

Fig. 9.45. Plot of the content of sodium in the sediment of Lake Gościąg, in comparison with the annual sum of precipitation.

rise of Fe lasting (depending on trophic indicator) 8–12 years. If the variations of Fe and Mn concentrations were driven by lake productivity through the sulphide or circulation mechanisms, they should be correlative with the indicators of organic productivity. As shown in Fig. 9.44, the variations of non-carbonate Fe and Mn concentrations show some delay with respect to the changes of potassium content (see Fig. 9.42). The asymmetry of correlation as a function of delay is reasonable, as the changes of organic productivity affect the rate of sulphide production in several following years but do not act back in time. Such a delayed correlation strongly confirms that the measured variations of element concentrations were not an artefact of simple interference with other elements (e.g. Ca) in the analytical process, but they document real dynamic ecological process.

Unlike potassium, iron, and manganese, all reflecting mostly human influence, the concentration of sodium seems to comprise the climatic information. This as well as potassium may be taken as an index of chemical weathering in the drainage basin and/or the erosive transport of soil particles to the lake (Engstrom & Wright 1984, Dean 1993). The concentration of sodium was compared with the mean annual sum of precipitation in Warsaw (ca. 100 km east of Lake Gościąg). The instrumental meteorological data were collected by S. Paczos and H. Maruszczak (Paczos 1993, Maruszczak 1988). In the analysed period AD 1825–1960, the Na concentration is significantly positively correlated with the annual sum of precipitation (Fig. 9.45), suggesting that the slope wash rather than chemical weathering is the main factor controlling the variations of Na content in lake sediment. The more detailed comparison, showing the weakest Na-precipitation dependence during summer season, when the soils are most stable against erosion, seems to support this interpretation. The concentration of potassium, however, is not correlative to precipitation. This was unexpected, since potassium undergoes less intense weathering and thus a stronger effect of erosion than sodium. As discussed earlier, similar behaviour of both elements was found in Lake Amersee in Germany (Michler et al. 1980).

The concentration of lead in the Lake Gościąg sediments (Fig. 9.43) increased first after AD 1880, and once again between AD 1950 and AD 1960. The lead concentrations in lake sediments were frequently used to study the effects of anthropogenic pollution (e.g. Renberg & Segerström 1981, Renberg 1986). The record from the Lake Gościąg sediments, however, seems seriously affected by the mobility of lead above AD 1950, clearly evidenced by the non-monotonic profile of ^{210}Pb concentrations (Goslar, Chapter 9.2.2, Fig. 9.31). As discussed by Wachniew (1993), lead may be easily mobilized in reductive environments when the lack of sulphur inhibits fixation of Pb in form of sulphides. Therefore the profile of Pb in Gościąg, though it documents the increase after Second World War, is probably strongly flattened. Mobilization of lead in the upper part of the sediment of Lake Gościąg is concordant with effects explaining the Fe and Mn profiles.

The changes of other elements amounts are difficult to interpret. Those of Ni, Cd, and Li (Fig. 9.38) could reflect the industrial pollution by these metals; nevertheless, observed increases after AD 1960 are very low, perhaps because of situation of Lake Gościąg far from industrial centers.

9.2.4. POLLEN RECORD OF ANTHROPOGENIC CHANGES OF VEGETATION IN THE LAKE GOŚCIAŻ REGION FROM AD 1660 UNTIL RECENT TIMES

Magdalena Ralska-Jasiewiczowa & Bas van Geel

In the sediment cores from Lake Gościąg, obtained by means of piston corer, the quality of annual laminations deteriorates in the upper part of the sediment sequence until nearly total disappearance of laminae in the top 1.26 m. Thanks to the application of freezing *in situ* technique (Walanus, Chapter 4.1.2) the youngest part of sediment, except for its topmost ca. 50 cm, revealed also the existence of annual lamination, which enabled the construction of a continuous chronology based on correlation of laminae in 20 short frozen cores back to the middle of the 17th century (Goslar, Chapter 9.2.2). The new longest

core from 1995, very well correlated with the piston-core sequences, allowed some age corrections to close the sequence between the dates AD 1660 and 1990.

The samples for pollen analysis collected by T. Goslar come from cores G21f (AD 1990–1940), G32f (AD 1941–1906), G31-3f (1894–1816), and G33f (AD 1779–1662) (Goslar, Chapter 9.2.2, Fig. 9.25). The average time resolution of counted samples in the part covering yrs AD 1818–1990 is ca. 2.9 yr, and between AD 1660 and 1779 it appeared to be slightly over 5 yr, because of the correction of time scale. The pollen samples were prepared at Palaeobotanical Laboratory in Cracow (see Chapter 4.6.1). The calculations were based, as in core G1/87, on the combined pollen spectra from M. Ralska-Jasiewiczowa and B. van Geel. As the volume of the samples was not quite uniform, the calculation of pollen influx was too rough to be useful.

Construction of pollen diagram and significance of some microfossil taxa for palaeoecological interpretation

The subdivision of the pollen diagram (Fig. 9.46) is supported by numerical analyses (CONSLINK, Principal Component Analysis) based on selected most frequent pollen taxa (Fig. 9.47). The basic division shows in the first component (39% loading) two main parts of the diagram, with the boundary around the 1820s (GF1c/GF2): the older part is distinguished by higher proportions of *Quercus*, *Alnus*, and *Betula* and by lower contribution of human indicators except for *Cannabis sativa* cf.; the younger part by maximum of *Pinus*, higher *Juniperus*, and maximum of anthropogenic pollen taxa. These proportions change gradually in the 2nd half of 20th century because of a decrease of human indicators and increase of *Betula* and *Alnus*, as shown distinctly by 2nd component (17% loading). The 2nd component points to one more boundary of lower rank around the 1750s, distinct also in CONSLINK analysis (Fig. 9.47) and constrained probably by the fall of *Cannabis* values.

