ACTA PALAEOBOTANICA
27 (1): 251—268, 1987

W. NIEWIAROWSKI

DEVELOPMENT OF LAKE STRAŻYM (BRODNICA LAKE DISTRICT) DURING THE LATE-GLACIAL AND HOLOCENE

Rozwój jeziora Strażym (Pojezierze Brodnickie) w późnym glacjale i w holocenie

ABSTRACT. In the place of the present Lake Strażym there existed during the Oldest Dryas a vast shallow lake developed over buried ice in a subglacial channel, which was drained by the Drwęca River. The shallow lake reappeared again during the older part of the Alleröd and was overgrown during the Alleröd younger part. At the end of the Alleröd the buried ice melted completely and the Lake Strażym has come into existence. Its Holocene lowest level was during the Pre-Boreal, c. 9500 BP, lover by 5 m than contemporary. At 6000 BP the level was still lower by 3.2 m and in 4000 BP by 1.8 m than contemporarily. The Holocene highest level — 4—5 m above the present one-existed during the Sub-Atlantic time. Causes of lake level fluctuations are discussed.

INTRODUCTION

Studies on development of Lake Strażym are part of the author's research on subglacial channels on morainic plateaus (Brodnica Lake District) carried out within Research Project MR I/25 "Changes in Poland's geographical environment", coordinated by the Institute of Geography and Spatial Organization, Polish Academy of Sciences. They are also correlated with IGCP Project No. 158 B, coordinated by M. Ralska-Jasiewiczowa of the Institute of Botany, Polish Academy of Sciences. Eight cores frome Lake Strażym deposits were collected from ice on March 6, 1984 and March 12, 1985 with Więckowski's (1961) piston corer. Macroscopic description of the deposits was done by the author and more detailed physical-chemical analyses of profiles 3 and 6 and upper part of profile 1 was done by K. Lankauf. Palynological analyses were done by B. Noryśkiewicz and plant macrofossil analyses in profiles 3 and 6 by U. Boińska. Analyses of *Cladocera* occurrence in profile 3 was done by L. Błędzki. The analyses of ^{18}O and ^{13}C isotope composition of carbonates in profiles 3, 6 and 7 were done by K. Różański. Radiocarbon datings of 7 samples of organic deposits were done by M. Pazdur.

CHARACTERISTICS OF THE BRODNICA LAKE DISTRICT AND OF LAKE STRAŻYM

The Brodnica Lake District, about 630 km^2 in area is a separate mesoregion constituting a part of the Chełmno — Dobrzyń Lake District macroregion (Kondracki 1968). It is situated within the area of the Last Scandinavian Glaciation (Vistulian).

The Brodnica Lake District has a young glacial relief, formed mainly during the Kuyavian and Krayna—Wąbrzeźno subphases — approximately 17 000 years ago — during stops of active ice margin and melting out of stagnant ice. The most important relief features are flat and undulate morainic plateaus end moraines, eskers and kames and outwash plains (Fig. 1). Radial and marginal subglacial channels still hold numerous lakes, the deepest being Lake Zbiczno with 41.6 m depth and the largest Lake Wielkie Partęczyny with 323.9 ha. In the Brodnica Lake District there are about 90 lakes of area over 1 ha (5.6 % of the total Lake District area). Many, especially shallow lakes, have disappeared and the existing ones are surrounded by lake terraces or peatbogs.

A characteristic feature of the subglacial channels is — among others — that after stoppage of glacial water-flow for several thousand years they were conserved by buried ice, covered by glacial or outwash deposits. The best proof is that the channels are common also within outwash plains. The great radial channels despite having been conserved by buried ice, predisposed proglacial outwash waters to flow along their line. After buried ice melt-out, outwash deposits settled on channels bottom or preserved within or in close vicinity in the form of narrow outwash shelves.

The channel holding lakes Ciche—Zbiczno—Strażym—Bachotek is about 14 km long with maximum width of ca 1 km. The lake Strażym joins lake Bachotek through the Skarlanka River which is the tributory of the Drwęca River. Its level fluctuates between 0.8—1.5 m depending greatly on water level fluctuations in the Drwęca River. The lake surface lies 50 m lower than morainic plateau on the east (Fig. 2), which is diversified by kettles and edges transformed by denudational processes. Eastern slope is 8—26 m high and the western 14—19 m. Along its western slope, there have remained fragments of West Brodnica outwash, 100 m a.s.l., and a wide East-Brodnica outwash shelf elevated at 85—90 m a.s.l. In immediate vicinity of the southern part of Lake Strażym there is a large esker fragment within the channel, about 700 m long, and with maximum width of 160 m. The esker separates the channel into 2 parts. In the eastern part, outside Lake Strażym, there is a vast peatbog and vanishing Lake Skrzynka, 3.5 ha in area. In the western part there is also a peatbog through which flows the Skarlanka River. Lake Strażym is a transfluent lake because it is reached by small streams from Lake Skrzynka and Lake Zbiczno and by the Skarlanka River.

According to the measurements of the Inland Fisheries Institute of Olsztyn from 1960 the lake surface at 71 m a.s.l. is 73.4 ha, maximum length is 2 km and maximum width 550 m. 280 soundings show (Fig. 3) that the maximum

