Acta Palaeobot. 32 (1): 123–249, 1992

MAN AND VEGETATION IN THE POLLEN DIAGRAMS FROM WOLIN ISLAND (NW POLAND)

Człowiek i szata roślinna w diagramach pyłkowych z wyspy Wolin (Polska północno-zachodnia)

MAŁGORZATA LATAŁOWA

Department of Plant Ecology and Nature Protection, University of Gdańsk,
Aleja Legionów 9, 80–441 Gdańsk

ABSTRACT. Pollen, charcoal and ash content data complemented by 26 ^{14}C dates from three small (4–5 ha) basins on Wolin Island (NW Poland) enabled a detailed chronological reconstruction of human impact on vegetation during the last 8000 years. Locally, woodland was already actively changed in the Mesolithic. Animal husbandry and cereal cultivation were probably initiated by the people representing the Ertebølle culture. The first *Ulmus* decline is radiocarbon dated in two profiles at ca. 5800 BP and seems to be caused mainly by human activity. In the Neolithic and Bronze Age coppicing changed the forest structure; animal husbandry was the main form of farming at that time. Cultivation increased in importance in the Lusatian culture and in the Iron Age, but the considerable extension of arable land did not take place until the early Middle Ages. On the poor sandy soils *Calluna* heath developed in the Neolithic due to intensive burning and grazing in the *Pinus-Quercus-Betula* forest.

Several palaeohydrological events are analysed with respect to anthropogenic forest disturbances, climatic changes and fluctuations in the level of the Baltic Sea.

KEY WORDS: pollen analysis, anthropogenic indicators, Wolin Island (NW Poland), vegetational history, prehistoric agriculture, *Calluna* heath, palaeohydrology

CONTENTS

INTRODUCTION

One of the best indicators of the natural environment is vegetation. Being dependent on orographic, hydrological, edaphic, climatic and anthropogenic factors, it is a synthesis of the ecological conditions characteristic of a particular area. The potentialities offered by pollen analysis in studying past vegetation make it one of the most important research tools for reconstructing the environment in which man has lived and assessing the effects of his activities on a variety of natural systems. Studies of the influence of prehistoric man may also provide a basis for estimating the resistance of the environment to various kinds of human pressure in different topographical, soil and climatic conditions.

Wolin Island is a highly rewarding place for studies of this kind. Its nature is diverse and, being located at the cross-roads of ancient routes of communication, it has been infiltrated by groups of humans since earliest times (Filipowiak 1973).

Among the abundant lakes and peatbogs, three small sites were found in different geomorphological and edaphic situations. Such sites are considered the most suitable for investigating man's influence (Berglund 1985, Behre & Kučan 1986, Ammann 1988, Gaillard & Berglund 1988, Groenman-van Waateringe 1988), since the pollen spectra obtained from these sites are often rich in sporomorphs, and pollen grains from plants normally under-represented in diagrams (e.g. cereals) are usually more frequent. Pollen data from small sedimentation basins mostly illustrate the succession of plant communities flourishing in the close vicinity of the site and do not present averaged pictures strongly affected by long-distance transported pollen which is of great importance in the spectra from larger basins (Jacobson & Bradshaw 1981).

The principal aim of this paper is to analyse the different effects of human impact on the vegetation of Wolin Island since the Mesolithic, with respect to the intensity and type of economy and the natural environment. Certainly one should also look for signs of anthropogenic influence in the period earlier then ca. 8000 years BP, the oldest limit considered in this paper. Charcoal dust and pollen of plants typical of disturbed woodland were found in the older samples, too. However, this early period of Holocene woodland development needs special attention because of the natural participation of light demanding species in the forest communities. Moreover, in the profiles investigated, the early Holocene sediments are characterized by a very low sedimentation rate, which restricts the precision of the chronological and palynological interpretation. In the present paper the indication of man-made changes starts with a distinct increase in the pollen frequency of several herbs typical of anthropogenic habitats. This means that, on Wolin Island, these changes began at least as early as ca. 8000 BP.

Several sites have been examined palynologically in the western part of the Baltic coastal zone of Poland and its immediate hinterland and these studies have yielded quite a lot of information. The works of Nietsch (1934) and Szafrański (Celiński 1962) in the neighbourhood of Szczecin, and those of Mianowska and Zachowicz (Wypych 1980) from the Szczecin Lagoon are among the most important. From Wolin Island itself there are pollen diagrams from peatbogs developed in the depressions on the Świna Bar, produced during studies on the age and origin of the podzols on the brown dunes (Prusinkiewicz & Noryśkiewicz 1966), and also pollen tables from two sites in the Pleistocene and Holocene landscape of the island (Orwat 1958). However, whether due to the outdated methods employed or the specific character of the material, these papers fail to answer the basic questions concerning the history of vegetation, not to mention the part played by man in its transformation.

The second important aim of this paper is, therefore, to update the palynological information from the western part of the Polish Baltic coastal zone. The material included here is part of a wider project carried out within the framework of the International Geological Correlation Programme (IGCP–158 B) in 1978–1988 (Latałowa 1989b, Ralska-Jasiewiczowa & Latałowa, in print) which dealt with the general palaeoecological problems of this region.

THE PRESENT-DAY NATURAL ENVIRONMENT

LOCATION AND GEOMORPHOLOGY

Wolin Island (Fig. 1) straddles the mouth of the river Odra and is the most northwesterly point in Poland. It is separated from the mainland and Uznam Island by two former arms of the Odra – the rivers Dziwna in the east and Świna in the west; in the south it is washed by the waters of the Szczecin Lagoon, while its northern shores overlook the Baltic Sea.

According to the regional division of Poland made for IGCP project 158 B (Ralska-Jasiewiczowa 1989), Wolin Island belongs to the Baltic shore (P-u) region, which is a part of the larger unit: the South-Baltic coastal zone s.l.

The present-day island has a surface area of 254 km^2. It comprises a Pleistocene nucleus and adjoining Holocene formations. The western side of the Pleistocene part is an

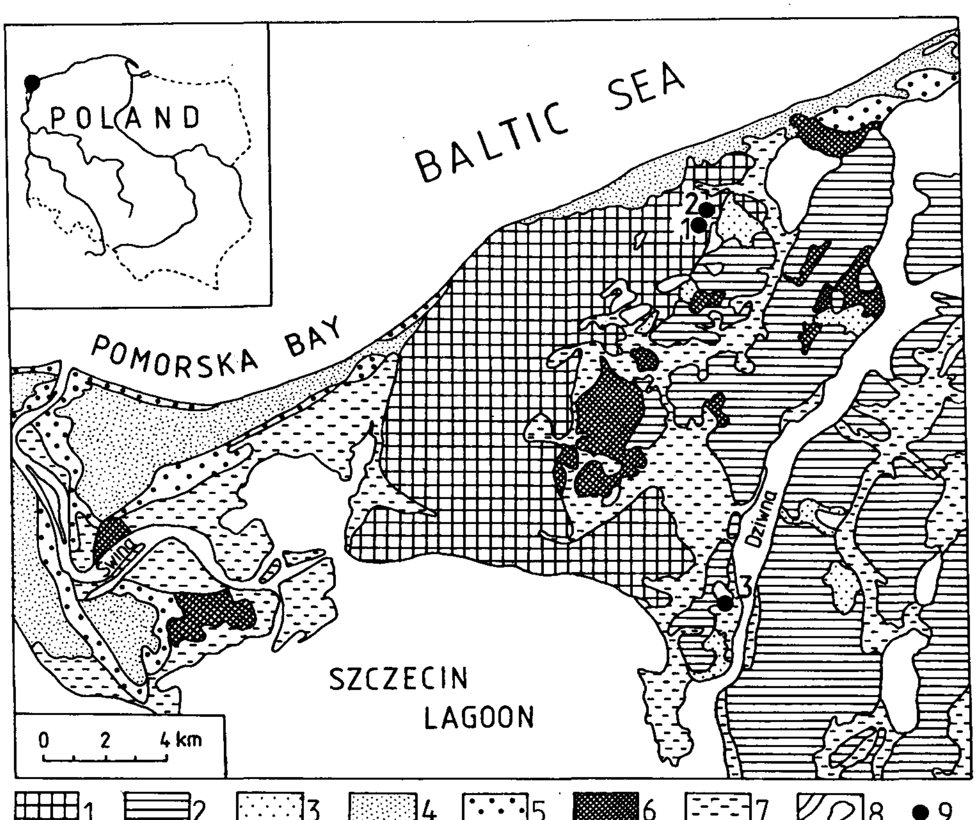

Fig. 1. Quaternary deposits of Wolin Island and adjacent areas (after Mapa Geologiczna Polski, 1:200.000, 1977 – slightly simplified) and location of the sites investigated. 1 – silt, sand, gravel and clay of kames; 2 – boulder clays of ground moraine; 3 – outwash sand and gravel; 4 – eolian dune sands; 5 – marine silt, sand and gravel; 6 – muds and sands of lake and river origin; 7 – peats; 8 – lakes and rivers; 9 – the sites investigated: 1-Kołczewo, 2-Lake Racze, 3-Wolin II

arch-shaped zone of the glacitectonically uplifted terminal moraine of the Gardno (Copenhagen) phase (Krygowska & Krygowski 1965) which reaches an altitude of 115 m. Numerous erosion forms and glacial channels, some of which are occupied by lakes, give this upland its varied relief. The foreland of the terminal moraine, on the southeast side, consists of three terraces of an accumulation plain where outwash-plain sands have been deposited; there are many kame terraces. The eastern part is composed mainly of flat or gently undulating ground moraine.

Wolin Island was formed during the Holocene as a result of the successive phases of the Littorina transgression in the southern Baltic. In the early Holocene, and even in the earliest phase of the Littorina transgression, dry land stretched further north for a distance of several tens of km (Fig. 2). Evidence of this are the Holocene peats and limnic sediments buried beneath marine sediments at the bottom of Pomorska Bay (Kolp 1976, Kotliński 1991). At the start of the Littorina transgression, some 7000 years ago, the ground water table rose, and then, probably during the II Littorina phase, sea water inundated the land, forming the Szczecin Lagoon, the area of which increased still more during the succeeding phase (Wypych 1980). At the same time, sandbars began to grow in the east and west (Rosa 1984). Also during the Holocene, the extensive depressions, both in the moraine area and in the accumulation plain, became filled with peats.

To this day the shore line is subject to active change. While the high cliffs on the sea side are being worn away by abrasion, the low shore on the southern side is continually being extended by the addition of peat islands that form as a result of the silting up of

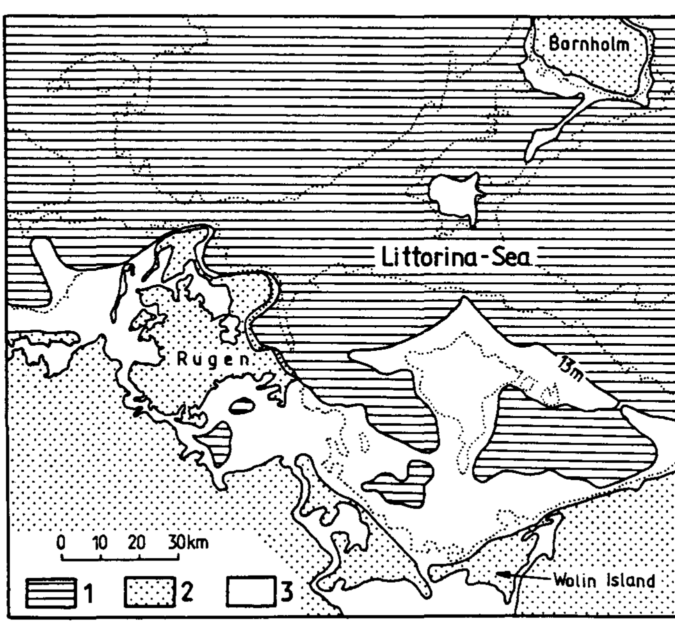

Fig. 2. Location of Wolin Island with respect to the former Baltic Sea shore line in the initial phase of the Littorina transgression (after Kolp 1976). 1 – Littorina Sea; 2 – present-day land; 3 – extent of former land determined by the position of the early Littorina Sea level 13 m below the present-day Baltic Sea level

the Szczecin Lagoon.

In the present paper the area of sandbars is neglected being a specific area with particular problems which require special methods and separate investigations.

CLIMATE

According to Romer's (1949) classification, Wolin Island belongs to the region of Baltic climates, i.e. climates influenced by the sea. The winters are relatively warm and mild with an average January temperature between 0° and -0.6°C. The summers are rather cool, with an average July temperature between 17.0° and 17.5°C. The average annual temperature is 7.5° to 8.0°C. In comparison with other areas of Pomerania, the beginning of the growing season is a little delayed, but the season lasts longer, extending even into November (Młodzikowski 1986).

The annual precipitation is rather moderate (average 550–650 mm), but there is considerable diversity depending on the season, the distance from the sea and the morphology of the terrain. Periodic rainfall deficits, especially in spring and early summer, are compensated for by the high humidity of the air, due to the proximity of the Baltic Sea and the lagoon.

Winds, particularly those from the west, are strong on a large number of days, so that oceanic air masses play a big part in the general atmospheric circulation of Wolin Island (Młodzikowski 1986).

WATER REGIME

Wolin Island has always had abundant lakes and bogs; the low ground now flooded by the Szczecin Lagoon was, prior to the Littorina transgression, also dotted with peat-bogs and small bodies of water (Wypych 1980). This area must, therefore, have been attractive to early prehistoric man, whose survival depended largely on hunting and fishing.

The lakes of Wolin are clustered in the north-eastern part of the island. Their origins are various; channel lakes are the most common type. With the exception of Lake Racze, the kettle-holes are filled with peat. The largest lake is a coastal one – only a sandbar separates it from the sea. Except for the stream joining the series of channel lakes, there are no natural watercourses to speak of.

The ground water regime is of great importance to the development of vegetation. Over a wide area, these conditions are very poor. In the moraine upland, the water table lies at considerable depth – more than 10 m below the ground surface, whereas the low boggy area is often inundated, so that here surface and ground water are constantly in contact (Choiński et al. 1978).

SOILS

The soils of Wolin Island are generally rather poor. Large areas of the ground moraine are covered with loose, slightly clayey podzols formed in sands. The soils of the terminal moraine are more diverse; both acid brown soils in various stages of podzolization and podzols occur here. On dune sands only podzols are formed, while boggy soils are frequent on the peaty substrates. More fertile brown soils occur on a chalk outcrop in the south-west of the island (Borowiec 1969).

VEGETATION

A characteristic feature of the Wolin vegetation is the presence of a number of species and communities with a western-type range which are absent elsewhere on the Polish coast (Piotrowska 1966 b). Some 70% of the species reported by Czubiński (1950) from northwestern Poland (Pomerania) as belonging to the "Atlantic element" s.l., are present on Wolin Island. Here one finds the easternmost localities of the continuous distribution of many species. Many communities are similar in their means of formation and often also in their species composition to western European communities. The influence of the Atlantic climate also shows in the tremendous dynamism of beech and oak (*Quercus robur*), unknown elsewhere in the Polish coastal zone (Piotrowska & Olaczek 1976).

The Wolin vegetation exhibits a great richness and diversity of communities, as a result of the considerable variety of habitats. Woodland dominates the west and centre of the island. There are acid beechwoods (*Luzulo pilosae-Fagetum*) on the higher parts of the terminal moraine, whereas in the lower positions mixed beech-oak (*Fago-Quercetum*) or pine-oak (*Pino-Quercetum*) forests occur. Fertile beechwoods (*Melico-Fagetum*) are present only on the rich calcareous soils in the south-west of the island. The dune-covered sandbars support coastal pine forest (*Empetro nigri-Pinetum*), while on lower-lying accumulations of sand there are some *Betulo-Quercetum* phytocoenoses. Patches of this association, with distinctly different features, also occur on the light, sandy soils of Pleistocene origin (Piotrowska unpubl.). Alder swamps are found mainly in the waterlogged depressions between the dunes. More oligotrophic organic substrata support marshy pine forest (*Vaccinio uliginosi-Pinetum*) and marshy birch woods (*Betuletum pubescentis*)(Piotrowska 1966 b, Piotrowska & Olaczek 1976, 1987). Eastern Wolin has been almost totally deforested.

As regards the non-woodland vegetation, the various wetland communities (including the halophilous ones) and communities typical of sandy habitats are spatially of greatest importance on the flat fringes of the island. Swards have developed on many deforested areas (Piotrowska, Celiński 1965). The *Corynephoretum canescentis* association is widespread on the dry sandy formations of the gently undulating ground moraine, while small patches of *Festuco-Armerietum* have been found on a rather fresh substratum. The presence of *Festuco-Koelerietum glaucae* is particularly interesting. The phytocoenoses of this continental association cover a very small area on the sunny, south-facing cliff slopes overlooking the Szczecin Lagoon, where the substrate is exceptionally rich in calcium carbonate.

Arable land, with its characteristic poor segetal communities, is very common on the moraine (Nowiński 1964). The extensive wetlands have mostly been reclaimed for meadows and pastures and communities of the order *Molinietalia* are most frequent there.

ARCHAEOLOGY

Due to favourable natural conditions, the area under investigation was probably already penetrated or periodically inhabited by man in the earliest prehistory. Archaeological information on the oldest habitation is very scarce, however, and concerns only one locality, possibly of Mesolithic age, on the lakeland in the moraine area (Sajkowska 1987, 1991). This shortage of data is caused primarily by the substantial environmental changes following the transgressions of the Baltic Sea, but a lack of proper investigations is also of importance.

In terms of the aim of this paper, the Mesolithic/Neolithic transition is of special interest, even if archaeological data are not available from the area itself. Wolin Island lies close to the territory which, in the late Mesolithic, was occupied by the Ertebølle-Ellerbek-Lietzow culture (Gramsch 1978, Czarnecki 1983). During the last few years, two localities of this culture (Fig. 3A) have also been discovered in Poland (Ilkiewicz 1989, Galiński in print), and this has changed the former idea of its extent. The presence of suitable natural conditions, namely light sandy soils, an abundance of lakes and bogs and sea and lagoon shores, make it highly probable that Ertebølle people lived on Wolin Island, too. At the same time, i.e. beginning around 6300 years BP (Wiślański 1969, 1983), the Neolithic, Linear Pottery culture flourished on the fertile soils in the Pyrzyce region (Fig. 3B). The few archaeological artifacts typical of this culture which are known from Wolin Island suggest direct intercultural contacts with the Ertebølle tribes (Wiślański 1979a). However, in the proper area of the Baltic coastal zone, the Funnel

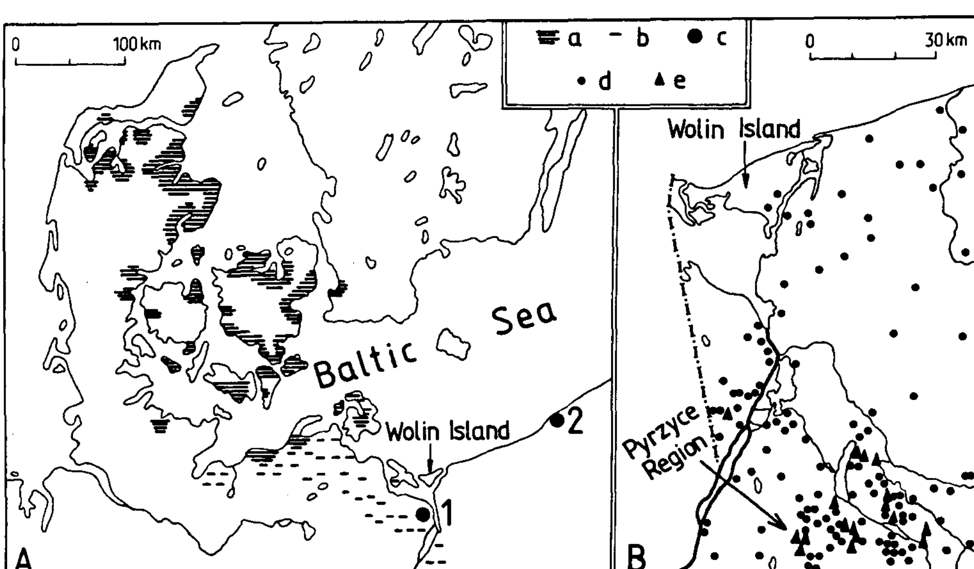

Fig. 3. A. The range of the Ertebølle-Ellerbek culture on the southwestern Baltic coast (after Czarnecki 1983, supplemented): a – settlement zones; b – stray finds; c – the newly discovered settlements in Poland: 1-Tanowo (Galiński, in print), 2-Dąbki (Ilkiewicz 1989). B. The distribution of Linear Pottery culture sites in northwestern Poland (after Wiślański 1969): d – stray finds of stone tools; e – settlements

Beaker culture was the first Neolithic culture and it did not develop before 5000 BP (Wiślański 1979a, Jankowska 1983).

According to archaeological records several settlements of the Funnel Beaker culture developed between ca. < 5000–4500 BP and may have lasted even up to 3800 BP in the area investigated (Fig. 4A). The settlements were located on small hills covered with light soils, close to water bodies of different sizes, and their character mostly suggests a seminomadic existence (Cnotliwy 1961, 1966). Nevertheless, archaeobotanical data from the settlement discovered within the present town of Wolin shows that at least barley and wheat were cultivated at that time (Klichowska 1967a).

It is questionable whether the Globular Amphorae culture existed on Wolin Island or not. Three settlements were identified by Wiślański (1969) as belonging to this culture, but this identification was not confirmed by Siuchniński (1972). The Globular Amphorae culture is dated at 4700±4000 BP in this region (Siuchniński 1983).

The youngest Neolithic culture – the Corded Ware culture (4400±3500? BP) – is poorly represented both on the island and in its surroundings (Cnotliwy 1966, Siuchniński 1972). Only two small settlements have been discovered (Fig. 4A). Stray artifacts are much more common and they are known mainly from patches of rather fertile soils, especially suitable for pasture (Cnotliwy 1966). The Corded Ware peoples probably lived in this area also during the early Bronze Age.

During the early and middle Bronze Age settlement regressed (Cnotliwy 1966) and a new occupation took place in the IVth period of the Bronze Age when the Lusatian culture expanded (ca. 3000 BP). Numerous settlements (Wojtasik 1958) came into existence in different parts of Wolin Island but the most frequent remnants were recorded along the Dziwna banks and in the lake district (Fig. 4B). The settlements differ in age. Some of them had already collapsed by the end of the Bronze Age, others continued to develop or were even founded in the Hallstatt period. The archaeobotanical data indicate that barley, wheat, millet, peas and broad bean were cultivated (Klichowska 1967b).

During the late Iron Age, settlement generally declined on Wolin Island (Fig. 4C) as it did in the region as a whole (Domańska & Wołągiewicz 1981). The small number of finds from the La Tène (pre-Roman) period cannot be identified precisely but probably people of the Jastorf culture lived on the island (Wołągiewicz oral inf.). They moved away to the east in late pre-Roman time. A new occupation phase took place during the Roman period, when people representing the Gustow group from Rügen expanded into this area (Wołągiewicz 1981, 1986). The settlements were rather scarce and located on better soils because of the increasing role of plant cultivation (Wołągiewicz 1981). In the Migration Period the Germanic tribes left the island and the adjacent areas, but small settlements of the Dębczyno group, which appeared at the end of the Roman period, survived. Such settlements have been found on the southern shore of the Szczecin Lagoon (Wołągiewicz 1983) and probably existed close to the crossing of the Dziwna (Filipowiak 1986).

The oldest Slavonic settlement was discovered within the present town of Wolin and is dated to the 6/7th century (Filipowiak 1986). This settlement developed in the 7th and 8th centuries and, in the middle of the 9th century, a big town of 8–10 thousand inhabi-

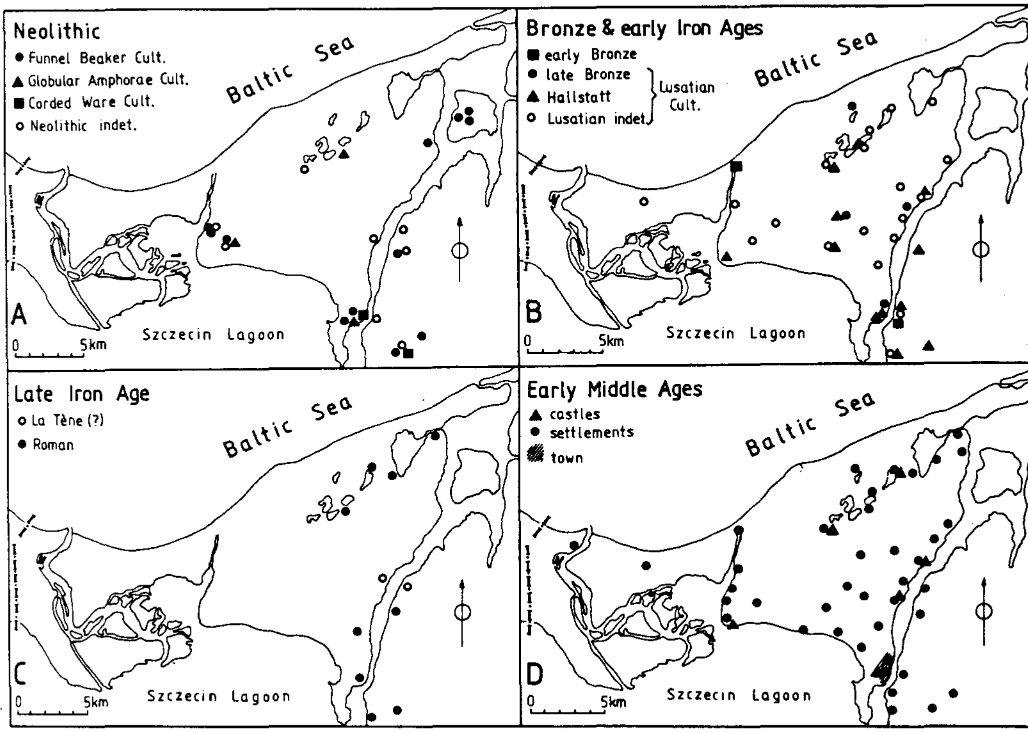

Fig. 4. Prehistoric settlements and burial grounds on Wolin Island and adjacent areas (compiled by Sajkowska 1987, 1991)

tants arose. In the early Middle Ages numerous open settlements and some castles were established on the island, especially along the banks of the Dziwna (Fig. 4D). The early Medieval town of Wolin with its port was one of the biggest trade centers in the Baltic Sea region (Filipowiak 1988).

The archaeological information quoted above, including the maps illustrated in Fig. 4, certainly does not present the full picture of the prehistoric settlement development. The area of Wolin Island has never been systematically explored and these data (with some exceptions) come mostly from surface investigations, which are especially unsuccessful in the moraine area, which is covered by a dense woodland today. Large-scale investigations have been made only within the town of Wolin and the best data refer to early Medieval time.

METHODS

SAMPLING, LABORATORY WORK AND ^{14}C DATING

Three sites were selected after test investigations of seven mires and four lakes.

After several reconnaissance borings, at the mires Kołczewo and Wolin II, two peat profiles, were sampled at each site, with a 10-cm-diameter Russian corer.

The distribution and thickness of the sediments in Lake Racze were investigated using an echosond (M. Rybak unpubl.). Two profiles were collected from a raft with a 6-cm-diameter piston sampler (Wright 1967). The uppermost, loose sediments were taken with a sampler designed by Digerfeldt and Lettevall (1969).

The peat deposits and lake sediments were briefly described in the field, and in more detail in the laboratory, using Troels-Smith's system (1955) with some simplifications introduced by Aaby (1979). The degree of humification was also determined according to von Post's (1924) method. The sampling intervals were 1, 2 or 5 cm.

Pollen samples, 1 or 2 cm^3 in volume, were boiled in 10% KOH in a water bath and than treated with acetolysis; minerogenic matter was removed with HF (Faegri & Iversen 1975). 2–4 *Lycopodium* tablets were added to the sediment in order to enable pollen concentration to be calculated (Stockmarr 1971). For the most part at least 1000 AP grains were determined.

In the course of pollen counting, microscopic charcoal particles larger than 25 μm were tallied from the same slides. According to Tolonen (1986a), charcoal of this size should be mostly indicative of local fires. The results are expressed as relative (percentage) values (AP+NAP+charcoal particles = 100%) and as particle concentration and influx values (Figs 9, 13, 18). The data obtained from this analysis cannot be interpreted precisely; it was observed, in some cases, that some larger particles were retained during the sieving of the pollen samples.

The ash content was investigated only for the lake sediments and the ombrogenic peat deposits. Since the $CaCO_3$ content was virtually insignificant in these profiles, the ignition residue after ashing at 550°C, was calculated. The values are expressed as percentages of dry matter (Figs 7, 9, 11, 13).

26 ^{14}C dates were determined for the sections of the profiles presented in this paper. The datings were done in the ^{14}C Laboratory of the Silesian Technical School in Gliwice. All the dates are given in uncalibrated radiocarbon years BP; their laboratory numbers are specified in figures 6, 10, 15. Estimated dates, calculated from the rate of accumulation curves, are marked with an asterisk.

POLLEN DIAGRAMS

The main pollen diagrams (Figs 7, 11, 16) show percentage values; the results of the pollen concentration and influx calculations are presented in complementary diagrams (Figs 8, 12, 17).

The basis of all the percentage calculations is the AP+NAP sum; AP comprise pollen grains of all trees and shrubs, while NAP include sporomorphs of terrestrial herbs, graminids and some of pteridophytes (e.g. *Pteridium aquilinum*, *Polypodium vulgare*). The list of taxa excluded from the total sums differs from one profile to another and is determined on the basis of the sediment composition, investigated by means of macrofossil analysis (Latałowa unpubl.). In general, pollen of limnophytes, telmatophytes, amphiphytes and spores of *Polypodiaceae*, *Sphagnum* and *Equisetum* are not included in the calculation sum. *Calluna*, *Ericaceae* and *Comarum* type are excluded from that part of the Kołczewo profile composed of ombrogenic peat, just as cf. *Cannabis* is excluded from the Lake Racze profile, and *Cyperaceae* and *Phragmites* type are eliminated from the Wolin II profile. All calculations were made using an IBM-PC computer and the POLPAL program prepared by A. Walanus for the Polish Palynological Database.

