ACTA PALAEOBOTANICA
XXII (1): 47—63, 1982

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MAJOR ASPECTS OF THE VEGETATIONAL HISTORY IN THE EASTERN BALTIC COASTAL ZONE OF POLAND

Główne problemy historii roślinności wschodniej części polskiego Pobrzeża Bałtyku

ABSTRACT. Three profiles from the Lake Żarnowiec area in Northern Poland have been analysed for their pollen content. These results are presented as total pollen diagrams. 21 radiocarbon dates permit the use of a time scale. Eight pollen assemblage zones are described which cover the period from around 11 000 years BP to the present day. The diagrams show that man's impact on the vegetation began already in the early Neolithic. Settlement of this area was most intensive during the Hallstatt C and D periods and the Middle Ages.

INTRODUCTION

This paper contains the most important results of the palynological analysis of cores from the Lake Żarnowiec area in Northern Poland. This area has been included as a reference area to Project 158-B of the International Geological Correlation Programme. The area is representative of the eastern part of the Baltic coastal zone sub-region within the region of Western Pomerania (see p. 4 of this volume). A basic feature of the flora of this sub-region is the occurrence of species of the Atlantic element s. l. (Czubiński 1950). Fig. 1 illustrates the position of the investigated area in relation to the range limits of a number of interesting species. Complete palynological material, results of macrofossils analysis, basic physical and chemical properties of sediments, and data relating to human interference and the history of the basins are presented in the dissertation: "Postglacial vegetational changes in the eastern Baltic coastal zone of Poland" (in print).

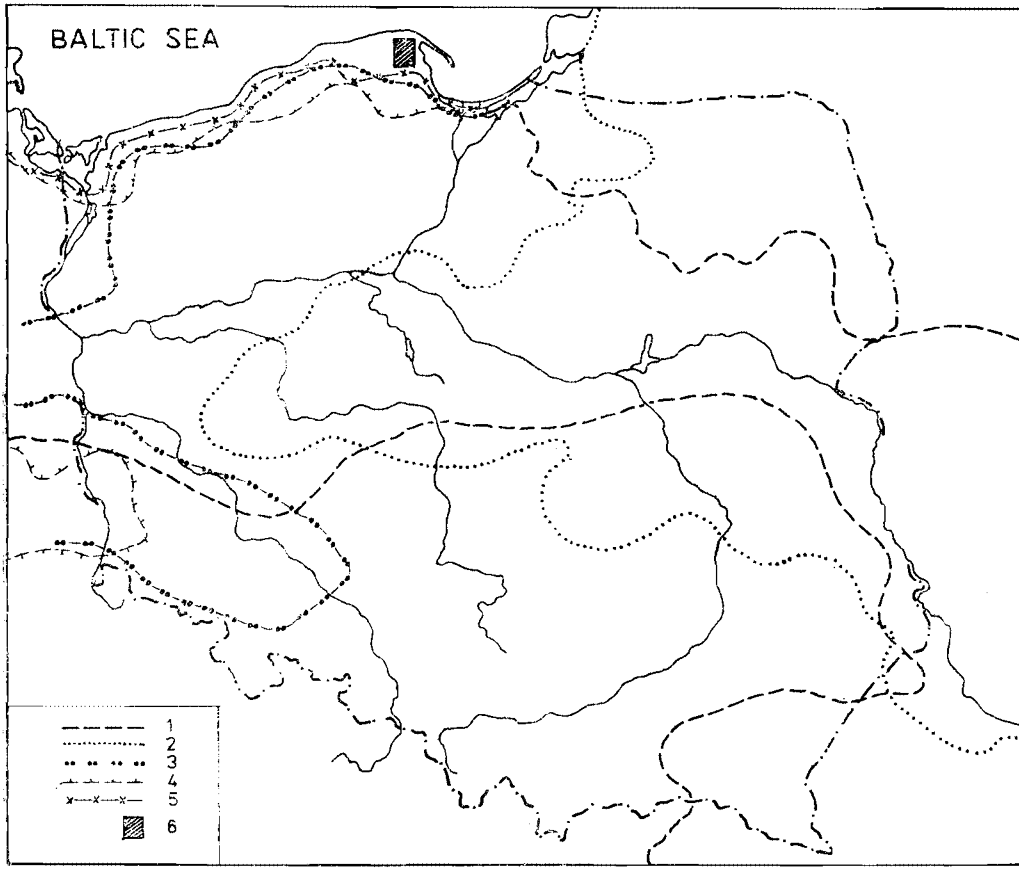

Fig. 1. Location of the study area with respect to the range limits of selected species (after Szafer 1972)
1 — *Picea abies* (NE and SW limits); 2 — *Fagus sylvatica* (NE limit); 3 — *Lonicera periclymenum* (E limit); 4 — *Myrica gale* (SE limit); 5 — *Erica tetralix* (SE limit); 6 — study area

PHYSIOGRAPHICAL OUTLINE

Geomorphology and soils

This area was formed by the action of the last glaciation. The environs of Lake Żarnowiec belong to those areas which in comparison with other parts of Poland remained longest under the ice (Fig. 2).

The dominant morphological forms are Pleistocene uplands of flat or slightly undulating ground-moraine and a well-developed system of deep ice-marginal valleys. The moraine hills are mostly built of boulder clay and loamy sand on which brown soils have been formed (more rarely, pseudopodsolic soils). In the vicinity of Lake Żarnowiec these soils do not contain calcium carbonate; they are leached and acidic. In the ice-marginal valleys and tunnel-valleys, covered mainly by peats, the soils are hydrogenic. To the south of the lake, the Piaśnica outwash plain occupies a fairly large area. This is composed of outwashed sands and gravels, over which poor sandy soils predominate. However, the irregular depth of outwash plain sands and the patches of gla-