The comparison of the GF pollen diagram with the corresponding part of diagram G1/87 (Fig. 9.48) shows the convergence in the basic division of both sequences into main periods (see Chapter 9.1.3, Fig. 9.15). The section from the middle of the 17th century up to the end of 18th or early 19th centuries, with rather high *Quercus* and slightly increased *Corylus*, appears in both diagrams as a time of decreased economic activities in the area, the only essential difference being the lower and earlier maximum of *Cannabis* (AD 1625) in G1/87, which however, might be the effect of poor sample resolution in G1/87 and lack of pollen spectra below 1662 in the GF sequence. The section from the 1820s to recent times shows in both cases the intensification of agriculture.

The patterns formed by pollen taxa of minor quantitative importance allowed for further subdivision of the GF

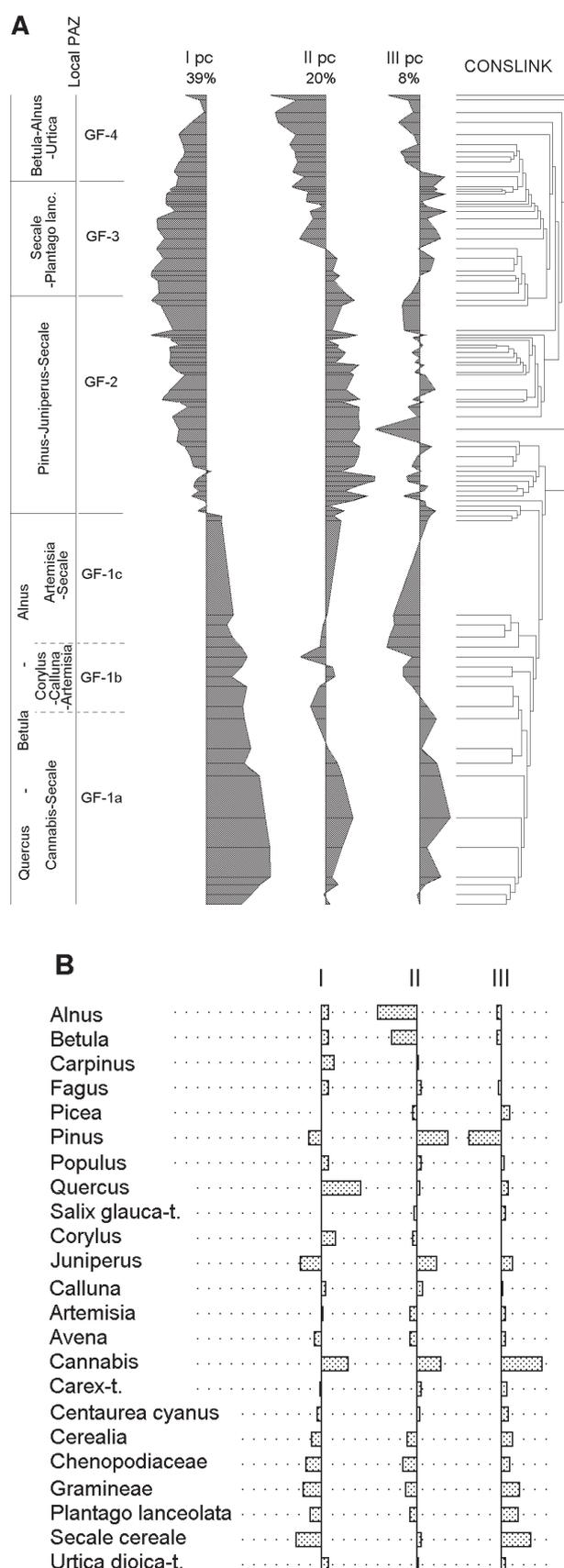


Fig. 9.47. Numerical analysis of GF pollen sequence from Lake Gościąg. Three first principal components (A) along with the loadings of pollen types on each of them (B) are given. The results of the constrained single link analysis (CONSLINK) applied to the same pollen sequence for the zonation purpose are shown to the right, compared with the finally used local pollen assemblage zones (PAZ).

Correlation of selected pollen curves from GF (frozen) and G1/87 (piston sampler) profiles