In the main diagrams curves are arranged as follows:

a. AP/NAP ratio and minerogenic content (ash);

b. high-competitive, shade-tolerant trees and shrubs ordered according to their edaphic demands – from damp, fertile soils to light soils;

c. low-competitive, light-demanding trees and shrubs;

d. cultivated plants and field weeds;

e. ruderals;

f. herbs of disturbed woodland;

g. plants of grasslands from dry, fresh to wet habitats;

h. herbs of different forests;

i. taxa ecologically undefined;

j. limnophytes, telmatophytes and amphiphytes as well as *Algae* and *Rhizopoda* are arranged in different ways in the individual diagrams, according to the lithology of the deposit;

k. unidentified and rebedded sporomorphs;

The synthetic diagrams (Figs 22, 23, 26, 27, 28), are constructed on the uncalibrated radiocarbon time-scales, which are based on the accumulation rate values. The accumulation rate was calculated by joining the points for the mean age and the mean depth of each dated sample (see Berglund & Ralska-Jasiewiczowa 1986). The human impact diagrams (Fig. 26) show the percentage pollen values of total anthropogenic indicators calculated in relation to the AP+NAP sum. The list of taxa included to this group is presented in Tab. 1.

The pollen diagrams are divided into local pollen assemblage zones (local paz) and subzones (pa subz), in the sense of Cushing (1964) (after Birks 1986b). They represent rather large and very distinct units and are mainly based on the AP composition. In addition to the local paz, anthropogenic phases were distinguished in order to illustrate man-made changes. This division is based mainly on the NAP composition and records the minor AP fluctuations. The botanical nomenclature follows Flora Europaea, whereas the accuracy of the pollen determination is described according to Birks (1973).

ANTHROPOGENIC INDICATORS

GENERAL COMMENTS

In recent years, the interpretation of the occurrence of certain plants in pollen diagrams as anthropogenic indicators has received much attention. The problem has been tackled in a variety of ways. In addition to the tendency to analyse the value of taxa as indicative of different forms of land utilization (Behre 1981, Hicks 1988, Kaland 1986, Vuorela 1970, 1986), attempts are being made to obtain a synthetic presentation of the contribution of indicator plants in the form of grouped curves (Ralska-Jasiewiczowa 1981, Gaillard & Berglund 1988), cumulative curves (Pawlikowski et al. 1982) or synthetic diagrams (Berglund & Ralska-Jasiewiczowa 1986). One of the most speculative ways of presentation is that practised by Lange (1971, 1975, 1986) in which the *Plantago lanceolata*: *Cerealia* index presented in the form of pie diagrams is expected to be indicative of land use.

The synthetic presentation of the results of pollen analysis has many advantages, the most important one being that non-pollen analysts find it fairly easy to use them. On the other hand, a number of objections have been raised (Behre 1981, Groenman-van Waateringe 1988).

The indicator role of individual taxa is usually equivocal. This applies not only to "non-species" identifications (genus, family or type) but also to the majority of species. Genera and families often include plants with opposing ecological requirements, and only exceptionally are indicative of a specific habitat conditions (e.g. *Chenopodiaceae* include mostly nitrophilous plants). Moreover, many of the anthropogenic indicators identified to the species level, find suitable conditions not only on diverse man-made habitats but also on natural ones. The problem has been comprehensively discussed by Behre (1981) who draws attention to the ecological and synecological scales of the species assumed to be indicators of various forms of land utilization and recommends a

Table 1. A list of the anthropogenic indicators, their requirements with respect to habitat and occurrence in the profiles and archaeological periods or cultures Taxon: * – taxa described in p. 141, ◆ – archaeophytes (after Zając 1979)

Anthropogenic plant communities (after Behre 1981): A -winter cereals, B -summer cereals and root crops, C – fallow land, D – wet meadows and pastures, E – dry pastures (heath), F – grazed forest, G – footpath and ruderal communities, Columns: x – occurrence, ▲– main occurrence
Soils (after Zarzycki 1984): moisture: dr – dry, fr – fresh, mo – moist, fertility: ol – oligotrophic, me – mesotrophic, eu – eutrophic, Columns: x – occurrence Sites: K – Kołczewo, R – Lake Racze, W – Wolin II, Columns: x – occurrence, ● – particular abundance
Occurrence in archaeological periods: pN – preNeolithic, N – Neolithic, B – Bronze Age, L – Lusatian culture, I – Iron Age, MA – Middle Ages, Columns: r – single pollen grains, + – in small numbers, ✻ – numerous, ■ – abundant

Taxon	Anthropogenic comunity							Soils						Sites			Occurrence in archaeolog. periods					
								moisture			fertility											
	A	B	C	D	E	F	G	dr	fr	mo	ol	me	eu	K	R	W	pN	N	B	L	I	MA
Anthoceraceae																						
Anthoceros punctatus	x	x								x		x		x						r		
Boraginaceae																						
Echium vulgare			x				x	x				x				x						r
Campanulaceae																						
Campanula	x		x		x	x		x	x			x		x	x	x	r		r	r	r	r
Jasione montana			x		▲	x		x			x			x	x	x	r	r	r	r	r	✻
Cannabaceae																						
* *cf. Cannabis sativa*		x												x	●	x					+	■
Caryophyllaceae																						
◆ *Agrostemma githago*	x														x	x						+
Cerastium	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x		r	r			
Herniaria			x		▲		x	x			x				x							r
Melandrium cf. album	x		x				x		x				x	x	x					r		r
◆ *Scleranthus annuus*	▲	x	x		x			x			x	x		x	x	x			r	r	r	r
Scleranthus perennis	x	x	x		▲			x			x			x	x	x				r	r	+
Silene cf. nutans						x		x				x		x							r	
◆ *cf. Spergula arvensis*	▲	x	x					x				x·	x	x	x	x						r
Stellaria cf. media	x	▲	x				x		x	x			x		x							r
Chenopodiaceae																						
Chenopodiaceae undiff.	x	x	x				▲		x			x	x	x	x	x	+	+	+	■	+	■
* *cf. Chenopodium album*	x	x	x				▲		x				x	x		x				✻	r	r
Compositeae																						
*Asteroideae*undiff.	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	r	+	+	+	r	✻
Anthemis t. (A. arvensis)	x		x				x	x	x	x		x	x		x	x			+	+	+	+
Artemisia		x	x		x	x	▲	x	x		x		x	x	x	x	+	+	✻	■	✻	■
Bellis t.			x	x	x		x		x	x	x	x		x				r				

Table 1. Continued

Taxon	Anthropogenic comunity							Soils: moisture			Soils: fertility			Sites			Occurrence in archaeolog. periods					
	A	B	C	D	E	F	G	dr	fr	mo	ol	me	eu	K	R	W	pN	N	B	L	I	MA
*◆ *Centaurea cyanus*	▲	x	x						x			x		x	x	x		r	r			✻
Centaurea jacea t.			x	x			x		x				x	x	x	x	r	r	r	r	r	r
Centaurea scabiosa t.			x		x			x	x			x				x			r			r
Cirsium t.		x	x	x	x		x		x	x	x	x	x	x	x	x	r	r	r		r	✻
Senecio t.		x	x	x	x	x	x	x	x	x	x	x	x	x	x				r			r
Cicorioideae undiff.	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	■	+	+	■	✻	■
Lapsana t. (L. communis)		x	x				▲		x				x	x		x		+	+	■	r	■
Convolvulaceae																						
* *Convolvulus arvensis*	▲	x	x				x	x	x			x		x	x					r		r
Crassulaceae																						
Sedum			x		x			x			x			x	x		r	r				
Cruciferae																						
Cruciferae undiff.	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	r	r	+	+	+	■
Cupressaceae																						
Juniperus					▲	x		x				x		x	x	x	r	r	r	r	r	■
Cyperaceae																						
cf. Cyperus	x	x								x		x		x						✻		
Dipsacaceae																						
Knautia arvensis	x		x		▲		x	x				x	x	x	x							r
Scabiosa columbaria					x			x				x				x			r			r
Succisa pratensis			x	▲	x				x	x		x	x	x	x	x	r		r	r		r
Ericaceae																						
Calluna vulgaris					▲	x		x	x		x			x	x	l	+	+	■	■	✻	+
Gramineae																						
Gramineae undiff.	x	x	x	▲	▲	x	x	x	x	x	x	x	x	x	x	x	✻	✻	✻	■	✻	■
* *Avena t.*		▲	x											x	x	x						+
* *Cerealia* undiff.	x	x	x											x	x	x	r	+	r	+	✻	■
* *Hordeum t.*	x	▲	x											x	x	x	r	r	r	r	r	✻
* *Secale cereale*	▲	x	x											x	x	x		r	r	r	+	■
* *Triticum t.*		▲	x											x	x	x		r	r	+	+	■
* *Zea mays*		x														x						r
Guttifereae																						
Hypericum			x	x	x		x	x	x	x		x	x	x		x	r	r	r	r	r	r
Hypolepidaceae																						
* *Pteridium aquilinum*			x	x	x	▲			x		x	x		x	x	x	■	■	▲	▲	▲	▲

Table 1. Continued

Taxon	Anthropogenic comunity							Soils: moisture			Soils: fertility			Sites			Occurrence in archaeolog. periods					
	A	B	C	D	E	F	G	dr	fr	mo	ol	me	eu	K	R	W	pN	N	B	L	I	MA
Isoetaceae																						
* *Isoetes*											x				x							r
Leguminosae																						
Leguminosae undiff.	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	r	r	r	r	r	+
Lathyrus	x	x	x	x	x	x	x		x			x	x	x	x		r	r		r		r
Trifolium	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	r	r	r	r		+
Trifolium pratense			x	▲			x		x				x		x	x				r		r
Trifolium repens	x	x	x	▲	x	x	x	x	x				x	x	x					r		r
Vicia t.	x	x	x	x	x	x	x		x			x		x	x			r	r	r		r
Vicia cf. cracca	x		x	▲					x				x	x								r
Liliaceae																						
Alium vineale t.			x		x			x				x			x							r
* *Anthericum ramosum*						x		x			x			x			r	r	r			
Lythraceae																						
* *Peplis portula*	x	x								x		x		x						+		r
Onagraceae																						
Epilobium angustifolium						x	x		x			x	x		x	x		r	r			r
Papaveraceae																						
◆ *Fumaria officinalis*		▲	x						x				x			x					r	
*◆ *Papaver argemone*	x		x				x		x			x			x							+
◆ *Papaver rhoeas t.*	x		x				x		x				x	x	x	x			r		r	+
Plantaginaceae																						
Plantago lanceolata	x	x	x	▲	x	x	x	x	x	x		x	x	x	x	x		+	✻	■	✻	■
Plantago maior	x		x			x	▲		x	x			x	x	x	x	r	r	r	r	r	r
Plantago media			x	▲	x		x	x	x			x	x	x	x	x	r	r	r	r	r	r
Plumbaginaceae																						
Armeria maritima ssp. elongata					▲			x				x			x							r
Polygalaceae																						
Polygala vulgaris					▲			x	x			x			x							r
Polygonaceae																						
◆ *Bilderdykia convolvulus*	▲	x	x				x		x			x		x	x	x		r	r	r	r	✻
*◆ *Fagopyrum*		x	x											x	x	x		r				+
Polygonum aviculare	x	x	x				▲		x			x	x	x	x	x			r	+	r	✻
Polygonum persicaria t.	x	▲	x				x		x			x	x	x	x	x			r	r	r	r

Table 1. Continued

Taxon	Anthropogenic comunity							Soils						Sites			Occurrence in archaeolog. periods					
								moisture			fertility											
	A	B	C	D	E	F	G	dr	fr	mo	ol	me	eu	K	R	W	pN	N	B	L	I	MA
Rumex acetosa t.			x	▲		x	x		x	x			x	x	x	x	r	r	+	*	+	■
Rumex acetosella	▲	x	x	x	▲	x	x	x			x			x	x	x	+	*	■	■	*	■
Rumex cf. conglomeratus				x			x		x	x			x		x							r
Rumex cf. obtusifolius							x	x	x				x	x					r			
Primulaceae																						
◆ *Anagallis arvensis*	▲	x	x				x	x					x		x							r
* *Primula veris t.*					x	x		x				x		x	x		r	r	r	r	r	r
Ranunculaceae																						
Ranunculaceae undiff.	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	r	r	r	r	r	+
Ranunculus acris t.			x	▲		x	x		x	x			x	x			r	r	r	*	r	r
Ranunculus arvensis	x	x	x						x				x		x							r
Rosaceae																						
Alchemilla t.				x					x	x		x	x		x							r
Malus t.																x						r
Prunus t.														x								r
Rosa t.			x			x		x	x			x	x	x	x			r				
Rubus			x		▲	x	x		x			x	x	x	x	x	+	r	+	+	+	*
Rubiaceae																						
Galium t.	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	r	+	*	r	r	*
Scrophulariaceae																						
Melampyrum					x	▲			x		x			x	x	x	r	r	+	+	*	*
Rhinanthus	x	x	x	x	x				x	x		x				x			r	r		*
Umbelliferae																						
Umbelliferae undiff.			x	x	x	x	x	x	x	x	x	x	x	x	x	x	r	r	+	*	+	■
* *Pimpinella (saxifraga)*			x		x		x	x				x				x	r	+	+	+	*	*
Urticaceae																						
Urtica		x	x			x	▲		x	x			x	x	x	x	+	+	+	+	+	■
Valerianaceae																						
* *Valerianella locusta*					x			x	x			x				x			r			
Violaceae																						
◆ *Viola arvensis t.*	x	x	x		x				x			x	x		x			r				

critical approach to the interpretation of their presence in pollen diagrams. In the light of his data (especially Fig. 2), some forms of synthetic diagram (see Berglund & Ralska-Jasiewiczowa 1986 – Fig. 22.10) appear to be over-simplified. In particular, the rigid attribution of certain taxa to particular groups of anthropogenic indicators, arouses many doubts because their pollen may come from plants growing on various habitats. What is not taken into account in such a treatment is the fact that over the last 6000 years agriculture has changed a great deal: not only have anthropogenic communities undergone transformations but soils have too, so the pollen of a given taxa at different stages in the history of human settlement may well have come from different plant communities and be associated with different forms of land use (Behre 1981, Groenman-van Waateringe 1988).

Cumulative curves or graphs linking up pollen and macrofossil data for plants having similar requirements with respect to selected ecological factors, such as soil or water pH, fertility and moisture or light, appear to be much less prone to error. A thorough analysis of the habitat conditions surrounding the site combined with a knowledge of a particular settlement location furnish interesting and reliable results (Wasylikowa 1989).

In the present paper a long list of anthropogenic indicators (Tab. 1) is discussed. The interpretation is dependent on the context in which these taxa occur in the diagrams and on the local habitat conditions in the surroundings of the individual sites. Special attention is paid to the evaluation of the supposed apophytes, which only exceptionally are indicative of a strictly specified habitat. By definition, they are components of both natural and man-made communities (Linkola 1916) and the term "apophyte" is strictly linked with the secondary occurrence of a plant on a habitat altered by man. Since it is not possible to identify with absolute certainty the places of origin of pollen grains present in the sediment, the apophytic status of plants represented in a pollen diagram is only presumed and, especially in the levels illustrating early settlement, may be doubtful. A cautious approach to the separation and interpretation of apophytes in pollen diagrams is therefore advised (Borowik-Dąbrowska 1985).

In the main pollen diagrams (Fig. 7, 11, 16) the anthropogenic indicators are ordered according to their preferred habitat conditions, however, the groups are not definitively separated and mostly overlap each other.

The synthetic diagrams (Fig. 26) illustrate the total proportion (%) of all anthropogenic indicators, with *Cerealia*, *Gramineae* and *Calluna* being shown separately.

LIST OF TAXA

The list of indicator taxa (Tab. 1) is ordered alphabetically according to families. The division of anthropogenic communities into seven groups (A-G) follows Behre (1981). The present-day occurrence of individual taxa within these groups is demonstrated according both to Behre (1981) and to the phytosociological information compiled for Poland (Matuszkiewicz 1982) and for Wolin Island (Piotrowska 1966 b) in particular. The demands in respect to soil fertility and humidity are indicated after Zarzycki (1984). The archaeophytes were marked according to Zając (1979).

Among the indicators, apophytes with broad ecological ranges prevail. Most of the taxa are indicative of dry or fresh, mesotrophic or slightly eutrophic soils. Archaeophytes and cultivated plants reach ca. 20% of all indicators. Numerous taxa (41%) occur as single pollen grains only. Weeds typical of fertile soils, which are very rare in the

Wolin flora today (e.g. *Fumaria officinalis, Ranunculus arvensis, Silene cf. nutans, Melandrium cf. album*) belong to this group.

NOTES ON THE DETERMINATION AND OCCURRENCE OF SELECTED TAXA

cf. *Cannabis sativa*

The separation of *Cannabis sativa* and *Humulus lupulus* pollen is a difficult problem from the pollen-morphological point of view (Punt & Malotaux 1984, Whittington & Gordon 1987). In the present investigations the following criteria were used to determine *Cannabis* pollen: 1. features of the form of the porus, such as its elevation, a distinct rim between porus and annulus, the width of the annulus larger than the porus diameter and the rather circular shape of the porus; 2. pollen size was treated as an additional criterion, but it is worthy of note, that the great majority of cf. *Cannabis* pollen determined by morphological criteria were 26–31 µm in size, which is accepted as typical for this taxon (Punt & Malotaux 1984, Whittington & Gordon 1987). Determination to the species level was only partially possible, therefore, in the pollen diagrams the curves of cf. *Cannabis sativa* and cf. *Humulus lupulus* are present as well as that of *Cannabis/Humulus.*

In the material from Wolin Island pollen of cf. *Cannabis* appears in small quantities in the pre-Roman Iron Age in the Kołczewo profile, single grains are present in the uppermost section of the Wolin II profile, while in the upper part of Lake Racze profile (630±80 BP) it reaches up to 40% of the total pollen sum (cf. p. 181).

cf. *Chenopodium album*

Chenopodiaceae is a stenopollenic family, however, attempts to differentiate pollen types within this family are known (Monoshon 1973, Uotila 1974).

The presence of a great number of uniform, large *Chenopodiaceae* pollen grains in the samples from Kołczewo corresponding to the Lusatian culture encouraged the author to try further determination. Pollen grains 27–30 µm in diameter were examined. They were characterized by a great pore number (min. 50) which is in agreement with the data published by Monoshon (1973). The sculpturing features were compared with those of the reference material under 1200x magnification.

Identification is supported by the fact, that in the same level several seeds of *Chenopodium album* were found together with diaspores of other plants coming from the area close to the investigated site. Moreover, of the two species which have very similar pollen grains to those of *Ch. album, Ch. viride* was not recorded while *Ch. vulvaria* is a very rare plant in the area (Piotrowska 1966 a). Pollen grains determined as cf. *Chenopodium album* constitute only a part of the total pollen of this species; the smaller specimens were included to the *Chenopodiaceae* curve.

Centaurea cyanus

In the present-day plant communities cornflower is usually associated with weed communities of winter cereals, especially with rye (Behre 1981), and grows on poor sandy or sandy-clayey soils. The first pollen grains of *Centaurea cyanus* are recorded in the Wolin II profile in the sample of Neolithic age just before the first occurrence of rye pollen grains. Such an early appearance of this species is also known from two other localities in northwestern Poland (fruits: Biskupin, Klichowska 1972; pollen: Żarnowiec mire, Latałowa 1982b).

Probably, at that time cornflower spread together with the *Secale*-weed in cultivated fields. Similarly, Andersen (1988b) supposes an accidental introduction of *Centaurea cyanus* by the Neolithic people to Denmark.

Convolvulus arvensis

Convolvulus arvensis is a typical weed growing with winter cereals and on ruderal habitats. It prefers mesotrophic clayey-sandy soils. Several pollen grains were found in the samples dated to the Lusatian culture from the Kołczewo profile and single pollen grains were encountered in the layers of historical time from Lake Racze.

Cerealia

The cereal determinations were made with the aid of phase contrast microscopy and were based on criteria described by Beug (1961) and Andersen (1979) as well as on a reference collection. The greater part of the pollen was identified only as *Cerealia* undiff., because of the poor pollen preservation, especially in the Wolin II profile and in the upper part of the Lake Racze profile. It seems, that these corroded pollen grains came into the basins as a result of increasing soil erosion. The first *Cerealia* undiff. were recognized in the Wolin II profile in the layer dated to 5400*–5300*BP which can be correlated with the Ertebølle culture; in the Kołczewo and Lake Racze profiles they appeared in the samples dated to the late Neolithic.

Avena type is represented in all the profiles in the early Medieval and historical levels. In the archaeobotanical material from Wolin Island caryopses of *Avena sativa* were not found prior to the early Middle Ages (Klichowska 1972).

The first *Hordeum* type pollen grains appear in the Wolin II profile in the same sample as the first *Cerealia* undiff. pollen (see above). Barley is also present in the other diagrams in the younger settlement phases. A significant rise in the *Hordeum* type curves (Lake Racze, Kołczewo) is dated to early Medieval time. In the upper part of the Lake Racze profile, among pollen identified as this type, several specimens resembling *Agropyron repens* are present (cf. Vorren 1986). It is difficult, however, to be exact about the separation of these species because of the bad preservation of the pollen grains, which restricts the reliability of the identification.

In the macrofossil material from Wolin Island some imprints of *Hordeum vulgare* were identified on the ceramics of the Funnel Beaker and Lusatian cultures, while in the samples from early Medieval times this species was abundantly present and outnumbered the remnains of the other cereals (Klichowska 1972). Single charred grains of *Hordeum vulgare* were also found in the samples from the early Medieval port on Wolin Island (Latałowa in print).

Single pollen grains of *Secale cereale* are present from the Neolithic (Wolin II profile). Their number increases slightly in the Iron Age (Kołczewo), while in the early Middle Ages and later, they form continuous, very high curves.

The earliest finds of rye macrofossil on Wolin Island come from the Lusatian culture (2 imprints); a large number of charred grains is known from the early Medieval layers (Klichowska 1972).

In the light of the palynological and macrofossil data quoted above, it seems, that this abundantly flowering, wind-pollinated species was not cultivated before the Roman Iron Age, that is the point at which, in the pollen diagrams, its curve exceeds the curves of the other cereals. The earlier finds probably come from the rye-weed. Intensive *Secale* cultivation started in the early Middle Ages.

Triticum type appears in the late Neolithic (Wolin II) and as single pollen grains it is present up to the layers dated to the Lusatian culture, when its role increases slightly (Kołczewo). Pollen of this type becomes more frequent in the sections of the Iron Age, especially in its younger phase, but the real rise in the pollen curve is observed in those parts of the diagrams which represent the early Middle Ages.

Among the plant remains found on the site of the Funnel Beaker culture one imprint of *Triticum sp.* was recorded, while in the samples dated to the Lusatian culture two imprints of *Triticum sp.* and one of *T. aestivum* were discovered. In the layers of the early Middle Ages *Triticum* remains increase considerably, but they are not as numerous as those of *Hordeum* and *Secale*. *Triticum aestivum*, *T. compactum* and single grains of *T. dicoccum* were determined (Klichowska 1972).

A single pollen grain of *Zea mays* was found in the uppermost sample of the Lake Racze sediments.

Pteridium aquilinum

Pteridium aquilinum is mainly characteristic of different oakwood communities (Matuszkiewicz 1982) and prefers acid, well-drained soils (Poel 1961). Bracken is favoured by a good light supply and its sporal regeneration is correlated with the presence of ash in the soil (Oinonen 1967). Usually the presence of *Pteridium* spores is regarded as evidence of woodland disturbed by fire and grazing and also of dry heath, pastures and fallow land (Behre 1981). Göransson (1986) suggests the importance of this species as a fodder plant in prehistoric times.

Pteridium aquilinum spores are very abundant in all the profiles from Wolin Island, especially in the Wolin II diagram, where they reach up to 7% of the total pollen sum.

Isoëtes

Several microspores of *Isoëtes* were found in the upper part of the Lake Racze sediments. This typically oligotrophic water plant may be indicative of soil erosion in the lake catchment area prior to eutrophication (Vuorela 1980). A few decades ago *Isoëtes lacustris* grew in Lake Racze and was recorded by several botanists, but then it disappeared due to the increasing eutrophication of the lake (Piotrowska 1966 a).

Anthericum ramosum

Anthericum ramosum is characteristic of xerothermic communities of forest edges and glades (Matuszkiewicz 1982), and so, it could be regarded as evidence of forest clearance. Recently, it has been recorded from seven localities on Wolin Island (Piotrowska 1966 a). Four pollen grains of *Anthericum ramosum* were found in the Kołczewo profile (cf. Tab. 1).

Peplis portula

Peplis portula is a component of ephemeral communities of small terophytes growing on moist sand. Apart from its natural habitats like the sandy shores of stagnant water bodies, it is recorded, particularly in rainy seasons, on such anthropogenic habitats as pathways, field trenches and stubble fields (Kornaś 1972). On Wolin Island only one locality of this species was recorded by Lucas (1860), but it was not confirmed later by Piotrowska (1966 a). Several pollen grains of *Peplis portula* were noticed in the Kołczewo profile, in the samples dated to the Lusatian culture, and one in the upper part of the profile.

Papaver argemone

Several pollen grains of *Papaver argemone* were found in the upper part of the Lake Racze profile. Its pollen is 6 pantoporate, 35–36 μm in diameter, slightly quadrangular in outline; the pori are slightly sunken, with an irregular margin, without an annulus and covered with a granulated operculum; the sexine is scabrate (cf. Kalis 1980).

Papaver argemone is a weed typical of winter cereals; it grows on fallow land and sometimes on ruderal habitats as well. It prefers light soils. Numerous localities of this plant are known from the agricultural areas on Wolin Island (Piotrowska 1966 a).

Fagopyrum

Fagopyrum pollen is present in the sections representing the early Middle Ages. In addition, one small grain (39–23 μm in size) was found in a sample of Neolithic age (ca. 4200–4300 BP) in the Kołczewo profile. This last finding is of special interest.

Fagopyrum pollen grains are dimorphic, larger in brevistyled and smaller in longistyled flowers (Erdtman et al. 1961, Florin 1969). The grain from the Kołczewo profile falls in the size range characteristic of pollen of *Fagopyrum tataricum* from longistylic flowers.

Fagopyrum pollen grains from earlier than the Iron Age are very rare. The earliest record is that reported by Florin (1969) from the pollen zones III/IV and IV in Sweden. A few others come from the Neolithic (Troels-Smith 1953, Göransson unpubl.- after Gaillard & Berglund 1987). All these finds probably represent wild buckwheat *Fagopyrum tataricum*. Cultivated *Fagopyrum esculentum* spread over northern Europe in the Viking Time and in the early Middle Ages (Gaillard & Berglund 1987).

***Primula veris* type**

Single pollen grains of the *Primula veris* type were found in several samples in the Kołczewo and Lake Racze profiles (see Tab. 1) whereas no *Primula* species is present in the recent flora of Wolin Island (Piotrowska 1966 a). Lucas (1860), however, reported the occurrence of *P. veris* as a rare species in the vicinity of Kołczewo. It is possible that this plant was much more common in the past and receded gradually with the increase in agriculture and the loss of suitable habitats, such as thickets and dry grasslands developed after oakwoods.

***Pimpinella* type**

Numerous pollen grains of *Pimpinella* type were recorded in the Wolin II profile. They follow the *Calluna* curve and seem to originate from *P. saxifraga*, a plant common in heath communities. It is a frequent species on various dry, sandy habitats on Wolin Island, today.

Valerianella locusta

One pollen grain of this plant was found in a sample from the Bronze Age. *Valeria-*

nella locusta is a rather rare species on Wolin Island; it occurs on habitats of dry, sandy waste land (Piotrowska 1966 a). It was used as a vegetable in prehistoric times (Kruk 1980).

THE BACKGROUND TO THE PALAEOECOLOGICAL INTERPRETATIONS

KOŁCZEWO

THE SITE

The ca. 4 ha peatbog lies within a kame terrace some 200 m west of Lake Kołczewo (Fig. 5a, b) and fills part of a once-larger kettle-hole. The edge of the bog is minerogenic; traces of long-disused drainage ditches are visible. It is a raised bog, currently dominated by *Molinia caerulea; Oxycoccus quadripetalus, Andromeda polifolia, Drosera intermedia, D. rotundifolia, D. longifolia, Eriophorum vaginatum, Rhynhospora alba* are present in smaller amounts, and *Sphagnum fallax* is the most common *Bryophyte*. Scattered mature and juvenile specimens of *Pinus sylvestris* grow on the bog

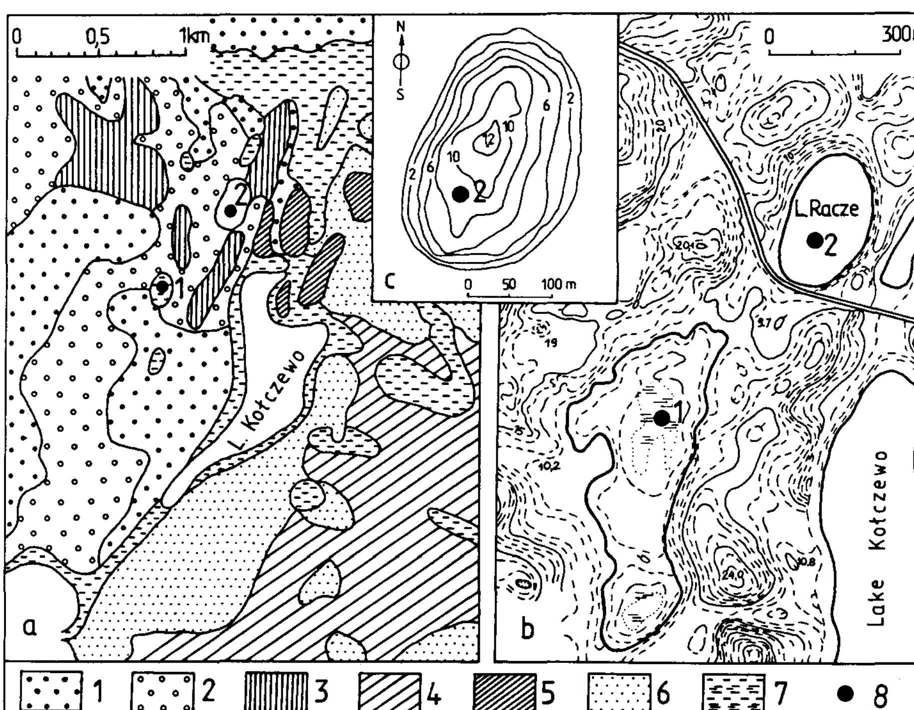

Fig. 5. Maps of the northern part of Wolin Island showing: a – Quaternary deposits (after Mapa Geologiczna Polski 1:50.000); b – topography; c – Lake Racze bathymetry; 1 – sand and gravel of kame plateau; 2 – clayey sand of kame plateau; 3 – clays of kame plateau; 4 – clayey sand on boulder clays; 5 – boulder clays; 6 – outwash sand and gravel; 7 – Holocene peats and muds of lake and river origin; 8 – location of the profiles investigated: 1-Kołczewo, 2-Lake Racze

and there are also young specimens of *Betula pendula* and *Quercus robur*. The cores for the present study were taken from the centre of the bog.