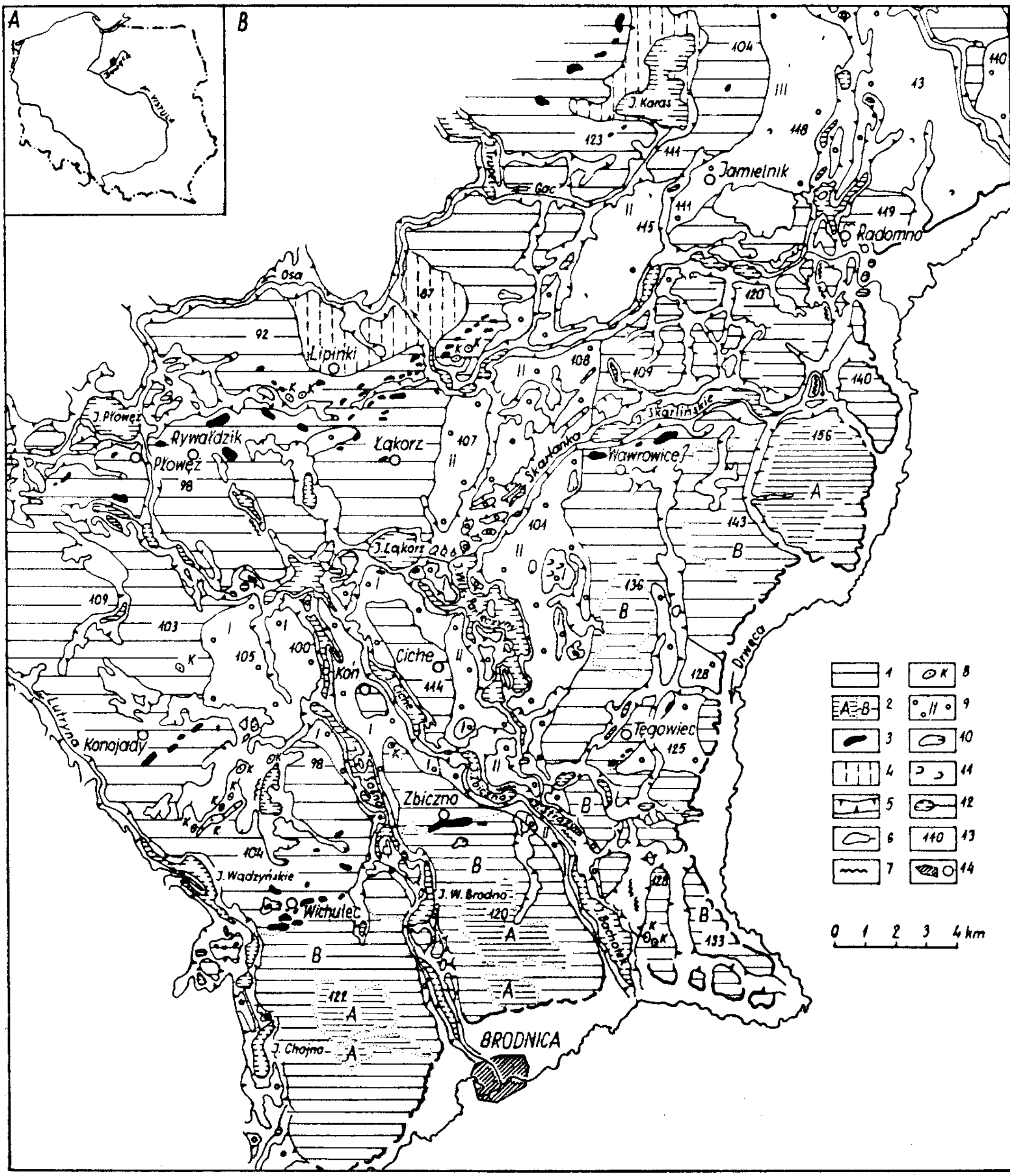
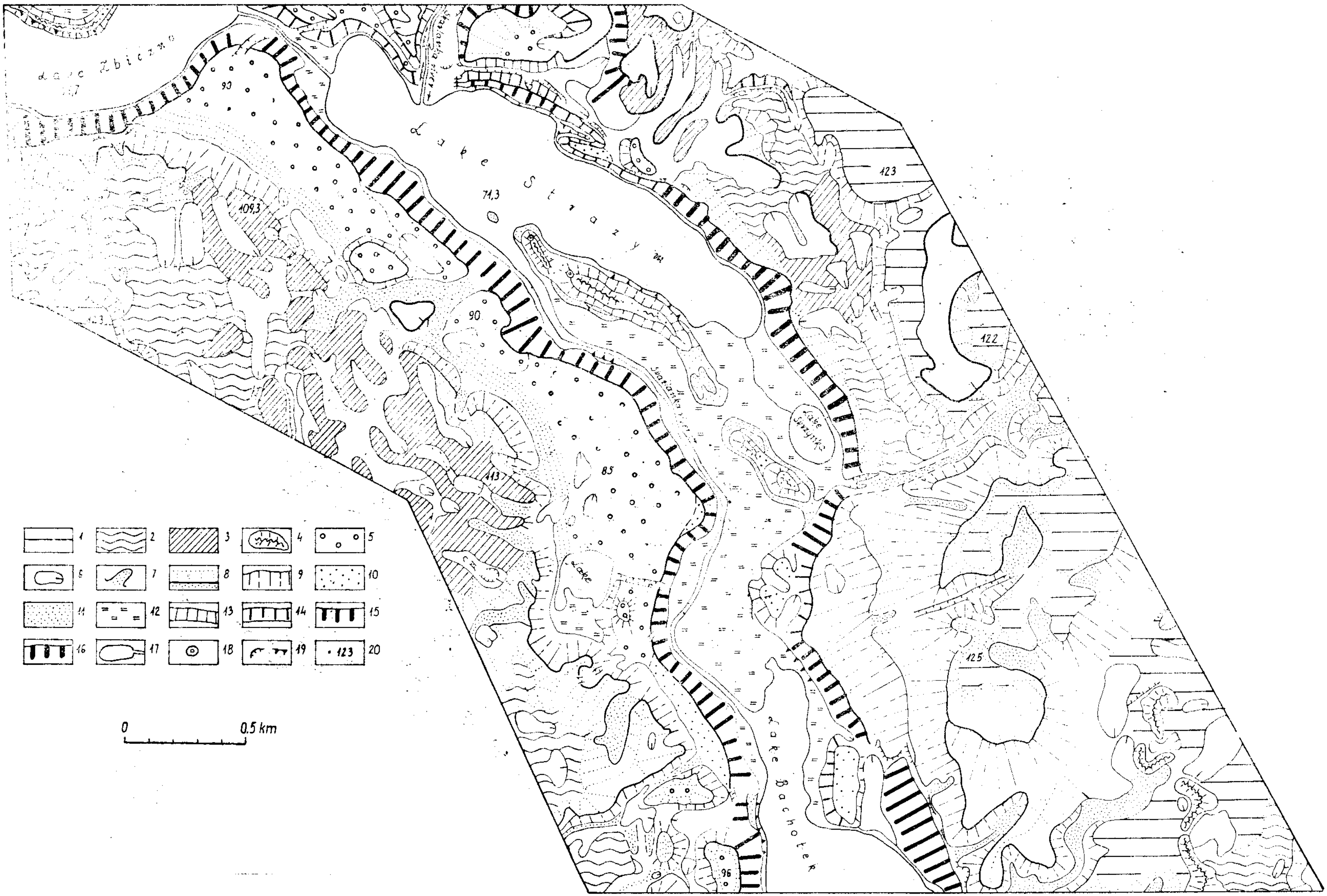