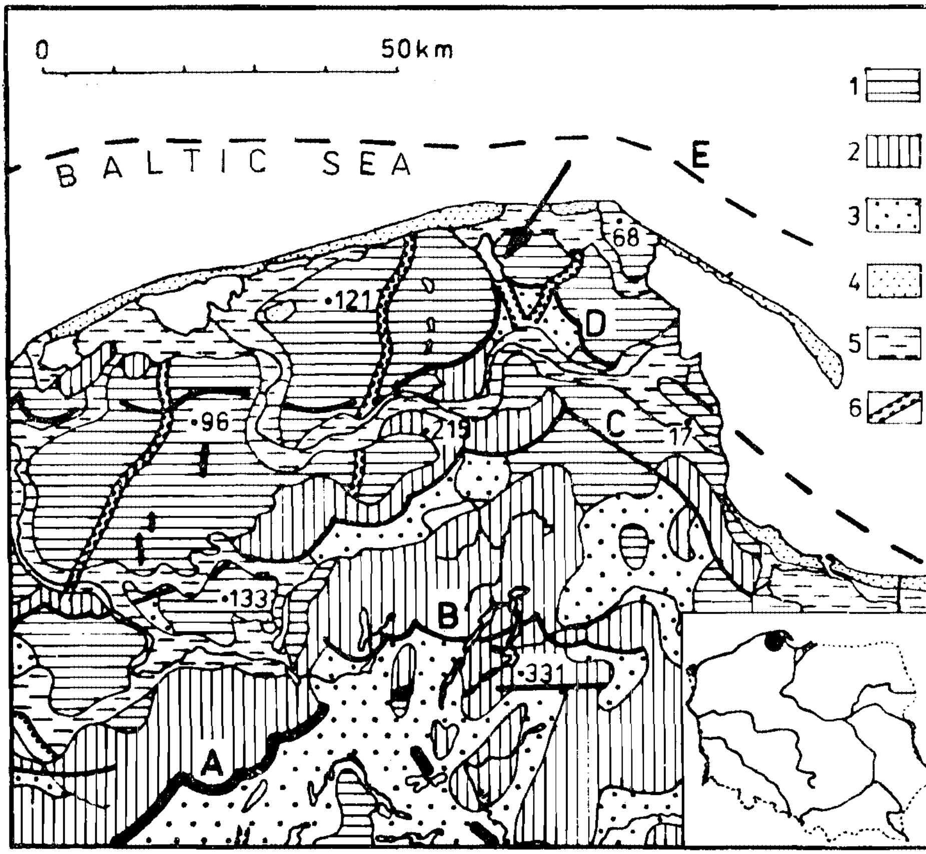

Fig. 2. A geomorphological outline of the recession stages of the last icesheet in the eastern part of Western Pomerania (after Liedtke 1975). 1 — flat or undulating moraine landscape; 2 — hummocky moraine landscape; 3 — outwash plain; 4 — inland dunes, blown sand areas, high shore dunes; 5 — bogs; 6 — main subglacial channels. Stages and phases in the recession of the ice-sheet: A — Pomeranian stage; B — Szczecin phase (Kashubo-Warmian); C — Koszalin phase; D — Gardno phase (Copenhagen); E — Bornholm phase. The arrow indicates Lake Żarnowiec

cial drift covering the surface in many places have effected quite a wide differentiation of the soils occurring here (Augustowski 1969; Witek, Byczkowski & Chalecki 1974).

Climate

An essential feature of the climate of this area is the influence of the sea. The proximity of the Baltic gives a high air humidity with relatively cool summers and mild winters: mean January temperatures range from —0·5 to —1°C, July means from 16 to 17°C; the annual mean is 7—7·5°C. The mean annual rainfall is around 600 mm (Kwiecień & Taranowska 1974).

Present-day vegetation

The present-day plant cover around Lake Żarnowiec is to a great extent the consequence of human activities. By far the larger part of the area has been deforested and occupied by pasture and arable land. The bogs lying in the ice-marginal valleys and tunnel-valleys have been almost entirely drained and cultivated.

The remains of forests on the moraine upland are comprised for the most part of beech. There are several types of beech community, *Luzulo-Fagetum* being prevalent among them. Mixed forest *(Pino-Quercetum)* are to be found on the moraine formations, especially in the transition zone between the upland and outwash plain. Among communities containing pine, a relatively large area of the south-eastern part of the Piaśnica outwash plain is covered by pine forests (*Vaccinio myrtilli-Pinetum* s. l.). Hornbeam forests *(Stellario-Carpinetum)* are found over small areas only, though their survival suggests they were more widespread in the past (Dąbrowski 1978).

Archaeology

The oldest archaeological data from the neighbourhood of Lake Żarnowiec come from the Neolithic period. The peoples of successive Neolithic cultures were engaged in animal husbandry and fishing, cultivation being of lesser importance. The number of archaeological finds increases in the late Bronze Age along with the influx of the Lusatian culture (Kashubian group) which flourished during the early Iron Age (Hallstatt C). Agriculture was intensified during this period. Further settlement was by peoples of the Eastern Pomeranian culture (Hallstatt D) (Łuka 1977); after this, the rate of colonization declined. The Lake Żarnowiec area was practically uninhabited during the 5th and 6th centuries AD (Migration Period) (Szułdrzyński & Żurawski 1978). Settlement gathered momentum again in the early Middle Ages (c. 9th century), and since that time, the area has been continually subject to human activity.

DESCRIPTION OF LOCALITIES

The localities from which profiles were taken for pollen analysis differ with respect to the size of sedimentation basin and to the topographical position. They were to be representative of past vegetation both local and regional (Fig. 3).