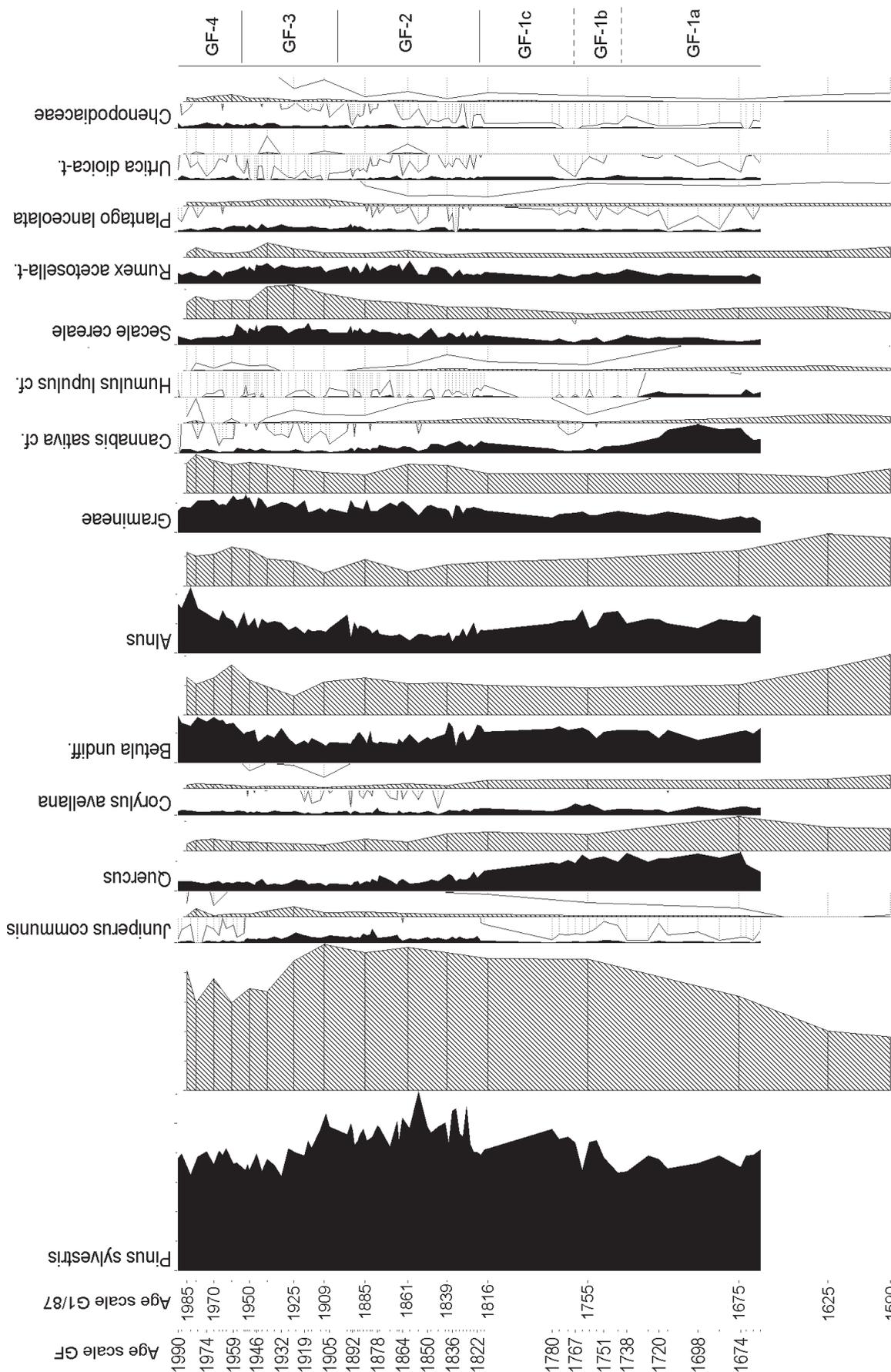


Fig. 9.48. A comparison of selected pollen curves from the GF pollen sequence (black silhouettes) and from the top part of G1/87 pollen diagram (hatched silhouettes) based on the common calendar time scale.

diagram, leading in some cases to the exact correlation of changes in the pollen record with economic and historical events known from archival sources. Sometimes the lack or delay of response of the pollen spectra to the known facts was observed. This altogether may be of methodical value for the interpreters of pollen diagrams, as it is seldom the case that a pollen record can be correlated with an event with such a time accuracy. As the subdivision into the local pollen zones has mostly been based on many subtle changes in pollen composition, their description has not been separated from interpretation in order to avoid too many repetitions.

The treatment of pollen samples with the acetolysis destroys more delicate palynomorphs. Due to this reason only selected non-pollen microfossils with more resistant wall could be found in pollen spectra. The records of some microfossil taxa (*Aphanizomenon*, *Anabaena*, *Tetraedron*, *Trichocerca cylindrica*, *Tintinnopsis lacustris*, *Staurophyra* and especially *Pediastrum*; Fig. 9.49, see also Goslar et al. in print) seem to be indicative for the changes in water chemistry and lake trophy. *Pediastrum* coenobia, combined here into one group – genus *Pediastrum* – are mostly planktonic, but some species grow also in other wet habitats. Round (1973) mentions *Pediastrum* as epipellic, growing on sediments and according to Cronberg (1982) in some lakes in southern Sweden high increases of *Pediastrum* were found in connection with the periods of increased lake pollution. This can also result from the coincident development of macrophyte zone creating suitable habitats for periphytic *Pediastrum* species. In records from Lake Gościąg *Pediastrum* is also indicative for the periods of increasing eutrophication.

Description of local pollen zones and interpretation of vegetational changes in connection with the history of settlement

Four local anthropogenic pollen zones and three sub-zones have been distinguished in the GF pollen sequence. The recovered process of vegetation changes may be described and explained as follows:

GF-1 *Quercus-Betula-Alnus* LPAZ (AD 1662–1820)

Quercus, *Betula*, and *Alnus* pollen values exceeding generally 10% each. *Corylus* and *Carpinus* 1–2%, *Pinus* below 40%, *Cannabis* at maximum of ca. 10% in the lower part of the zone, then declining, *Secale* up to 2%, other farming and grazing indicators continuously present but with low pollen values.

These pollen proportions, as compared with the section of the G1/87 pollen diagram of earlier age (AD 1525–1625) (Ralska-Jasiewiczowa & van Geel, Chapter 9.1.3, Fig. 9.15) indicate the time of rather reduced though functioning settlement in the area. This is in agreement with the history of Masovian lands, where the

most of the 17th century was a time of economic depression. The crisis was caused first by too oppressive villager services, which generated wrong farming practices (continuous dominant cultivation of cereals, lack of fertilization bringing impoverishment of soils, etc.) and resulted in mass exodus of farmers to the towns (Szczepański 1990). The following great invasion of Poland by Swedes (in AD 1655–1660), with burning of towns and villages and progressing depopulation, ruined the economy of the area.

The pollen zone discussed can be divided into 3 sub-zones:

Cannabis-Secale PASZ (GF-1a: AD 1662–1740)

Continuous (up to 1–2%) *Carpinus*, *Fagus*, and *Corylus* and initially continuous but later interrupted occurrences of *Fraxinus*, *Ulmus*, and *Tilia cordata*, evidence the still existing small fragments of mixed deciduous woods. *Quercus*, its pollen percentages exceeding 10%, contributed to these and other forest communities, growing probably most frequently in mixed pinewoods common on more elevated poorer habitats. The importance of this tree of high value in the area of dominating pinewoods (e.g. its acorns were certainly used for feeding pigs) was documented by the use of its name (Dąb) for naming settlements in the lake surroundings (Goslar, Chapter 9.2.1). Alderwoods were widespread around the lake, and *Betula* occurred in different often devastated wood types.