The soils surrounding the site are poor, formed mostly in sands or clayey sands (Fig. 5a). The ground adjacent to the bog is covered largely by a 35-year-old close-canopied pine plantation. This is on former arable land, as traces of nitrophilous vegetation, including *Sambucus nigra, Urtica dioica, Galeopsis tetrahit, G. pubescens* and others, testify. Nearby, there are also fragments of fertile beech-oak woods with planted pine, and an admixture of hazel and single hornbeams. The somewhat higher-lying phytocoenoses suggest *Betulo-Quercetum* habitats, because, among other indications, numerous specimens of *Lonicera periclymenum* were found, some in flower.

PEAT STRATIGRAPHY

Layer no	Depth (cm)	
1	0–30	light brown *Sphagnum* peat with admixture of *Molinia* and *Eriophorum* peat, Tb^1(Spha)3, Th^1(Mol)1, Th^1(Erioph)++, Tl^1(Ericac)+, Gs++, nig2, elas1, strf0, sicc3, humo1 (H2);
2	30–60	light brown *Sphagnum* peat with admixture of *Eriophorum* peat, Tb^1(Spha)3, Th^1(Erioph)1, nig2, elas1, strf0, sicc3, humo1(H2), lim. sup. 0;
3	60–130	light brown *Sphagnum* peat, Th^1(Spha)4, nig2, elas1, strf0, sicc3, humo1(H2), lim. sup. 0; at 80–60 cm depth slightly lighter intercalation;
4	130–235	brown *Sphagnum* peat Tb^2(Spha)4, nig3, elas1, strf0, sicc3, humo2(H5), lim. sup. 0; at 235–210 cm depth slightly lighter intercalation of pure *Sphagnum* peat Tb^2(Spha)4;
5	235–250	brown *Sphagnum* peat with differing admixture of *Eriophorum* and Ericaceae peat, Tb^2(Spha)2–3, Th^2(Erioph)2–1, Th^1(Ericac)++, nig3, elas2, strf0, sicc2, humo2(H5), lim. sup. 0;
6	250–295	light brown *Sphagnum-Eriophorum* peat with admixture of Ericaceae (*Andromeda polifolia, Oxycoccus quadripetalus)* and *Scheuchzeria* peat, Tb^2(Spha)3–1, Th^2(Erioph)1–3, Th^1(Ericac)+++, Th^2(Sch)++, nig2, strf0, sicc2, humo1–2(H3-H5), lim. sup. 0; at 272–260 cm depth slightly lighter intercalation of pure *Sphagnum* peat Tb^2(Spha)4;
7	290–313	light brown *Sphagnum-Eriophorum* peat (as above), with fine sand, Tb^2(Spha)1, Th^2(Erioph)1, Gs2, Th^2(Sch)++, Th^1(Ericac)++, nig2, strf1, sicc2, humo1–2 (H3-H5), lim. sup. 0;

8	313–316	light yellow-greyish fine sand Gs4, Sh++, Ld^2+++, nig1, elas0, strf0, sicc2, lim. sup. 1;
9	316–378	light brown *Sphagnum-Eriophorum* peat (*Sph. magellanicum, Sph. cuspidatum*) with admixture of *Scheuchzeria* and *Ericaceae* peat (*Andromeda polifolia, Oxycoccus quadripetalus*), Tb^2(Spha)3–1, Th^2(Erioph)1–3, Th^1(Ericac)+++, Th^2(Sch)+++, nig2, strf0, sicc2, humo1–2 (H3-5), lim. sup. 2; at 350–320 cm depth slightly lighter *Sphagnum* peat Tb^2(Spha)4;
10	378–405	brown moss peat (mainly *Calliergon trifarium*), $Tb^2$2, $Ld^3$2, Gs++, nig3, strf0, sicc3, humo2–3 (H5-8), lim. sup. 1;
11	405–440	brown moss peat (mainly *Calliergon trifarium*), $Tb^2$3, $Ld^3$1, nig3, strf0, sicc3, humo2–3 (H5-8), lim. sup. 0;
12	440–485	dark brown moss peat (mainly *Calliergon trifarium* with admixture of *Drepanocladus revolvens*), $Tb^2$4, nig4, strf0, sicc3, humo2 (H5), lim. sup. 0, 465–475 cm – increasing water content;
13	485–510	brown detritus gyttja with moss peat (mainly *Drepanocladus revolvens*), $Ld^3$3–2, $Tb^2$1–2, Gs++, nig3, strf0, sicc3, humo2–3 (H5-H8), lim. sup. 0;
14	510–550	brown detritus gyttja, $Ld^3$4, Tb^2+++, (mainly *Calliergon trifarium & Drepanocladus revolvens*), nig3, strf0, sicc3, humo2–3 (H5-H8), lim. sup. 0;

THE PEAT ACCUMULATION RATE AND THE RELIABILITY OF THE PALYNOLOGICAL AND CHRONOLOGICAL DATA

The rate of peat formation depends on several factors (Aaby 1986a). In this paper, however, the main interest is to recognize the time span represented by the particular sections of the profiles.

The peats and limnic sediments in the Kołczewo profile are very different with respect to their accumulation rate (Fig. 6), but since the calculations are based on the restricted number of ^{14}C dates, it was necessary to test these results with the pollen concentration data.

It is generally known, that pollen concentration is conditioned by different parameters such as basin and catchment size, erosional processes, sediment properties and vegetation type. The main factor causing changes in pollen concentration in the sediments is, however, the growth rate (Hicks 1975, Latałowa 1982, Middeldorp 1982). In the Kołczewo profile, a very clear negative correlation between pollen concentration and accumulation rate is observed (Fig. 6B), which generally confirms the reliability of the ^{14}C dates and the correctness of the calculations.

The accumulation rate is a very important factor in palaeoecological reconstructions.

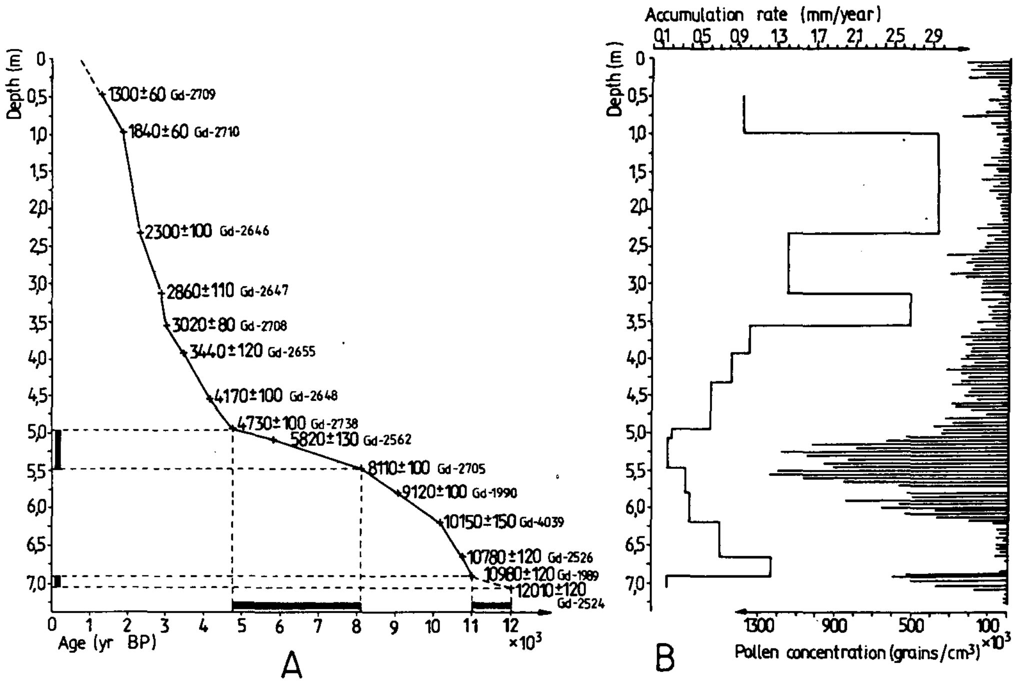

Fig. 6. A. The time-depth curve of the complete Kołczewo core; black bars indicate sections with a very low accumulation rate. B. The accumulation rate and AP+NAP concentration

In the Kołczewo profile very low values (0.15–0.2 mm/year) are indicated in the section 5.5–4.9 m (8110±100 – 4730±100 BP). The approximate calculations show, that for this section each pollen sample (1 cm^3 in volume) represents ca. 50–60 years, while the time gap between adjacent samples is ca. 250–330 years. This means, that the pollen data from this part of the profile is insufficient for the reconstruction of short-term changes and an extrapolation of the ^{14}C dates could be misleading. A different record is abtained from the sections 3.55–3.1 m (3020±80 – 2860±110 BP) and 2.3–1.0 m (2300±100 – 1840±60 BP), where the highest accumulation values (2.69 and 2.96 mm/year) are found. In these levels each pollen sample represents 3–4 years and the time gap between the samples is ca. 17–20 years. This means that we get very detailed pollen evidence of plant succession. The youngest peat layer is missing from this profile.

LOCAL POLLEN ASSEMBLAGE ZONES

Five local pollen assemblage zones and six subzones (Fig. 7) are characterized in Tab. 2. The pollen zones have consecutive numbers according to the division of the complete profile (Latałowa 1989b).

Table 2. Kołczewo, description of local pollen assemblage zones

Local paz	Name of paz	Depth (cm)	Approx ages BP	Description of pollen spectra
		550	8.110±100	
K–7	*Quercus- -Ulmus- -Tilia- -Betula*			Corylus decreases by 10% and from ca. 7.500 BP *Pinus* curve also falls by 15%; *Quercus* increases from 5 to 12%, *Ulmus* gains its first culmination (5%), *Tilia* and *Fraxinus* curves appear; relatively high frequencies of *Betula* (mean 21%); among NAP heliophytes are present: singly - *Artemisia, Melampyrum, Rumex acetosella* type, continuous curves - *Pteridium aquilinum, Calluna*; very high pollen concentration. K-7/K-8 limit: *Ulmus* decreases, *Corylus* increases.
		512	5.820±130	
K–8	*Quercus- -Corylus- -Tilia- -Ulmus- -Fraxinus*			high frequency of broad-leaved tree pollen: Quercus (mean 23%, max. 27%), *Tilia* (mean 3%, max. 5%), *Ulmus* (mean 2%, max. 7%), *Fraxinus* (mean 2%, max. 5%) and *Corylus* (mean 19%, max. 32%); regular occurrence of *Acer* and *Hedera*; *Fagus* and *Carpinus* curves rise; fluctuations of tree pollen values are strictly correlated with variable participation of anthropogenic indicators; the course of *Corylus, Pinus* and *Betula* curves is the base of the division into subzones; K-8/K-9 limit: decrease of *Ulmus, Fraxinus, Tilia, Quercus, Corylus, Alnus*; increase of NAP and beginning of the constant rise of *Fagus* curve.
subzones: K-8a		512– –392	5.820±130– –3.440±120	*Corylus* (max. 30%) and *Quercus* (max. 27%) dominate; low frequencies of *Pinus* (max. 19%) and *Betula* (max. 26%); K-8a/K-8b limit: *Corylus* decreases, *Pinus* and *Betula* increase.
K-8b	*Pinus-Betula*	392– –322	3.440±120– –2.860±110	high values of *Betula* (max. 40%) and *Pinus* (max. 30%); great role of *Quercus* (mean 20%) as formerly; *Corylus* decreases while *Carpinus* curve rises exeeding 1%.
		322	2.860±110	
K-9	*Pinus- -Fagus- -Gramineae*			percentages of *Ulmus, Tilia, Fraxinus* 1%; *Quercus* (mean 8%) and *Corylus* (mean 5%) decrease; slight increase of *Fagus* (max. 7%) and *Carpinus* (max. 3%); *Pinus* and *Betula* dominate especially in younger part of the zone; the course of *Betula* and *Pinus* curves is the base of the division into subzones; K-9/K-10 limit: *Fagus* and *Betula* increase, *Pinus* and NAP decrease
subzones: K-9a	*Gramineae- -Cyperaceae- -Plantago lanceolota*	322– –292	2.860±110– –2.700*	high frequencies of NAP (max. 55%), mainly of anthropogenic indicators (*Plantago lanceolata* 10%). K-9a/K-9b limit: NAP decreases, *Pinus* and *Betula* increase;
K-9b	*Pinus*	292–	2.700*	NAP decreases (max. 20%), but pollen of anthropogenic indicators still of importance; curves of *Pinus, Betula* and *Fagus* are rising;

Table 2. Continued

Local paz	Name of paz	Depth (cm)	Approx ages BP	Description of pollen spectra
		207	2.200*	
K-10	*Fagus-Pinus-Carpinus*			high frequencies of *Fagus* (mean 17%, max. 39%) and *Pinus* (mean 37%, max. 60%); *Carpinus* increases (max. 10%), NAP decreases, irregular occurrence of anthropogenic indicators; the course of *Fagus* and *Quercus* curves is the base of the division into subzones; K-10/K-11 limit: rapid decrease of *Fagus*, increase of NAP.
subzones: K-10a	*Quercus -Fagus*	212–-167	2.200*–2.100*	relatively high frequencies of *Quercus* (mean 11%) and *Betula* (mean 21%), increase of *Fagus* (max.12%), decrease of *Pinus* (mean 34%); continuous curves of *Plantago lanceolata* and *Rumex acetosella* type. K-10a/K-10b limit: *Quercus* decreases, *Fagus* and *Pinus* increase.
K-10b	*Fagus*	167–-27	2.100*–1.000*	*Fagus* (mean 20%, max. 39%) and *Pinus* (mean 39%, max. 60%) dominate; pollen of anthropogenic indicators scattered;
		27	1.000*	
K-11	*Pinus- - Gramineae- -Cerealia- -Juniperus*			among AP *Pinus* (mean 26%) dominates, pollen curves of other trees are very low; *Juniperus* curve appears; among NAP (mean 40%, max. 51%) high values of *Gramineae* and all of anthropogenic indicators, including *Cerealia*.
		0	800*	

CHARCOAL PARTICLE AND ASH CONTENT

There are considerable differences between the charcoal curves presented as concentration and influx values, especially in the bottom part of the profile, whereas the relative values generally follow those of the influx (Fig. 8). The greatest divergences refer to those sections of the profile which are distinguished by an extremely low (5.5–4.9 m) or fast (3.55–3.1 and 2.3–1.0 m) peat accumulation rate (cf. Fig. 6). This means that the influx and the relative values should be regarded as the basic data.

The charcoal dust content is substantial right from the bottom of the profile. Both curves culminate in accordance in the levels dated at ca. 4730±100, 2860±110 – 2700* BP and ca. 1000*–800*BP, while, in the same way the lowest values are registered in the section dated at 1840±60 – 1300±60 BP. In the samples dated to ca. 2200* BP no charcoal particles were found; the characteristic minor depressions are at ca. 4500*, 3700*, 3300*, 2600* years BP.

The minerogenic matter (ash) content (Fig. 7, 8) culminates in the same levels as the charcoal dust, i.e. ca. 2860±110 – 2700* BP and ca. 1000*–800* BP. A distinct peak is

→

Fig. 7. Relative pollen diagram from Kołczewo: 1 – detritus gyttja; 2 - brown-moss peat; 3 – *Eriophorum* peat; 4 – *Ericaceae* peat; 5 – *Sphagnum* peat; 6 – *Molinia* peat; 7 – fine sand

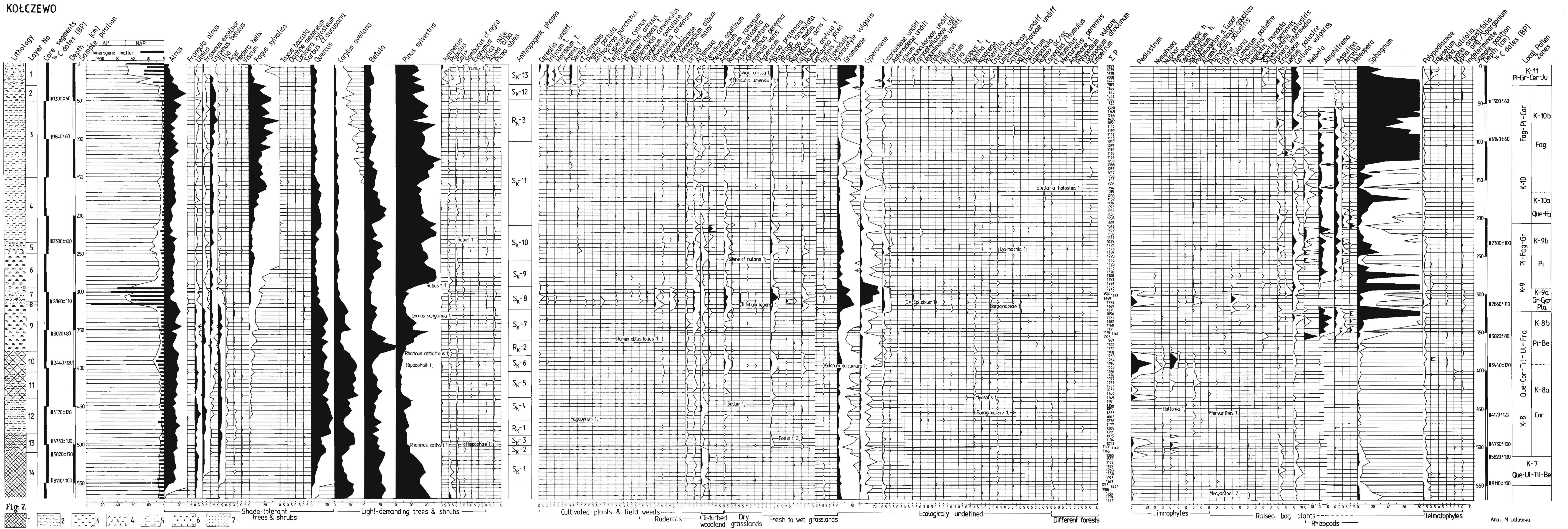
KOŁCZEWO
Lithology
Layer No
Core segments
¹⁴C dates (BP)
Depth (cm)
Sample position
AP
NAP
minerogenic matter
Alnus
Frangula alnus
Ulmus
Fraxinus excelsior
Carpinus betulus
Tilia
Acer
Hedera helix
Viscum
Fagus sylvatica
Taxus baccata
Daphne mezereum
Lonicera xylosteum
Sorbus t. aucuparia
Quercus
Corylus avellana
Betula
Pinus sylvestris
Juniperus
Populus
Salix
Sambucus cf. nigra
Euonymus
Myrica gale
Abies alba
Picea abies
Anthropogenic phases
Shade-tolerant trees & shrubs
Light-demanding trees & shrubs
Cerealia undiff.
Triticum t.
Hordeum t.
Avena t.
Secale
Cannabis
Artemisia
Pteridium aquilinum
Rumex acetosella
Plantago lanceolata
Gramineae
Cyperaceae
Calluna vulgaris
Sphagnum
Pediastrum
Nymphaea
Nuphar
Nebela
Amphitrema
Assulina
Arcella
Heleopera
Polypodiaceae
Equisetum
Typha latifolia
Local Pollen Zones
Cultivated plants & field weeds
Ruderals
Disturbed woodland
Dry grasslands
Fresh to wet grasslands
Ecologically undefined
Different forests
Limnophytes
Raised bog plants
Rhizopods
Telmatophytes
Anal. M. Latałowa

Fig. 7.

also found in the samples dated to 3440±120 BP. The lowest values are recorded in the section composed of ombrogenic peat, which is characteristic of such kinds of deposit (van Geel et al. 1989). In this section of the profile each small increase in the ash curve is correlated with a peak in the charcoal curve, stressing the anthropogenic nature of the phenomenon.

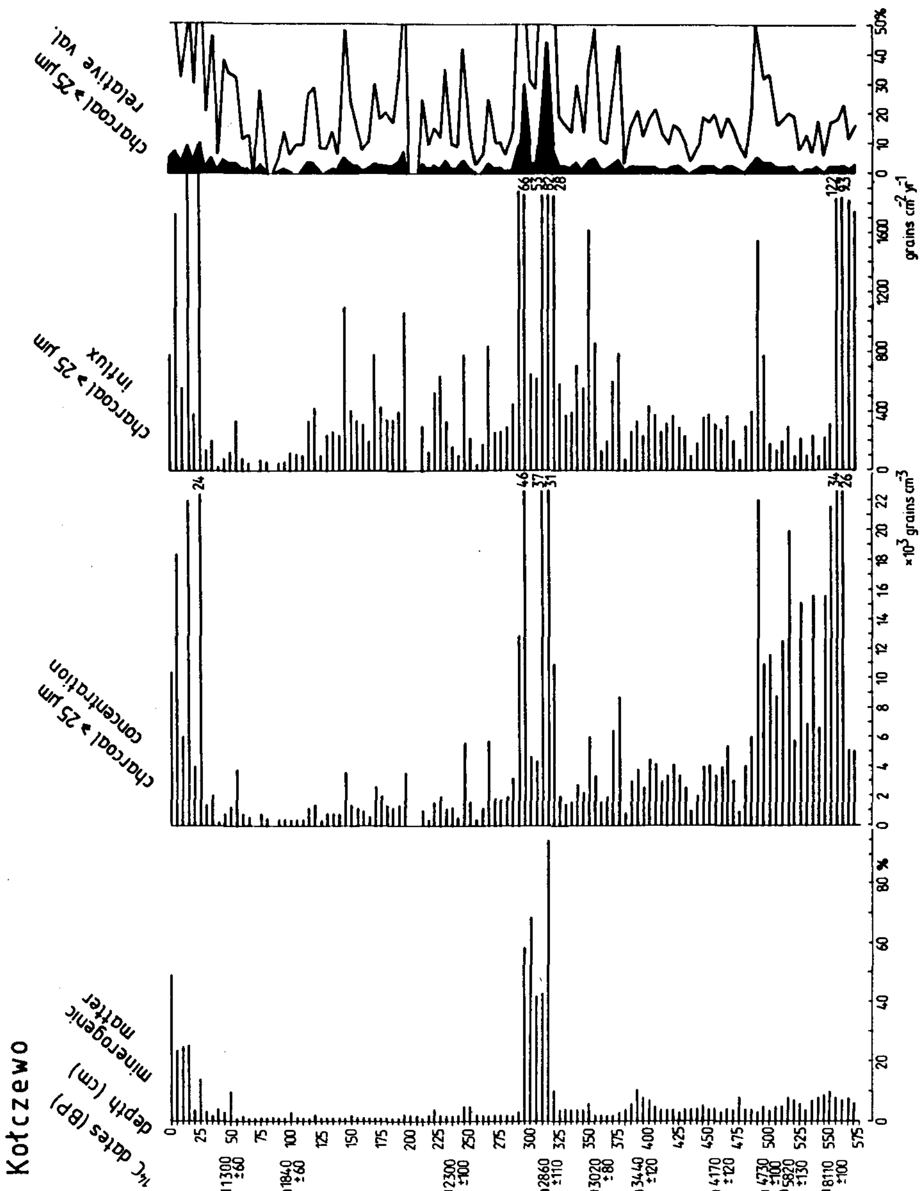

Fig. 8. Minerogenic matter and charcoal particle diagram from Kołczewo

ANTHROPOGENIC PHASES

In the diagrams from Kołczewo (Fig. 7, 9) sixteen anthropogenic phases are distinguished. There are thirteen "settlement phases" (SK), which illustrate clear, though differing in intensity, human influence on the vegetation and three "regeneration phases" (RK) which show settlement regression resulting in the regeneration of forest communities.

SK-1 (550–512 cm). The age of this phase is between 8110±100 and 5820±130 BP. Its characteristic features are a decrease in *Corylus* and *Pinus*, increase in *Quercus, Ulmus* and *Tilia* and the great importance of *Betula*. Among the NAP, *Pteridium aquilinum* is represented by high percentages (mean 1.2%) and pollen grains of other heliophytes are present – *Calluna vulgaris, Melampyrum, Anthericum ramosum, Rumex acetosella, Artemisia*. The content of charcoal dust in the sediments is substantial.

SK-2 (512–500 cm). The first fall in *Ulmus* (510 cm) is marked in both the percentage (Fig. 7) and concentration (Fig. 9) diagrams and is dated directly to 5820±130 BP. This date must, however, be treated with great caution because of the very low sedimentation rate in this part of the profile. The first *Ulmus* fall is accompanied by small depressions in the *Alnus* and *Fraxinus* curves, a sharp rises in the *Quercus* and *Corylus* curves and increases in *Tilia* and *Betula*; the first pollen grains of *Fagus* and *Carpinus* appear. There is no distinct correlation between the fall in *Ulmus* and the NAP changes; high percentages of *Pteridium* and pollen of some heliophytes are also present in the former phase; the first two pollen grains of *Plantago lanceolata* appear in the sample above the first *Ulmus* fall. The peak in the *Pediastrum* curve is an important feature.

SK-3 (500–487 cm). Pollen values of *Ulmus* remain low, *Quercus* decreases rapidly, while the curve of *Hedera* is interrupted. At the same level *Corylus* and *Tilia* increase and *Acer* appears. There is a distinct rise in the Gramineae and *Plantago lanceolata* curves, *Pteridium* spores are less abundant than in the former phases. A new peak in *Pediastrum* occurs. There is a substantial increase in AP and NAP influx (Fig. 9). The charcoal particle content rises sharply. The middle of the phase is dated directly to 4730±100 BP, while the end is at ca. 4600*BP.

RK-1 (487–467 cm). This phase lasted from ca. 4600* to 4400* BP. It is distinguished by a decrease in *Corylus* and by the lower contribution of pollen of heliophytes; the curves of *Plantago lanceolata* and *Artemisia* are interrupted. *Quercus, Ulmus* and *Fraxinus* increase concurrently; the slight depressions in the *Quercus* and *Tilia* curves are accompanied by culminations of *Betula*. AP and NAP influx decreases. Charcoal particles are distinctly less frequent than in the preceding phase.

SK-4 (467–437 cm). The beginning of this phase (ca. 4400* BP) is determined by the rise in the curves of *Pteridium, Plantago lanceolata* and *Corylus*. In the first part of this phase *Ulmus* and *Fraxinus* percentages increase, while *Pteridium* and *Plantago lanceolata* do not reach high values. The second *Ulmus* decline is dated directly to

---

→

Fig. 9. Combined diagram of the selected pollen percentage, concentration and influx data from Kołczewo

KOŁCZEWO
Pollen percentages & concentration
Pollen influx
Lithology
Layer No
^{14}C dates (BP)
Depth (cm)
Sample position
Alnus
Pinus sylvestris
Betula
Corylus avellana
Quercus
Ulmus
Fraxinus excelsior
Tilia
Carpinus betulus
Fagus sylvatica
NAP
Anthropogenic phases
AP
AP+NAP
1300±60
1840±60
2300±100
2860±110
3020±80
3440±120
4170±120
4730±120
5820±130
8110±100
×10³ grains cm⁻³
×10³ grains cm⁻² yr⁻¹
Anal. M. Latałowa

Fig. 9.

4170±120 BP; in the same sample *Quercus* decreases distinctly and then a fall in *Fraxinus* and – by the end of this phase – a drop in *Tilia* are also recorded. Moreover, the beginning of the continuous pollen curves of *Carpinus* and *Fagus* and the increase in *Pinus* are correlated with the second fall in *Ulmus*. Among the NAP, *Pteridium* culminates first, and later *Plantago lanceolata* forms a peak. Both, AP and NAP influx rises. The charcoal content increases. The end of this phase is dated on the basis of the sedimentation rate to ca. 3900*BP.

SK-5 (437–403 cm). This phase lasted about 400 years (3900*–3500*BP) and is distinguished by a small increase in *Ulmus* and *Quercus*; the percentages of *Corylus* fluctuate slightly but attain their highest values. Among the anthropogenic indicators *Pteridium aquilinum* and *Plantago lanceolata* form continuous curves but at a lower level than in the previous phase. The first pollen grain of *Cerealia* indet. appears.

The total AP influx increases, mainly due to the considerable input of *Corylus* pollen. With respect to the preceding SK-4 phase, the NAP influx also increases. These data indicate that the decrease in anthropogenic indicators in relative terms, is probably apparent. The charcoal content fluctuates but generally remains at a similar level to that of the previous phase.

SK-6 (403–382 cm). This phase is dated to 3500*–3300*BP. In this section of the diagram *Ulmus, Quercus, Fraxinus* and *Tilia* decrease, *Corylus* increases slightly but later decreases, too. There is a distinct rise in the curves of such anthropogenic indicators as *Plantago lanceolata* (2%) and *Rumex acetosella* (2%) and to a lesser degree *Pteridium* (0.8%) and *Rumex acetosa* type. The following taxa are recorded at lower values: *Jasione montana, Melampyrum, Artemisia, Urtica, Chenopodiaceae, Vicia, Bilderdykia convolvulus, Ranunculus acris* type, single pollen grains of *Cerealia (Triticum* type, *Secale, Cerealia* indet.) appear. The AP influx decreases while that of NAP increases. High amounts of *Pediastrum* (max. 25%) and *Nympheaceae* (pollen and hairs) are present. The distinct rise in minerogenic material is a characteristic feature of this part of the diagram.