Fig. 1. Geomorphological sketch of the Brodnica Lake District. 1 — moraine plateau; 2 — moraine plateau levels; 3 — end moraines; 4 — terminal basins; 5 — subglacial channels; 6 — elevations in the bottom of subglacial channels; 7 — eskers; 8 — kames; 9 — outwash with levels; 10 — kettles; 11 — dunes; 12 — lakes and rivers; 13 — altitude points; 14 — settlements



Lake Zbiczno
Lake Strażyn
Lake Bachotek
Lake
0
0.5 km
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
123
122
125
109,3
71,3
90
85
96

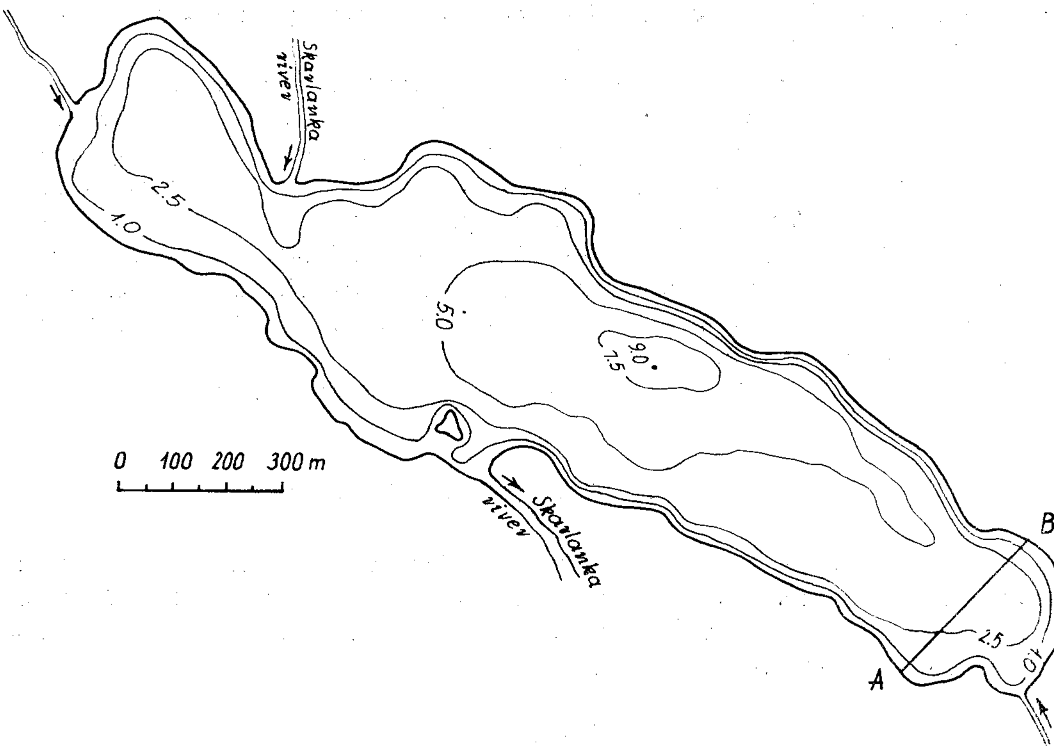


Fig. 3. Bathymetry of Lake Strażym after the Inland Fisheries Institute at Olsztyn. A—B — cross-section of Lake Strażym sediments

depth is 9 m, average depth 3.5 m and the water volume 2.565 thousand m³. Along the cross-section line (Fig. 4) a depth of 7.5 m was found, not considered in this part of bathymetric plan.

Geological structure. The plateau surface is built of a sandy till 5 to 14 m thick. The moraine plateau slope is covered by loamy-sandy denudational periglacial deposits. Below 100 m a.s.l. there are sandy outwash deposits 3—4 m thick. Also fragments of lake terraces are built of sandy deposits with interbeddings of lacustrine marl and chalk. In the bottoms of channels and kettles in lieu of former lakes lie organic deposits, mainly peat and gyttja.

Soils. The moraine plateau is covered by combisols, locally luvisols, while sandy outwash and lake terrace deposits by various podzolic soils. On peatbogs

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Fig. 2. Geomorphological map of the neighbourhood of Lake Strażym. 1 — flat moraine plateau; 2 — undulant moraine plateau; 3 — moraine hummocks and ridges; 4 — eskers; 5 — outwash; 6 — kettles; 7 — lateral valleys (mostly periglacial); 8 — zones of degradation and aggradation; 9 — denudational slopes; 10 — lake terrace from the Oldest Dryas time; 11 — lake terraces from the Subatlantic time; 12 — peat plains; 16 — height of edges: 13 — to 5 m; 14 — 5—10 m; 15 — 10—20 m; 16 — above 20 m; 17 — lakes; 18 — ancient fortified settlement; 19 — scarps; 20 — altitude points

there developed histosols and in the places with lower ground water level — muck soil.

Climate. The Brodnica Lake District, like most of Poland, has moderate transitional climate. The weather variability both annual and multiannual is manifested in mean annual temperature (for period 1881—1960) being 7.0—7.5°C, for January — 3.0 to — 4.0°C and mean July temperatures about 18°C. In 1891—1960 the mean annual precipitation was 514—530 mm (Wiszniewski 1953) and in 1961—1970 — 625 mm (Wójcik & Ziembińska 1984). The number of days with snow cover in 1950—1960 was about 60 cm and snow thickness 5—10 cm. The western winds are predominant. Vegetation period lasts from 193 to 246 days.

Vegetation will be described by Noryśkiewicz (this volume).