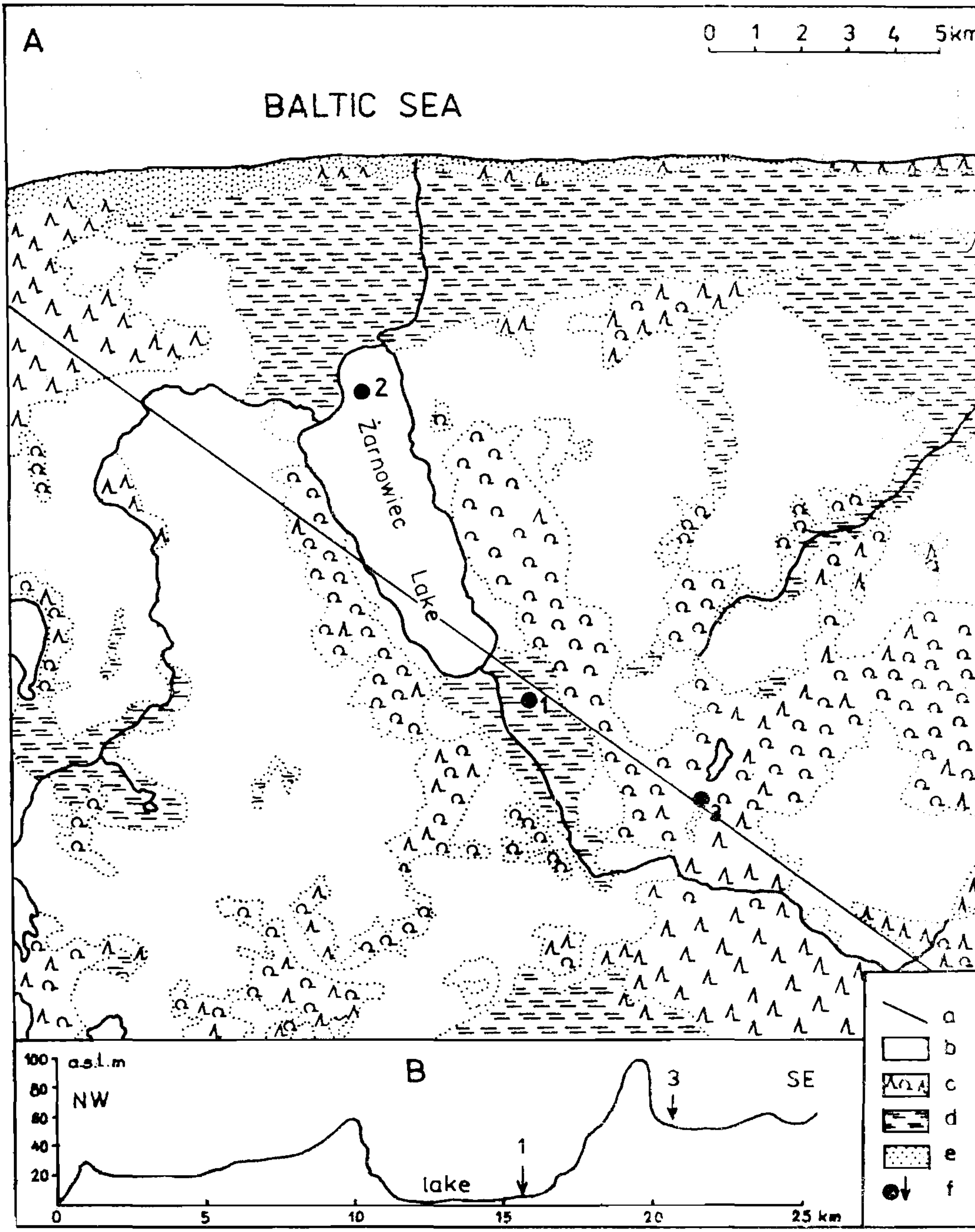

Fig. 3. A— Sketch map showing the vegetation of the study area and the position of the localities. a — line of geomorphological cross-section NW—SE; b — deforested areas (pasture and arable land); c — forests; d — peatbogs; e — coastal sand-dunes; f — positions of localities: 1 — profile Żar/76, 2 — profile J. Żar/78, 3 — profile P. Darż/78. B — Geomorphological cross-section along line a

Lake Żarnowiec (locality 2)

The lake is situated in the northern part of the Lake Żarnowiec channel. The channel is 13 km long and has a maximum width of about 3·5 km. The maximum height of the surrounding moraine hills is about 100 m a.s.l. They are largely covered by forests, the dominant communities being beechwoods and acidophilous oakwoods. The river Piaśnica flows down along the axis of the valley (Dąbrowski 1978).

It is an open lake, differentiated with respect to depth and the formation and thickness of bottom sediments. Deposits of calcareous gyttja, up to 20 m thick, are of great importance in these sediments. The maximum depth of water in the centre of the lake is 19·5 m. The profile was taken from the northern part of the lake where the water is shallowest, about 2 m deep. The lake is mesotrophic, though with a strongly eutrophic littoral zone (Ozimek & Pieczyńska MN). The location of profile J. Żar /78 is about 400 m from the western shore and 1·5 km from the northern end of the lake.

Peat-bog near Lake Żarnowiec (locality 1)

The peat-bog is situated in the southern part of the Lake Żarnowiec tunnel-valley. The peat-bog vegetation is devastated; at present, meadow communities of the *Cirsio-Polygonetum* type are dominant. Swamp species and some low-moor species occur in places. The profile Żar/76 is located some 2 km to the south of the lake.

Peat-bog in Darżlubie Forest (locality 3)

This locality lies within the upland area (Fig. 3B), in the tunnel-valley of Lake Dobre. The valley is c. 100 m wide here, its slopes are somewhat raised and grown over with pine and oak-pine woods. Wet meadow communities of the order *Molinietalia* cover the surface of the peat-bog. Typical low-moor and transition bog species occur in the flora of these meadows. The location of profile P. Darż/78 is about 1 km to the south-west of Lake Dobre.

METHODS

Laboratory methods

The peats were sampled using a Russian "Instorf" corer 10 cm in diameter. The bottom sediments from Lake Żarnowiec were taken with a Boros corer; the topmost sediment layers (37–125 cm) were sampled with a plastic tube 5 cm in diameter.

Samples for pollen analysis were taken with a volumetric sampler of 1 cm^3. To calculate the sporomorph concentration per cm^3 of sediment, tablets containing *Lycopodium* spores were used (Stockmarr 1971, 1973). As the sporomorph frequency in the sediments was generally low, two spore tablets per sample were usually used. The minimum number of sporomorphs counted was 1000 tree pollen grains. In the samples with very low pollen frequency also in the Late Glacial spectra, counting was restricted to 1000 grains of AP+NAP. Pollen grains on the whole area of the cover-slip were counted.

Diagrams (Figs. 5, 6, 7 under the cover)

The diagrams in this paper include only the pollen curves of trees and shrubs, total curves for NAP, light-demanding plants (incl. also ***Betula***, ***Populus***, *Salix*, *Juniperus*) and culture indicators s. l. The calculation sum for the AP diagrams is AP=100%, while that for NAP curves, heliophytes, culture indicators and the bottom profiles sections (down to zone 2 inclusive) is AP+NAP=100%. The diagrams are based on a time scale, that facilitates comparison of profiles in which the various sections differ as to the accumulation rate of sediments. In the topmost and bottom sections of diagrams Żar/76 and P. Darż/78, and in the whole diagram J. Żar/78, this time scale is approximate because of the lack of ^{14}C dates.

Zonation

The diagrams have been divided into biostratigraphic units which correspond to pollen assemblage zones (PAZ) (Birks & Berglund 1979; West 1970). In order to facilitate comparison with other pollen diagrams, the Blytt-Sernander system of division has also been applied.

^{14}C DATING AND SEDIMENT ACCUMULATION RATE

Radiocarbon dating was carried out in the ^{14}C laboratory of the Silesian Polytechnic in Gliwice. The age of the samples was calculated assuming a ^{14}C half-life of 5568 years (uncorrected).

In calculating the accumulation rate, the mean age of samples 16 and 17 (8830±65 BP) was used; sample 18 was not taken into account.

Profile Żar/76 and P. Darż/78 differ considerably with respect to the accumulation rate of peat deposits. In profile Żar/76 (Fig. 4A), the rate is fairly regular. This is in agreement with the results of macrofossil analyses (Latałowa, in print, b) which confirm the presence of reed-swamp communities almost throughout the whole period of peat-bog formation.

The accumulation rate varies widely from section to section in profile P. Darż/78 (Fig. 4B). This agrees with the varying floristic content of the macroscopic remains found in the different sections. The fastest rate of accumulation was calculated for communities in which brown mosses and species of ***Sphagnum*** were dominant (1·3–2·9 mm/year). Peat accumulated most slowly when aquatic plants such as ***Potamogeton***, ***Sparganium*** and ***Characeae*** were primarily involved in its formation (about 0·115 mm/year) (Latałowa op. cit.).

The time scale diagrams were based on ^{14}C dating and on peat accumulation rate curves.