RK-2 (382–362 cm). In this phase, dated to 3300*–3100*BP, *Betula* is represented by high percentages (max. 40%), the *Pinus* curve rises (max. 23%), while *Corylus* decreases. *Quercus, Tilia, Ulmus* and *Fraxinus* decrease slightly, but increase again in the upper part of this phase; the *Carpinus* curve exceeds 1%, the curve of *Fagus* is continuous but very low. The frequencies of all the anthropogenic indicators diminish distinctly. The total AP influx increases due to the significant input of *Betula* and *Pinus* pollen; the NAP influx falls. The charcoal content fluctuates considerably while that of minerogenic matter declines.

SK-7 (362–322 cm). This phase lasted about 200–300 years (3100*–2860±110 BP). The main feature is the gradual increase in the relative and influx values of NAP, mainly – *Artemisia, Plantago lanceolata* and *Pteridium*. Single pollen grains of *Cerealia* are present. In this phase there are several pronounced culminations of *Corylus, Betula* and *Pinus*. Pollen of these taxa are responsible for the high AP influx. The curves of *Quercus, Ulmus, Fraxinus* and *Tilia* fluctuate and fall towards the end of this phase. The charcoal and mineral matter input are higher than in the preceding section.

Sk-8 (322–292 cm). This phase is dated to 2860±110 – 2700*BP and differs from the previous phase in the much more pronounced changes in the pollen curves. NAP dominates over AP and very high frequencies of anthropogenic indicators are recorded: *Plantago lanceolata* (max. 10%), *Rumex acetosella* (max. 5%), *R. acetosa* type (max. 1%), *Artemisia (*max. 2%), *Lapsana* type (max. 2%), *Ranunculus acris* type (max. 2%); among the *Chenopodiaceae* pollen, numerous grains of cf. *Chenopodium album* were recorded (see p. 18). Moreover several pollen grains of *Convolvulus arvensis, Polygonum aviculare, Bilderdykia convolvulus, Scleranthus annuus, S. perennis, Trifolium repens, Peplis portula,* cf. *Cyperus* and spores of *Anthoceros punctatus* are present. Among cereals *Hordeum* type, *Triticum* type and *Secale* were determined. The percentages of *Ulmus, Tilia* and *Fraxinus* fall below 1%, and the contribution of *Quercus, Corylus* and *Alnus* also diminishes. The pollen curve of *Carpinus* remains at a low level, while the *Fagus* curve rises, exceeding 1%. At a depth of 320–315 cm sand is interbedded in the sediments and, in the pollen slides, a great amount of charcoal particles is recorded; at this level peaks of *Pediastrum* (max. 8%) and *Potamogeton* (max. 1%) are also noted. AP influx decreases sharply while NAP influx clearly increases.

Sk-9 (292–257 cm). This phase represents a time span of about 200 years (2700*–2500*BP) and is distinguished by a sharp decrease in NAP, including all the anthropogenic indicators. Pollen of some of these indicators (e.g. *Plantago lanceolata*) form continuous but low curves; cereal pollen disappears completely. After a sharp rise (max. 53%) the *Pinus* curve drops distinctly, while *Betula* (max. 21%) and *Fagus* (max. 7%) increase. The AP influx attains its maximum values, while the NAP influx decreases. Minerogenic matter and charcoal content are both low.

Sk-10 (257–212 cm). This phase is dated to 2500*–2200*BP. The increasing role of NAP is recorded. At first *Pteridium,* then *Artemisia, Plantago lanceolata, Rumex acetosella, R. acetosa* type and *Melampyrum* increase. Several pollen grains of cereals and numerous pollen grains of cf. *Cannabis* are present. The total pollen influx falls whereas charcoal and ash content rise slightly.

Sk-11 (212–102 cm). This part of the profile reflects the period from ca. 2200* to 1840±60 BP. Its main feature is the general decrease in NAP and the gradual increase in *Fagus*. The pollen of the anthropogenic indicators do not form continuous curves, but the frequency of cereals increases. An important feature is the beginning of the regular occurrence of *Secale* pollen starting at ca. 2000* BP. Total pollen influx falls. The minerogenic matter content remains very low, that of charcoal fluctuates strongly.

Rk-3 (102–47 cm). This section is dated to 1840±60 – 1300±60 BP and is characterized by the minimal contribution of herb pollen, especially of plants typical of settlement; concurrently the maximum values of *Fagus* (max. 39%) occur. Very low AP influx is recorded and NAP influx has its minimum values. Charcoal particles are present in small quantities.

Sk-12 (47–27 cm). In this phase dated to 1300±60 – 1000*BP, the contribution of *Fagus, Carpinus, Pinus* and *Alnus* diminishes gradually and the pollen frequency of the anthropogenic indicators increases – *Gramineae, Artemisia, Pteridium* and *Plantago lanceolata,* in particular. AP influx is at its minimum while NAP influx increases slightly.

The input of minerogenic matter and charcoal is greater than previously.

Sk-13 (27–0 cm). This phase probably represents a time span of about 200 years (1000*–800*BP). The percentages of *Fagus, Alnus* and the other trees decrease sharply, while *Juniperus* and NAP increase. *Artemisia, Rumex acetosella, R. acetosa* type, *Plantago lanceolata, Cerealia (Triticum* type, *Hordeum* type, *Avena* type, *Secale),* cf. *Cannabis* and *Centaurea cyanus* attain high percentage values. There is a considerable rise in the AP and NAP influx curves. The content of minerogenic matter and charcoal increases towards the top of the profile.

LAKE RACZE

THE SITE

Lake Racze (Fig. 5) lies within a kame terrace in the zone bordering the terminal moraine upland and forms a cryptodepression (9 m below sea level). It is a small kettle-hole lake (Choiński 1978), oval in shape, 4.95 ha in surface area and 12 m deep. The lake shore is mineral. In the last and at the beginning of the present centuries the lake was classified as oligotrophic because of the considerable purity of its waters and the presence of species typical of so called "Lobelia lakes", i.a. *Isoëtes lacustris, Lobelia dortmanna, Ranunculus reptans* (Lucas 1860, Piotrowska 1966a). Now, with increasing eutrophication, beds of reeds and other littoral plants, e.g. *Phragmites australis, Scirpus lacustris, Carex rostrata, Cicuta virosa, Ranunculus flammula, Eleocharis palustris, Acorus calamus*, have become established in many places along the shore. The "*Lobelia* lake" species were not found in a recent investigation. Nevertheless, in spite of the proximity of arable land, farm buildings and a main road, the lake waters are still relatively pure, probably because of its considerable depth and very small drainage area.

The core was taken ca. 80 m from the southern shore, between the 8 and 10 m isobaths (Fig. 5c).

Lake Racze lies in an area of soils formed in the light sandy clays covering the kame terrace (Fig 5a). Although the immediate vicinity has been completely deforested, the weed flora indicates that the fields and grasslands here were laid out on a beech-oak (*Fago-Quercetum*) woodland habitat.

SEDIMENT DESCRIPTION

Layer no	Depth below water level (cm),	
1	800–890	brown silty fine detritus gyttja; minerogenic matter and water content distinctly increase towards the top of the profile; $Ld^1$2–1, As2–3, Gs1, nig2, elas0, strf0, sicc3–4;
2	890–908	brown fine detritus gyttja with silt, $Ld^1$4, As+++, Gs++, Tb^1+, nig3, elas0, strf0, sicc3, lim. sup. 0;

3	908–928	dark brown fine detritus gyttja with sand, 920–921 cm – layer of grey sand; Ld^{1}1–2, Gs1, As1–2, nig3, elas1, strf0, sicc3, lim. sup. 0;
4	928–937	yellow-brown medium and coarse sand with gravels, Ga&Gs4, Gg+++, As&Ag+++, Ld^1+++, nig1, elas0, strf0, sicc3, lim. sup. 1;
5	937–942	grey-brown fine and medium sand with brown fine detritus gyttja, Ga&Gs3, Ld^{2}1, As&Ag+++, nig2, elas1, strf0, sicc3, lim. sup. 1;
6	942–948	yellow-brown medium and coarse sand with gravel, Ga&Gs4, Gg+++, As&Ag+++, Ld++, nig1, elas0, strf0, sicc3, lim. sup. 0;
7	948–1000	dark brown fine detritus gyttja, Ld^{1}4, As&Ag+++, nig3, elas2, strf0, sicc3, lim. sup. 2;

THE SEDIMENTATION RATE AND THE RELIABILITY OF THE PALYNOLOGICAL AND CHRONOLOGICAL DATA

The Lake Racze sediments are characterized by a very low sedimentation rate (Fig. 10A). Only in the uppermost part of the profile, representing the last ca. 1550 years, has the sediment accumulation rate become faster because of the increasing input of minerogenic material. The extremely low sediment accumulation of ca. 0.05 mm/year

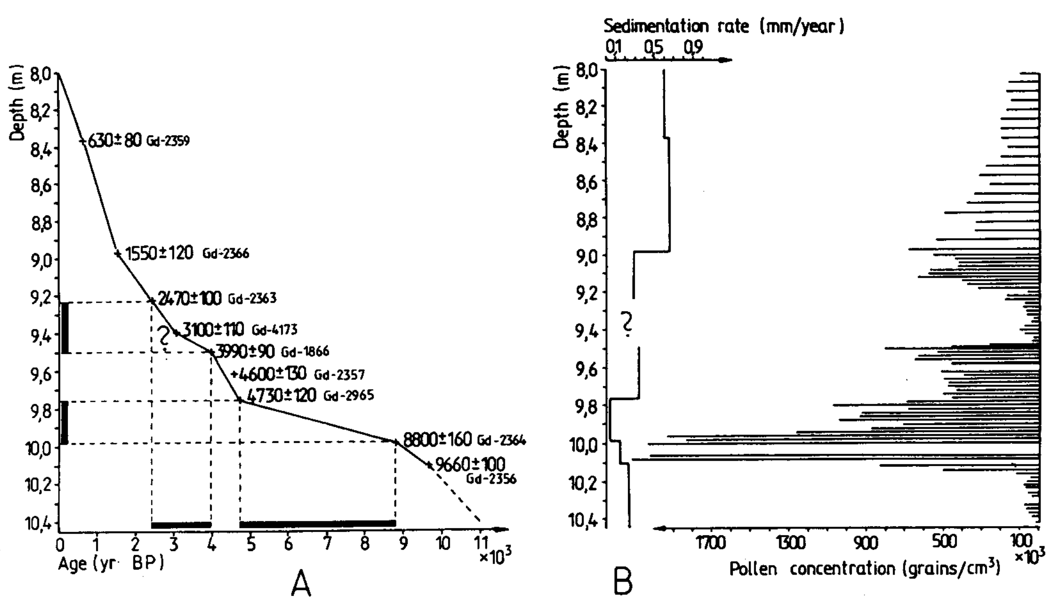

Fig. 10. A. The time-depth curve for the complete Lake Racze core; black bars indicate sections with a very low sedimentation rate. B. The sedimentation rate and AP+NAP concentration

calculated from the time-depth curve (Fig. 10A) for the section 10.0–9.75 m (8800±160 – 4730±120 BP) may, however, reflect minor hiatuses caused by slipping of the sediments. This assumption is based on pollen concentration values which are much lower in this section of the diagram than in the preceding one and point to a faster rather than slower sedimentation rate. A slipping of the sediments is quite probable because the coring point is situated on the bottom slope (cf. Fig. 5c). This part of the profile must be interpreted with great caution, particularly with regard to extrapolated ^{14}C dates.

The other level of the profile, which requires a critical approach is the section 9.5–9.24 m (3990±90 – 2470±100 BP), which is composed of coarse sand with gravel with a small admixture of detritus gyttja. It is possible that material eroded from the lake shore destroyed some of the earlier sediments so that it is impossible to say which time span this section represents. In all probality it illustrates two periods of very intensive erosion, separated by a short time of relative stabilization (the intercalation of detritus gyttja dated to 3100±110 BP).

LOCAL POLLEN ASSEMBLAGE ZONES

Five local pollen assemblage zones and three subzones (Fig. 11) are characterized in Tab. 3. The pollen zones have consecutive numbers according to the division of the complete profile (Latałowa unpubl.).

Table 3. Lake Racze, description of local pollen assemblage zones

Local paz	Name of paz	Depth (cm)	Approx ages BP	Description of pollen spectra
		989	8.000*	
R-5	*Quercus-* *-Ulmus-* *-Tilia-* *-Betula*			fall of Corylus (by 10%) and Pinus (by 12%); *Quercus* increases from 4% to 12%, *Tilia* from 1% to 4%, *Fraxinus* pollen appears; relatively stable frequencies of *Ulmus* (mean 3%), Alnus (mean 13%); high percentages of *Betula* (mean 24%) and regular occurrence of heliophytes (*Artemisia, Pteridium aquilinum, Calluna*); very high pollen concentration; R-5/R-6 limit: *Ulmus* decreases, *Corylus* increases;
		981	5.500*	
R-6	*Quercus-* *-Corylus-* *-Tilia-* *-Ulmus-* *-Fraxinus*			high frequencies of pollen of broad-leaved trees: Quercus (mean 21%, max. 30%), *Tilia* (mean 6%, max. 9%), *Ulmus* (mean 2%, max. 5%), *Fraxinus* (mean 2%, max. 5%) and *Corylus* (mean 21%, max. 32%); relatively stable values of *Alnus* (ca. 15%); pollen of *Acer* and *Viscum* occur regularly, while *Hedera* is not so regular; low percentages of *Pinus* and *Betula* (mean 13%); varied role of anthropogenic indicators; R-6/R-7 limit: *Quercus, Corylus, Tilia, Ulmus, Fraxinus* decrease, while *Pinus, Fagus, Carpinus*, NAP increase;
		948	3.900±90	
R-7	*Pinus-* *-Fagus-* *-Tilia-* *-Gramineae*			Pinus (mean 25%, max. 38%) dominates among AP, pollen values of *Alnus* remain high (mean 15%); curves of *Fagus* and *Carpinus* rise gradually; decrease of *Quercus* (mean 10%), *Ulmus* (mean 1%), *Tilia* (mean 1.4%), *Fraxinus* (mean 1%); rapid increase of NAP and occurrence of numerous anthropogenic indicators;

Table 3. Continued

Local paz	Name of paz	Depth (cm)	Approx ages BP	Description of pollen spectra
				R-7/R-8 limit: *Quercus* and *Fagus* increase, *Pinus*, *Corylus*, *Tilia*, *Ulmus*, *Fraxinus* decrease;
		923	2.470±100	
R-8	*Fagus-* *-Alnus-* *-Carpinus*			high frequencies of *Fagus* (mean 16%, max. 36%), relatively high percentages of *Quercus* (mean 13%, max. 21%), *Alnus* (mean 14%) and *Carpinus* (mean 3%);
				R-8/R-9 limit: *Quercus* decreases, increase of NAP;
subzones K-8a	*Quercus-* *-Fagus*	923– –913	2.470±100– –2.100*	high values of *Quercus* (mean 19%, max. 21%); *Fagus* increases, substantial contribution of anthropogenic indicators;
				R-8a/R-8b limit: *Quercus* and human indicators decrease;
R-8b	*Fagus*	913– –890	2.100*– –1.300*	*Fagus* culminates (max. 36%), *Quercus* decreases (mean 11%); human indicators scattered;
				R-8b/R-8c limit: *Fagus* and *Alnus* decrease, rapid increase of NAP;
R-8c	*Quercus-* *-Fagus-* *-Alnus*	890– –860	1.300*– –1.100*	mean values of *Fagus* 13%, *Quercus* 12%, *Alnus* 11%, *Carpinus* 3%; very low frequencies of other trees; substantial participation of all anthropogenic indicators, including *Cerealia*;
		860	1.000*	
R-9	*Pinus-* *-Gramineae-* *-Cerealia-* *-Juniperus*			NAP (mean 55%) dominates; *Pinus* (mean 17%, max. 23%) gains the highest values among AP; *Juniperus* increases (max. 7%), high frequencies of *Gramineae* (mean 20%) and of cultivated plants.
		800	0	

CHARCOAL PARTICLE AND ASH CONTENT

In the Lake Racze the profile charcoal concentration and even the influx values are strongly affected by the sedimentation processes. The relative curve, therefore, seems to be the most reliable (Fig. 12). In general, the charcoal content is very high throughout the whole profile, with the exception of the level dated to ca. 4500*– 4400* BP, where charcoal is practically absent, and that of ca. 1550±120 – 1300* BP, where charcoal values decline rapidly. The highest values are recorded in the sections dated to younger than 3990±100 BP and from ca. 800* BP to recent times.

The minerogenic matter content (Figs 11, 12) shows a similar pattern to that of charcoal. It should be stressed, however, that in the lower part of the profile, despite the fact that samples were analysed at 6–4 cm intervals, the data are highly unreliable due to the very low sedimentation rate.

⟶

Fig. 11. Relative pollen diagram from Lake Racze: 1 – detritus gyttja; 2 - sand; 3 – silt

LAKE RACZE

Fig. 11.

ANTHROPOGENIC PHASES

In the diagrams from Lake Racze (Fig. 11, 13) eight settlement phases (SR) and of two regeneration phases (RR), were distinguished.

SR-1 (989–981 cm). The beginning of this phase is dated to ca. 8.000*BP and is characterized by a decrease in *Corylus* and *Pinus*, an increase in *Alnus*, *Quercus*, *Ulmus* and *Tilia* and the relatively high, continuous curves of *Pteridium aquilinum* (mean 1.5%) and *Calluna vulgaris*; single pollen grains of *Urtica*, *Chenopodiaceae* and *Lathyrus* appear. Charcoal dust is abundant and, from the 984 cm depth, minerogenic matter increases and the *Pediastrum* curve begins.

SR-2 (981–977 cm). The first fall in *Ulmus* (980 cm) is not radiocarbon dated directly. The estimated date (5500*BP) may not be accurate because of the extremely low sedimentation rate in this part of the profile. It is significant, that the decrease in *Ulmus* pollen percentages is not concurrent with the decrease in its concentration (Fig. 13), which is marked in the next sample. This indicates that the *Ulmus* decline at the 980 cm depth is apparent and results from the considerable increase in *Quercus*, *Betula* and *Corylus* pollen concentration; the simultaneous increase of *Ulmus* pollen concentration is much less than that of the heliophilous trees. This first *Ulmus* fall is accompanied by a small peak of *Populus*, a high value for *Pteridium* spores (max. 2%) and single pollen grains of *Jasione* and *Plantago media*; no negative reaction of *Fraxinus* is recorded and *Tilia* is rising. Both AP and NAP influx is very low, as in the previous phase. The charcoal input is much higher than earlier.

SR-3 (977–973 cm). This phase is dated to 4730±120 BP. There is a sharp decrease in *Quercus* and *Fraxinus*, the *Ulmus* curve remains at its low level and the *Hedera* curve declines and than becomes interrupted. *Corylus* attains high values, the *Tilia* curve rises and *Acer* appears. Among the NAP, in addition to *Pteridium*, several pollen grains of *Plantago lanceolata* and *Melampyrum* are noted. The pollen influx of the trees and shrubs as well as that of the herbs increases distinctly. Charcoal content decreases in relative values but increases in the influx diagram.

RR-1 (973–963 cm). The approximate age of this phase is 4600*–4300* BP. The characteristic feature is the decrease in *Corylus* and increase in *Ulmus*, *Fraxinus*, *Quercus* and *Hedera*. The *Tilia* and *Acer* curves are relatively high, and those of *Pinus* and *Betula* remain low (13% and 11% respectively). Small depressions in the *Quercus* and *Tilia* curves are correlated with the presence of *Plantago lanceolata* pollen and with single records of other anthropogenic indicators e.g. *Viola arvensis* type, *Bilderdykia convolvulus*, *Melampyrum*, *Rumex acetosella* and *Ranunculus acris* type. AP and NAP influx show only a slight decrease. The minerogenic matter content is a little lower but the amount of charcoal falls distinctly in relation to the previous phase.

SR-4 (963–948 cm). The beginning of the second *Ulmus* decline (962 cm) cannot be dated precisely; the approximate date is 4300*BP (4400*–4200*BP); this decrease appears both in the relative and concentration values (Fig. 13). The *Quercus*, *Tilia*, *Fraxinus* and *Hedera* pollen curves also go down, while the *Corylus* curve rises. The pollen frequency of the anthropogenic indicators increases, a peak of *Pteridium aquilinum* oc-

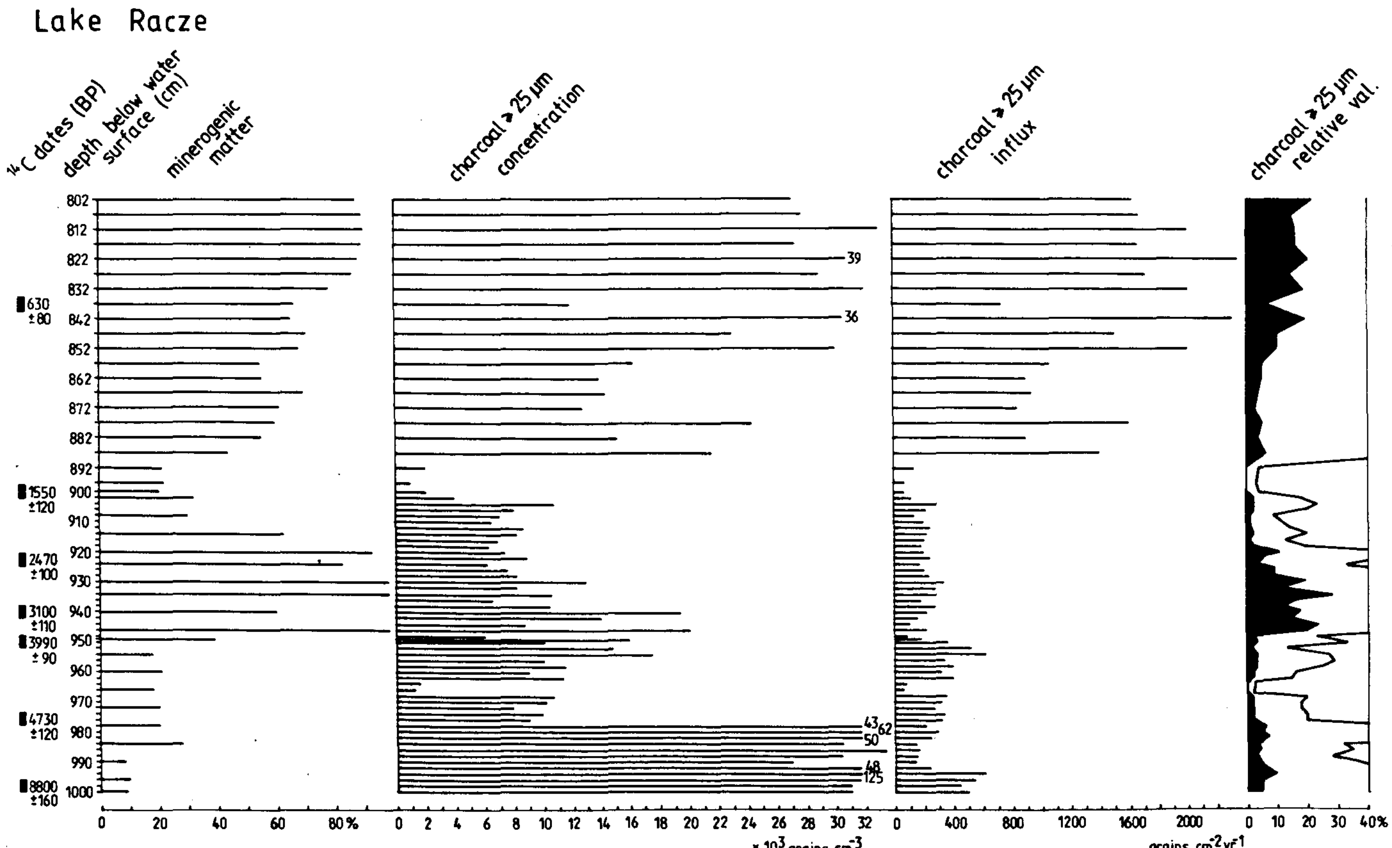

Fig. 12. Minerogenic matter and charcoal particle diagram from Lake Racze

Fig. 13. Combined diagram of the selected pollen percentage, concentration and influx data from Lake Racze

LAKE RACZE
Pollen percentages & concentration
Pollen influx
Lithology
Layer No
14C dates (BP)
Depth below water surface (cm)
Sample position
Alnus
Pinus sylvestris
Betula
Corylus avellana
Quercus
Ulmus
Fraxinus excelsior
Tilia
Carpinus betulus
Fagus sylvatica
NAP
Anthropogenic phases
AP
NAP
AP+NAP
Sample position
Depth (cm)
14C dates (BP)
Ld1 2-1
As 2-3
Gs 1
Ld1 4
Ld1 1-2
Gs 1
As 1-2
Ga&Gs4
GaGs3 Ld1 1
Ga&Gs4
Ld1 4
630±80
1550±120
2470±100
3100±110
3990±90
4600±130*
4730±120
8800±160
SR-8
SR-7
RR-2
SR-6
SR-5
SR-4
RR-1
SR-3
SR-2
SR-1
×10³ grains cm⁻³
×10³ grains cm⁻² yr⁻¹
anal. M. Latałowa

Fig. 13.

curs, *Plantago lanceolata* is regularly present and the first pollen grains of cereals (*Cerealia* indet. and *Triticum* type) are recorded. Single pollen grains of *Anagallis arvensis, Polygonum aviculare* and *Plantago maior* are present. The upper limit of this phase is dated to 3990±90 BP. This is, however, an artificial boundary, which coincides with the fairly sharp limit between gyttja and the overlying sand layer containing a considerable amount of gravel and stones (up to 3 cm in diameter). This suggests, that the delicate, fine-detritus gyttja could be partly outwashed. The AP and NAP influx is considerably higher than in the previous phase. The charcoal and ash content increase distinctly.

Sr-5 (948–923 cm). The beginning of this phase is younger than 3990±90 BP and older than 3100±110 BP, and it came to an end before 2.470±100 BP. This phase is recorded mainly in the coarse minerogenic sediments and, despite an apparently consistent palynological picture, it probably does not illustrate a continuous plant succession. In this phase *Ulmus, Quercus, Fraxinus, Tilia* and *Corylus* decrease whereas *Fagus, Carpinus, Pinus* and *Betula* increase. Several taxa of anthropogenic habitats are present at high frequencies e.g. *Pteridium, Plantago lanceolata, Artemisia, Rumex acetosella, Melampyrum, Calluna* while others, such as *Juniperus, Sambucus nigra, Scleranthus annuus, S. perennis, Polygonum aviculare, P. persicaria* type, *Plantago maior, P. media* and *Bilderdykia convolvulus* occur in small numbers. Pollen grains of cereals are present in small quantities. The very low pollen influx values do not reflect pollen deposition but rather the sedimentation process. In all samples a very high charcoal input is recorded in the percentage values.

Sr-6 (923–903 cm). This phase covers the time span 2470±100 – 1550±120 BP and is distinguished by a higher AP curve than in the previous phase. *Quercus, Fagus* and *Carpinus* increase, while *Pinus* decreases. The pollen of the anthropogenic indicators form continuous curves, but at lower values than in phase Sr-5, however, the pollen frequency of *Cerealia* increases and the first *Secale* pollen grains appear.

Rr-2 (903–890 cm). This part of the diagram is dated to 1550±120 – 1300*BP. *Fagus* dominates (max. 36%), *Pinus, Betula* and *Carpinus* increase, and *Quercus* and *Corylus* decrease. The curves of *Plantago lanceolata, Rumex acetosa* type, *R. acetosella* and *Pteridium* become interrupted and the curves of the other anthropogenic indicators decline. Minerogenic matter, charcoal and *Pediastrum* decrease considerably. There is also a substantial fall in the AP and NAP influx.

Sr-7 (890–860 cm). The beginning of this phase is marked by a sharp decline in *Fagus*, which is dated to ca. 1300*BP. The pollen curves of *Alnus* and the other trees, fall simultaneously. The *Fagus* curve continues to decline for the whole of the phase, while the *Quercus* and *Alnus* curves, rise again after the depression. From the beginning of the phase, high frequencies of anthropogenic indicators, including cereals and taxa typical of poor sandy habitats (*Calluna, Melampyrum, Jasione, Rumex acetosella*) are present. The content of *Pediastrum*, minerogenic matter and charcoal in the sediments increases. Pollen influx (AP and NAP) is higher than in the preceding phase.

Sr-8 (860–800 cm). This phase probably represents the period from ca. 1000*BP to the present-day. It is characterized by a further decline in the *Quercus, Fagus, Alnus* and *Carpinus* curves. The *Pinus* curve rises slightly and *Juniperus* attains 7%. The contribution of all the anthropogenic indicators rises, including the cultivated plants (*Cerealia* indet., *Triticum* type, *Hordeum* type, *Avena* type, *Secale, Fagopyrum,* cf. *Cannabis sativa*), and the weeds (*Centaurea cyanus, Papaver argemone, P. rhoeas* type, *Polygonum aviculare, Bilderdykia convolvulus, Scleranthus annuus, Agrostemma githago, Stellaria* cf. *media*). In the 847–817 cm horizon a high amount of cf. *Cannabis sativa* pollen grains occurs, together with culminations of *Centaurea cyanus* and *Bilderdykia convolvulus.* The AP influx drops quite noticeably. In this section, the maximum values of *Pediastrum* are recorded and there is a curve of *Isoëtes.* The minerogenic matter rises to 90% and charcoal particles occur abundantly.

WOLIN II

THE SITE

The mire which is a ca. 5 ha in area (Fig. 14), lies within the boundaries of the present-day town of Wolin, ca. 400 m west of the river Dziwna and is probably part of a former large mire complex which extended along the river banks. Communities of the class *Phragmitetea* with *Phragmites australis, Glyceria maxima, Carex elata, Equisetum limosum, Agrostis stolonifera* predominate. In places, *Lysimachia thyrsiflora, Sium latifolium, Lycopus europaeus, Rorripa armoracioides, Cicuta virosa* are frequent species. Much of the present mire is covered by regularly-shaped pits (Fig. 14b) now filled with water, which are the remnants of peat cutting. *Typha latifolia* grows in abundance on their edges. The coring was made half way between the eastern edge of the mire and these pits, in a spot devoid of evidence of peat cutting.