BOTTOM DEPOSITS OF LAKE STRAŻYM

The cores have been collected from ice (30 cm thick) in the southern part of the lake along cross-section marked on Fig. 3. In description of profiles ice was included in water and deposits are given from lake bottom surface. The sequence of deposits is as follows:

Profile 1

Depth in m	Sediment description
0.0—1.65 —	water
0.0—0.60 —	dark slime with plant detritus
0.60—1.20 —	fine sand with organic matter in the bottom with plant interbeddings
1.20—1.70 —	peat dated at the top at 4750±50 BP (Gd — 1915)
1.70—4.70 —	gyttja, in upper part (30 cm) detritus gyttja; below calcereous gyttja, at the base with sand admixture
4.70—5.58 —	dark grey sands with silt admixture
5.58—5.64 —	dark gyttja with fragments of wood
5.64—5.94 —	dark grey sands
5.94—6.00 —	dark gyttja with fragments of wood
6.00—6.20 —	light sands with plant detritus

Profile 2

0.00—2.10 —	water
0.00—0.60 —	light fine sands with a great number of mollusc shells
0.60—1.40 —	peat
1.40—4.30 —	gyttja
4.30—4.40 —	sand

Profile 3

0.00—1.75? — water

For this profile no top part of deposits with thickness of 0.5—1.0 m has been collected

0.00—1.46 — peat; its top was dated at 3960±120 BP (Gd — 2266) at depth of 0.55 m — 4990±150 BP (Gd — 2417) at 1.10 m — 5920± 130 BP (Gd — 2419) and at 1.40—1.45 m — 5890±140 BP (Gd — 2265)

1.46—4.75 — gyttja

4.75—5.28 — fine sand with silt admixture, with mollusc shells and humus interbeddings

5.28—5.33 — peat

5.33—5.40 — grey fine and medium-grained sand

Profile 4

0.00—3.80 — water

0.00—0.60 — light grey gyttja

0.60—0.70 — peat

0.70—0.80 — undrilled tree trunk of radiocarbon age 9530±100 BP (Gd — 1786)

Profile 5

0.00—4.60 — water

0.00—1.53 — gyttja with admixture of plant detritus

1.53—1.55 — peat

1.55—1.64 — detritus gyttja

1.64—1.72 — peat

1.72—1.75 — grey sand, fine and medium-grained

1.75—1.76 — peat

1.76—1.86 — grey sand, fine and medium-grained

Profile 6

0.00—5.75 — water

0.00—10.30 — gyttja

10.30—10.40 — sand interbedded with gyttja

10.40—10.45 — peat dated at 11910±210 BP (Gd — 2418)

10.45—10.60 — dark grey sand with organic matter admixture

10.60—10.65 — sand with gravel admixture

Profile 7

0.00—7.50 — water
over 7.8 — grey gyttja — undrilled

Profile 8

0.00—2.65 — water
0.00—0.30 — lake silt with bits of wood
0.30—1.10 — sands with gravel (grain diametr up to 4.0 cm)

The obtained geological cross-section of Lake Strażym sediments (Fig. 4) show that the basin of the lake prior to accumulation had a much more diversified bottom than now. Two channels were distinctive — western shallower

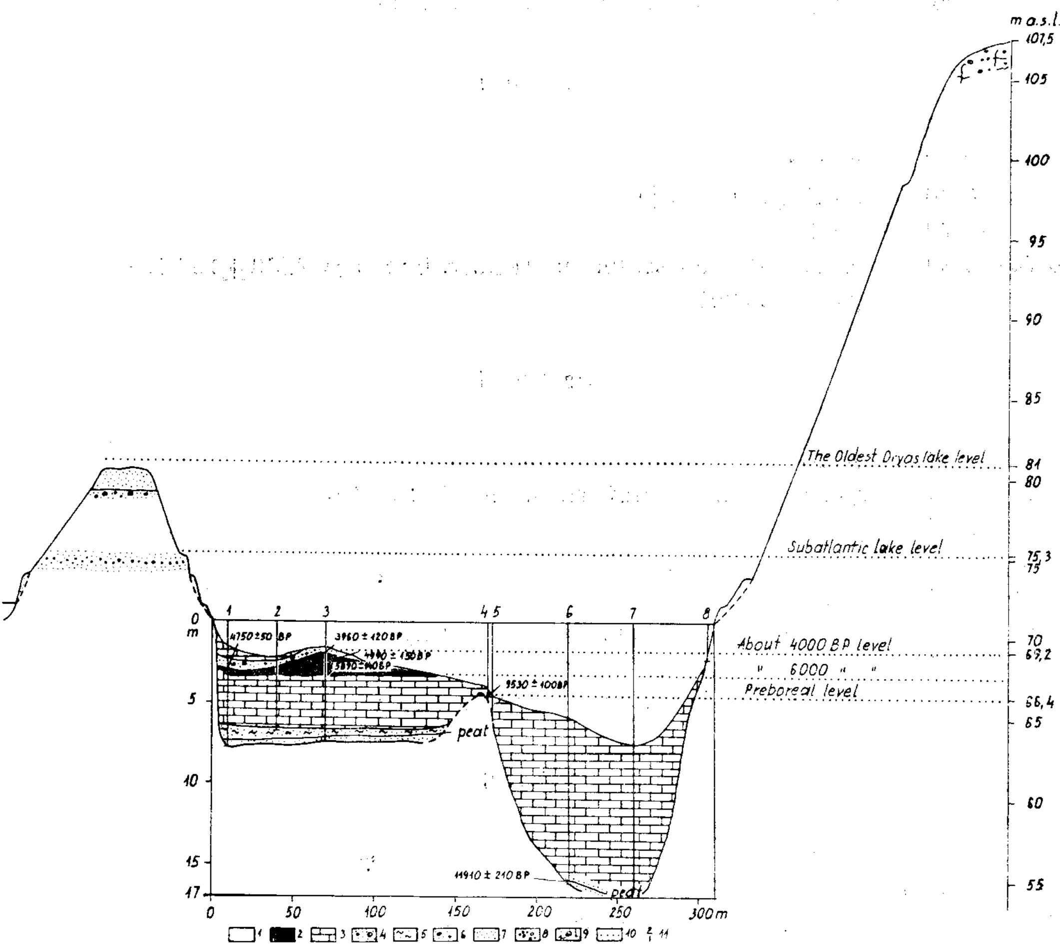

Fig. 4. Cross-section of Lake Strażym sediments 1 — water; 2 — peat; 3 — gyttja; 4 — sands with shells; 5 — silty sand; 6 — medium-grained sand; 7 — fine sand; 8 — gravel; 9 — till; 10 — lake levels; 11 — core numbers