The local presence of farmlands is well recorded and shows the structure of cultures changing in time: *Cannabis* pollen curve, up to 10% in the lower part of the zone (hemp retting in the lake?), declines after ca. 1713, while from AD 1698 cereal-growing (mostly *Secale*, but possibly also *Hordeum*) seems to increase in area, as is also stressed by field weeds (*Centaurea cyanus*, *Rumex acetosella*, *Polygonum aviculare*, *Scleranthus annuus*, *Bilderdykia convolvulus*). Around 1713–1720 *Fagopyrum* and probably some crucifer plants appear in cultivation. At the same time a *Humulus lupulus* curve, rather substantial from the diagram base, drops rapidly to single scattered occurrences in the whole overlying part of the profile. It is impossible to decide whether *Humulus* pollen originated from its native habitats in alderwoods or from cultures. However, the peasant tributes in hops are mentioned from that time, in connection with the existence of breweries at nearby Duninów and at slightly more distant Gostynin and Gąbin. Each of them produced in AD 1630 300–450 barrels of beer per year (Szczepański 1990). The brewery at Duninów ran from at least the 16th century, and no information was found when it stopped working. All this makes the supposition about hop cultivation in the area very probable. AD 1720 would then be the end of its cultivation, the overlying scattered occurrences of its pollen coming from natural sites.

Around that time the peaks of Cyanobacteria (*Aphani-*

zomenon and *Anabaena*, Fig. 9.49) suggest the eutrophication of lake water with phosphates (Van Geel et al. 1994, 1996).

The situation described above corresponds and slightly follows in time the temporary improvement of economic conditions reported from the part of Masovia discussed for the 1680s and 1690s (Szczepański 1990). In 1674 at Dąb village, situated close to Lake Gościąż, 55 families were reported to pay rents (Pelisiak & Rybicka, Chapter 9.1.2). However, the next subzone seems to reflect the resumption of economic crisis:

Corylus-Calluna-Artemisia PASZ (GF-1b: AD 1740–1767)

The diagram records the first reaction to the abandoning of some terrain utilized earlier by farmers, i.e. the spread of ruderals initiated by *Chenopodiaceae*, then *Artemisia*, *Rumex crispus* -t., *Urtica dioica*, and sporadically *Echium*. Some rise of *Juniperus* and less distinctly increasing *Betula*, *Populus*, *Salix*, and *Alnus*, followed with a 20–30 yr delay by small rises of *Carpinus*, *Corylus*, and *Ulmus* pollen frequencies may evidence the successional overgrowing of abandoned lands and local regeneration of woods. The changes in the AP record are not, however, that conspicuous; more significant are depressions in the pollen curves of the cultivated plants: *Secale cereale*, *Hordeum* -t., *Cannabis sativa* cf., *Cruciferae* (?), and of the weeds *Centaurea cyanus*, and *Rumex acetosella*. Some less frequent cultivated or weed taxa like *Fagopyrum*, *Polygonum aviculare*, *Scleranthus annuus* periodically disappear. The overgrowth of open spaces on poor sandy soils is evidenced by rising *Calluna* and appearance of *Jasione*, *Sedum*, and *Scleranthus perennis* pollen; the indicators of fresh meadows do not reveal any distinct changes on those habitats.

The lake trophy was then low, as suggested by the low frequencies of Cyanobacteria in the pollen spectra (Fig. 9.49).

Artemisia-Secale PASZ (GF-1c: AD 1767–1820)

The first signs of new economic activity are registered in the pollen record from ca. AD 1770, but the criteria for defining this section of the zone as a separate subzone are poor and mostly negative. They include small falls of *Carpinus* and *Corylus* but also of *Populus*, *Juniperus*, and *Calluna* pollen frequencies, indicating probably local clearings of overgrown surfaces both on more fertile and on sandy, rather poor habitats. Small rises of *Secale*, *Cannabis* and different weed and ruderal pollen taxa evidence some renewal of farming activities. Unfortunately, the sequence of changes is disrupted at 1779 by a ca. 30 yr gap, but similar AP proportions with some indices of slowly developing agriculture occur also in the first decades of the 19th century. A distinct change in pollen record is indicated only from ca. AD 1820.