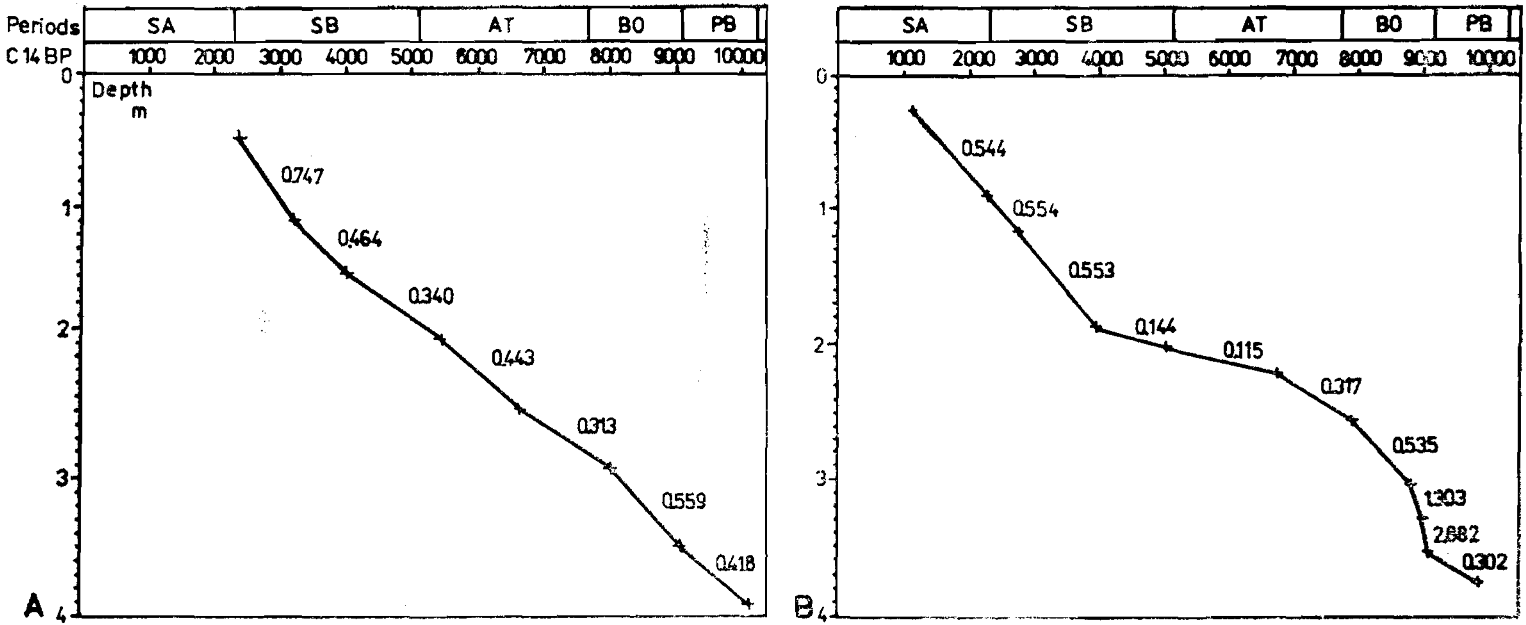

Fig. 4. Graph showing the accumulation rate of peat-bog sediments: A — peat-bog near Lake Żarnowiec (profile Żar/76); B — peat-bog in Darżlubie Forest (profile P. Darż/78). The accumulation rate is given in mm/year

Sample No.	Sample symbol	Depth (cm)	Laboratory No.	Age (years BP)
1	Żar/76	45–50	Gd-685	2400±60
2	Żar/76	107–112	Gd-598	3230±70
3	Żar/76	142–152	Gd-1030	4035±60
4	Żar/76	191–200	Gd-595	5460±60
5	Żar/76	245–250	Gd-686	6635±100
6	Żar/76	288–298	Gd-596	8090±70
7	Żar/76	343–352	Gd-1029	9065±70
8	Żar/76	387–397	Gd-1031	10 130±120
9	P. Darż/78	23–33	Gd-1032	1125±55
10	P. Darż/78	87–98	Gd-599	2310±65
11	P. Darż/78	113–123	Gd-1033	2770±60
12	P. Darż/78	183–193	Gd-1058	4035±65
13	P. Darż/78	201–205	Gd-1124	5075±75
14	P. Darż/78	220–225	Gd-1125	6775±115
15	P. Darż/78	253–263	Gd-625	7895±110
16	P. Darż/78	303–313	Gd-1113	8780±85
17	P. Darż/78	303–313	Gd-626	8885±95
18	P. Darż/78	327–332	Gd-1126	9165±110
19	P. Darż/78	332–337	Gd-1154	8995±85
20	P. Darż/78	350–358	Gd-1059	9080±85
21	P. Darż/78	373–381	Gd-1060	9840±115

SHORT DESCRIPTION OF POLLEN ASSEMBLAGE ZONES

The pollen zones show great similarities in all diagrams, and can probably be applied regionally.

Pinus-Juniperus-herbs assemblage zone (1)
Diagrams: Żar/76, J. Żar/78

High values of NAP (mean 57·5%, 31·4%), high percentages of *Juniperus* pollen (max. 6·1%, 13·9%), and of other heliophytes. Mean percentages of *Pinus*: 23·9%, 37·4%; of *Betula*: 11·1%, 18·8%. Pollen of plants characteristic of *Dryas*-flora (sensu Iversen 1954, 1973) is found. The upper boundary is marked by a rise in the *Juniperus* curve.

Juniperus-Pinus-Betula assemblage zone (2)
Diagrams: Żar/76, J. Żar/78, P. Darż/78

Maximum values of *Juniperus* pollen (6·6%, 24·1%, 20·1% AP+NAP). The pollen curves of *Pinus* and *Betula* rise, while high frequencies of NAP, *Salix* and *Artemisia* are maintained. The upper boundary of the zone is given by a fall in the pollen curve of *Juniperus* and NAP while *Betula* and *Pinus* continue to ascend. This boundary has been dated in diagram Żar/76 at 10 130±120 BP and in P. Darż/78 at 9840±115 BP.

Pinus-Betula assemblage zone (3)
Diagrams: Żar/76, J. Żar/78, P. Darż/78

High pollen values of *Pinus* and *Betula*; quite a high percentages of light-demanding species *(Populus, Salix, Betula nana, Artemisia)*. The upper boundary is placed where the *Corylus* pollen curve exceeds 1%. This boundary is synchronous in diagrams Żar/76 and P. Darż/76 and P. Darż/78 and falls at around 9100 BP.

In the diagram of the peat-bog near Lake Żarnowiec three sub-zones can be distinguished; they are also discernible in the J. Żar/78 diagram.

Pinus-Betula-Filipendula assemblage sub-zone (3a)

An increase in the percentage of *Pinus* and *Betula* pollen; a decrease in NAP. *Filipendula* is of great importance among the herbs (max. 4·0%). A fall in the *Pinus* curve and a rise in the *Betula* curve mark the upper boundary of this sub-zone.