one about 8.0 m deep (63 m a.s.l.) in relation to the present lake level, and eastern deeper channel about 16 m deep (ca. 55 m a.s.l.), separated by an elevation of about 66.5 m a.s.l. Relative height between this elevation and the deepest part of the lake was about 11.5 m. Morphology of the previous lake bottom displays characteristics typical of subglacial channel, with uneven displays characteristics typical of subglacial channel, with uneven bottom and steep slopes. In the western part, 10 m off the shore, the original depth — as compared with the contemporary lake level — was about 7.65 m, and in the eastern part the greatest depth was reached already about 60 m of the lake shore. Only in the eastern part — exposed to wave abrasion, the abrasion platform about 15 m wide has been formed.

There are also great differences in bottom deposits between eastern channel filled only with gyttja and the western channel where above gyttja there is a submerged peat layer. Thickness of lake deposits, disregarding bottom sands, is variable. It is smallest (about 1.8 m) on bottom elevation, in western channel it reaches up to 6.2 m, and in eastern channel exceeds 10.6 m. In this deeper channel lake sedimentation continued independently of lake level fluctuations while in the western part of the lake during 6—4000 years BP the lake had been overgrown by peat.

The bottom layer show significant similarities, starting with fine bottom sands. In most p1ofiles on the sands lies a thin layer of peat with thickness of about 5—10 cm. Radiocarbon age of that peat (11910±210 BP) in profile 6 is probably too high, as palynological analysis points rather to the younger part of the Alleröd chronozone with pine dominance. The peat has been formed probably at the same level (profiles 3 and 6) while the difference in present hight of peat (9.1 m) occurred after dead ice melting.

On the Alleröd peat, or on detritus gyttja there lie fine lake sands with admixture of medium-grained sand or silts, often interbeded with thin gyttja layers. Their thickness at the western shore in profile 1 reaches 1.24 m and in the lake deepest part only 10 cm (profile 6). According to palynological analysis, the sands had been deposited during the Younger Dryas. During that period also the bottom gyttja in profiles 3 and 6 had been deposited. The character of the deposits and occurrence of *Cladocera* fauna (Błędzki, this volume) and macrofossils of aquatic plants (Boińska, this volume) indicate fully developed and deep lake.

Somewhat different deposits are seen at the elevation of the lake bottom. There, in p:ofiles 4 and 5, Pre-Boreal peat with tree trunks was found (profile 4). This shows that at least during a part of the Pre-Boreal period this hummock constituted a forest bearing island. The profile documents quite accurately the height of lake level at the time. The Younger Dryas deposits and the Pre-Boreal peat at the hummock are covered by gyttja of varying thickness. In the shallower western part on gyttja lies a submerged peat layer dated between 5900 and 3900 BP. These dates and the peat layer permit a precise fixing of lake level at that time. Variable thickness of peat (0.40—1.46 m) is due to the fact that the upper peat layer in profiles 1 and 2 had been removed during later lake transgression. This is supported by dating of top peat horizon in profile 1, which is older by 800 years than in profile 3. Occurrence of aquatic plants in top part of peat in profile 3 proves that submergence of peat began about 4000 yrs BP. Occurrence of gyttja and sands on peat proves that later lake conditions settled again.

WATER LEVEL FLUCTUATIONS OF LAKE STRAŻYM

Hitherto knowledge and dating of bottom deposits of Lake Strażym permit a relatively precise determination of lake level position during some periods but they do not permit a correlation of all fluctuations found in Northern Poland (Ralska-Jasiewiczowa & Starkel in press). However, additional data are supplied by geomorphological and geological data from the whole channel of lakes Ciche—Zbiczno—Strażym—Bachotek. I found in this channel (Niewiarowski 1983, 1986) proofs for occurrence of two generations of lakes: an older lake existing before melting of buried ice and younger after melting. A proof of older generation is the occurrence of lake terraces at 82—78 m a.s.l., that is about 7—11 m above the present level of lakes. The height of former lake cliffs permits a conclusion that it had been a vast but shallow lake whose depth did not exceed 2—4 m. Most often there is found only one lake terace but at some places as e.g. SW part of Lake Bachotek 2 terraces are, separated by a 1 m high cliff.

These older lake terraces are built mainly of fine and medium-grained sands, locally with silt admixture and in some places laminated, derived from the adjacent terrain. For example, around Lake Zbiczno outwash plain is built of fine sands and their percentage in lake terrace reaches 83%. In SW terrace of Lake Bachotek situated at the foot of moraine plateau the fine sand percentage is 25—56%, and medium-grained sand is 32—48%.

Lacustrine origin of these sands is documented by occurring therein carbonate deposits with thickness up to 1.1 m, of lacustrine silty marl containing 37% $CaCO_3$, or lacustrine silty chalk with $CaCO_3$ contents up to 83%. Only in carbonate deposits a small amount of organic matter occurs. In sands there is no organic matter either pollen. Besides local occurrence of calcareous deposits, the terrace sands are without $CaCO_3$ or its contents reach 1—2% only. The thickness of lake deposits ranges from 1 m to 2.6 m.