To understand the settlement processes in the area dis-

Lake Gościąż Profile GF

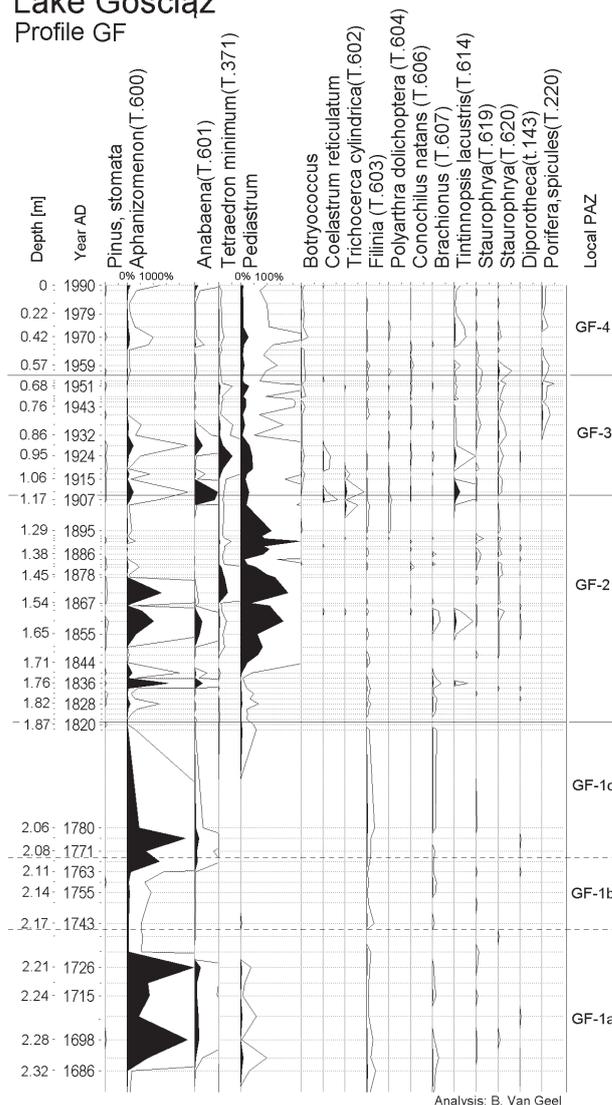


Fig. 9.49. Lake Gościąż, profile GF – diagram of non-pollen palynomorphs, selected pollen taxa. The scales of frequencies for the palynomorphs of *Aphanizomenon* through *Tetraedron minimum* is 1 tick = 1000%, and for the other palynomorphs – 1 tick = 100%.

cussed some general historical knowledge should be recalled. The German colonization on the Gostynińskie lands, developing from the second half of the 18th century with the so-called “Hollandii” (Hauländer?) settlement as one of its widespread forms, was connected with the foundation of several new villages in the area (see Goslar, Chapter 9.2.1). The dates of their establishment are not quite certain (AD 1746 by Zimecki 1990, AD 1789 by Tomczak 1977), but the dates for the introduction of “oładę” settlers in particular estates are mostly grouped in the last 15 yr of the century (Szczepański 1990). On the map from 1802 published by Gilly (Goslar, Chapter 9.2.1, Fig. 9.22) the open lands approach Lake Gościąż from N-NE, surrounding already Lake Wierchoń. During the passages of Napoleonic troops in 1806–

1812 the area was heavily exhausted because of frequent requisition of goods and animals, which, however, brought also some economic activation, especially the development of small towns and intensification of food production (Kociszewski 1976). After the formation of the “Congress Kingdom” in 1816, the upgrowth of small towns in the Gostynińskie Lands initiated by the new administration was to be based on cloth production (Szczepeński 1990). This resulted in an increased exploitation of wood and stimulated sheep breeding. All those events led to essential changes in the functioning of the local economy influencing the environment, as is clearly recorded in the diagram from ca. 1820.

GF-2 *Pinus-Juniperus-Secale* LPAZ (AD 1820–1910)

The zone is distinguished by the highest *Pinus* (up to 60%), generally lowered *Betula* and *Alnus* pollen curves, and substantial *Juniperus* values (up to 4%); *Quercus* is much reduced (to ca. 3–5%), *Carpinus* and *Corylus* decrease to 1% or less, and other deciduous tree taxa are sporadic. *Cannabis* slowly declines, but *Secale* and *Rumex acetosella* increase distinctly throughout the zone, Cruciferae reach up to 1%, and *Fagopyrum* appears regularly in the lower and upper parts of the zone.

All those changes are evidence of intensive settlement connected with the felling of woods. The clearing included secondary woods overgrowing old abandoned farmlands, the alderwoods in the lake surroundings (beside *Betula* and *Alnus*, depressions of *Populus* and *Salix* curves), the still existing fragments of mixed deciduous woods, and even drastic extermination of oak trees. The dominant pinewoods might have also been affected, as suggested by increased flowering of *Pinus*, and spread of *Juniperus*, and of dry heath-grassland vegetation (*Calluna*, *Melampyrum*, *Jasione*, *Sedum*, etc., and ferns – Filicales monoletae ca. 2%).

Agriculture was developing. The pollen-analytic data point to *Secale* as the dominant cultivated grain, the other cereals being in deep minority. How far would such record be affected by their different pollination type (wind transport for *Secale* and clystogamic pollination for the other cerealia)? In the Gostynin Land, as documents from the beginning of the century say (Szczepeński 1990), agriculture functioned in a three-field rotation system: winter cereals (*Secale*, seldom winter *Triticum*); spring cereals (*Hordeum*, *Avena*, seldom spring *Triticum*) or *Fagopyrum*, *Pisum*, *Panicum*, potatoes; and fallow land. However, it was in fact based primarily on rye. Two times less barley and oats, and four times less wheat and potatoes were grown. In the pollen record this pattern is resembled, but proportions are much exaggerated.

Solanum nigrum -t. pollen, representing most probably *S. tuberosum*, appears sporadically from AD 1818, and then more regularly in the top part of profile. The historical sources are not quite positive about the intro-

duction of potatoes to Poland supposed for the end of 17th century. They certainly became widespread from the time of partition of Poland a century later, and particularly after the passages of Napoleon troops during AD 1802–1812 (Nowiński 1970, Herse 1980). The development of potato cultivation in Poland in the first decades of 19th century was interrupted by a fungus pest (*Phytophthora infestans*) spreading throughout Europe in ca. 1840–1851 (Nowiński 1970, Körber-Grohne 1988). It reached the study area in 1847–1850 (Chudzyński 1968). The single appearances of *Solanum nigrum* -t. span times before (AD 1818, 1830) and after (AD 1870) the epidemic.