Adjacent to the mire is an area of light sandy soils formed in patches of the outwash plain and the ground moraine. The south-eastern part of Wolin Island has been completely deforested. Acid meadows and pastures are dominant on the reclaimed wetlands, arable land prevails on the mineral soils. The small hills near the town of Wolin are covered with thickets of *Rhamnus cathartica, Ligustrum vulgare, Ulmus laevis, Crataegus ssp.* and other introduced shrubs. Their slopes support a number of plants characteristic of dry swards such as *Armeria elongata, Jasione montana, Thymus serpyllum, Helichrysum arenarium, Dianthus carthusianorum, Sedum sexangulare, Ranunculus bulbosus, Pulsatilla pratensis, Calamintha acinos, Pimpinella saxifraga, Corynephorus canescens* and others. This vegetation, as well as the occasional patches of *Calluna vulgaris* indicate, that heathland, replacing the original oakwoods, may once have existed here.

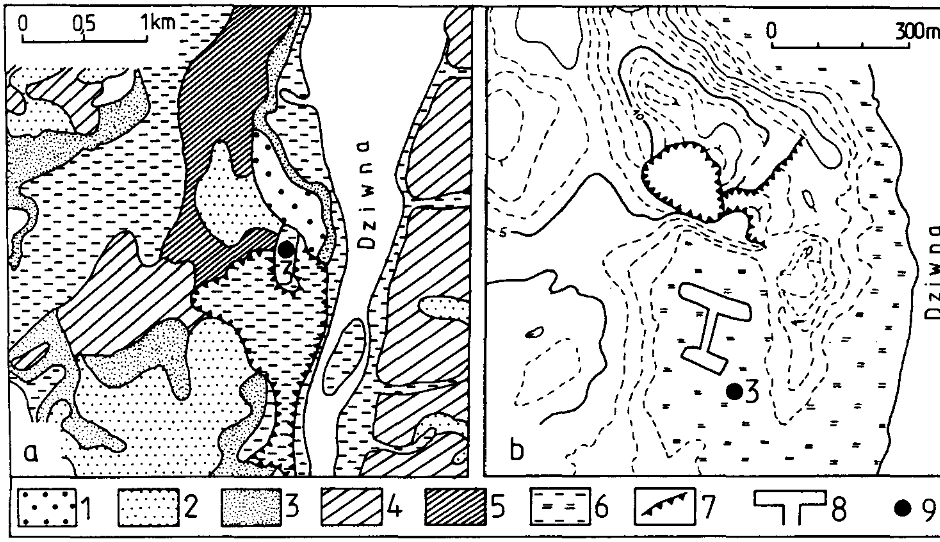

Fig. 14. Maps of the southeastern part of Wolin Island showing: a - Quaternary deposits (after Mapa Geologiczna Polski 1:50.000); b - topography; 1 – sand and gravel of eskers; 2 – outwash sand and gravel; 3 – Pleistocene sand and gravel of lake and river origin; 4 – clayey sands on boulder clays; 5 – boulder clays; 6 – Holocene peats and muds; 7 – artificial embankment; 8 – water-filled pits left after peat cutting; 9 – the Wolin II profile

PEAT STRATIGRAPHY

Layer no	Depth (cm)	
1	0–8	brown, highly decomposed, dried-up Carex peat with an admixture of sand, $Th^{3-4}3$, Ga&Gs1, As&Ag+++, nig3, elas1, strf0, sicc1, humo3–4 (H8-H10);
2	8–40	dark brown highly decomposed and compressed Carex-Phragmites peat with an admixture of sand, $Th^{3-4}3$, Ga&Gs1, As&Ag+++, nig3, elas1, strf1, sicc2, humo3–4 (H8-H10), lim. sup. 0; an interbedding of silt and sand at a depth of 17–18 cm;
3	40–150	dark brown, highly decomposed, amorphic peat, distinctly drier towards the top of this section, $Th^{4}4$, Ga&Gs++, nig3, elas2, strf0, sicc2, humo4 (H10-H11), lim. sup. 0;
4	150–200	dark brown, highly decomposed peat, $Th^{4}4$, Ga&Gs+, nig3, elas1, strf0, sicc2, humo4 (H10), lim. sup. 0;
5	200–262	dark brown, highly decomposed Cladium-Phragmites peat, $Th^{4}4$, Ga&Gs+, nig3, elas1, strf0, sicc2, humo3 (H8), lim. sup. 0;

6	262–273	brown-grey sand with highly decomposed peat, Ga&Gs3, $Th^{3-4}1$, As&Ag++, Sh+++, nig2, elas0, strf0, sicc2, humo3–4 (H8-H10), lim. sup. 1;
7	273–300	brown-grey sand with silt, Ga&Gs3, As&Ag1, Th^{3}+++, Sh+++, nig2, elas0, strf0, sicc2, lim. sup. 0.

THE PEAT ACCUMULATION RATE AND THE RELIABILITY OF THE PALYNOLOGICAL AND CHRONOLOGICAL DATA

The variations in the rate of peat accumulation at the Wolin II site are illustrated in Fig. 15.

In the bottom part of the profile (2.8–1.5 m) there is no clear relationship between growth rate and pollen concentration, probably due to poor pollen preservation, which has caused the complete decay of some pollen grains. This phenomenon is related to peats formed mainly by different reed swamp communities in connection with a relatively low water level. In this section, two levels: 2.75–2.35 m (7320±520 – 6340±70 BP) and 1.65–1.45 m (4930±60 – 4130±60 BP) are distinguished by their relatively low growth rate (0.28 and 0.25 mm/year) which limits the precision of palynological and chronological data.

Between the depths of ca. 1.5 and 0.8 m the pollen grains are well preserved and pollen concentration increases distinctly; a negative correlation between pollen concentration and the rate of accumulation is recorded. For the section 0.8–0.5 m (3370±60 – 980±60 BP) a very low accumulation rate (0.14–0.15 mm/year) is again registered. The reliability of the calculations is confirmed by the high pollen concentration, comparable to the concentration values obtained for sediments with the same rate of deposition from the Kołczewo profile. Both, the palynological and chronological data for this section of the profile, are of restricted significance. In the uppermost part of the profile

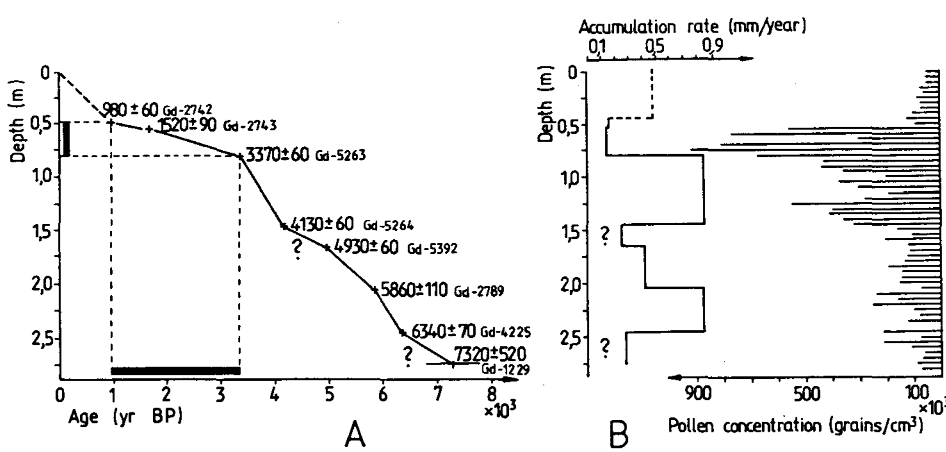

Fig. 15. A. The time-depth curve for the Wolin II core; black bars indicate sections with a very low accumulation rate. B. The accumulation rate and AP+NAP concentration

(0.5–0.0 m) the peat accumulation rate is moderate, while the pollen concentration is affected by poor sporomorph preservation.

LOCAL POLLEN ASSEMBLAGE ZONES

The five local pollen assemblage zones and five subzones distinguished in the "Wolin II" profile (Fig. 16), are described in Tab. 4.

Table 4. Wolin II, description of local pollen assemblage zones

Local paz	Name of paz	Depth (cm)	Approx ages BP	Description of pollen spectra
		280	7.320±520	
WII–1	*Alnus-Pinus-Betula*			high frequencies of *Pinus* (max. 58%), *Alnus* (max. 30%) and *Betula* (max. 25%); all pollen curves strongly fluctuate; high percentages of *Asteroideae* and *Cicorioideae; Pteridium aquilinum* curve rises to 4%; WII-1/WII-2 limit: *Pinus* decreases, *Quercus* increases;
		257	6.340±110	
WII–2	*Pinus-Quercus-Ulmus-Pteridium*			gradual decrease of *Pinus*, slight increase of *Corylus; Quercus* curve rises in the first two subzones and falls in the third; high values of Betula (mean 12%) and high frequencies of *Pteridium* (mean 3%, max. 7%); curves of *Ulmus, Tilia, Fraxinus* fluctuate; WII-2/WII-3 limit: sharp *Calluna* increase;
subzones: WII–2a	*Pinus*	257–−202	6.340±110–−5.860±110	*Pinus* curve remains high (max. 52%), *Quercus* increases (max. 15%), culmination of *Pteridium* (7%); WII-2a/WII-2b limit: *Pinus* decreases rapidly, *Corylus* and *Quercus* increase;
WII–2b	*Corylus-Quercus*	202–−167	5.860±110–−4.930±60	*Pinus* drops to 20%, Quercus increases to 26%, and *Corylus* to 10%; *Pteridium* remains at the high level (mean 3%); WII-2b/WII-2c limit: sharp decrease of *Quercus*
WII–2c	*Alnus-Betula*	167–−152	4.930±60–−4.300*	*Quercus* decreases by 12%, *Pinus* remains stable at about 20%; *Pteridium* steeply declines, *Plantago lanceolata* continuous curve begins concurrently with the increase of *Rumex coll.* curve;
		152	4.300*	
WII–3	*Corylus-Quercus-Tilia-Calluna*			*Pinus, Betula* decrease, *Corylus* increases (max. 18%); relatively high frequencies of *Tilia* (max. 4%); high percentages of *Calluna* (mean 10%, max. 17%) and *Rumex coll.* (mean 1.5%); *Pteridium* is represented by low values, *Plantago lanceolata* forms continuous curve; scattered pollen grains of *Cerealia*. WII-3/WII-4 limit: *Quercus* and *Corylus* decrease; *Tilia* and *Ulmus* percentages drop to less than 1%;
subzones WII-3a	*Corylus-Tilia*	152–−102	4.300*–−3.600*	*Corylus* curve rising and later dominates (max. 18%); relatively significant proportion of *Tilia*; *Pinus* and *Quercus* decrease; WII-3a/WII-3b limit: *Corylus, Quercus* and *Tilia* decrease, *Pinus* increases;

Table 4. Continued

Local paz	Name of paz	Depth (cm)	Approx ages BP	Description of pollen spectra
WII-3b	*Pinus-* *-Quercus*	102– –67	3.600*– –2.300*	the role of broad-leaved trees diminishes with the exception of *Fagus* and *Carpinus* which are rising; increasing values of *Pinus*, *Plantago lanceolata* and *Cerealia;*
		67	2.300*	
WII-4	*Pinus-* *-Fagus-* *-Calluna*			*Tilia, Ulmus, Fraxinus* are represented in low percentages (1%), *Corylus* (mean 5%); *Pinus* (max. 39%) and *Fagus* (max. 2.5%) increase; *Calluna* decreases while *Cerealia* increases; WII-4/WII-5 limit: sharp decrease of AP and *Calluna*, increase of cultivated plants and field weeds;
		50	1.520±90 980±60	
WII-5	*Pinus-* *-Gramineae-* *-Cerealia-* *-Juniperus*			NAP dominates over AP; *Pinus* (max. 49%) shows the highest values among AP; Juniperus curve appears (max. 4%), high frequencies of *Cerealia* (mean 10%) and *Rumex coll.* (mean 5%, max. 9%), while *Calluna* and *Plantago lanceolata* are present at low percentages; culmination of *Potamogeton* (mean 30%) and of *Pediastrum* (mean 4%).
		0	0	

CHARCOAL PARTICLE CONTENT

Throughout the whole of the Wolin II profile a great abundance of charcoal particles is recorded, irrespective of the method of presentation of the results (Fig. 17). These data indicate that, during the time illustrated by the diagram, intensive burning took place in the immediate vicinity of the Wolin II site. Some of the charcoal certainly comes from fires from the settlements which flourished in the neighbourhood of the investigation site throughout prehistoric times (cf. Fig. 4). The most striking feature of the diagram is the culmination of the charcoal curve in the section dated at 6340±70 – 5860±110 BP.

ANTHROPOGENIC PHASES

Eight consistent phases of human impact (Sw) are distinguished in the diagrams from the Wolin II site (Fig. 16, 18).

Sw-1 (257–217 cm), 6340±110 – 6000*(5860±110) BP. Among the anthropogenic indicators, *Pteridium aquilinum* dominates (mean 3%, max. 7%); *Calluna vulgaris* and *Rumex acetosa/acetosella* are present at low percentages and significant values of nitrophilous plants (*Urtica, Chenopodiaceae*) are recorded. *Pinus* gradually decreases, *Quercus* increases. *Betula*, after an initial rise, remains at a stable, relatively high level (mean 12%, max. 16%), while the pollen of *Ulmus, Fraxinus, Tilia* and *Corylus* fluctuates at relatively low frequencies. Charcoal particles are very abundant.

Sw-2 (217–167 cm), 6000* (5860±110) – 4930±60 BP. High frequency of *Pteridium aquilinum*, single pollen grains of *Jasione montana* and *Melampyrum*, a distinct *Pinus* decrease and a *Quercus* increase are characteristic features of this phase. AP and NAP

Fig. 16. Relative pollen diagram from the Wolin II site: 1 – herbaceous, amorphic peat; 2 – *Cladium-Phragmites* peat; 3 – sand; 4 – silt

influx decreases slightly. The charcoal curve fluctuates but always at a high level.

The first fall in the *Ulmus* curve (215–205 cm) is radiocarbon dated to 5860±110 BP and follows a slight depression in the *Tilia* curve. It is accompanied by a drop in the

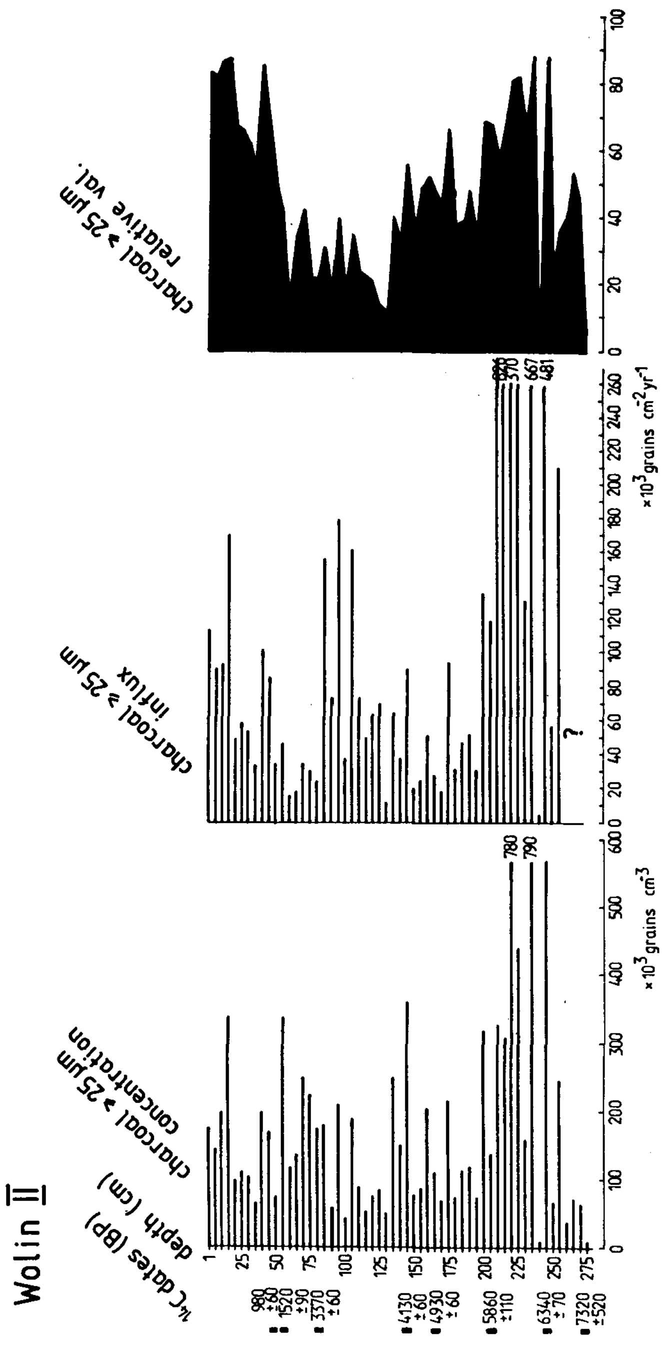

Fig. 17. Charcoal particle diagram from the Wolin II site

Fraxinus curve and an increase in that of *Rumex*, followed by the appearance of the first *Plantago lanceolata* pollen grain.

The second *Ulmus* and *Fraxinus* decline (185–175 cm) is concurrent with a small depression of the *Tilia* curve, a distinct peak of *Plantago lanceolata* (1.5%) and the occurrence of the first pollen grains of *Cerealia indet. and Hordeum* type. It is dated to ca. 5400*–5300*BP.

Sw-3 (167–152 cm), 4930±60 – 4300*(4130±60) BP. *Quercus, Ulmus* and *Tilia* decrease, *Fraxinus* and *Corylus* fluctuate; the *Pteridium* curve declines gradually, while the curves of *Rumex coll., Artemisia* and *Urtica* increase; the continuous curve of *Plantago lanceolata* begins. Total pollen influx is lower than in the previous phase. The charcoal curve remains high.

Sw-4 (152–127 cm), 4300*(4130±60) – 3800* BP. *Calluna vulgaris* (mean 8%, max. 12%) dominates among the anthropogenic indicators. The *Rumex acetosa/acetosella* curve (mean 1.3%) increases, *Plantago lanceolata* forms a continuous curve; pollen of *Cerealia* (*Hordeum* type, *Triticum* type and *Secale*) and single *Centaurea cyanus* grains are important features of this phase. AP and NAP influx increases distinctly. The charcoal content is lower than before.

Sw-5 (127–102 cm), 3800*–3600* BP. *Calluna vulgaris* dominates (max. 17%), *Rumex coll.* occurs at high percentages, *Cerealia* and *Plantago lanceolata* decrease; culminations of Corylus, Tilia and Quercus occur. Single pollen grains of *Plantago major, Bilderdykia convolvulus, Scabiosa columbaria, Succisa pratensis, Polygonum aviculare, P. persicaria* type are recorded. Total pollen influx rises once more. The charcoal curve falls, but still remains high.

Sw-6 (102–67 cm), 3600*–2300* BP. The increase in *Plantago lanceolata* and cereals is accompanied by a decrease in the percentages of all the trees, except *Pinus, Carpinus* and *Fagus*, whose curves rise reciprically. Total pollen influx drops distinctly. The charcoal content is a little higher than in the previous phase.

Sw-7 (67–52 cm), 2300*–?1520±90 BP. A decrease in *Calluna*, a considerable increase in cereals and the great amount of *Pimpinella* (*saxifraga*) pollen are characteristic features of this section. A rapid rise in *Pinus* and a small peak in the *Fagus* curve occur. A considerable decrease in pollen (AP and NAP) influx is observed. The charcoal content increases.

Sw-8 (52–0 cm), 980±60 BP – 0. Pollen of *Cerealia* and *Rumex coll.* dominate among the anthropogenic indicators; weeds of cultivated fields such as *Centaurea cyanus, Polygonum aviculare, Bilderdykia convolvulus* are well represented and their frequencies exceed 1%. Among the *Cicorioideae, Lapsana* type is frequent. The pollen curve of *Plantago lanceolata* declines, and in the upper samples, is below 1%, *Juniperus* increases (max. 4%). *Pinus* (mean 38%, max. 49%) dominates the AP, and the other trees are represented at low values. The minimum AP influx is recorded in this part of the diagram. The charcoal curve reaches a maximum.

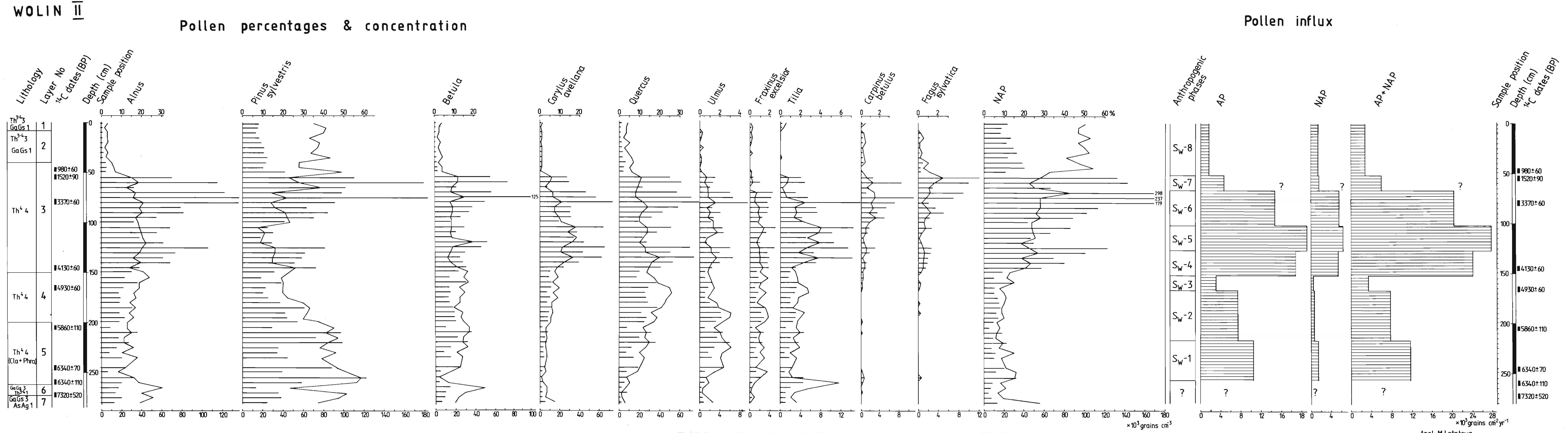

Fig. 18. Combined diagram of the selected pollen percentage, concentration and influx data from the Wolin II site

VEGETATION HISTORY WITH SPECIAL REFERENCE TO ANTHROPOGENIC CHANGES

CORRELATION OF THE LOCAL POLLEN ASSEMBLAGE ZONES AND THE ANTHROPOGENIC PHASES

The principles established for distinguishing local pollen assemblage zones (paz) on the one hand and anthropogenic phases (cf. p. 135) on the other, serve different purposes. Pollen assemblage zones are based primarily on the AP curves and illustrate the general trends in the vegetational changes of the study area. The anthropogenic phases are distinguished mainly on the basis of the appearance and disappearance of the pollen of plants accepted as indicators of human activity (cf. Tab. 1); they form the basis for the detailed interpretation of local changes in the vegetation induced by man.

A comparison of both divisions (Fig. 19) shows that there is a strong correlation between the paz boundaries and the boundries of the most important anthropogenic phases in each of the three profiles, which suggests that human activity has significantly influenced changes in the vegetation on Wolin Island.

Lake Racze and the Kołczewo peatbog are comparable in area, and also with regard to the geomorphological and edaphic conditions surrounding the sites (cf. Fig. 5). Because of the nature of the deposits (limnic sediments, brown moss peat and various kinds of *Sphagnum* peat), the pollen spectra of both the profiles include only a small number of sporomorphs of locally occuring plants which might be difficult to eliminate from the basic pollen sum. There are, however, significant differences between these sites with in terms of the rate of accumulation and therefore, in the accuracy of the palynological records. This is expressed by the much more detailed division of the pollen diagram from Kołczewo, which allows a more reliable reconstruction of the vegetational succession at and around this site. A comparison of the pollen assemblage zones (Fig. 20) and the anthropogenic phases (Fig. 21) shows that individual events coincide very well, which confirms the correctness of the radiocarbon dates and the chronological interpretation of critical points in these two diagrams. The small differences in the dating of particular boundaries still fall within the standard deviation limits of the ^{14}C dates. It should be emphasized, however, that the chronological positions of the pollen assemblage zones and the anthropogenic phases are approximate and based largely on interpolated dates.

The description of the vegetational changes in the morainic part of Wolin Island is based on local pollen zones and anthropogenic phases based on the combined data from the Kołczewo and Lake Racze diagrams or on data from Kołczewo merely supplemented by information from Lake Racze. The history of the last thousand years is based chiefly on the Lake Racze diagram because the top of the Kołczewo profile is missing. A delimitation of regional paz has not been attempted because it is expected that pollen analysis of the sediments from the much larger Lake Czajcze, situated in the same landscape, which are at present in progress, will allow a better reconstruction of regional events (Latałowa, in preparation).

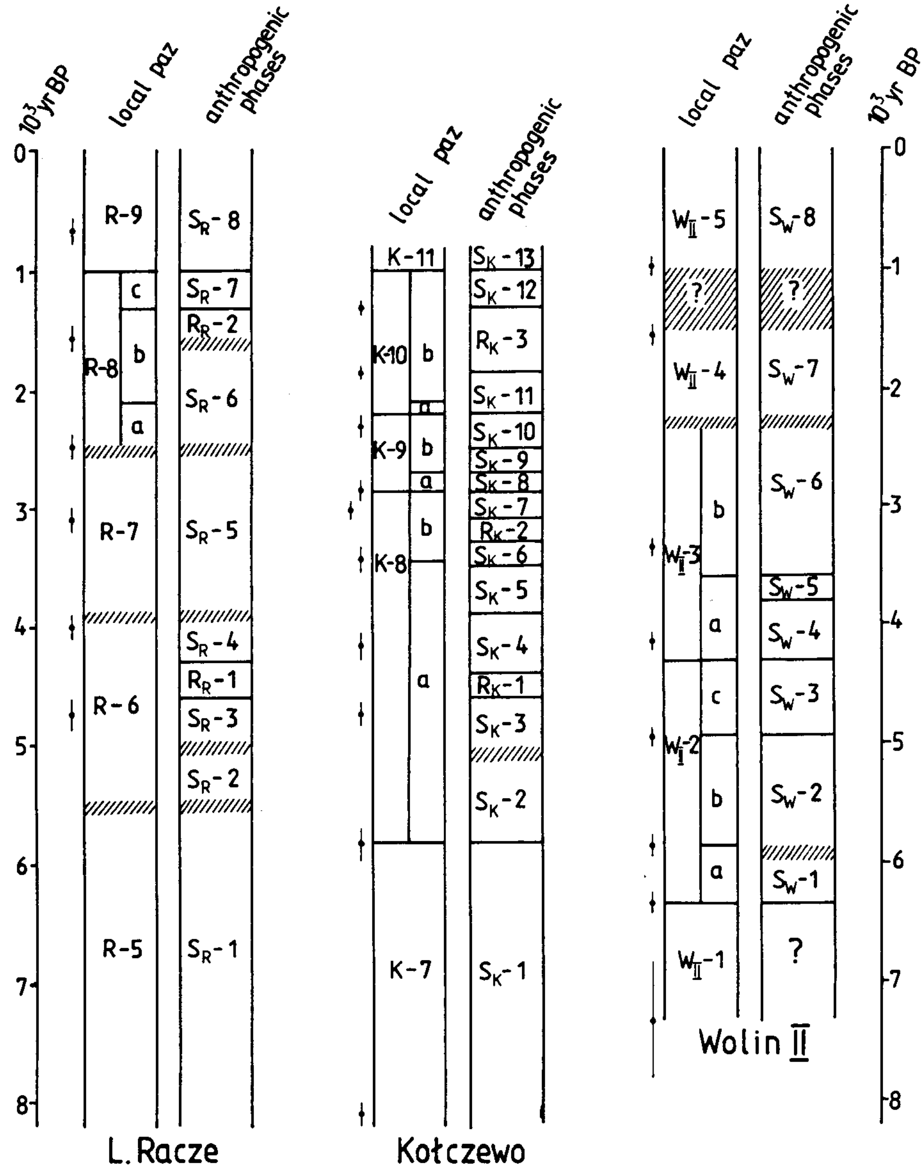

Fig. 19. Correlation of pollen assemblage zones and anthropogenic phases for each pollen diagram from Wolin Island; limits of uncertain chronology are shown hatched

Only a limited correlation of the pollen zones and anthropogenic phases in the diagrams from the morainic part of the island and with those of the Wolin II site is possible. These diagrams illustrate the history of completely different plant communities, resulting from the different geomorphology and soils around these two sites. It is interesting, however, that the anthropogenic phases 1–4 (Fig. 21) coincide chronologically, testifying to parallel changes in the vicinity of all three sites.