The age of the older generation lake is difficult to establish exactly due to absence of organic matter for radiocarbon dating and of pollen. In the vicinity of the lake, sands from lake terrace at 79 m a.s.l. were dated by J. Butrym at Lublin thermoluminescence (TL) method. Sand sample from 0.8—1.0 m depth showed the TL age 11600±1700 BP (Lub — 779), and from depth of 1.8—2.0 m 12000±1800 BP (Lub — 780). Due to a large measurement error the TL data can be treated as approximate. Above mentioned lake terraces join the VII and VI terraces of the Drwęca River what make possible parallelisation. On the basis of age determination of higher terraces (XI—IX) of the Drwęca River (Niewiarowski 1969) and overflood terrace (Niewiarowski & Noryśkiewicz 1983) their age may be estimated at the Oldest Dryas, i.e. 13000—14000 years BP, which is not contradictory to the TL datings. The lake of older generation existed prior to buried ice meltout what is proved by existing kettles and subglacial channels branches not filled by lake deposits. Absence of Late Glacial terraces below 78—79 m a.s.l. indicate that the lake had been drained by the Drwęca River and disappeared already in the Oldest Dryas. The older generation lakes were also found in other channels on the Chełmno — Dobrzyń Lake District (Niewiarowski 1986). It is assumed earlier (e.g. Stasiak 1971, Czeczuga 1975) that e.g. on Masurian and Suwałki Lake Districts after the drainage of proglacial lakes waters, there followed a several thousand years long lakeless period and that new lakes appeared in the Alleröd. The existence of the lakeless period may be referred to maximum of Pomeranian phase (about 15000 BP) when on the forefield of inland ice a polar desert existed. Later however there existed appropriate conditions for shallow lake formation, developing above buried ice. Lake sand cover on esker in the vicinity of Lake Strażym and on channel slope permits to draw the conclusion that such lake existed also in the basin of Lake Strażym. The water level was approximately at 83—82 m a.s.l.

It should be stressed that the phase of lake basin conservation by buried ice through several thousand years is rather a peculiarity in this part of Peribalticum where thickness of glacial and aqueoglacial deposits from the last inland ice is several tens of meters, thus creating favorable conditions for burying dead ice. In Scandinavia or English Lake Districts with a thin cover of glacial and aqueoglacial deposits no clear phase of lake basins conservation by buried ice has been found. Pennington (1981) finds that in the English Lake District lake deposits about 14000 years old lie directly on glacial or fluvioglacial deposits. In Southern Sweden, and also in Northern Estonia very often in the bottom of lake deposits there lie varved clays which are a proof of gradual transition from proglacial lakes to Late Glacial lakes, with no lakeless phase. This may result also from the fact that shrinkage of inland ice there took place under much milder conditions of Late Glacial climate.

Another problem is to determine exactly the time of formation of younger generation lake at Strażym and meltout of buried ice conserving lake's basin. On the basis of examination of deposits underlying Alleröd peat and *Cladocera* remains found in it (Błędzki, this volume) and macrofossils of aquatics (Boińska, this volume) it may be stated that initially there appeared a lake during the Early Alleröd, presumably shallow, in which sands sedimented. Its shallowness is proved by the fact that during the warmer part of the Alleröd it had been overgrown. This lake existed above buried ice. The great differences in the present position of the peat in various parts of the lake and the fact that during the Younger Dryas, apart from sands, also gyttjas were deposited, and *Cladocera* fauna and macrofossil indicate a high lake level at that time, it can be stated that complete meltout of buried ice in the basin of Lake Strażym took place at the end of the Alleröd chronozone and the contemporary Lake Strażym has existed since that time.

The opinion that the Alleröd period had been the period of common melting out of buried ice not preclude the possibility that shallow buried ice and small thickness ice had melted out earlier, even in the Oldest Dryas, nor that deeply buried ice and great thickness ice could have melted out even during the early phases of the Holocene.

There are no sufficient and adequate data that would allow to determine exactly the level of Lake Strażym at the end of the Alleröd and Younger Dryas, but from the fact that neither in the surroundings of Lake Strażym nor on the entire Brodnica Lake District there is a lake terrace from that period we can infer that the lake level had been lower than that of modern lakes. There is, however, the evidence that about 9500 BP (Pre-Boreal) it was at about 66 m a.s.l., then lower by 5 m than the present level. During that time the depth of lake along cross-section line (Fig. 3) was about 2—10 m. Occurrence of peat with tree stumps on bottom elevation indicates that the peat lies in situ and that the island had been forested.

Bottom deposits of Lake Strażym offer no immediate evidence about lake level during the period between 9530 and 5890 BP. It may only be suggested that the level had not been lower than 66.4 m a.s.l. and not higher than modern level of the lake because no lake terrace from the older part of the Holocene was found in the vicinity of Lake Strażym and in the entire Brodnica Lake District.

Datings of bottom and top of submerged peat lying in the western part of the lake prove conclusively that peat growing began here about 6000 BP with the lake level about 68 m a.s.l. (3.2 m below the present level) and ended at the level of contemporary peat top in profile 3 about 4000 BP at the level of about 69.5 m a.s.l. (1.80 m below present level). Lack of hiatuses in peat or of sand and gyttja interbeddings proves that during peat accumulation the lake level rose by about 1.5 m and that no great lake level fluctuations occurred at the time. It is not excluded that peat top in profile 3 was eroded and therefore it is impossible to date exactly the time of peat submergence and reccurrence of lake conditions in the western part of the lake. The occurrence of aquatics in top part of the profile suggest that peat flooding indeed commenced about 4000 BP, but in profile 1 of deposits from the Sub-Atlantic occurrening on peat suggest the relatively rapid rise of lake level at the beginning of the Sub-Atlantic time. Further proof is supplied by Sub-Atlantic lake terraces developed in the Brodnica Lake District, which are the evidence of the lakes level rise of 4—5 m above the present lakes level. It was the maximum lake level rise during the Holocene. On the eastern shore of Lake Strażym there are fragments of lake terraces of that age of 2.0—2.7 m and about 3.5 m high. Fragments of these 2 terraces are found also in the channel of lakes Ciche—Zbiczno—Bachotek, in the channel of the Brodniczanka and Skarlanka Rivers, the higher terrace reaching up to about 4.0—4.5 m and the lower terrace being mostly 2—3 m high. During formation of the higher terrace the water level in lakes Strażym and Bachotek lay at about 76 m a.s.l.