Another rare and rather astonishing evidence is *Zea mays* pollen. Maize was probably introduced to Poland by the end of the 18th century from Roumania or Hungary (Herse 1980). Being, however, a plant of high climatic demands it presumably could grow in the warmest regions only. According to Körber-Grohne (1988), in Germany it was cultivated until the first decades of the 19th century mostly in regions suitable for the vineyards. It spread a little outside those regions after the first potato pest in 1805–6, and after the famine following the great plague in 1840–51 the new more resistant maize varieties were introduced in central and north Germany. The single finds of *Zea mays* pollen in Lake Gościąż profiles are dated at AD 1834 (GF profile) and around AD 1839 (G1/87 profile). Was *Zea mays* cultivated in central Poland that early? There was no mention about it in available sources.

No information was also found about the role of crucifer plants in the farming structure of the discussed time, though the diagram shows clearly their importance. The fields were very weedy, the more so because the soils were mostly poor. *Rumex acetosella* was the dominant cereal weed, as shown by its pollen curve strictly following the *Secale* curve, though it might have also grown in different disturbed biotops of sandy soils (Behre 1981). Its maximum contribution to the field flora falls between AD 1840 and 1870, and afterwards the fields might have been slightly cleaner. Besides, *Centaurea cyanus*, *Polygonum aviculare*, and many sporadic weed taxa appear. *Scleranthus annuus*, *Bilderdykia convolvulus*, *Polygonum persicaria* -t., *Spergula arvensis*, *Anagallis arvensis*, *Consolida* -t., *Nonea*, and later (AD 1860–70) also *Agrostemma* and *Viola arvensis*. Of cultivated Leguminosae plants only a single occurrence of *Vicia faba* was noted at AD 1848.

The existence of grazed surfaces close to the lake is evidenced by high Gramineae, substantial *Plantago lanceolata*, *Rumex acetosa* -t. pollen curves, and many other meadow taxa of different habitats occurring regularly (*Rhinanthus*, *Trifolium pratense*, *Trifolium undiff.*, *Lotus*, etc.), or sporadically (*Succisa pratensis*, *Geum*, *Lythrum*, *Polygonum bistorta*). A considerable proportion of eco-

logically undefined pollen taxa originated probably also from those vegetation types. However, the local farmers suffered heavily from a shortage of soils suitable for good pastures; the efficiency of cows was very low, lots of goats and sheep were bred, and pigs were fed also on pastures but mostly in woods.

The development of agriculture and animal breeding coincides with the increase of lake eutrophication as suggested not only by the increase of eutrophic Cladocera (Szeroczyńska, Chapter 9.1.4, Goslar et al., in print), but also by the rise of *Pediastrum* (Fig. 9.49).

In the younger part of zone, from between AD 1858 and 1864, some decline of *Pinus* was coincident with rises of *Juniperus* and *Populus* and with further reduction of *Carpinus*, suggesting devastation of pine and mixed woods. The AP changes are accompanied by growing frequencies of *Secale* and other cereals (*Hordeum* -t., *Avena* -t., *Cerealia* undiff.), of *Fagopyrum* and Cruciferae, field weeds and ruderals, as well as by increases of some fresh meadow indicators (e.g. *Plantago lanceolata*) and rising diversity of taxa.

All those changes tend to show the growing density of population and intensification of agriculture resulting from new waves of German colonisation in response to Polish insurrections; after the first one in 1831, but particularly after the second one in 1863. We should expect that the development of “Dąb Borowy” village (Dąb = oak; Borowy = in pine forest), closest to Lake Gościaż, in the late 1880s (Goslar, Chapter 9.2.2) would find a direct reflection in pollen spectra, but not much change is to be seen in connection with this date: these are only small falls in *Quercus*, *Betula*, and *Populus*, single evidence of newly planted taxa (*Aesculus* and *Vitis*), and rise of *Plantago lanceolata*. Unfortunately, another gap, between AD 1894 and 1906, disturbs the observation of the following changes. However, it seems rather obvious that substantial changes in pollen spectra start from around 1912 only.

The disturbance of lake ecosystem by the settlements approaching the lake shores is then evident: the blooms of *Tetraedron minimum* start appearing from AD 1868. The other symptoms of this disturbance are described by Goslar (Chapter 9.2.3).

GF-3 *Secale-Plantago lanceolata* LPAZ (AD 1912 –1953/58)

The zone is distinguished by reduced *Pinus* and *Populus* and increased *Salix* pollen values. *Juniperus* is initially high, but after AD 1928 decreases slightly, coincidentally with a rise of *Betula* and *Alnus*. The indicators of agrarian economy are at maximum values, with dominant *Secale* exceeding 10% between ca. 1932 and 1941, high *Rumex acetosella*, and peaks of *Centaurea cyanus* and Cruciferae at AD 1917–1930. *Cannabis* and *Avena* -t. are continuous up to 1%, other cereals are less frequent, and

Fagopyrum, *Solanum nigrum* -t., and *Zea mays* pollen occur regularly. The frequencies of most common ruderals (*Artemisia*, Chenopodiaceae, *Urtica*), lowered at the zone beginning, start rising around 1940. The pollen values of plants associated with fresh/wet meadows are quite high (Gramineae, *Plantago lanceolata*, *Rumex acetosa* -t.), as is the representation of those communities rich in taxa (*Lychnis flos-cuculi*, *Polygonum bistorta*, cf. *Vicia cracca*, *Succisa pratensis*, *Centaurea jacea* -t., *Trifolium pratense* -t., *Rhinanthus*, *Lotus*, *Cirsium* -t., *Euphrasia*, *Mentha* -t., etc.), including many taxa which are ecologically undefined.

According to the historical sources (Chudzyński 1990) the first decade of 20th century in the study area was the time of economic stagnation, deepened still by extreme climatic phenomena (years of drought alternating with years of too high precipitation). However, the poverty and primitive economy of farmers of this historical stage can hardly find any expression in the pollen record. Some progress began in the second decade, but it was soon interrupted by the outbreak of the First World War.