Dating: c. 10 130—9800 BP.

Betula-Empetrum assemblage sub-zone (3b)

The percentage of *Pinus* pollen falls, that of *Betula* rises, that of NAP rises slightly. *Empetrum* is of great significance (max. 15·7%). The upper boundary of the sub-zone is placed in the point where the *Pinus* pollen curve rises and the *Betula* curve falls.

Dating: c. 9800—9560 BP.

Pinus assemblage sub-zone (3c)

The *Pinus* pollen curve shows a tendency to rise whereas *Betula* curve falls. *Ericaceae* pollen values are high (max. 9·8%).

Dating: c. 9560—9100 BP.

Corylus-Pinus assemblage zone (4)
Diagrams: Żar/76, P. Darż/78, partially J. Żar/78

This zone includes the rise of the *Corylus* pollen curve and its first post-glacial maximum. High percentages of pine are found (mean: 80·9%, 57·6% AP). The *Ulmus* pollen curve rises and attains its maximum value of 4·5% in the second half of the zone. *Quercus* pollen appears regularly. There is a marked rise in percentage values of *Alnus* pollen in the upper part of the zone this being the criterion for dividing the zone into the *Corylus* (4a) and *Corylus-Alnus* (4b) sub-zones. The upper boundary of the zone is indicated by a fall in the percentage of *Corylus*.

Dating: Żar/76: c. 9100–8340 BP, P. Darż/78: c. 9100–7740 BP.

Tilia-Ulmus-Pinus assemblage zone (5)
Diagrams: Żar/76, P. Darż/78

The percentage values of *Tilia*, *Quercus* and *Fraxinus* pollen increase in this zone, while the *Pinus* pollen curve tends to fall. The upper boundary is marked by a distinct increase in *Quercus* and *Corylus* pollen.
Dating: Żar/76: c. 8340–5580 BP, P. Darż/78: c. 7740–4700 BP.

Quercus-Corylus assemblage zone (6)
Diagrams: Żar/76, J. Żar/78, P. Darż/78

This zone is distinguished in all diagrams by maximum values of *Quercus* pollen (max. 14·2 %, 23·5 %, 43·3 %) and a second *Corylus* maximum, which is accompanied by low percentages of *Pinus* pollen (mean 48·3 %, 12·5 %, 14·9 %). The percentage values of *Ulmus*, *Tilia* and *Fraxinus* pollen remain high during this zone. The upper boundary is placed at the point where the *Quercus* and *Corylus* pollen curves start to descend and the *Carpinus* curve begins to rise.
Dating: Żar/76: c. 5580–2740 BP, P. Darż/78: c. 4700–2840 BP.

Quercus-Carpinus assemblage zone (7)
Diagrams: Żar/76, P. Darż/78

Characteristic features of this zone are high percentage values of *Carpinus* pollen (Żar/76: mean 2·6 % AP; P. Darż/78: mean 11·1 %, max. 25·2 % AP), and the relatively high values of oak pollen (Żar/76: mean 7·3 % AP; P. Darż/78: mean 14·0 % AP). Hazel pollen is not much represented and the *Ulmus, Tilia* and *Fraxinus* curves almost completely disappear. On the other hand, the *Betula* and *Pinus* pollen curves ascend abruptly.
The upper boundary is distinct only in the Darżlubie Forest diagram since the appropriate material was missing from the other profiles. It is indicated by a sharp fall in the *Carpinus* curve and an increase in the percentage value of *Fagus* pollen.
Dating: Żar/76: c. 2740–? BP, P. Darż/78: c. 2840–1200 BP.

Pinus-Fagus-Juniperus assemblage zone (8)
Diagram: P. Darż/78

This zone was distinguishable only in the Darżlubie Forest diagram. It is characterized by maximum percentages of *Fagus* pollen (mean 3·1 % AP; max. 5·4 % AP), a sharp rise in the *Pinus* curve (visible in part B of the diagram), and the appearance of *Juniperus* (mean 1·7 %). At the same time, there is a distinct decrease in the amounts of pollen from *Carpinus*, *Corylus* and *Quercus*. Pollen of plants indicating human activity reaches its culmination.
Dating: P. Darż/78: c. 1200 BP — present.

Pinus-Juniperus-herbs assemblage zone (1)

This zone can be interpreted as representing the park-tundra which was common over Northern Europe during the Younger Dryas time. Of great significance in the Lake Żarnowiec area were herbs ***(Artemisia, Chenopodiaceae)***, shrubs *(Juniperus, Salix)* and dwarf shrubs ***(Betula nana, Empetrum)*** communities. Clumbs of birch, pine and aspen were formed. Among determinated species some of the so-called *Dryas*-flora components are present; ***Selaginella selaginoides*** reaches high values. Among the macroscopic remains, one seed of ***Arctostaphylos alpina*** and a leaf fragment of ***Dryas octopetala*** were identified.

The high percentages of *Juniperus* pollen which are accompanied by numerous ***Empetrum nigrum*** seeds may indicate that the climate of the Lake Żarnowiec area during this period was more maritime than in other parts of Poland.

Juniperus-Pinus-Betula assemblage zone (2)

During this zone, the climate became warmer and as a result the range of pine and birch expanded. High percentages of *Juniperus* pollen indicate that juniper thickets were widespread. This is characteristic of areas immediately adjacent to the polar forests limit (van der Hammen 1952).

Pinus-Betula assemblage zone (3)

This zone, most clearly represented in the diagram from the peat-bog near Lake Żarnowiec, comprises three distinct sub-zones.

Pinus-Betula-Filipendula assemblage sub-zone (3a)

The rise of the *Pinus* and *Betula* pollen curves and the fall in the herb pollen values is evidence of the continuing improvement of the climate. During this time, pine forest spread over the study area. The presence of a number of light-demanding species shows that the forest cover was quite open.

Betula-Empetrum assemblage sub-zone (3b)

During this sub-zone there was a short-lived deterioration of the climate and the forest communities became more open as compared with sub-zone 3a. A fall in the *Pinus* pollen curve (20%) and a rise in the *Betula* curve (30%) indicate the predominance of birchwoods with some pine. High percentages of *Empetrum* pollen (max. 15·7%) are proof of the spread of heaths. This picture is characteristic for cool periods in areas influenced by a maritime climate.

Pinus assemblage sub-zone (3c)

In this sub-zone the climate improved again; this was manifested by the expansion of pine and the gradual decline of birch. The regular occurrence of *Ulmus* pollen demonstrates the incipient spread of this tree (c. 9300 BP).

These three sub-zones and zone 2 are chronologically equivalent to the Preboreal time and probably correspond to the climatic oscillations of this period described by Behre (1967, 1978). According to the nomenclature recently proposed by Behre (1978), zone 2 and sub-zone 3a (indicating a climatic improvement) are equivalent to the Friesland Oscillation, 3b to the Youngest Dryas and 3c to the late Preboreal period.