These lake terraces are built mainly of sands with silt admixture and shells of molluscs. Quite common interbeddings of carbonate deposits of lacustrine marl and chalk with organic matter content ca. 6% are. Locally carbonate deposits lie on the surface. Absence of peat layers within terrace deposits and poor occurrence of plant pollen in carbonate deposits makes it difficult to determine the exact age of terraces. Nevertheless, two radiocarbon datings obtained so far and approximate determination of peat submergence in Lake Strażym prove that they are terraces of the Sub-Atlantic time. On the narrowing between lakes Zbiczno and Karaś, lying 3.5 m above Lake Zbiczno level, built of lake deposits, in silts with great admixture of organic matter and mollusc shells at the depth 2.5 m the radiocarbon age was 2370 ± 50 BP (Gd — 1374) and in the narrow arm of Lake Bachotek in which the bottom now rises about 2.0 m above lake level in lacustrine silts at depth of 0.8 m the radiocarbon age was 2610 ± 50 BP. Both datings show that the maximum level of the lakes in the Holocene was younger than these two datings.

Basing on the results obtained in the Brodnica Lake District it is possible to state that since the end of the Alleröd lake level fluctuations are sinchronous and that the main cause of these fluctuations, to the time of intense human activity, may be primarily climatic changes. The influence of human activity on the lake level fluctuations in this region is indistinct and little known. It is only known that regulatory and drainage works conducted in the valleys of the Drwęca and Skarlanka rivers caused the ground water level to fall by 0.5—0.7 m (Glazik 1970). Lake level lowering related to this human activity may have been of the same order. It is quite likely that deforestation and cultivation caused lake level to rise but this cannot explain its great variation in the Sub-Atlantic. Probably climatic changes overlap with those caused by human economic activity.

COMPARISON OF LAKE STRAŻYM WATER LEVEL FLUCTUATIONS WITH OTHER LAKES IN NORTHERN POLAND

Our knowledge about the lakes evolution has many gaps and dating of palaeohydrological events is little precise. It is also known that causes of lake level fluctuations are diversified (geological, climatic, human activity) and it is not always clear which of them played the most important role and whether they have a general or merely local or regional character. The rises or falls of lake level in hitherto studies are seldom expressed metrically or referred to the modern level. There are too few general studies taking into account all possible methods. Under such circumstances it is possible only to discuss general trends in evolution of lakes.

An important problem in palaeohydrological studies of Northern Poland is to determine when lakes began to appear after the deglaciation and drainage of proglacial lakes. Often expressed opinion (e.g. Stasiak 1971, Czeczuga 1975, Ralska-Jasiewiczowa & Starkel, in press) that lakes in Northern Poland appeared as late as the beginning of Alleröd, preceded by a lakeless period is — in my opinion — untenable. A documented finding that there had existed in the Chełmno—Dobrzyń Lake District (Niewiarowski 1986) an older generation of lakes (Pre-Alleröd) clearly opposes such an opinion. Existence of Pre-Alleröd lakes has been documented in the Janoszyce channel by Lamparski (1979), in the channel of Lake Gopło (Niewiarowski 1978) and on the GDR teritory (the so-called "protogene Seen") by Nitz (1986) and others. They were relatively shallow lakes developed over buried ice and their water level, as a rule, higher than contemporary lake levels were conditioned by lowerings filled with buried ice and by much higher level of riverbeds.

In the channel of lakes Ciche—Zbiczno—Strażym—Bachotek an older generation lake existed most probably during the Oldest Dryas but in other areas they may have existed during various phases of the Late Glacial, while in the areas of the Leszno and Poznań phases even before and during the Pomeranian phase. They disappeared as a result of river (drainage) development and the trace of their existence are mineral lake deposits which mostly lack plant remains and pollen, thus they have not been the subject of palynologists' interest. It is also possible that some sandy-silty levels in the subglacial channels, regarded as kame terraces, are remnants of those lakes.

An important problem of lake level fluctuations is the time of definite meltout of buried ice. It is beyond doubt that is was a long period, dependent on the ice volume and thickness of covering deposits. The ice meltout caused the lake bottom to fall. Kozarski (1962) assumes that definite buried ice meltout in the Great Poland took place already during the Alleröd. That is when happened in Lake Gopło, the largest lake of the Kuyavian Lake District (Niewiarowski 1978) in the basin of Lake Strażym and most probably in lakes of the whole Chełmno — Dobrzyń Lake District. In regard to the Masurian Lake District, Więckowski (1966) suggest that in the channel of Lake Mikołajki dead ice melted out at the Alleröd/Younger Dryas transition, Stasiak (1971) also refers the beginnings of Masurian lakes to the Alleröd period but she claims that the Alleröd melting out was not complete and the process continued during the Pre-Boreal and Boreal ending at the beginning of the Atlantic period. The view is rather isolated and requires confirmation. It is obvious that in the basins where the process was completed during the Alleröd (in my opinion it was in most cases) the lake level was controlled primarily by climatic changes like in rivers thus displaying similar trends to water level fluctuations.

In Poland and elsewhere there are few papers in which lake level fluctuations are expressed quantitatively and reffered to contemporary lake level. Such lake level curves for Masurian lakes are offered in the works by Kondracki

