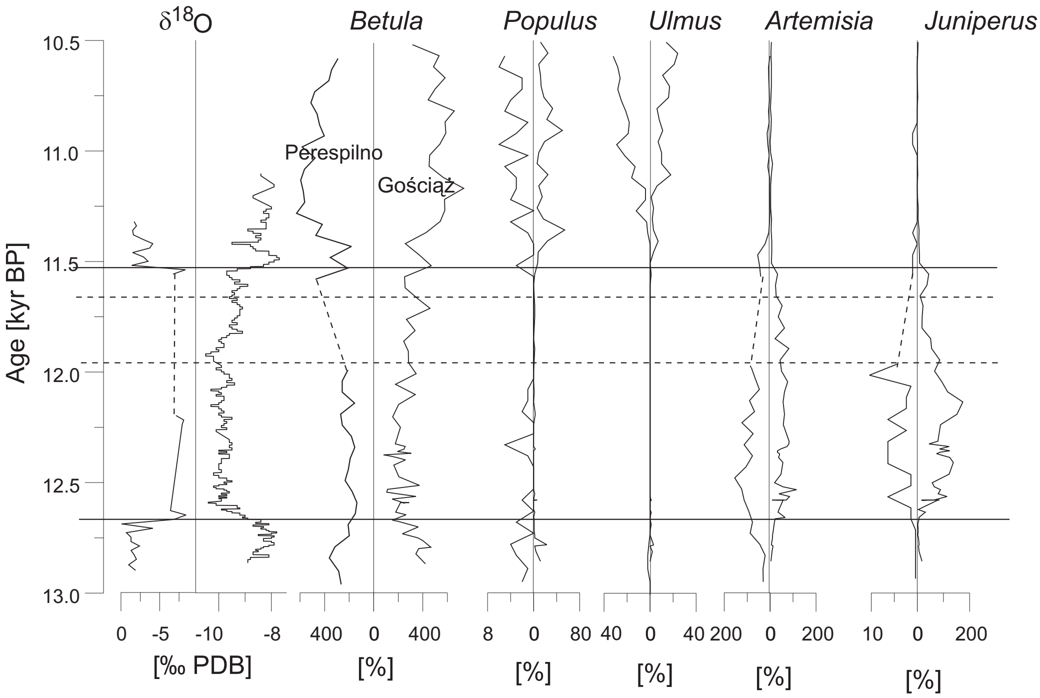


Fig. 7.55. Diagram comparing the $\delta^{18}O$ and selected pollen taxa curves in Lake Gościąż (right side) and Lake Perespilno (left side of oridinates). The absolute age of two sections of Perespilno sediments (shifted by ca. 330 years, dashed lines) was determined by synchronization with Lake Gościąż sediments, based on rapid $\delta^{18}O$ changes marking the Younger Dryas in both lakes.

The $\delta^{13}C$ profile reveals in general similar shape to that of ^{18}O, but the absolute values of changes at transitions are much smaller, and a general increase of ^{13}C concentration is observed.

Comparison with records from the Lake Gościąż sediments

This study points to interesting material which could deliver new information on climatic parameters reflected by vegetation cover and stable isotopes in lake sediments, at the point distant from the maximum of the Vistulian glaciation. Especially interesting is the comparison of reconstructions with those for Lake Gościąż, since Lake Perespilno is situated in an area of weaker influence of the Atlantic ocean, and characterized by more continental climate. At present, the annual amplitude of temperature in Perespilno area is 2–3°C higher than in Gościąż region (Wójcik & Przybylak, Chapter 2.3).

The $\delta^{18}O$ curves and selected pollen taxa from both lakes are compared in Fig. 7.55. To derive an absolute time scale for Lake Perespilno data, the major $\delta^{18}O$ changes in both lakes were assumed to be synchronous. This, however, requires broadening of the gap between samples 200 and 205 to ca. 320 years. The boundaries of *Artemisia*-Chenopodiaceae PAZ, corresponding to the Younger Dryas period, are not exactly simultaneous with the major shifts of $\delta^{18}O$, though the rates of changes of most indicator taxa in both lakes are similar. Unlike in Gościąż, most taxa (e.g. *Ulmus*, *Artemisia*, *Juniperus*) show 50–100 yr delay in response to climate amelioration at the beginning of Holocene. Surprisingly, major changes in vegetation precede those of $\delta^{18}O$ at the onset of Younger Dryas. Another distinct difference is the amplitude of $\delta^{18}O$ changes, and absolute percentages of many pollen taxa. The more precise synchronization of records from both lakes and interpretation of observed differences will be a matter of further study.

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