Corylus-Pinus assemblage zone (4)

Hazel became widespread during this zone (c. 9100 BP). and attained its first post-glacial maximum. Percentage pollen values of *Corylus* in the Żar/76 diagram are very low (max. 11% AP): this is typical for poor soils and cool habitats. Somewhat higher values are observed in the P. Darż/78 diagram (max. 27·9%). At this time, pine forests dominated the area; during the early stages of the zone, other light-demanding trees such as *Betula* and *Populus* were of some importance too. In the second half of the zone these trees were no longer of any significance, while hazel expanded much more rapidly; elm-woods with oak appeared in damp, fertile habitats. Having found suitable habitats along the shores of the lake, alder spread towards the end of the zone (sub-zone 4b) — c. 8300 BP.

Tilia-Ulmus-Pinus assemblage zone (5)

Tilia and *Fraxinus* spread during this zone (c. 7660 BP). These trees along with elm and oak, gradually superseded pine in the more fertile habitats; the latter has increased in importance in comparison with the previous zone. None the less, the relatively high pollen values of *Pinus* in diagrams Żar/76 (mean 76·6%) and P. Darż/78 (mean 55·7%) show that pine communities continued to play a significant part in the forest cover. As shade-tolerant species extended their range, the role of hazel decreased. The first pollen grains of *Viscum* and *Hedera* are evidence for the continuing improvement of the climate.

The first definite signs of human activity appear in diagram Żar/76 and refer to the first and second phases of Neolithic settlement.

Quercus-Corylus assemblage zone (6)

Deciduous forests developed further. Acidophilous oakwoods, which had ousted pine even from the poor outwash plain soils, were probably dominant. Evidence for this are the very low pollen values of *Pinus* in pollen diagrams P. Darż/78 (mean 14·9%) and J. Żar/78 (mean 12·5%). Higher *Pinus* values are to be found in diagram Żar/76; this is probably connected with the selective decomposition of sporomorphs, mostly of oak pollen. Hazel became much more common in forests. Mesophilous deciduous forests with lime, elm and ash were still of importance. These forests occupied the more fertile habitats near the edges of the uplands and at the foot of their slopes. Hornbeam began to spread during this zone (c. 4000 BP), although it was as yet of minor significance in forest communities. The high percentage of deciduous tree pollen, the regular appearance of *Hedera* pollen (more frequent than *Viscum* pollen) and the sporadic occurrence of *Lonicera periclymenum* indicate the maritime character of the climate.

The next two phases of human settlement are signified in the pollen diagrams: (3 — late Neolithic (Żar/76, P. Darż/78); 4 — Bronze Age (Żar/76)).

Quercus-Carpinus assemblage zone (7)

As a result of intensive settlement (settlement phases 5 and 6), essential changes in vegetation took place. The fall in oak pollen values and the almost complete extinction of *Ulmus*, *Tilia* and *Fraxinus* point to a serious reduction in the area covered by mesophilous forests, and by acidophilous oakwoods. In the more fertile habitats they were replaced by oak-hornbeam forests, while the poorer soils were occupied by pine, its pollen curve rising distinctly in this section of the diagram. Hornbeam forests spread mainly on the upland. The low percentages of hornbeam pollen in diagram Żar/76 indicate that in the immediate neighbourhood of the lake, oak-hornbeam forests covered but small areas. This was probably due to the lack of suitable habitats and the intensive settlement taking place in the Lake Żarnowiec tunnel-valley.

Pinus-Fagus-Juniperus assemblage zone (8)

Man has become the dominant factor in all further vegetational changes in the study area (settlement phase 7). The percentage pollen value of culture indicators is high, herb and pine pollen frequencies increase while those of broad leaved trees (including hornbeam) decrease; all this is indicative of the further reduction of areas covered by forests, especially where the habitats are fertile. The fall in the hornbeam pollen value in diagram P. Darż/78 coincides with the expansion of beech (c. 2100 BP) which became dominant on moraine uplands covered with boulder clay.

The prevalence of species toleranting acidic soils such as pine, oak or beech, and the presence of species characteristic of sandy habitats are a consequence of soil impoverishment. This is a natural process which has been accelerated by man (Iversen 1954).

THE IMPACT OF MAN ON THE VEGETATION OF THE LAKE ŻARNOWIEC AREA

In the pollen diagrams presented in this paper, seven settlement phases have been distinguished. They correspond well with the results of archaeological studies in the Lake Żarnowiec tunnel-valley (Szułdrzyński & Żurawski

1978). These phases have been marked on the pollen diagrams (Figs. 5, 7) on the basis of the total sum of culture indicators s. l. and in particular, of the pollen values of the plants most typical of human activity such as *Plantago lanceolata* and Cerealia (Latałowa, in print, a and b).

Phases 1, 2 and 3 correspond chronologically with the Neolithic. The first two phases were distinguished on the basis of single pollen grains of *Plantago lanceolata* (phase 1) and Cerealia (phase 2); at this time the pollen curves of deciduous trees were slightly depressed. Phase 3 (c. 4100 BP) is much more clearly defined: *Plantago lanceolata* and *Triticum* are present; there is a marked decline in the pollen values of elm, lime and ash.

During the phase 4 (II/III period of the Bronze Age) meadow indicators *(Plantago lanceolata)* are far more common than Cerealia pollen. The first *Secale* pollen grains appear; percentage values of *Quercus, Ulmus, Tilia, Fraxinus* and *Corylus* fall. The presence of a people of the Kashubian group of the Lusatian culture and of the East Pomeranian culture (Hallstatt C and D) are marked in the diagrams as settlement phases 5 and 6. Drastic changes in the woodland communities followed this settlement. By destroying the oakwoods, man facilitated the expansion of hornbeam.

Human activity in the early Middle Ages (phase 7) significantly contributed to the spread of beech, the last of the tree species to arrive in the Lake Żarnowiec area. The oak-hornbeam forests having been destroyed, beech was able to take over new, open habitats unopposed; the continual leaching of the soil and deterioration of the climate played a big role in enabling this to happen. Pine also became wide-spread at this time.

SUMMARY AND CONCLUSIONS

The pollen diagrams from the Lake Żarnowiec area differ considerably despite the fact that the localities are all within 5 km of one another. These differences are not only the consequence of different habitat types in the vicinity of the investigated localities, but also connected with the more local (locality 3) or regional (localities 1 and 2) types of pollen spectra. Selective pollen grain decomposition has an adverse effect: this is most evident in diagram Żar/76. Nevertheless, the pollen assemblage zones show great similarities and can be assumed to have a regional application.