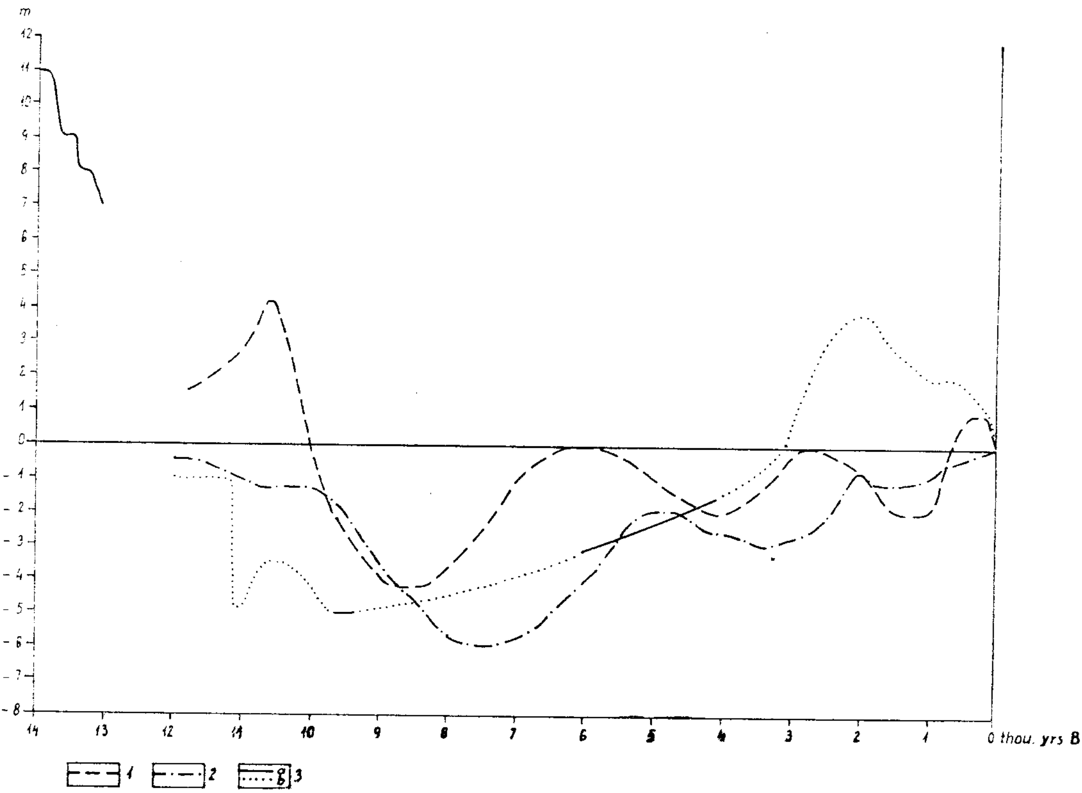

Fig. 5. Curves of the oscillations of lake levels. 1 — Great Masurian lakes, after Kondracki (1969); 2 — lakes of the Masurian Lake District, after Stasiak (1971); 3 — Lake Strażym, a — established; b — presumable, after author

(1969) and Stasiak (1971). They are presented on Fig. 5 — which includes also results of studies on the Brodnica Lake District. According to Kondracki (1969) during the Alleröd, Younger Dryas and at the beginnings of the Pre-Boreal the lake level was higher than now, and according to Stasiak (1971) it was higher than in the later periods but lower than contemporary. Our results from the Brodnica Lake District are more in accord with Stasiak's view.

In Lake Strażym the lowest water level was found in the Pre-Boreal about 9500 BP, while Kondracki (1969) and Stasiak (1971) claim the lowest level in Boreal. The low lake level in the Pre-Boreal (c. 10000—9500 BP) according to Gaillard (1985) is found commonly in Scandinavia and Central Europe and is certainly connected with relatively warm and dry climate. This ought to be reflected also in other lakes existing since the Alleröd in Northern Poland. It is worth mentioning that the lowest level in Lake Strażym during the Pre-Boreal coincides with the lowest situation of the lower Vistula River channel at the beginning of the Holocene. It is possible that later rise of the lake level and flooding of Pre-Boreal peat is related to more humid climate phase during the 8500—8000 BP period (Ralska-Jasiewiczowa & Starkel, in press), but this rise must have not been very important because lake level was much below the present state.

Results of studies on Lake Strażym level fluctuation confirm the results obtained by the authors who find that throughout most of the Boreal and during the Atlantic period the lake level was relatively stable and still lower than modern level. Level fluctuations curve for this lake during the Atlantic period is similar to Stasiak's curve (1971) and greatly differs from Kondracki's (1969) curve, who believes that the level of Masurian lake rose to the contemporary level.

As has been stated before, in Lake Strażym during the period 6000—4000 BP water level rose by about 1.5 m. It is possible that this rise was due to the more humid climatic phase distinguished by Ralska-Jasiewiczowa & Starkel (in press) during the period 5000—4400 BP. So far, no evidence has been found in Lake Strażym for the fall of lake levels during the period 3500—3000 BP, commonly found in Scandinavia and other areas in Europe (Gaillard 1985), what does not preclude its existence. There is, however, a lot of evidence in the Brodnica Lake District for lake level rise of at least 5 m during the Sub-Atlantic time, which is the highest in the Holocene. Kondracki (1969) believes that in great Masurian Lakes the water level increased to present-day level during 750—400 BC, fell by 2 m during 1000—1400 AD, and reached maximum level, higher by 1 m than now, during the period 1500—1800 AD. Stasiak (1971) believes that the lake level of Masurian lakes rose at the beginning of our era but not exceeding contemporary level. It should, however, be added that Korolec (1968) claims existence of Sub-Atlantic lake terrace 1.5—2.0 m above the recent level of laye Mikołajki, and Stasiak (1971) found in the Suwałki Lake District lakes of the Sub-Atlantic age in lowerings not water-logged before, what proves high level of underground waters. Also Czeczuga (1975) accepts for Lake Wigry and other lakes of North Eastern Poland a maximum rise in the Holocene during the period 2470—1970 BP. In Lake Pakość on Kuyavian Lake District I found the water level rise above the level of 1975 shortly before Hallstadt D, while maximum level was about 2100—1900 BP (Niewiarowski 1976). It is quite likely that the maximum level in the Brodnica Lake District occurred also during that time in connection with humidification of climate, assumed to occur in Western Europe 3000—2500 BP (Ragnon 1983), and according to Shnitnikov (1973) in most of Europe during 2400—1900 BP. According to Ralska-Jasiewiczowa & Starkel (in press) this rise started between 2800—2400 BP. Gaillard (1985) states that the phenomenon of remarkable rise of lake level after 3000 BP was common in Scandinavia, Great Britain and Central Europe. Hence the suggestion by Ralska-Jasiewiczowa & Starkel (in press) that lake level changes in Northern Poland after 4500—4200 BP were metachronous and that there is little evidence for lake level rise around 2500 BP seems little substantiated. Dispite unquestionable influence of human activity on lakes at the time, the rise of lake level in various regions, especially that of large lakes, was primary influenced by climatic conditions.

AKNOWLEDGEMENTS

I would like to express my gratitude to all my colaborators and students for their help during field research and to Dr. M. Banach for his help in collecting sediment samples.

Institute of Geography, Nicholas Copernicus University, ul. Fredry 8, 87-100 Toruń
Instytut Geografii UMK

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