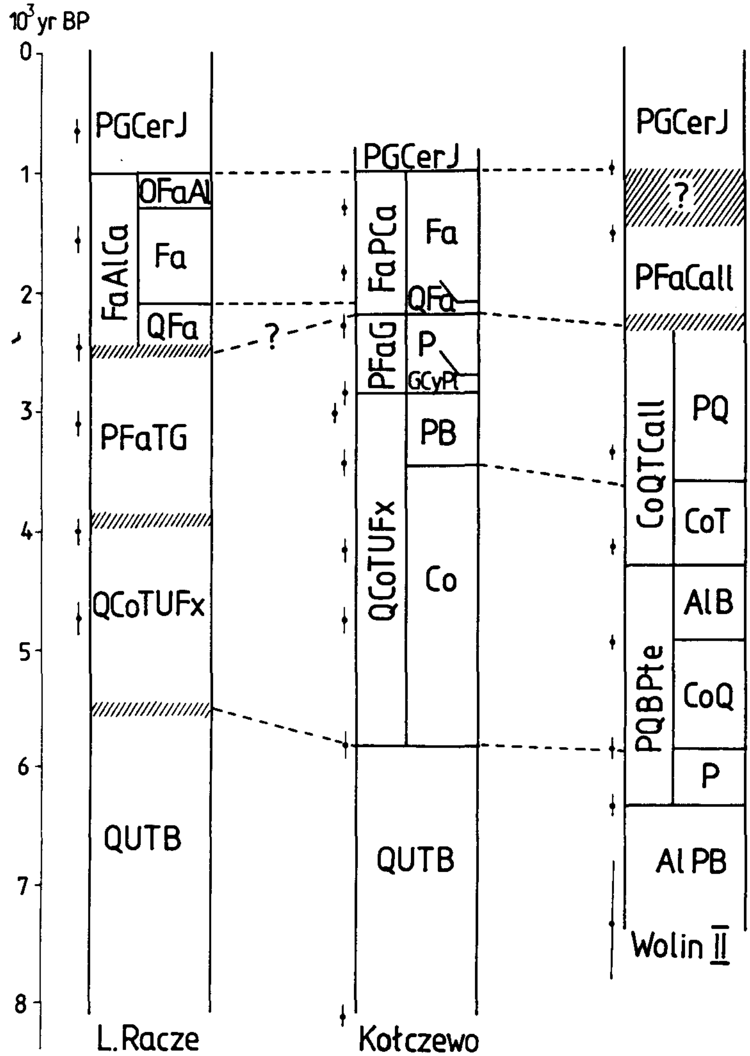

Fig. 20. Correlation of the pollen assemblage zones distinguished in the pollen diagrams; limits of uncertain chronology are shown hatched

VEGETATION CHANGES IN THE MORAINIC LANDSCAPE

Quercus-Ulmus-Tilia-Betula local paz, 8000*–?5820±130 (5500*) BP (Kołczewo and Lake Racze)

This pollen zone is synchronous with the settlement phases Sk-1, Sr-1 (8000*–?5820±130 BP). At that time, natural changes were gradually taking place in the communities surrounding both sites. Lime and oak spread onto the lighter soils, while on the moister, more fertile soils oak, elm, and from ca. 7400* BP, also ash increased in import-

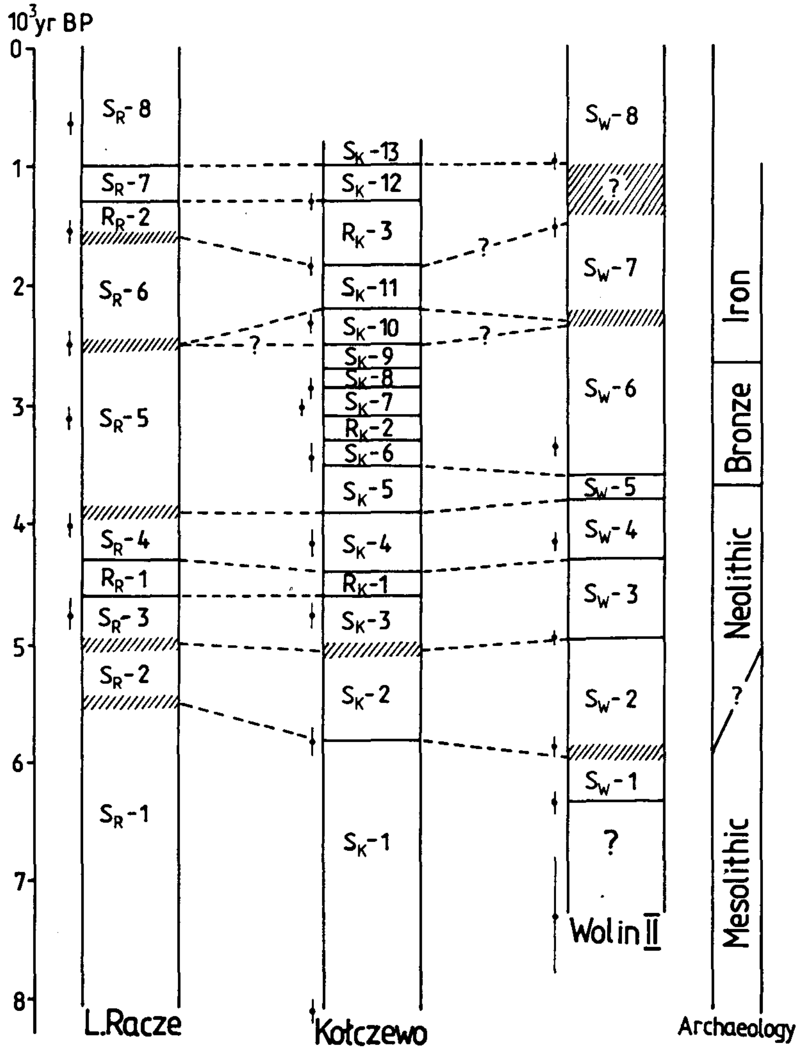

Fig. 21. Correlation of the anthropogenic phases distinguished in the pollen diagrams; limits which are of uncertain chronology are shown hatched

ance. These shade-tolerant and overshadowing species restricted the growth of hazel and pine. Even so, the oakwoods, especially those on the lighter substrata, were not close-canopied which is shown by the high values of *Betula, Populus* and *Pteridium aquilinum* pollen. Moreover, at the forest edge and within glades different heliophilous communities with *Melampyrum, Calluna vulgaris, Anthericum ramosum, Rumex acetosella* and probably *Primula veris,* developed.

The fact that charcoal dust is regularly present in the sediments of Lake Racze and Kołczewo mire suggests that the open structure of these woodlands could be man-made. Regular, natural fires in deciduous woodland are rather improbable (Rakham 1988a). It was probably mainly the undergrowth that was burnt. Fires leading to the destruction of tree stands within the catchment would have to be reflected, if only occasionally, in the sediments of these small water bodies, by layers containing a high proportion of minerogenic matter and large charcoal particles and by depressions in the tree curves. It is only at the end of this phase however, that a slight increase in the ash content becomes discernible in the Lake Racze sediments (Fig. 11). Simultaneous with this the *Pediastrum* curve begins. Evidently, erosion in the drainage basin intensified and, as a result, the input of nutrients to the lake water increased. Nitrophilous communities with *Artemisia, Urtica* and *Chenopodiaceae*, pollen of which is well represented in both the diagrams, could develop in connection with of seasonal hunter's camps. The surroundings of both sites provided very good conditions for such camps.

***Quercus-Corylus-Tilia-Ulmus-Fraxinus* local paz, ?5820±130 (5500*) – 2860±110 BP (Kołczewo and Lake Racze)**

This pollen zone reflects the history of the deciduous woodlands with oak, elm, ash and lime on better soils and oak with pine on the poorest habitats. The considerable contribution of *Corylus* suggests that the forests were probably coppiced. Hazel also played the leading role in the regenerating woodland communities, up to ca. 3500* BP (*Corylus* pa subz), a role which was later taken by pine and birch (*Pinus-Betula* pa subz). In places in these woodlands there were excellent light conditions which allowed the development of patches of heliophilous, vegetation with a high proportion of *Pteridium aquilinum* and the presence of the other plants such as *Melampyrum, Calluna* and *Rumex acetosella*, in particular. Human activities, during this whole period, varied in intensity as the successive anthropogenic phases demonstrate.

Corylus local pa subz

At the beginning of the settlement phases SK-2, SR-2 (?5820±130 – 5000*BP) a probably selective destruction of elm took place in the woodland. Other trees growing on low-lying ground, such as *Fraxinus* and *Alnus*, were only slightly affected, if at all. It must be remembered that this process was taking place in woodland communities that had already been subjected to intense human activities for a long time (SK-1, SR-1 phases). The elm decline could therefore have been caused by the excessive exploitation of this tree as a source of leaf fodder, although the question cannot be decided unequivocally (cf. p. 209).

The decreasing proportion of elm in the woodland communities not only contributed to a distinct change in the tree stands, where the increased inflow of sunlight allowed hazel and oak to flower vigorously and probably to spread, but it was also probably one of the most important causes of the rise in the water table at the Kołczewo site (*Pediastrum* peak) and of increased erosion in the neighbourhood of both sites (increased content of minerogenic matter in the sediments). In fertile, moist habitats elm had, hitherto, been the dominant species and probably also occurred in the form of almost pure patches of elmwood. The elimination of elm from communities in which it was only a minor element, could not have induced such distinct changes in the water and soil regimes.

The woodland which regenerated had a strong undergrowth of *Corylus* with an admixture of *Sambucus nigra*. On the drier and more acid soils the herb layer was dominated by *Pteridium aquilinum*. Judging from the increased production of *Corylus* and *Quercus* pollen, the woodland may have been partly coppiced. In such transformed forests, patches of grazed meadows with *Plantago lanceolata* and *Plantago media* could develop. On the poor dry soils swards with *Calluna vulgaris, Melampyrum, Jasione montana* and *Rumex acetosella* gradually increased in importance.

The identical dates (4730±110 and 4730±130 BP) for the settlement phases SK-3, SR-3 (5000*–4600* BP) in both diagrams give an age to the continuing intensive exploitation of the lower-lying, fertile habitats with oak, elm and ash woodland. Hazel expanded even more in these communities. The substantial increase in AP influx (mainly *Corylus*) suggests a further development of coppicing practices. Small areas were also probably cleared of forest, as is illustrated by the distinct depressions in the *Quercus* curves in both the relative and concentration diagrams of both sites. Pastures with *Plantago lanceolata* occupied more extensive area than in the preceding phase. The destruction of the woodland initiated a renewed, though short-lived, rise in the ground water table, which enabled the development of aquatic vegetation with *Nymphaeaceae* and an abundance of *Pediastrum* on the Kołczewo mire.

Phytocoenoses with oak and lime dominated the lighter soils. The high percentage and concentration values of lime pollen and the decline in the *Pteridium* and *Calluna* curves (also the *Melampyrum* curve in the Kołczewo diagram) probably indicate that the poorer, dry habitats were not utilized intensively at that time.

Animal husbandry was probably gaining in importance in this phase, with the animals grazing in open-canopied coppiced woodland and in tiny meadows. Trees were probably pollarded for leaf-fodder, which practice could also be responsible for the disappearance of *Hedera* pollen in both diagrams (cf. Troels-Smith 1953, 1983).

The regeneration phases RK-1, RR-1 (4600*–4400*BP) illustrate the partial regeneration of woodland communities and the reduced intensity of settlement in the study area. Oak, ash and elm, expanded in the forests and the increasing shade reduced the growth of hazel and of many herbaceous heliophytes. The importance of anthropogenic communities in the surroundings of both sites clearly diminished, but around the Kołczewo mire this process was more distinct (*Plantago lanceolata* curve is interrupted), than in the vicinity of Lake Racze (pollen of *P. lanceolata* continue to be recorded). These facts, as well as the small depressions in the *Tilia* and *Quercus* curves, accompanied by peaks of *Betula* are evidence that, although in general human pressure on the vegetation was letting up, small-scale clearing continued, especially on the lighter soils. Irregular, restricted fires are confirmed by the presence of charcoal dust in the sediments.

The course of the tree curves in the settlement phases SK-4, SR-4 (4400*–3900* BP) is difficult to interpret unequivocally. The beginning of the phase undoubtedly illustrates the development of coppice woods in which all the deciduous trees were coppiced or pruned. This is shown by the synchronous rise of the curves of all the shade-tolerant trees (except *Tilia*), and of light-demanding species *Corylus* and *Pteridium aquilinum*. Moreover, a considerable increase in pollen influx, especially in that of the AP, indicates good light conditions in the forests. The high percentages and influx of tree pollen do not, therefore, reflect the regeneration of high forest but rather the existence of loose, open-canopied communities. Such a forest structure was probably typical of coppice woods, in which coppicing and controlled pruning led to a good light supply and resulted in intensive pollen production (Göransson 1986).

In the later part of this phase the role of the trees diminished in the following order: *Ulmus, Fraxinus* (also *Hedera*) and finally *Tilia*. Such a picture may have come about as a result of the concomitant use of a variety of forest management methods (coppicing, pollarding, shredding, clearing), the exploitation of different habitats and the varying regenerative capabilities of the individual tree species.

Animal husbandry became distinctly more important during this period. Animals presumably grazed in the woodland (*Pteridium* peak) and in small open pastures (*Plantago lanceolata*). Leaf fodder was obtained from the coppices and by pollarding and ivy was also gathered (disappearance of *Hedera* pollen). Cereals were cultivated on a small scale, which is indicated by the first pollen of *Triticum* type and *Cerealia* indet., recorded in the Lake Racze diagram.

Settlement phase Sk-5 (3900*–3500* BP) probably represents a time of the maximum development of coppice-woods in the investigation area, caused by intensive human activity. However, pollen of anthropogenic indicators is present at relatively low frequencies, which is probably an apparent phenomenon. First, the coppice-wood structure formed a very effective curtain restricting the spread of pollen, especially from herbs growing close to the ground and from tiny fields and pastures situated within such woods (Göransson 1986). Moreover, the very high AP influx, including *Corylus*, screens the NAP values, especially in relative terms (Aaby 1988).

In general, this phase can be characterized as a time of intensive animal husbandry and probably small-scale cereal cultivation (the first pollen grain of *Cerealia* indet. in the Kołczewo profile).

Also in this period habitats on the lighter soils were exploited with increasing intensity. *Acer* (probably *A. pseudoplatanus*) grew in the openings in lime and lime-oak forests (its pollen regularly accompanies the *Tilia* curve and its frequency rises markedly in conjunction with slight depressions in this curve). On the disturbed poorest habitats patches of light-demanding vegetation with *Rumex acetosella* or *Melampyrum ssp.* spread. During this settlement phase a new rise in the ground water table took place, which resulted in the development of aquatic vegetation with *Nymphaea, Nuphar, Sparganium, Potamogeton* and *Pediastrum* on the surface of the Kołczewo mire.

Pinus-Betula local pa subz

During the settlement phase Sk-6 (3500*–3300* BP) deforestation took place in all kinds of woodland. This activity caused the ground water table to rise sharply which resulted in a new luxuriant grows of aquatics on the Kołczewo site. On the deforested land, on better soils, pastures with *Plantago lanceolata, Plantago media, Ranunculus acris* (?) and *Rumex acetosa* (?) developed, while on acid dry soils swards with *Rumex acetosella, Calluna vulgaris* and *Jasione montana* were of importance. In places *Junipe-*

rus groves appeared. Animal husbandry was still of major importance. Only single pollen grains of cereals (*Cerealia* indet., *Triticum* type) occur indicating their cultivation on a small scale. One pollen grain of *Secale* comes probably from the rye-weed. *Bilderdykia convolvulus* was probably also growing as a field-weed.

The large quantities of pollen of plants typical of poor sandy soils, especially *Rumex acetosella*, together with a higher proportion of minerogenic material in the sediment show that the poor, light soils in the immediate vicinity of the mire were exploited and that human settlement brought about their gradual degradation.

Regeneration phase RK-2 (3300*–3100* BP) illustrates the decline of agricultural activities during this ca. 200 year period. In the surroundings of the Kołczewo site, the area previously occupied by pastures or fields, probably became completely overgrown by forest.

In comparison with the earlier phases, woodland regenerated in a different way. The main feature was the rapid expansion first of birch and later of pine, whereas hazel receded markedly. One of the reasons for such a succession was that during phase SK-6, around the Kołczewo site, it was mainly the oak-lime woods on light soils which were disturbed, and the edaphic conditions of these habitats were more favourable to birch and pine than to hazel. The Kołczewo diagram shows a clear correlation between even slight depressions in the *Tilia* curve and peaks in the *Betula* curve (well seen in Fig. 9). Modern research on the secondary succession of deciduous woodland on sandy-clayey soils has demonstrated that *Betula pendula* is one of the most important species in the regeneration of such communities (Markowski 1982). It seems, however, that during the period in question, birch also replaced hazel in the succession on more fertile woodland habitats with elm, oak and ash.

The reasons for the hazel decline (ca. 3200* BP) in this area are undoubtedly complex. This is a well known phenomenon in pollen diagrams from north-west Europe and both climatic (Dupont & Brenninkmeijer 1984) and human (Aaby 1988) factors are thought to have been significant. In the study area, men could, indeed, have played a major role. For a number of reasons, hazel had earlier been favoured by man, and the maintenance of coppice-woods helped to keep this species in prime condition. Later overgrazing and the cropping of large numbers of shoots (e.g. for fencing off fields), as well as the detrimental edaphic changes observed in phase SK-6 may have contributed to its reduction. The negative correlation which is evident between the *Corylus* curve and the slowly rising *Carpinus* curve is noteworthy. By spreading onto fertile habitats, hornbeam could have been of importance in the recession of hazel, because of the competition between these two species.

At the end of this phase, ca. 3100* BP, an important transformation on the Kołczewo mire itself took place. The mire vegetation lost its contact with the ground water and a succession of ombrogenic communities began. Species of oligotrophic hummocks (*Sphagnum magellanicum, Eriophorum vaginatum*) and hollows (*Sphagnum cuspidatum, Scheuchzeria palustris*) appeared (Latałowa unpubl.). The huge numbers of a rhizopod, *Nebela* (mostly *N. collaris*), probably shows an initial dystrophic phase in the raised bog development (Tolonen 1986b).

The settlement phase SK-7 (3100* – 2860±110 BP) illustrates the intensifying land occupation in the surroundings of the Kołczewo peatbog. A range of habitats were exploited, mainly in connection with animal husbandry. The lower-lying fertile elm-ash forests were probably coppiced and pollarded (rather sharp fluctuations of the relative and concentration pollen values) or they were partly transformed into meadows and pastures. *Carpinus betulus* gradually spread onto disturbed habitats. The return to coppicing (after its cessation in the RK-2 phase) resulted in a new development of *Corylus*. At the same time, the *Tilia* forest did not suffer so much. Judging from the *Tilia* percentage and concentration curves this tree was of great importance at that time. Perhaps, also, the practice of shredding may have resulted in its abundant flowering (Andersen 1988a). However, greater disturbances also took place on the habitats dominated by *Tilia*; in such places *Fagus* gradually expanded. On the poorest soils, deforested about 200–300 years earlier (in the SK-6 phase), forest communities with *Pinus* and *Quercus* were established. These were also disturbed in this phase; in particular, coppicing could have had a negative influence on the regeneration of pine (in the pollen diagram there is a clear negative correlation between the curves of *Corylus* and *Pinus*).

An interesting record, which could be correlated either with this or with the next phase, is one pollen grain of *Ilex aquifolium* found in the Lake Racze profile, which is the only Holocene find from Poland. Wolin Island lies close to the present eastern limit of the range of this species (Hegi 1965) and natural stands of *Ilex* are not known from the area today (Piotrowska 1966a). Even single records of its pollen are usually emphasized in the interpretation of diagrams from northern Europe as *Ilex* is regarded as an important indicator of mild climatic conditions (Iversen 1944, 1960), a plant used as leaf-fodder (Troels-Smith 1960) and a plant typical of pasture-woods (Pott 1984). The occurrence of *Ilex* pollen indicates local presence of the plant because of its low production and very poor pollen dispersal (Iversen 1960, Moore et al. 1986). It is very probable that *Ilex aquifolium* was growing in the coppice woods on Wolin Island at least about 3000* years ago.

Pinus-Fagus-Gramineae local paz, 2860±110 – 2200* BP (Kołczewo)

This pollen zone represents a period in which tremendous changes in the local woodlands took place. The ecologically more demanding species were brought to the verge of extinction. When the settlement pressure somewhat diminished, the main contributors to woodland regeneration were pine, birch and beech, with hornbeam and oak as subordinates.

The division into subzones illustrates vegetation changes during the very strong settlement phase in which large-scale deforestation took place (*Gramineae-Cyperaceae-Plantago lanceolata* pa subz) and in the time of gradual woodland regeneration (*Pinus* pa subz).

Gramineae-Cyperaceae-Plantago lanceolata local pa subz

Extreme deforestation and changes accompanying intensive settlement are characteristic features of this subzone, which corresponds to settlement phase SK-8 (2860±110 – 2700* BP).

All woodland communities were affected by deforestation, even alder swamps, which had hitherto only been slightly exploited, were destroyed. Burning was one of the methods used, as is demonstrated by the abundance of charcoal dust and charcoal fragments in the peat deposit.

Pollen of numerous plants indicate the development of diverse anthropogenic plant communities. Near the peatbog ruderal vegetation with *Urtica, Plantago major, Polygonum aviculare, cf. Melandrium album* and *Chenopodium album* was common. Seeds of the last species were found in the peat (Latałowa unpubl.).

Animals were pastured both on the more fertile habitats with *Plantago lanceolata, P. media, Trifolium repens, Succisa pratensis, Hypericum, Ranunculus* and *Rumex acetosa* and on the poorer ones with *Scleranthus perennis, Jasione montana, Rumex acetosella* and *Juniperus.*

Cereal cultivation was of increasing importance. *Triticum* and *Hordeum* were certainly grown, but the fact that only one *Secale* pollen grain was found in these rich spectra leads one to infer that rye was not yet cultivated as a separate crop.

The weeds of arable land included *Convolvulus arvensis, Scleranthus annuus, Bilderdykia convolvulus, Polygonum persicaria* (?), *Lapsana* (*communis* ?), *Cruciferae* and no doubt *Rumex acetosella, Plantago lanceolata* and other species mentioned earlier as typical of pastures or ruderal habitats. Cultivation of the light soils in the vicinity of the peatbog contributed to soil erosion. Evidence of this is the presence of a fine well sorted sand layer in the peat. In the moist field trenches or in the pathways along field edges, ephemeral communities of small therophytes with *Peplis portula, Anthoceros punctatus* and *Cyperus* may have come into existence.

Settlement during this phase also brought about important changes in the ground water regime of the area. The surface waters of the raised bog, which had been developing for some 150±100 years, once more came into contact with the ground water. The succession of ombrogenic communities was interrupted and aquatic plants typical of eutrophic water bodies such as *Potamogeton sect. Eupotamogeton, Ceratophyllum, Nymphaea, Alisma plantago-aquatica* and *Pediastrum*, appeared again.

Pinus local pa subz

This subzone represents the period when the woodlands of the study area were dominated by pine and birch. Two settlement phases are distinguished on the basis of the presence of pollen of anthropogenic indicators.

In phase SK-9 (2700*–2500* BP), the settlement moved away from the immediate neighbourhood of the Kołczewo site, presumably because the environment had been extensively exploited during the preceding phase (SK-8). Woodland regenerated on the fallow land, but it was largely pine, birch and some beech that participated in this succession. It is hard to tell from the diagrams whether the quantity of anthropogenic indicator pollen, which is still high, is derived from remote settlements or whether anthropogenic communities survived on fallow fields and pastures. It is also probable that some pastures, close to the site, were still exploited. Since cereal pollen were found only in the lowermost sample, the general break down of farming can be assumed.

Settlement phase Sk-10 (2500*–2200* BP) illustrates the renewed human occupation of the area. The land around the peatbog was used mainly for grazing, which took place on pastures with *Plantago lanceolata, P. media, Trifolium, Rumex acetosa* (?), *Ranunculus acris* (?) and *Cicorioideae* and probably in open forests, where *Pteridium aquilinum* and *Melampyrum* were of importance. Large quantities of *Rumex acetosella* pollen, and frequent records of *Jasione montana, Melampyrum* and *Pteridium*, correlated with a distinct depression in the *Pinus* curve, indicate that dry and rather barren soils were utilized, too.

Cereals and hemp were cultivated at this time, but the fields must have been at some distance from the peatbog, because there are only single grains of *Cerealia* pollen and only a very slight increase in mineral material in the sediment. The plant cover in the catchment area was evidently in good condition.

***Fagus-Pinus-Carpinus* local paz, 2200*– 1000* BP (Kołczewo) and *Fagus-Alnus-Carpinus* local paz, 2470±100 – 1000* BP (Lake Racze)**

As settlement once again regressed in the vicinity of the Kołczewo peatbog and Lake Racze, woodland spread, particularly forest communities with beech. The more fertile habitats supported oak communities with a small admixture of hornbeam.

There were differences in the vegetation and in the intensity of settlement near the two sites. Pine was of much greater significance in the woods around Kołczewo, where the peatbog is surrounded by light sandy-clayey soils. Near Lake Racze, on the heavier clay soils, beech was of major importance. The high *Alnus* curve, especially in the Lake Racze diagram, indicates that alder swamp communities were well established on the waterlogged organic soils which are particularly common north of the lake.

Beech expanded gradually across the morainic part of Wolin Island. The *Quercus-Fagus* pa subz in both diagrams illustrates this succession stage with prevalent oak which lasted for ca. 100 (Kołczewo) to 300 (Lake Racze) years. Between 2100* and 1000* BP the dynamic expansion of beech suppressed the role of oak (*Fagus* pa subz). A third, *Quercus-Fagus-Alnus* pa subz has been distinguished in the Lake Racze diagram and illustrates partial deforestation of the beechwood habitats and the increasing role of oak.

This pollen zone is not uniform with regard to the pollen content of the anthropogenic indicators.

In settlement phases Sk-11 (2200*–1840±60 BP) and Sr-6 (2470±100 – 1550±120 BP), the low values and irregular and broken curves of the anthropogenic indicators in the Kołczewo diagram and the low, but mostly continuous curves in the Lake Racze diagram, together with the concomitant increase in the proportion of shade-tolerant trees, especially oak and beech, and a decline in pine, suggest that settlement pressure in the area diminished. Nevertheless, the increased frequency of *Cerealia* pollen and, in the second part of the phase, especially that of *Secale*, shows that cultivation increased in importance at that time. It is likely that while the woodland regenerated around the two sites, settlement continued in other places which perhaps had hitherto, not been so heavily exploited.

Regeneration phases RK-3 (1840±60 – 1300±60 BP) and RR-2 (1550±120 – 1300* BP) undoubtedly reflect an economic recession and virtual total forest regeneration in the neighbourhood of the two sites. Most of the area became covered with beech and pine woods in accordance with the soil conditions. Small patches of more fertile and moister soils supported oak communities with an admixture of hornbeam and also ash in some places. In comparison with the earlier phases, non-woodland communities practically disappeared. The fall in the mineral content in the Lake Racze sediments and the Kołczewo peats provides evidence of soil stabilization. The decline in settlement activity is also reflected in the decrease in charcoal particles.

Both diagrams primarily reflect local events which occurred in the immediate neighbourhood of the sites, so it is difficult to deduce from them whether and in what way settlement was proceeding elsewhere on the island. Although this was definitely a period of economic recession, the possibility that small settlements existed on land farther away from Kołczewo and Lake Racze can be inferred from the small amount of anthropogenic indicator pollen, especially the single cereal pollen grains. Sharp fluctuations in the beech and pine curves (Kołczewo) may reflect shifting cultivation, i.e. a series of clearances followed by the reforestation of the fallow land at a considerable distance from the investigation sites. More clear settlement gap (disappearance of cereal pollen) occurred rather late (ca. 1500* BP) and lasted no longer than 200 years.

Settlement phases SK-12, SR-7 (1300±60–1000* BP) proceeded quite differently at the two sites. Near Lake Racze, the beechwoods were largely destroyed, and since the light conditions improved, oak began to spread again. Alder communities were also cleared. The extensive deforestation in the lake drainage area is also reflected in the high mineral content and large number of charcoal fragments in the sediments. Pastures and arable fields had been laid out in the close vicinity of the lake. Among the cereals, *Secale* began to be an important crop and *Avena* was probably cultivated for the first time. Among the field weeds, plants typical of winter cereals (*Rumex acetosella, Agrostemma githago, Ranunculus arvensis, Anagallis arvensis*) in addition to those growing mostly among summer cereals and root crops (cf. *Spergula arvensis, Polygonum persicaria* (?) were present. The weed flora was represented mainly by species indicative of poor soils, but single pollen grains of such plants as *Ranunculus arvensis, Anagallis arvensis* or cf. *Melandrium album* show that, in places, more eutrophic conditions existed. At this time different pastures became important. On better soils, meadows with *Plantago lanceolata, Ranunculus acris* (?) and other more demanding species developed. However, mainly poor dry grasslands with *Jasione montana, Scleranthus perennis, Knautia arvensis, Allium vineale* (?), *Rumex acetosella* and *Trifolium repens* and probably patches of heath with *Calluna vulgaris*, were of greatest importance.

The Kołczewo diagram shows much weaker signs of deforestation. Forest disturbances caused the spread of heliophilous communities with *Pteridium aquilinum* and *Melampyrum*. In the vicinity of the peatbog nitrophilous vegetation with *Artemisia, Urtica* and *Chenopodiaceae* developed. Cultivated fields and open pastures were probably at some distance from the site. The pollen of plants indicative of pasture and arable land, which are present in this part of the profile, may have been transported from other, not so distant, places.

***Pinus-Gramineae-Cerealia-Juniperus* local paz, 1000*–0 BP (Kołczewo and Lake Racze)**

This pollen zone coincides in both diagrams with the settlement phases SK-13, SR-8 (1000*–0 BP); the Kołczewo diagram illustrates only the beginning of the phase.

Some 1000* years ago the environs of both sites were entirely deforested. Intensive grazing brought about a deterioration of habitats and resulted in the further development of heath and dry swards resembling communities of the present day *Nardo-Callunetea* class (*Calluna vulgaris, Polygala vulgaris*) and sandy grasslands of the *Sedo-Scleranthetea* class (*Rumex acetosella, Jasione montana, Scleranthus perennis, Knautia arvensis, Armeria elongata, Herniaria glabra* and *Juniperus communis*). Patches of these communities must have existed in the immediate vicinity of Lake Racze because, amongst others, numerous *Calluna vulgaris* seeds were found in the sediments (Latałowa unpubl.).

The phases are characterized by the increasing importance of cultivation. *Triticum, Hordeum, Avena* and *Secale* were cultivated during the whole phase, while *Fagopyrum* was growing in the vicinity of Lake Racze during the period ca. 800*–600* BP. Hemp (cf. *Cannabis sativa*) was cultivated from the beginning of the phase. In the sediments from Lake Racze dated to ca. 800*–400* BP a very high numbers of cf. *Cannabis sativa* pollen were determined (cf. p. 141) which suggests that the retting of hemp was practised in this lake (cf. p. 230). Probably flax was also cultivated in the area because its seeds were found in the Lake Racze sediments (Latałowa in print). The high *Cruciferae* curve may give evidence of *Brassica* species or *Camelina sativa* cultivation, both of which are known from the archaeobotanical material from northwestern Poland (Klichowska 1972).

The weed flora, including *Centaurea cyanus, Bilderdykia convolvulus, Scleranthus annuus* and cf. *Agrostemma githago*, indicates that winter cultivation of rye and probably also barley was practised (cf. Behre 1981, Lange 1975) in addition to summer cultivation. *Papaver argemone, Convolvulus arvensis, Polygonum aviculare, P. persicaria* (?) and *Stellaria cf. media* also occurred among the crops, as did – no doubt – many species from the neighbouring grasslands, e.g. *Rumex acetosella*, or ruderal communities, like the numerous members of the *Cruciferae* family. Most of the above mentioned species are typical of poor segetal associations and occur on the arable land around Lake Racze and Kołczewo to the present day (Nowiński 1964).