The most important regional features are:

a) The presence of species classified among the *Dryas*-flora and the high frequency of *Juniperus* in the *Pinus-Juniperus*-herbs pollen assemblage zone.

b) High values of juniper pollen at the transition between the Younger Dryas and the Holocene (*Juniperus-Pinus-Betula* PAZ).

c) The climatic oscillations revealed in the *Pinus-Betula* PAZ as the presence of three distinct sub-zones: *Pinus-Betula-Filipendula* PASZ, *Betula-Em-*

petrum PASZ, and *Pinus* PASZ. This oscillations correspond to the climatic fluctuations of the Preboreal period described by Behre (1967, 1978).

d) The late (between 5600 and 4700 BP) maximum distribution of broad-leaved forests (*Quercus-Corylus* PAZ). In this zone the greatest frequencies of *Viscum* and *Hedera* pollen occur in all diagrams, the latter species prevailing. The very low pollen curve of pine indicates that it was not common in woodland communities. This distinctly distinguishes the study area from the remainder of Lowland Poland where pine was of much greater importance.

e) High pollen values of hornbeam, indicating that oak-hornbeam forests were widespread during the period 2800—1200 BP (*Quercus-Carpinus* PAZ). This is confirmed by other pollen data from Western Pomerania (Ołtuszewski 1948; Ołtuszewski & Borówko 1954; Szafrański 1961).

f) The late spread of beech over this area occurring in the early Middle Ages. The above mentioned features of the vegetational history in the Lake Żarnowiec area indicate the importance of the humid, maritime climate in the development of the natural plant cover in the stages of its post-glacial succession. The pollen diagrams show similarities to the pollen diagrams from these areas of North-West Europe influenced by a maritime climate, especially in their Late Glacial and the early Holocene parts.

The data presented in this paper also illustrates the significant part man has played in the vegetational history of this area. He has not only assisted the destruction of natural oakwood communities but has at the same time enabled the expansion of such trees as hornbeam, beech and pine.

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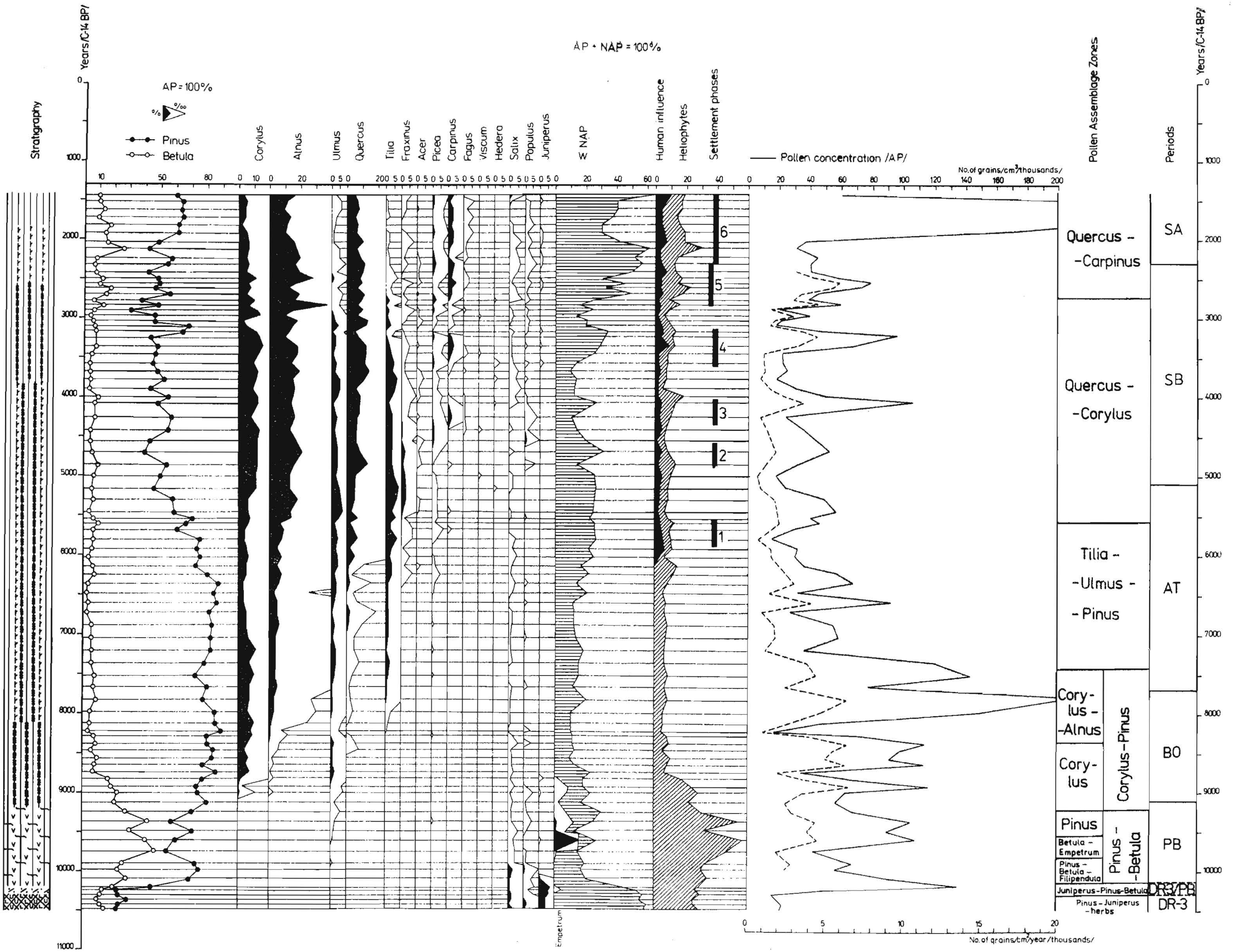

Fig. 5 Total pollen diagram of profile Żar/76; locality: peat-bog near Lake Żarnowiec (1). Sediment symbols according to T—S system (Troels-Smith 1955; Aaby 1979) — simplified. Other explanations, see text