The economic breakdown connected with the destruction of many villages by military actions in 1914, requisition of domestic animals and goods and other disasters, culminated in the famine winter 1917/18, called a “turnip cabbage (rutabaga) winter” (rise of Cruciferae pollen in 1917–21?). The German invaders heavily devastated local woods, breaking all the rules of extirpation and felling up to 70% of total tree stands (Chudzyński 1990). The *Pinus* fall and minor changes in AP frequencies following ca. 1918 might record the consequences of those events.

The post-war years 1918–39 of regained state independence witnessed the efficient development of the area, particularly of small local towns, which, however, was connected again with too extensive clearing of forests, its progress clearly evidenced in the diagram. On the map from 1927 (Goslar, Chapter 9.2.1), the cleared grounds surrounding Na Jazach lakes extend towards the east of Lake Wierzchoń, where houses are grouped, and towards the northwest along the Ruda stream to the broadly opened Vistula valley. From the south-southeast the forest approaches Lake Gościaż.

The lake eutrophication is strongly indicated during the time between two World Wars. Besides the development of Araphidinae diatoms (Goslar, Chapter 9.2.2 and Goslar et al., in print), *Aphanizomenon*, *Tetraedron minimum*, and *Coelastrum reticulatum* form then distinct maxima for the last time.

During the 2nd World War the gradual evacuation of German families from the closest Dąb Borowy settlement was concluded in 1944 by expulsion of the remaining Poles (Goslar, Chapter 9.2.1). A distinct increase of ruderals (*Artemisia*, Chenopodiaceae) reflects those events in the pollen record, and from 1944 *Secale* and *Avena* -t.

pollen curves begin to decline. The village was not settled again after 1945 as many other villages in the region were. However, for several years more some land was still in use by farmers from neighbouring settlements. As evidenced in pollen diagram they were still growing some cereals, mostly rye and possibly also *Fagopyrum*, hops, and usable Cruciferae species. Open surfaces were certainly used for animal grazing, as the increased *Plantago lanceolata* pollen values and other less frequent meadow taxa persist to the late 1950s, and only then decline or disappear. Increased contents of charcoal were found during sediment analysis by Goslar (in 1940/41, 1944 and from 1946 for several years, Chapter 9.2.2, Fig. 9.30) and during pollen analysis (1944, 1946/47, 1950 and later). The vegetation/landscape changes in consequence of depopulation proceeded in two steps: first the spontaneous overgrowth on abandoned land, and later the systematic forest plantation, but they are recorded in the pollen diagram as a slow gradual process. The only recognizable reaction to the fires from herb vegetation is the increase of ruderals. The rise of the *Betula* pollen curve starts in 1948 and of *Salix* in 1950, whereas the charcoal signals first serious war fires in 1940/41. This clearly corresponds with the time needed for *Betula* (*B. pendula*) to settle and then to pass from the juvenile phase to generative reproduction, estimated at 5–10 years on average and in extreme cases 2 years (Wareing 1959, Jonsson 1949, Stern 1961). The complexity of the *Salix* genus excludes any discussion on this matter.

GF-4 *Betula-Alnus-Urtica* LPAZ (AD 1953/1958–1990)

The top zone of GF pollen diagram reflects the last decades of vegetational change around Lake Gościąg up to 1990, when the frozen core was collected. It covers the times of methodical reforestation on abandoned or degraded lands, concluded with the foundation of Gostyńsko-Włocławski Landscape Park in 1979, with the Na Jazach lakes complex situated in its central-north part (Lenart 1994).

The years between 1952/3 and 1959 are recorded in the diagram as the time of substantial change: the decrease of *Juniperus* from 1953 (overgrown land cleared and then used for tree plantation?) is followed by a slight rise of *Corylus*, and from around 1959 by distinct rises of *Betula* and *Alnus* pollen. As the main planted tree in the area was pine (Zaluski & Cyzman 1994), it should be supposed that those young cultures were soon spontaneously overgrown by birch, and closer to the lake by alder. The marginal zones of the lake were afforested by 1954–56 (Goslar, Chapter 9.2.1), but the diagram suggests that the last near-by fields persisted till 1957. Besides the decline of *Secale* and *Rumex acetosella*, some taxa of cultivated plants and field weeds, if sporadic before, disappear at this time from the pollen record (*Fagopyrum*, *Solanum nigrum* -t., *Scleranthus an-*

nuus, *Spergula*, and many others), and the more frequent are reduced to single grains (*Hordeum* -t., *Triticum* -t., *Zea mays*, *Centaurea cyanus*, *Polygonum aviculare*). After 1957 *Secale cereale* and *Secale/Cerealia* pollen stabilize at values making together over 4%, *Avena* -t. oscillates up to 1%, as does cf. *Cannabis sativa*. These pollen types are still today transported in a forested area from fields located at a minimum of ca. 3.5 km to the lake centre, while *Rumex acetosella* -t. pollen at continuous values of 3–5% may originate partly from fields but also from any open sandy habitats (Behre 1981). The above data contribute to our knowledge about the transport of field pollen to bigger lakes. The areas of unused meadows and sandy grasslands are reduced by overgrowing (decline in *Plantago lanceolata*, *Rumex acetosa*, *Carex* -t., Compositae SF. Cichorioideae, and recently also Gramineae). Their composition becomes distinctly impoverished as evidenced by gradual disappearance of sporadic meadow and sandy grasslands pollen taxa (*Jasione montana*, *Plantago media*, *Ononis* -t., *Silene vulgaris* -t., Compositae SF. Cichorioideae, *Trifolium* -t., *Rhinanthus*, *Geum*, *Valeriana dioica*, *Melampyrum*). Some meadow taxa may now persist in other plant communities, e.g. in alderwoods. Ruderals expand (*Urtica dioica*, *Artemisia*, Chenopodiaceae, *Plantago major*, *Xanthium*, *Sambucus nigra*). As a result of fishing and tourist activities they find particularly suitable habitats at alderwoods edges and lake shores. However, as a whole, the taxa richness falls considerably.