A characteristic weed composition was found in the spectra with the large number of cf. *Cannabis* pollen. *Centaurea cyanus, Polygonum aviculare* and *Bilderdykia convolvulus* were certainly growing in the *Cannabis* fields, which could indicate, that hemp was sown in rotation with winter rye or barley. A similar picture has been obtained from a pollen diagram from southern Sweden (Gaillard & Berglund 1988), in which some weed species usually frequent in winter cereals (*Scleranthus annuus, Polygonum aviculare*) are especially common in the section indicating *Cannabis* retting. The other remarkable feature of this section of the Lake Racze diagram is the prevalence of immature pollen grains of these weeds, which is mainly seen in their smaller size and the absence of costae equatoriales. A similar phenomenon was described by Binka et al. (1991) for *Centaurea cyanus* pollen grains found in samples representative of hemp retting. This may be an indication that hemp was gathered in the early summer before the time of optimum weed flowering. Such a short growing season is typical of the northern variety of *Cannabis sativa* (Herse 1982) today.

The increasing amounts of mineral material towards the top of the profiles testify to serious soil erosion caused by the expansion of farming in the vicinity of both of the sites. These soils had already become practically devoid of calcium carbonate in the early stages of deforestation (Rybak et al. 1987) at the beginning of this phase.

VEGETATION CHANGES IN THE SANDY AREA OF SOUTHEASTERN WOLIN

Alnus-Pinus-Betula local paz, 7320±520 – 6340±110 BP

The interpretation of the bottom part of the Wolin II profile (Fig. 16) presents many difficulties, both in terms of the chronology, due to the large standard deviation in the ^{14}C date, and the reconstruction of the vegetation.

The fluctuations in the pollen curves may well be due primarily to local changes in water regime, which probably influenced alluvial woodland communities and caused alder to oust elm, ash and oak, and initiated peat deposition at the study site. The date for the bottom of the profile (7320±520 BP) could indicate a link between the rise in the ground water table and the first phase of the Littorina transgression in the southern Baltic, recorded in the sediments of the Szczecin Lagoon (see p. 128).

The high *Pinus* and *Betula* pollen percentages and the *Corylus, Tilia* and *Quercus* curves indicate that these trees were growing in various woodlands on sandy soils near the mire. In forest glades, on poor habitats, patches of heliophilous vegetation with *Calluna, Melampyrum* and *Pteridium aquilinum* developed. The high charcoal dust curve shows that it must have been an area constantly visited by man. The high *Alnus* curve underlines the importance of woodland swamp communities.

There were also places with open vegetation adjacent to the site. The large numbers of *Cicorioideae* and *Asteroideae* pollen and the scattered pollen grains of *Centaurea jacea, Filipendula, Lychnis* type, *Umbelliferae, Leguminosae* and *Caryophyllaceae* probably come from meadows. It is, however, impossible to reconstruct exactly the nature of these communities; they could have been strictly local forming the initial stage of the succession on the mire, they could have developed in the close vicinity of the site as a consequence of the sharp rise in the ground water table or, their spread could be a result of man's activity.

Pinus-Quercus-Betula-Pteridium local paz, 6340±110 – 4130±60 (4300*) BP

Further changes in the woodland, mainly in the *Tilia-Quercus* forest surrounding the peatbog, were initiated by fire (numerous charcoal fragments in the sediment and a peak in the curve for charcoal dust). The proportions of lime oak, hazel and birch fell abruptly. The high *Pinus* curve suggests that pine probably spread into the disturbed habitats. Pine continued to dominate the light, sandy soils until around 5800* years BP (*Pinus* pa subz) after which its proportion gradually dropped, while that of oak rose (*Corylus-Quercus* pa subz). The *Alnus-Betula* pa subz illustrates a decline of *Quercus* in the area at the time when forest communities on damp soils probably increased slightly in importance.

The *Pinus-Quercus-Betula* woodland had a rather open structure. Birch was an important constituent in these forests, and the herb layer was dominated by *Pteridium aquilinum*. The high proportion of bracken is evidence of a good light supply and the presence of the required amount of charcoal in the soil for spore formation (Oinonen 1967).

The thick herb layer with *Pteridium aquilinum* must have played a large part in restricting the amount of pine in the woodland adjacent to the peatbog. Markowski's research (1971), as well as that reported by Rakham (1980), has shown that the spontaneous renewal of pine is poor in bracken-dominated habitats. When present in large concentrations *Pteridium aquilinum* strongly shades the lower vegetation layers and inhibits the growth of heliophilous pine seedlings.

The above-mentioned *Pinus-Quercus-Betula* woodlands are probably comparable with today's communities of the order *Quercetea robori petreae* and especially with acidophilous oak-birch (*Betulo-Quercetum roboris*) woods. In Poland there are some *Betulo-Quercetum* localities on sandy substrata along the coast, but in comparison with the oak-birch woodlands of western Europe, the Polish ones are poorer and less diversified (Piotrowska unpbl.) Nowadays, phytocoenoses of this association occur on low rampart dunes, and in a different form, on Pleistocene sands on both Wolin and the neighbouring Uznam island; the absolute dominance of *Pteridium aquilinum* in the herb layer is characteristic of most patches strongly influenced by man (Piotrowska 1966 b).

Since the soils around the Wolin II site are mostly light sandy or peaty formations (Fig. 14), communities with elm and ash were always rather scarce in the area, which is indicated by the fairly low percentages of *Ulmus* and *Fraxinus* pollen in the diagram.

Man was the prime agent shaping plant communities in the study area throughout the period in question; three settlement phases are distinguished.

Settlement phase Sw-1 (6340±110 – 6000* (5860±110) BP) was characterized by regular burning in the *Pinus-Quercus-Betula* woods, a fact confirmed by the presence of charcoal particles in the peat and the high *Pteridium aquilinum* curve. This was probably a deliberate activity on the part of man in order to improve foraging conditions for the wild game, and later, the grazing for his domestic animals (cf. p. 205).

In addition to places densely covered with *Pteridium aquilinum* there were also forest glades in which patches of dry grassland probably with *Rumex acetosella* and heath with *Calluna* started to spread. The result of larger fires on the more fertile habitats was a rise in the ground water table and eutrophication, which in turn led to the spread of nitrophilous communities with *Urtica* and *Chenopodiaceae* which might also have existed close to human settlements. The appearance of *Plantago maior* is noteworthy, as this plant is regarded as a good indicator of primary meadows (Groenman-van Waateringe 1983) and ruderal habitats.

During phase Sw-2 (6000* (5860±110) – 4930±60 BP) striking changes occurred in the woodland on more fertile habitats, as is evidenced by the fluctuations in the *Ulmus*, *Fraxinus* and *Tilia* curves.

The first *Ulmus* and *Fraxinus* fall has been dated to 5860±110 BP and is preceded by a slight depression in the *Tilia* curve. Towards the end of this phase there is a second, much steeper decline in *Ulmus*, which as before, is linked with a drop in the *Fraxinus* and *Tilia* curves, and is dated by interpolation to ca. 5400*–5300* BP. The charcoal curve falls distinctly as does that of *Pteridium aquilinum*, whereas *Plantago lanceolata* appears in both of the layers in which the *Ulmus* declines are registered.

This section of the profile illustrates man-made changes to the woodlands, which can be linked with increasing animal husbandry. The fluctuations in the tree pollen curves described above, probably result from the intensive pollarding of elm, ash and lime and from small clearances which caused pastures with *Plantago lanceolata* to develop. Because of the destruction of these shade producing species, the better light conditions allowed oak and hazel to flower and spread more rapidly. It may also have been the result of coppicing.

As in the previous phase, the undergrowth was burnt and animals were then pastured in the *Pinus-Quercus-Betula* woodland, which gradually became impoverished as the light soils were destroyed. Open communities with *Calluna, Rumex acetosella, Jasione* and *Melampyrum* then developed. This may have forced people to look for other sources of fodder and led to disturbances in woodlands with *Ulmus, Fraxinus* and *Tilia*. Cereal cultivation began in this phase as is seen from the presence of *Cerealia indet.* and *Hordeum* type pollen.

During settlement phase Sw-3 (4930±60 – 4130±60 (4300*) BP) grazing was intensive both in the *Pinus-Quercus-Betula* woodland (high *Pteridium* curve) and on more fertile habitats (beginning of the continuous *Plantago lanceolata* curve). This resulted in the destruction of forest communities, in particular the proportions of oak, elm and lime fell, and in the expansion of meadows and pastures. In this phase the role of different anthropogenic communities increased noticeably and those characteristic of poor soils, were especially important.

Corylus-Quercus-Tilia-Calluna local paz, 4130±60 (4300*) – 2300* BP

The period represented by this pollen zone was characterized by the expansion of heathland. The proportion of deciduous trees in the woodland communities, gradually fell. The *Corylus-Tilia* pa subz illustrates the period when hazel increased in importance, while in the *Pinus-Quercus* pa subz pine spread over the area.

The heathland with *Calluna vulgaris* probably came into existence as a result of constant burning and grazing on the light sandy soils in the *Pinus-Quercus-Betula* forests. In addition to *Calluna vulgaris, Pimpinella (saxifraga ?), Rumex acetosella* and different species of *Gramineae* were of importance in these communities. *Rubus (idaeus ?)* thickets also spread as the result of frequent fires (cf. Vuorela 1986). Since the peat layer between the samples dated to 4930±60 and 4130±60 BP was growing very slowly, it is impossible to indicate the exact beginning of heath vegetation development near the Wolin II site.

The *Calluna* heath probably covered the sandy soils adjacent to the mire. This is shown by the high pollen percentages (av. 12%) and the presence of numerous pollen clumps of *Calluna*, which probably reached the mire by being washed out of the soils in the immediate vicinity of the site.

The destruction of woodland and spread of heathland on dry ground could quite possibly be linked with the rise in the water table at the mire, where aquatic communities with *Potamogeton, Sparganium* cf. *erectum, Sparganium sp., Alisma plantago-aquatica, Stratiotes aloides* and *Pediastrum* existed in places. The increased supply of nutrient poor, mineral material probably caused a change in the trophic status of the mire and hence the appearance of a number of mesotrophic species such as *Eriophorum vaginatum, Lycopodiella inundata* or *Sphagna* sect. *Palustria* (Latałowa unpubl.).

Man's activities during this period varied in intensity, as reflected in the following three settlement phases.

During phase Sw-4 (4130±60 (4300*) – 3800* BP), cereal cultivation was of importance. *Triticum* and *Hordeum* were probably cultivated, while *Secale*, represented by only two pollen grains, was not sown as a separate crop. The group of segetal weeds is interesting. Among them, annuals which usually grow in winter crop fields and are mostly typical of light, poor soils, such as *Centaurea cyanus, Scleranthus annuus, Bilderdykia convolvulus, Anthemis (arvensis ?)* were present. Other plants, such as *Lapsana (communis ?), Polygonum aviculare* and *Plantago maior* could have been growing either on cultivated fields or in ruderal communities.

Animal husbandry was certainly of importance, too. Poor heathlands and pastures with *Calluna vulgaris, Rumex acetosella* and *Jasione montana* spread. The ecotone between *Pinus-Quercus-Betula* forest and heathlands was probably covered by a rich vegetation with *Pteridium aquilinum, Rubus (idaeus ?), Pimpinella (saxifraga ?)* and *Melampyrum*. On better habitats pastures with *Plantago lanceolata, P. media* and *Centaurea jacea* existed. In this phase deforestation proceded on all kinds of habitats.

During settlement phase Sw-5 (3800*–3600* BP) not only heathland but also coppice-woods were of significance. The synchronic peaks of shade-tolerant and shade-giving *Tilia* and *Quercus* as well as light-demanding *Corylus* may be a reflection of the coppicing methods, where pruning promoted vigorous regeneration from suckers and the better light conditions within the forest enabled more abundant flowering. Such a supposition is confirmed by the concentration diagram (Fig. 18) in which the amounts of pollen rise sharply, especially that of *Quercus, Corylus* and *Tilia*, although there is no indication in the accumulation curve (Fig. 15) that this was caused by a low rate of peat accumulation. The relatively high *Tilia* pollen percentages and concentration suggest that this tree enjoyed particular favour, maybe as a source of leaf fodder (cf. Andersen 1988).

The small quantity of cereal pollen and the fall in the curves of several important anthropogenic indicators, e.g. *Plantago lanceolata* and *Rumex acetosa/acetosella*, are probably due to the "curtain effect" (Göransson 1986) and not to any decrease in farming activities in the area; the high charcoal dust curve, the considerable amounts of *Calluna* pollen and the presence of many other indicator species are evidence that a variety of anthropogenic communities still existed. Segetal and ruderal weeds included *Anthemis* (*arvensis* ?), *Papaver rhoeas (?), Bilderdykia convolvulus, Polygonum aviculare, P. persicaria (?), Lapsana communis (?), Plantago maior, Chenopodiaceae, Urtica* and *Artemisia*. The *Valerianella locusta* and *Scabiosa columbaria* pollen probably comes from dry grasslands.

Settlement phase Sw-6 (3600*–2300* BP) illustrates the increasing exploitation of woodlands on the more fertile habitats. The date 3370±60 BP determines the final destruction of forest with *Ulmus, Fraxinus* and *Tilia*. The tree which gradually began to regain its significance was pine. The low values of *Fagus* and *Carpinus* indicate that these trees may merely have been an insignificant admixture in the woodland of the southeastern part of Wolin Island, or else that their pollen is derived from long-distance transport.

This phase represents a long and very important period of human influence on the vegetation. However, it is recorded in a section of sediment characterized by a very low accumulation rate and so, it is not possible to reconstruct the anthropogenic changes in detail. Certainly it was a time of continued development in farming. Both, cereal cultivation and animal husbandry were intensive. In this phase the relatively fertile, fresh meadows and pastures with *Plantago lanceolata, P. media, Ranunculus (acris ?), Centaurea jacea* and *Trifolium pratense* probably reached their maximum extent in the area.

***Pinus-Fagus-Calluna* local paz, 2300*– ?1520±90 BP**

The vegetation history is not recorded accurately in this pollen zone because of the low peat accumulation rate (cf. Fig. 15) The zone is contemporary with the Sw-7 settlement phase.

During phase Sw-7 heathland declined in importance. The obvious negative correlation between the *Pinus* and *Calluna* curves could suggest that the exploitation of heathland had ceased in some places, which allowed pine to encroach. On the other hand, the rising cereal pollen curves, including that of *Secale*, show the continuation of settlement. The gradual disappearance of heathland may also have been caused by overgrazing (cf. Gimingham 1972). Perhaps both processes occurred at various times during these 800 years. The difference in intensity of human impact on the landscape is also shown by fluctuations in the curves of the other anthropogenic indicators, for example the interruption of the *Plantago lanceolata* curve.

By this time, the study area had been, to a large extent, deforested. The only woodlands that survived were patches of oak, birch and pine with hazel as an undergrowth, and the relatively well-preserved alder swamps. On the poorer soils the role of pine increased significantly.

***Pinus-Gramineae-Cerealia-Juniperus* local paz, ?1520±90 (980±60)-0 BP**

The beginning of intensified deforestation and agriculture, which corresponds with the beginning of this pollen zone and, the settlement phase Sw-8, is difficult to date, because the peat accumulation rate between 1520±90 and 980±60 BP was, as in the preceding section of the profile, extremely low. If, however, the radiocarbon date of 1520±90 BP is assumed to be correct for the level in which the *Quercus, Betula, Corylus, Alnus* and *Calluna* curves are still relatively high, and the cereal curves rise, it is highly probable that this denotes the beginning of early Medieval settlement in the area (cf. p. 203).

All the woodlands were destroyed during this period, even the hitherto little-affected alder swamps. The high *Pinus* curve is probably partly due to the transportation of pine pollen from farther away, e.g. from the dune areas in the west of the island where it has always been dominant in the vegetation (Prusinkiewicz, Noryśkiewicz 1966).

Heathlands almost completely disappeared from the vicinity of the site. The high *Pteridium aquilinum* and *Rubus idaeus (?)* values during the first part of this phase probably depict the plant succession on intensively grazed and burnt habitats, previously taken up by *Calluna* heath (cf. Gimingham 1972).

A characteristic feature of this phase is the decreasing role of the more fertile meadows and pastures with *Plantago lanceolata, Rhinanthus, Centaurea jacea* and other plants with similar requirements. This change was brought about by the rapid impoverishment of the sandy soils around the site. Grazing resulted in the spread of poor dry grasslands of the *Nardo-Callunetea* or *Sedo-Scleranthetea* classes rather than meadow communities. This is illustrated in the diagram by the distinct rise in the *Juniperus* and *Rumex acetosa/acetosella (R. acetosella)* curves. Moreover, to satisfy the increasing demand for cereals, the remainder of the more fertile habitats, hitherto used as pastures, may also have been cultivated.

The domination of the *Cerealia indet.* curve among the cereal pollen results from the poor state of pollen preservation, which precluded the possibility of a more precise determination. For this reason it is impossible to speculate on the proportions of the different cereals. For example, it is surprising that only two *Hordeum* type pollen grains were found, because we know from other studies that barley was one of the more important crops on Wolin Island during the early Middle Ages and historical times (Klichowska 1972). *Avena* pollen type was also only found in one sample. *Secale* was of some importance but probably did not dominate over the other cereals, because its curve does not exceed those of *Triticum* type and *Cerealia indet.* The same situation was registered in the pollen diagram from Lake Racze. In addition to cereals, *Fagopyrum* and probably *Cannabis* were cultivated in the area during this phase. Similarly the very high *Cruciferae* curve may partly reflect cultivation of *Brassica rapa, B. nigra, B. campestris* or *Camelina sativa*, which are known from archaeobotanical finds in northwestern Poland (Klichowska 1972); seeds of *Brassica nigra* and *B. campestris* have also been found in the fossil material from early medieval layers in the port of Wolin (Latałowa, in print b).

Among the field weeds plants characteristic of poor segetal communities growing mainly in winter cereals were well represented and *Centaurea cyanus* was of special importance. Weeds typical of summer cereals and root crops and of ruderal communities were very common, too. In the younger part of this phase the contribution of several weeds decreased, whereas *Rumex acetosella* seems to have spread vigorously and, no doubt, its pollen is largely derived from segetal communities. This may be an indication of increasing soil deterioration.

At the beginning of this phase a sharp rise in water level took place on the mire itself, and aquatic vegetation with *Potamogeton, Pediastrum, Sparganium erectum* and *Alisma plantago-aquatica* developed. These hydrological changes were probably a consequence of the post-Littorina transgression of the southern Baltic (Klieve & Janke 1978), and can be chronologically correlated with the rise in the water level at the port of Wolin, dated to the 10th century AD (Filipowiak, oral inf.) (cf. p. 228).

DISCUSSION AND CONCLUSIONS

VEGETATION CHANGES ON WOLIN ISLAND AS A RESULT OF FOREST MANAGEMENT IN DIFFERENT ECOLOGICAL CONDITIONS

The diversity of natural conditions on Wolin Island probably resulted in the differences in settlement patterns and economy in the northern and southern part of the area. These two factors – a natural and an anthropogenic one – strongly influenced woodland development in the past.

The synthetic diagrams (Fig. 22) show the general similarities and differences between the sites, expressed in the varying contribution of light-demanding and shade-tolerant trees. The two diagrams from the morainic part of the island are very similar to each other. They differ only in the proportions of oak and pine pollen in the levels reflecting forest regeneration, especially between ca. 2700*–1300* BP, as a result of the slightly different habitat conditions around the sites (Fig. 5) but probably due to differences in the intensity of human interference, as well.

A clear difference is seen in comparison with the Wolin II profile. The much lower values of *Ulmus, Fraxinus* and *Tilia*, the very slight participation of *Fagus* and *Carpinus* and the much higher frequency of NAP are the main features of this diagram. These reflect the prevalence of poor sandy soils around the site.

The contribution of the light-demanding trees (*Pinus, Betula, Corylus*) is of particullar value in interpreting man-made forest changes (Fig. 23). Each of these taxa reacts individually to particular methods of forest management.

Pinus (P. sylvestris) belongs to the most light-demanding tree species (Obmiński 1970) and deforestation enables its spread into cleared areas, especially on light sandy soils. Moreover, openings in the forest cause an increase in the long-distance transport component of the pollen rain, a component in which *Pinus* pollen grains are particularly important. Pine declines when overshaded by tall broad-leaved trees and its seedlings do not develop under a dense herb layer and undergrowth. As an easily combustible tree it is discouraged by fires (Rakham 1980). The coppicing practice in forests reduces its occurrence.

Betula (B. pendula as well as *B. pubescens)* is known from its ability to invade newly-available ground and for its utter intolerance of shade; it spreads readily on burnt ground (Iversen 1941), preferably on sandy-clay soils (Zarzycki 1979). Because of its dispersal powers and the very fast growth of its saplings, it colonizes even small gaps in the forest immediately. *Betula* decreases with grazing and the development of a permanent and dense grass vegetation (Aaby 1986). In pollen diagrams a *Betula* increase is very often, but not exclusively, correlated with those sections in which forest management by fire is presumed.

Corylus avellana flowers abundantly under conditions of a good light supply and it easily regenerates by shoots. Its pollen curve, therefore, increases in phases where coppicing is widespread (Rakham 1980). However, too intensive coppicing and permanent browsing by animals forms a limiting factor for hazel occurrence (Aaby 1986).

By comparing the synthetic diagrams (Fig. 22) and the curves of the light-demanding trees (Fig. 23) it is possible to distinguish five main stages of woodland development

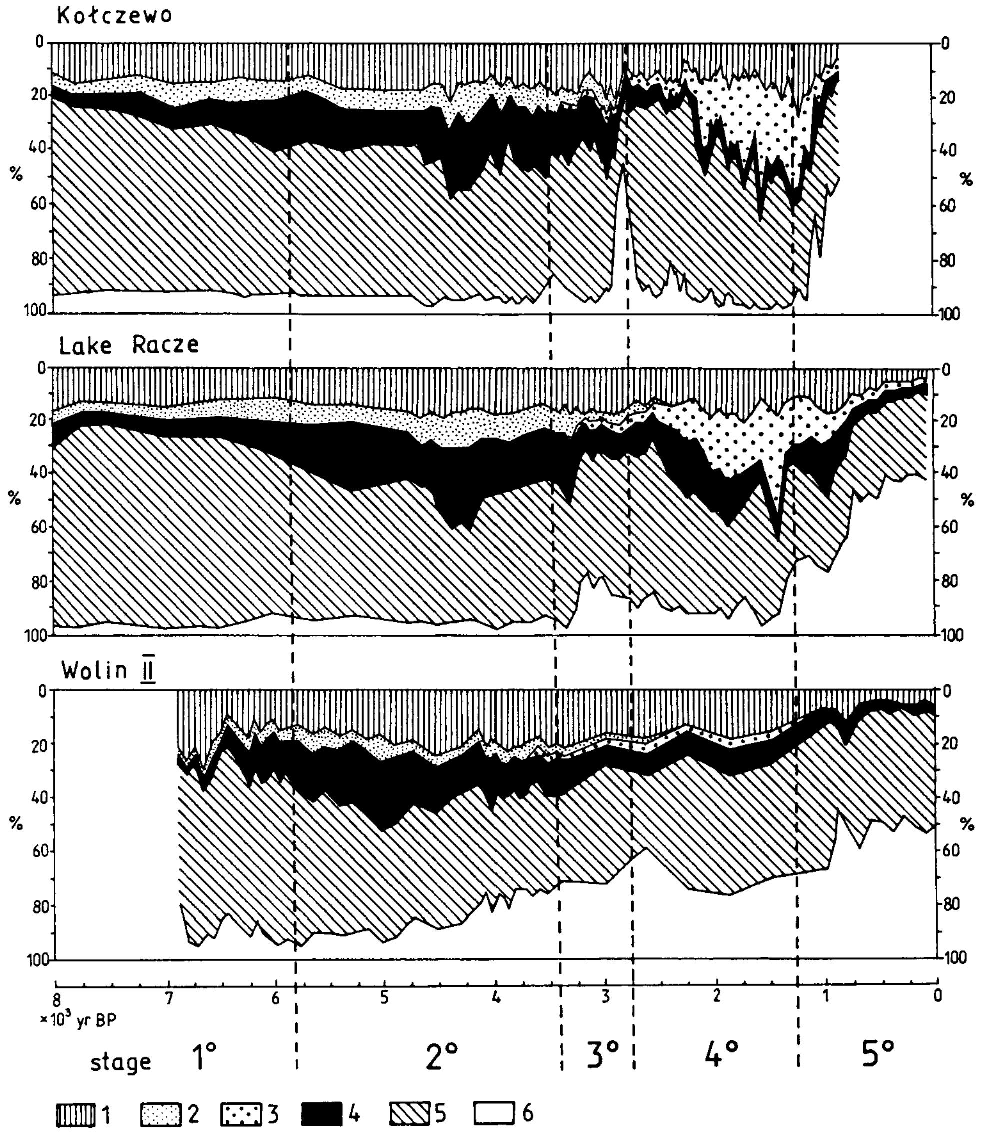

Fig. 22. Synthetic pollen diagrams on the same absolute time scale, illustrating the five main vegetation stages on Wolin Island. 1 - *Alnus*; 2 – *Ulmus*, *Fraxinus* & *Tilia*; 3 – *Fagus* & *Carpinus*; 4 – *Quercus*; 5 – *Pinus*, *Betula* & *Corylus*; 6 – NAP; basis of calculation AP + NAP = 100%; for other explanations see text

connected with different practices of forest management. The vegetation of these stages is reconstructed in a series of past-vegetation maps (Fig. 24, 25) for which, apart from the pollen diagrams, the following information sources were used: 1) map of Quaternary deposits – scale 1:50.000, 2) surface contour maps – scale 1:10.000, 3) map of present day vegetation of the Wolin National Park (Piotrowska & Olaczek unpubl.) – scale 1:25.000, 4) archaeological data (cf. p. 131).