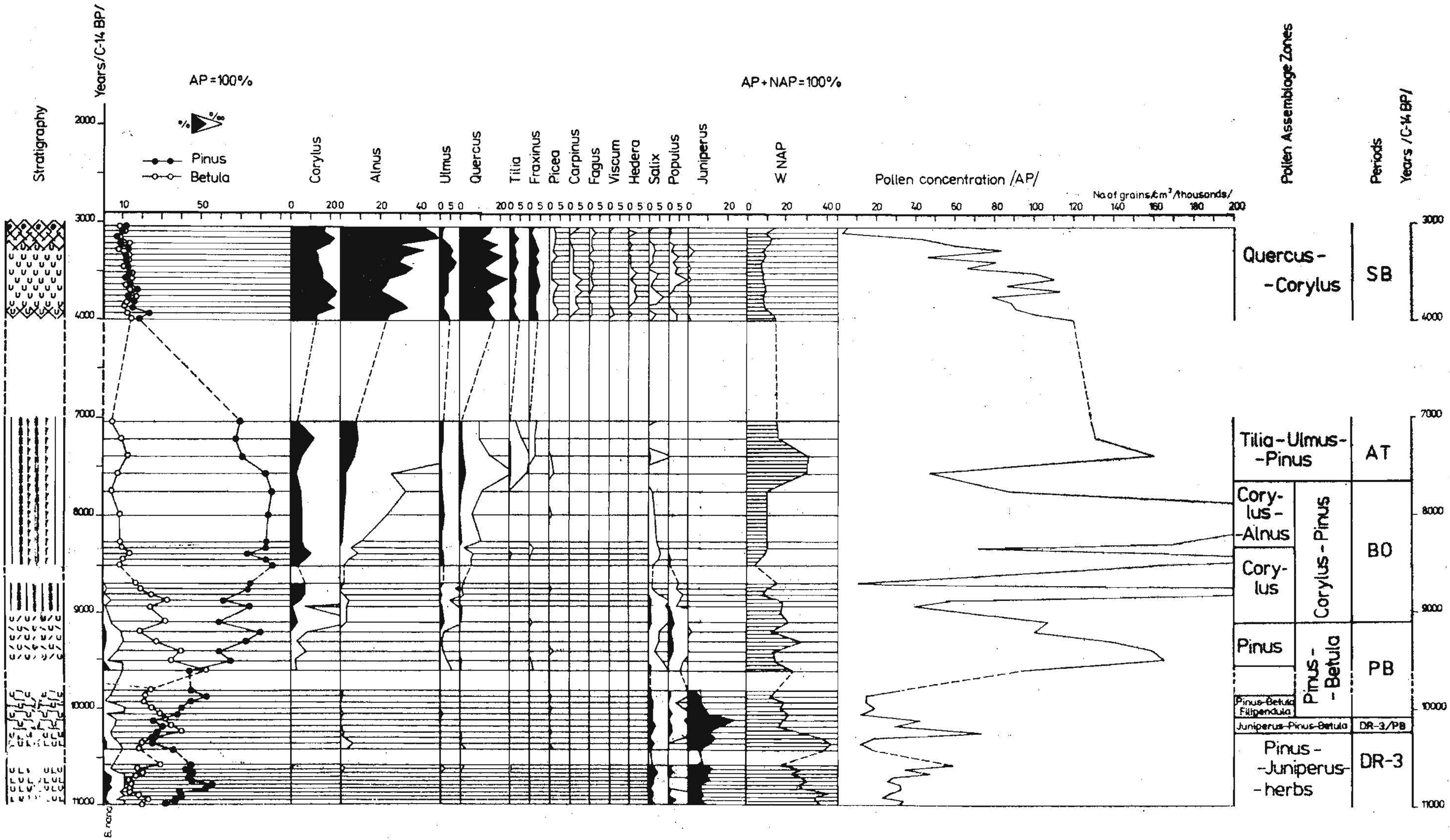

Fig. 6. Total pollen diagram of profile J. Żar/78; locality: Lake Żarnowiec (2). Explanations as for Fig. 5

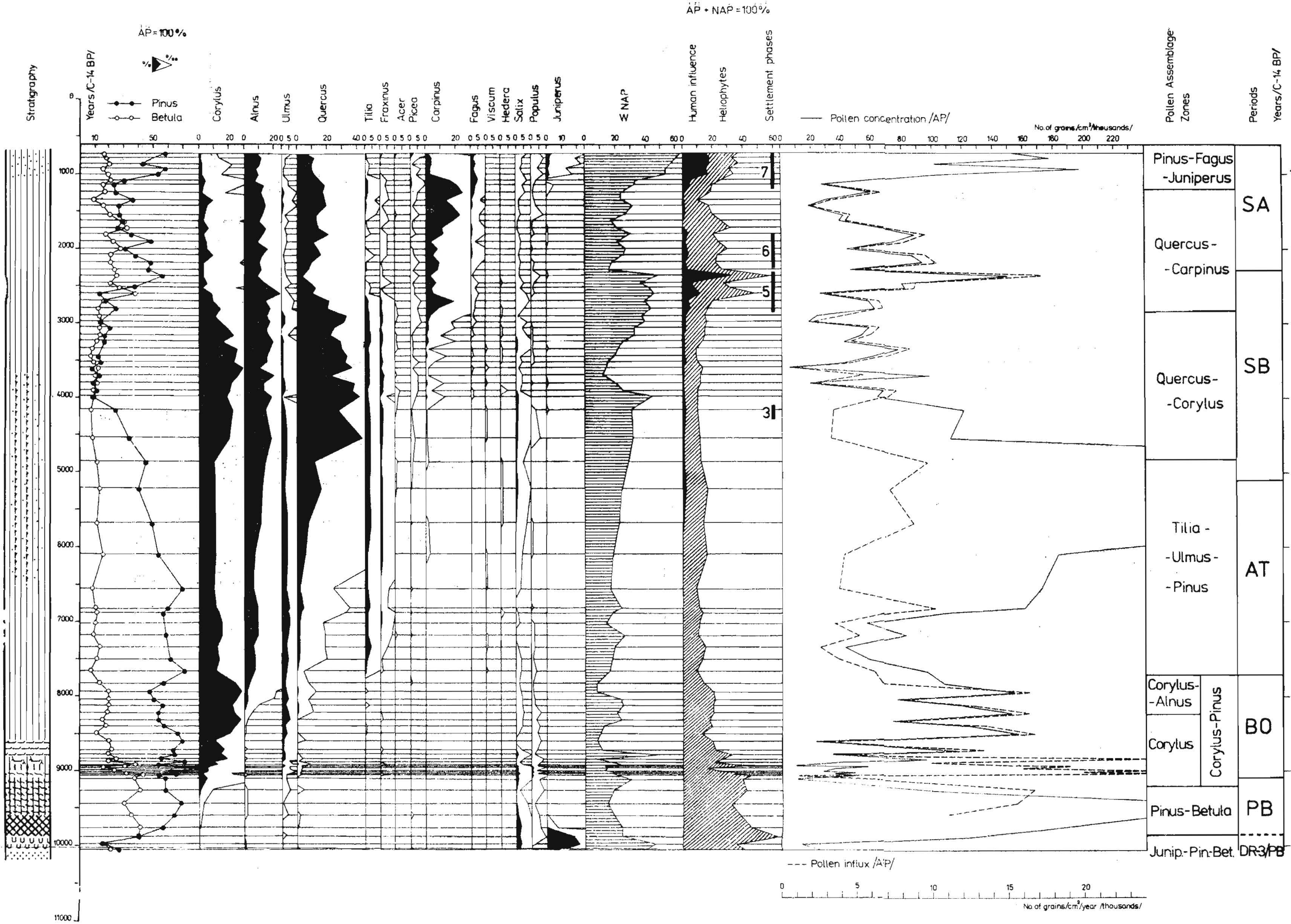

Fig. 7. Total pollen diagram of profile P. Darż/78; locality: peat-bog in Darżlubie Forest (3), Explanations as for Fig. 5