The decline and extinction of settlement activities started to influence the lake ecosystem surprisingly early, already for 1938 when the decrease of Cyanobacteria and Chlorophyceae is to be seen (Fig. 9.49).

The further pollen-analytic studies based both on top-sediment frozen cores and on surface samples should be continued parallel with the observations on recent changes of flora and plants communities under legal protection.

Conclusions

The last 330 years in the woodland versus settlement history of the Lake Gościąg region, as recognized in the pollen record, can be divided into 3 main stages:

1. AD 1660–1820 – dispersed small and primitive settlements, slowly growing in number from late in the 18th century, agriculture not much developed. Deciduous woodlands still existing in small fragments, but the dominant forest community is mixed pine forest with rather abundant *Quercus*. Devastated habitats overgrown by birchwood. Alderwoods surround lakes.

2. AD 1820–1944/1956 – the progressive development of farming and animal breeding, culminating during the time of regained state independence between the two World Wars (1920–1939), resulted in the final extermina-

tion of deciduous wood remnants. It heavily affected oak participation in pine forest and reduced secondary wood growth. *Juniperus* overgrowths were dominant in pine forest with frequent openings.

3. 1944/1956–1990 – after the depopulation of adjacent settlements and after a short intermediary phase of declining activities of farmers from more distant villages (1944–1956), a systematic plantation of pine on post-arable grounds and the spontaneous overgrowth on the rest of the abandoned land results in the covering of lake surroundings by secondary woods dominated by *Pinus* and *Betula*. Very small regeneration of *Corylus*, and *Carpinus* and spread of *Alnus* are recorded during the last decade (1980–1990). A significant transport of field pollen to the lake is constantly observed (dominant *Secale*), with closest fields at a distance of 3.5 km.

9.2.5. DISCUSSION AND CONCLUSIONS OF THE HUMAN IMPACT DURING THE LAST 330 YEARS

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The data presented in chapters 9.2.1 through 9.2.4 give a unique record of human impact on lacustrine environment and surrounding vegetation during the last 330 years. As reported previously (Goslar et al., in print), this record is very interesting for a few reasons. First, the lakes Na Jazach complex is located far from industrial centres, and its catchment is surrounded by forests, so the system was disturbed only through the agricultural activities in the few villages. Secondly, within the time span considered we could study the response of the system to the increasing anthropogenic stress as well as the return to more “natural” conditions after the withdraw of man from the lake vicinity. Third, the lamination of sediments enabled monitoring of events with the time accuracy to a single year.

In this chapter we attempted to confront the historical and palaeoecological data from individual chapters displayed on the common time scale (Tab. 9.13), and discuss them together. For reasons outlined in Introduction (Chapter 1) we decided not to refer our synthesis to the relevant regional or global data, but to focus it rather on the history of the Lake Gościąg region alone, in the local scale. This chapter will thus serve as a background for further research and more general discussion.

The different types of data are ordered in columns. The general historical background and the history of local settlement known from written documents is summarized in columns no. 1 and 2. Columns 3–6 show sedimentary records derived mostly from the analyses of cores collected by freezing *in situ* technique. Some supplementary data come from the uppermost part of profile G1/87. That profile was analysed with much lower time

resolution, and relevant data in Table 9.13 are shown by dashed lines. Column no. 3 describes the changes in sediment formation. The data on lacustrine biota (column no. 4) coming from frozen cores are completed with Cladocera record, transferred from analyses of G1/87 profile (Szeroczyńska, Chapter 8.4). Similarly, in the column no. 5 concerning the content of organic matter and selected minerals, outside the period AD 1840–1965 studied in frozen cores, the CaCO₃ analyses from the core G1/87 (Więckowski et al., Chapter 5.1) were quoted. Variations of chemical composition along the profile are shown in column 6. In the reconstruction of land vegetation (column no. 7) based on palynological studies there is a gap covering the period AD 1779–1818 where the samples were lacking.

The four stages of settlement following historical sources can be recognized in the history of human impact recorded in the Lake Gościąg sediments during the last 330 years: moderate impact phase of small local hamlets (before ca. AD 1770), increasing impact phase connected with the “Hollandii” settlement (ca. AD 1770–1863), German colonization phase (AD 1863–1944) with intensification of agriculture from ca. AD 1910, and phase of reduced rural economy and restoration of natural environment (after AD 1945). This subdivision is partly but not substantially different from the zonation of pollen diagram.

Phase of small local hamlets (before ca. AD 1770)

During this period, besides the dominant pine and mixed pine forests with abundant oak, some more fertile parts of the area were still covered by deciduous woods, and birch copses were frequent on grounds used earlier by man. The local settlement had a form of individual farms spread in the woods, jointly called the Dąb village. The agricultural activity was not very intensive (subzone GF-1a), what is especially well seen at the base of pollen record before ca. 1670 when it can probably be attributed to the general depopulation after Swedish invasion. The coinciding lack of *Bosmina longirostris* in sediments reflects rather low lake trophy. Some activation of farming after 1673 is marked by the distinct evidence of *Cannabis* cultivation (retting in the lake?) dominant till ca. 1710, by increasing crop of cereals (mostly *Secale*) after ca. 1695, and introduction of *Fagopyrum* after ca. 1715. The broad peak of *Aphanizomenon* and *Anabaena* (Cyanobacteria) at AD 1690–1730 indicates lake eutrophication at that time. A distinct fall of economy (GF-1b), connected with the increase of pests, and oppressive tributes resulting in the escape of farmers to towns, is reflected in the Lake Gościąg region after 1740. The area of cultivation was reduced significantly then, what left space for the spread of weeds and heaths (*Calluna*), and enabled small regeneration of deciduous woods (*Carpinus*, *Corylus*), this state prolonging through the next 50 years.