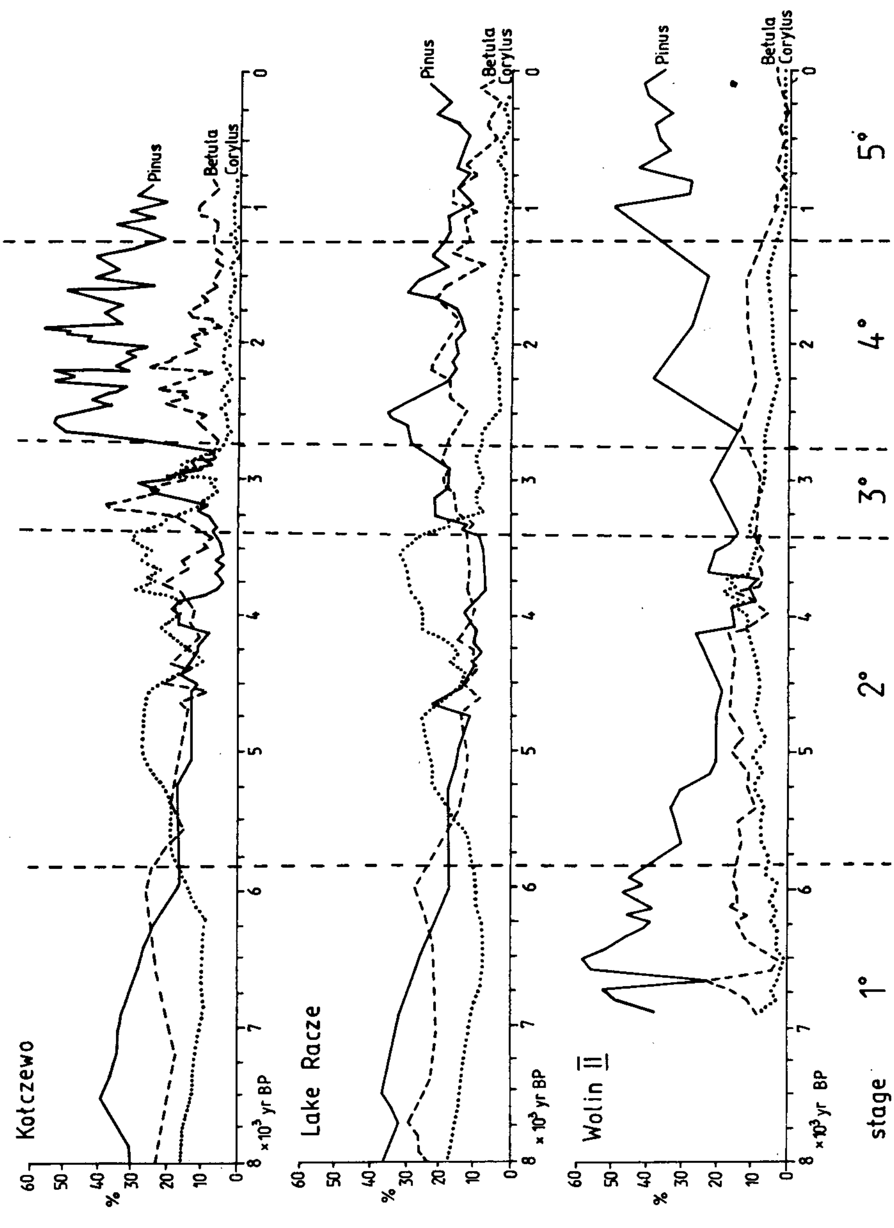

Fig. 23. *Pinus*, *Betula* and *Corylus* pollen curves for the three sites plotted on the same absolute time scale illustrating the role of these trees during the five main vegetation stages on Wolin Island; basis of calculation AP + NAP = 100%; for other explanations see text

1° stage (8000*- ca. 5800* BP) – *Quercus* was gradually replacing *Pinus* on the light sandy and sandy-clayey soils, as part of the natural succession resulting from the competition between these two species with respect to light (Iversen 1960). Locally, this

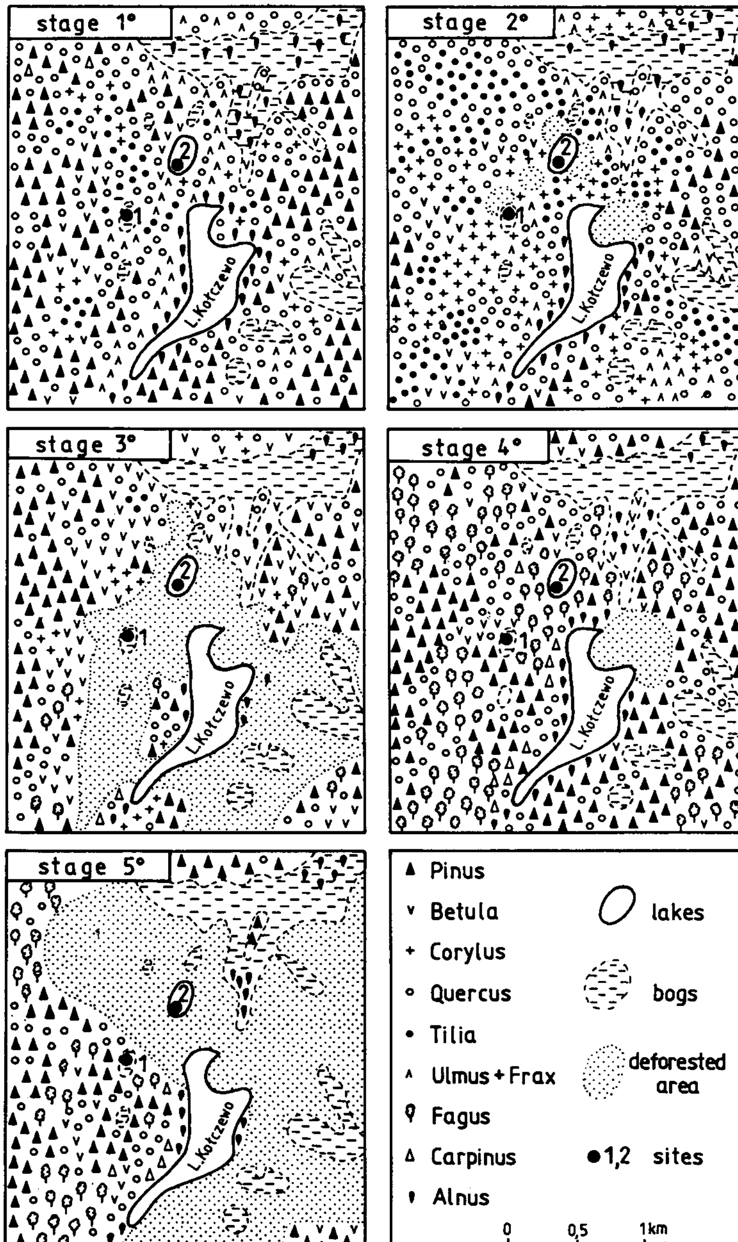

Fig. 24. Hypothetical palaeovegetation maps for the surroundings of the Kołczewo (1) and Lake Racze (2) sites, illustrating the five main vegetation stages (for explanations see text)

process could have been accelerated and intensified by man. The regular burning of the herb layer and, maybe, also the girdling or coppicing of some tall trees, caused the development of a rich herb vegetation dominated by *Pteridium aquilinum*, which would

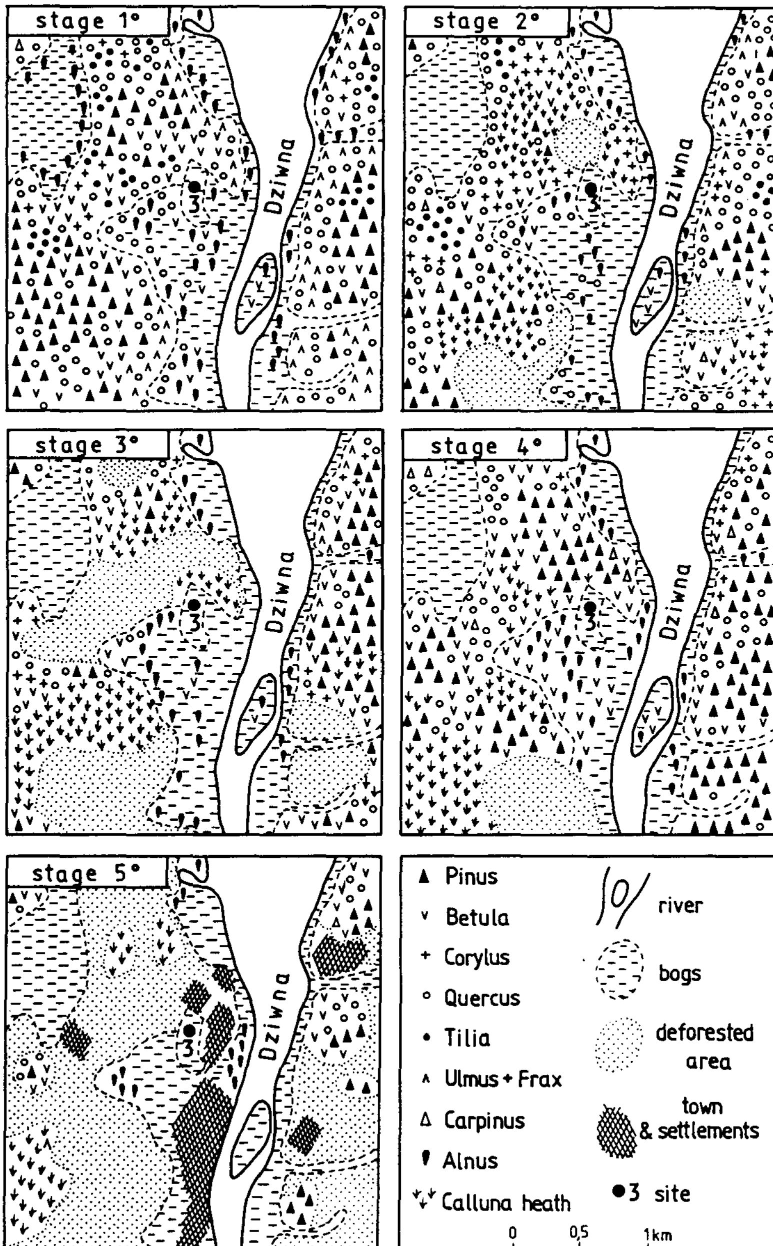

Fig. 25. Hypothetical palaeovegetation maps for the surroundings of the Wolin II site (3), illustrating the five main vegetation stages. Changes in the extent of the river banks have not been taken into consideration because of the lack of adequate data; for other explanations see text

hamper the regeneration of *Pinus* seedlings. The forest communities were characterized by a relatively high, stable proportion of *Betula* probably caused by the repeated use of fire.

On the more fertile habitats *Corylus*, which was frequent at the beginning of the stage, was slowly suppressed by *Quercus* and the other broad-leaved trees which became the dominant forest components. On these habitats, probably only small anthropogenic disturbances occurred.

2° stage (ca. 5800*–3400* BP) was characterized by distinct man-made changes in the woodlands. The high contribution of the pollen of broad-leaved trees, together with *Quercus* and the light-demanding *Corylus*, indicates that coppice woods were widespread throughout the area. A clear negative correlation between the *Pinus* and *Corylus* curves is found in those sections of the diagrams representing this stage, which could provide additional argument for the presence of coppice woods, making conditions especially unfavourable for pine. Small peaks in the *Pinus* and *Betula* curves show that limited clearances were also made. On the poor sandy soils in the neighbourhood of the Wolin II site *Calluna* heath started to develop during this stage. The formation of heathland was the result of regular burning and probably also intensive grazing and browsing in the *Pinus-Quercus-Betula* forests.

3° stage (ca. 3400*–2700* BP) – is distinguished by large-scale deforestation on all kinds of habitat. Forests with *Ulmus, Fraxinus* and *Tilia* were intensively exploited and successively destroyed during this stage, while *Corylus* was significantly restricted. *Betula* and *Pinus* were the most important pioneer tree species in forest regeneration on the fallow land. *Carpinus* and *Fagus* started to spread onto the moraine with its more clayey substrate, while *Calluna* heath increased in importance on the poor sandy soils in the vicinity of the Wolin II site.

4° stage (ca. 2700*–1300* BP) was a time of a gradual reforestation of the area due to a decrease in human activity. On the morainic area were woodlands with a predominance of *Fagus, Pinus* and *Quercus*. *Pinus* probably spread on the sandy soils of the southeastern part of the island but patches of open land still remained. In such habitats beech and hornbeam forests never developed.

5° stage began ca. 1300* BP. From that time general deforestation and a gradual formation of the present-day cultural landscape began.

The pollen diagrams from Wolin Island illustrate the important role of ecological conditions in determining different forest communities and their response to human interference. On the more fertile morainic areas disturbed woodland regenerated easily under the decreasing impact of man and probably maintained its ability for reproduction at the level of similar undisturbed forest communities up until the end of stage 2°. During the next stages, the unsettled ecological balance under conditions of gradual climatic deterioration, resulted in a new species composition for the regenerating woodland.

On the sandy soils of southeastern Wolin, changes were already more far reaching in stages 1° and 2° probably because of the stronger anthropogenic influence and a more delicate ecological balance. The *Calluna* heath, which spread as early as the Neolithic (stage 2°), never fully became reforested again.

The pollen diagrams, which form the basis of this paper, give a relatively large spectrum of the vegetational changes on Wolin Island, but do not cover its full ecological diversity. All the sites investigated are situated in the eastern, lower part of the island and we can expect, for instance, a slightly different vegetation development pattern in the higher, western part where morainic hills rise to more than 100 m above see level. In this area, which is mostly devoid of lakes and watercourses, settlement intensity was probably always rather low, and hunting, and later also pasturing, were probably the main land uses. An important element of the marginal part of the island and its surroundings are also the dunes, which started to develop after the maximum of Littorina transgression i.e. from ca. 4500 BP. Several pollen diagrams from peats deposited in the interdune depressions on the bay bars of the river Świna have been produced in order to resolve the age of the podzols on brown dunes (Prusinkiewicz, Noryśkiewicz 1966). These indicate, that since the dunes were formed, pine forest dominated on dry ground and *Alnus* swamps developed abundantly in the wet depressions along the river. Unfortunately, these diagrams offer no acceptable data on human impact because of their technical inadequacy.

The diagrams from Wolin Island are clearly distinct from the others known so far from the Baltic coastal zone of Poland and the adjoining area to the south (summarized by Latałowa, in preparation). Instead, they resemble the diagrams from sites located on the southwestern Baltic coast on the islands of Uznam and Rügen and on the Darss peninsula (Kliewe 1960, Fukarek 1961, Kolp 1976, Lange et al. 1986), where there is a similar geomorphological differentiation (Kolp 1976), climate and cultural history (Kozłowski 1981). These diagrams, and especially those from Rügen (Lange et al. 1986), show similar features of woodland development on more clayey, morainic soils and also on sandy soils of various origin. Unfortunately none of these diagrams are suitable for detailed comparisons because of a lack of ^{14}C dates, the presence of hiatuses in most of the profiles and the small number of taxons presented.

CHANGES IN THE INTENSITY OF HUMAN IMPACT; A COMPARISON OF POLLEN AND ARCHAEOLOGICAL DATA

GENERAL REMARKS

Changes in the intensity of human impact on vegetation may be illustrated in pollen diagrams in different ways. It can be characterized by fluctuations in the anthropogenic indicators curves (Berglund 1969), changes in the tree pollen curves (Aaby 1966b), pollen influx (Aaby 1988) or variations in species diversity (Birks et al. 1988, Odgaard 1988). Each of these provides valuable information and complements data obtained by the other methods. Changes in the content of non-sporomorph particles, such as ash (Vuorela 1983, Aaby 1986) or charcoal dust (Robinson 1987, Odagaard 1988, Tallis & Switsur 1990) are also of importance.

Fluctuations in the synthetic anthropogenic indicators curves (Fig. 26) reflect changes in the vicinity of the sites. Taking into account the disturbances in accumulation of the Lake Racze sediments (cf. p. 155), a high concurrence of the curves from this

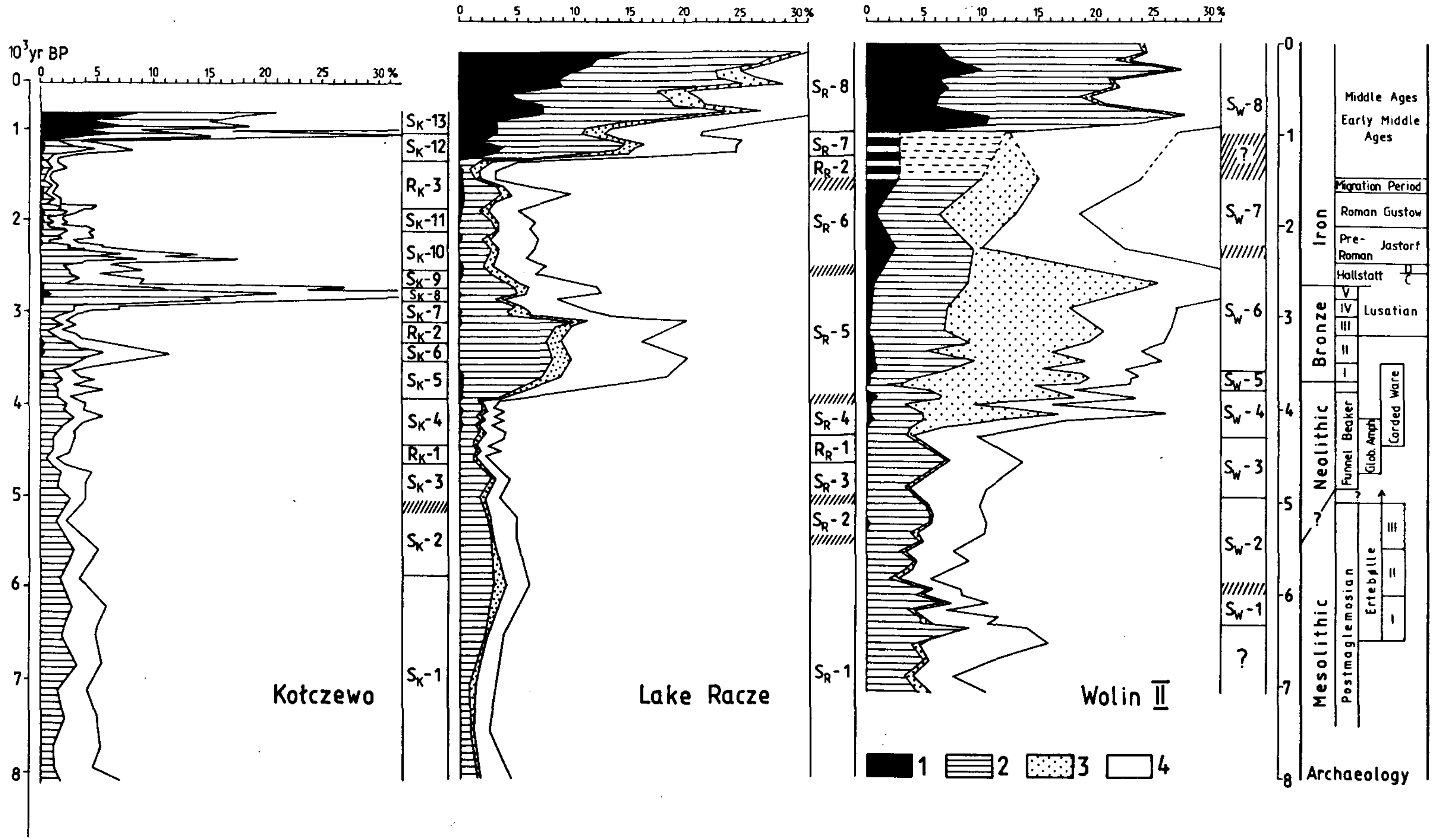

Fig. 26. The anthropogenic indicator diagrams and anthropogenic phases set against an absolute time scale: 1 – *Cerealia*; 2 – Σ of anthropogenic indicators excl. *Cerealia, Calluna & Gramineae*; 3 – *Calluna*; 4 – *Gramineae*. Archaeological chronology according to Kozłowski 1989 (Mesolithic), Vang Petersen 1984 (Ertebølle culture), Jankowska 1983 (Funnel Beaker culture), Siuchniński 1983 (Globular Amphorae, Corded Ware cultures and early Bronze Age), Wesołowski 1983 (Lusatian culture), Wołągiewicz 1983 (Iron Age)

locality and from Kołczewo is found in the sections corresponding to the Mesolithic and Neolithic. Generally however, it seems that human impact was more pronounced around Lake Racze. The curves from the Wolin II profile differ considerably from the others and show the strongest anthropogenic changes. In this profile, the evidence for the beginning of Neolithic cultivation, the great disturbances in the Bronze Age and the increasing role of cereal cultivation during the Iron Age are expressed in a different way but, chronologically, they correspond very well to similar events observed in the profiles from the morainic part of the island.

The main differences between the sites are not only in the intensity but also in the continuity of the human impact phases. In the diagrams from the morainic part of the island five phases of relatively weak human influence enabling forest regeneration are recorded, however, probably only phases RK-1 (RR-1), RK-2 and RK-3 (RR-2) reflect real settlement declines. The diagram representing the sandy soil area in the southeastern part of the island (Wolin II) does not show any typical settlement recession phase. It is possible, that this area was inhabited continuously, but two other explanations must also be taken into consideration: 1. in this poor sandy area the results of human impact could be irreversible and woodland was simply not able to regenerate in the relatively short time of settlement regression; 2. the diagram does not show a correct picture because of the very low accumulation rate, particularly in the section dated at ca. 5000*–4000* BP and in the upper part of the profile (cf. p. 163).

The presence of the pollen of anthropogenic indicators, especially those of cultivated plants, is the most reliable evidence of human activity (Behre 1981), but pollen-productivity, dispersal and deposition problems make the interpretation quite complex (Tauber 1965, Birks & Birks 1980). A low occurrence of human indicators does not necessarily mean weak anthropogenic interference. The distance from the pollen source (Vuorela 1973, Behre & Kučan 1986), the characteristics of the pollen catchment area (Birks & Birks 1980), the filtering of pollen by local vegetation (Tauber 1965), the "curtain effect" within the forest (Göransson 1986) and difference in pollen production and dispersal of particular taxa (Vuorela 1973, Randall et al. 1986) all influence the representation of anthropogenic indicators in pollen diagrams. These factors are of special significance when regarding early phases, which may be underestimated if the effect of a different forest structure is not taken into consideration (Aaby 1988). Therefore, other kinds of evidence must be used to complement data on the changes in the intensity of human impact within the area.

Fluctuations in the AP and NAP influx are an important device (Berglund 1986, Aaby 1988). In the diagrams from Wolin Island (Fig. 27) very high AP influx is recorded in the sections dated to the Neolithic and early Bronze Age, i.e. the time, when woodland was probably mostly transformed into coppice wood and the relatively open character of the forest communities favoured vigorous flowering, especially of the light-demanding species. Both the NAP influx and percentage values are relatively low in these sections. This is in agreement with the well known fact, that in those pollen spectra in which very high AP influx is recorded, NAP is underrepresented in the relative values (Aaby 1988) and in the diagrams presented here this feature can be especially linked with extremely bad herb pollen dispersal within coppice woods (Göransson 1986).

The above ascertions suggest that, during the Neolithic and Early Bronze Age, human interference was much stronger, than is suggested by the pollen of anthropogenic indicators, alone. It is also possible, that the decrease in anthropogenic indicators in the SK-5, SW-5 phase gives a false picture of settlement decline because, in both the

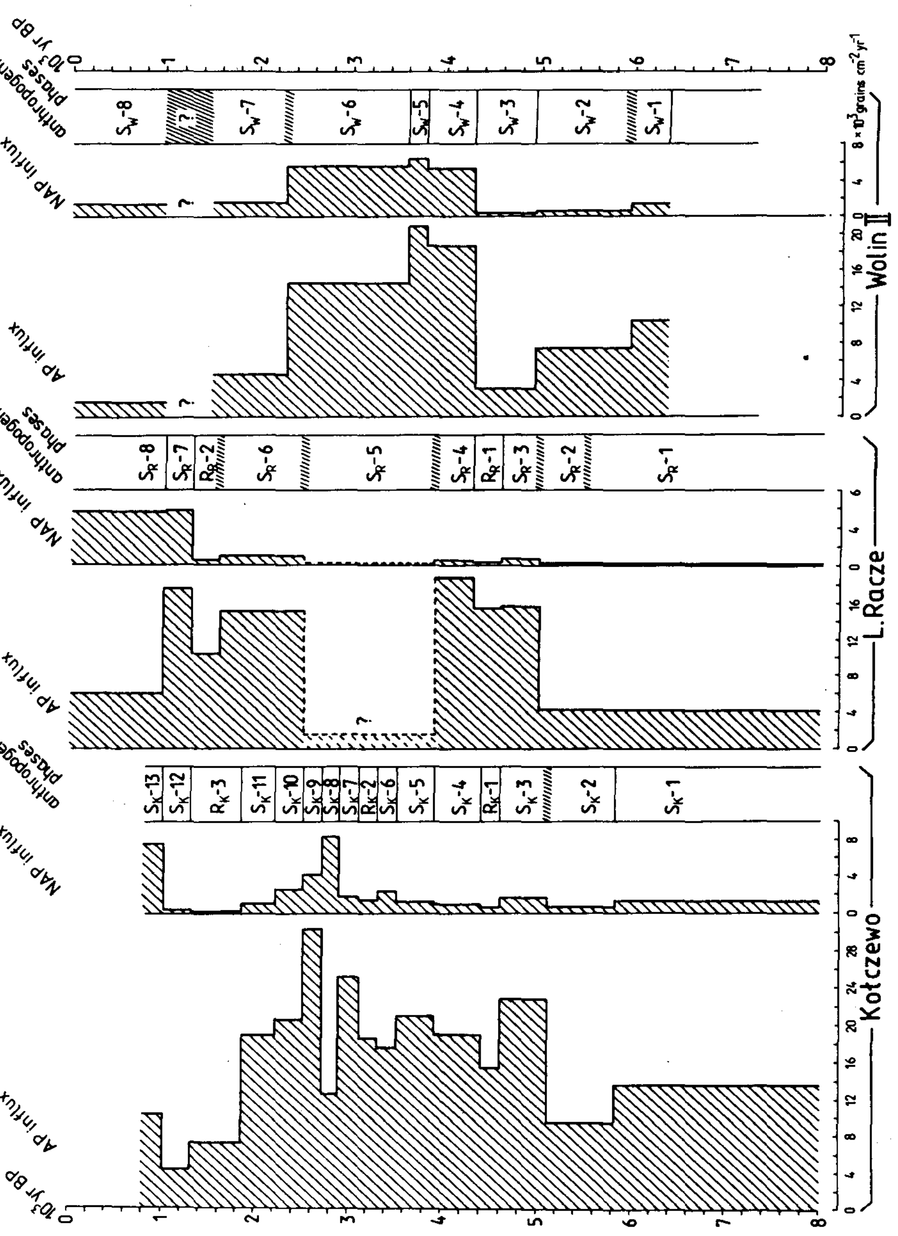

Fig. 27. Mean AP and NAP influx for the anthropogenic phases

profiles, it is a phase in which AP influx increases and the strongest evidence of coppicing is shown in the percentage diagrams.

In all three diagrams AP influx values fall considerably and NAP influx increases in

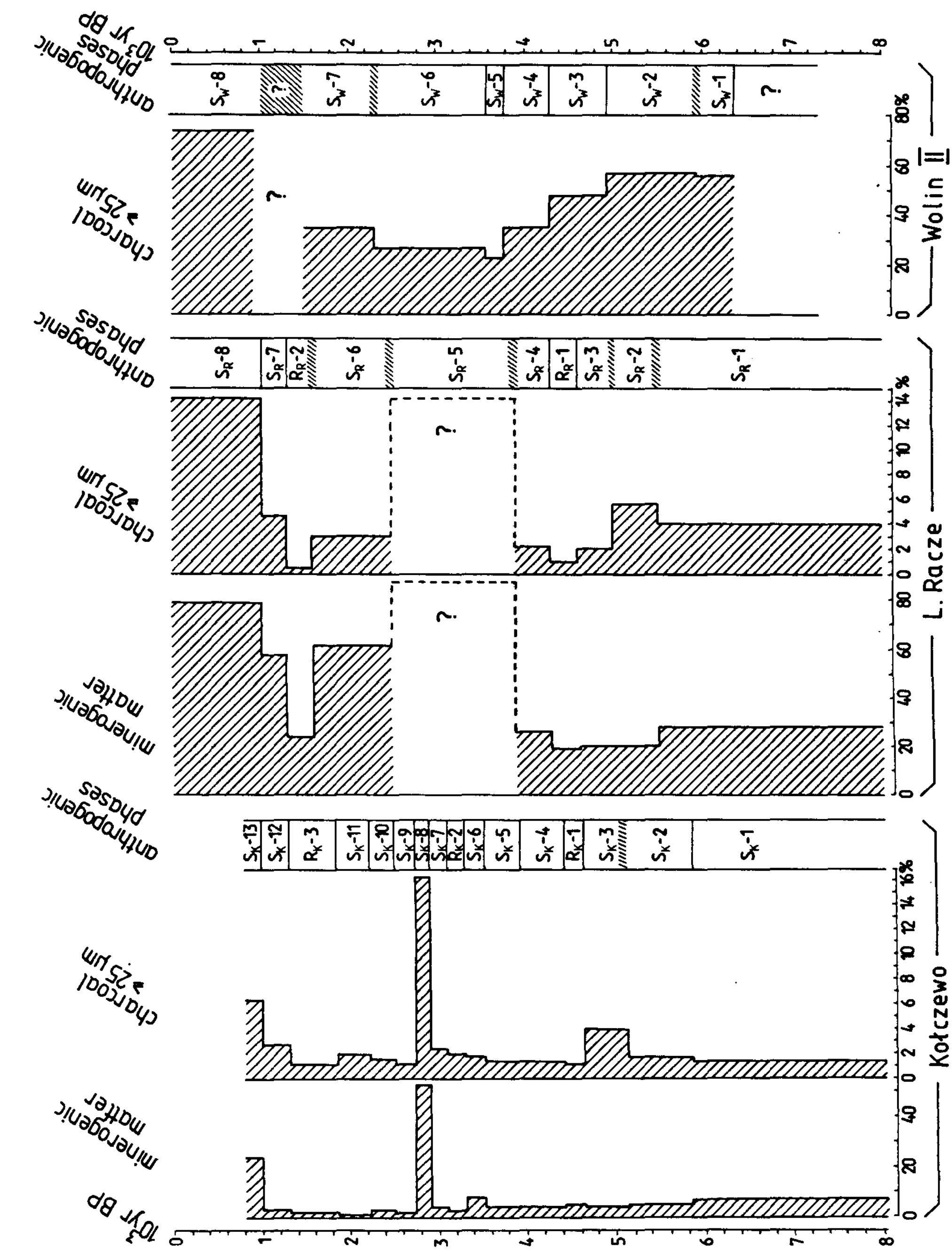

Fig. 28. Mean minerogenic material and charcoal particle percentages for the anthropogenic phases

the human expansion phases characterized by large-scale deforestation, especially in the time of the Lusatian culture and the period since the early Middle Ages. This agrees with the data obtained by Aaby (1988). Relatively low AP and NAP influx is recorded in both diagrams from the morainic part of the island for those sections illustrating regeneration of woodland in the late Iron Age, particularly in the Migration Period (RK-3, RR-2). This is not only the result of a rather close forest cover but also of the naturally low pollen production and dispersal by beech (Andersen 1970), being, at that time, one of the main forest constituents.

The charcoal dust and ash content (Fig. 28) depend on several factors such as the type of economy, the distance to a settlement, the openness of the area etc. and so, their fluctuations are not always simply correlated with settlement intensity. In the diagrams from Wolin Island the charcoal and ash information, which essentially complements the data based on anthropogenic indicators, refers to the Mesolithic and to the Migration Period. The high charcoal curves in all the sections correlated with the Mesolithic support the hypothesis of intensive man-made burnings within the forests. In contrast the very low frequency of charcoal particles and a decline in mineral material in the levels dated at the Migration Period in the Kołczewo and Lake Racze profiles show, that man was not active in the vicinity of these sites at that time.

THE MESOLITHIC

In all the diagrams traces of human interference are already well represented in the period which can be correlated with the Mesolithic (phases SK-1, SR-1, SW-1). The local forest changes and the development of an anthropogenic flora were probably initiated by tribes of the Maglemose culture which, at that time, were widely distributed in northern Europe (Kozłowski 1989). It is also probable, that in the later part of this phase (ca. 6300*–5800* BP) peoples of the Ertebølle culture were living, especially in the vicinity of the Wolin II site. As has been shown (cf. p. 131), archaeological evidences of the Mesolithic on Wolin Island are very slight while those of the Ertebølle culture were not found at all probably because of considerable changes of the island's shore line (cf. p. 128). Archaeological data from adjacent areas indicate (Kozłowski 1981, 1989), that Wolin Island was certainly inhabited at that time. It is not an exceptional case, when the vegetational changes detected by pollen analysis can be linked with the Mesolithic disturbances, although the area seems to be devoid of Mesolithic sites and artifacts (Chambers et al. 1988).

THE MESOLITHIC/NEOLITHIC TRANSITION

The transition between the Mesolithic and Neolithic is correlated in the diagrams from Wolin Island with settlement phases SK-2, SR-2, SW-2, which began with the first *Ulmus* decline about 5800* BP, and lasted up to about 5000* BP. The archaeological identification of these phases is only a speculative one, because of the lack of data from excavations (cf. p. 131). Chronologically they correspond to the younger Ertebolle culture (Schwabedissen 1981, Vang Petersen 1984, Ilkiewicz 1989, Galiński in print), which is described as a proto-Neolithic culture (Schwabedissen 1981). It is highly probable, that tribes of the Ertebølle culture lived on Wolin Island the more so as settlements of this culture have recently been discovered in Poland near Szczecin (Galiński, in print) and farther to the east in Dąbki – in the middle part of the Polish Baltic coast (Ilkiewicz 1989).

An additional argument for correlating this phase with the Ertebølle culture is the fact that, in this region, Neolithic cultures did not develop before 5000 BP (Wiślański 1979, Jankowska 1983).

THE NEOLITHIC

The correlation of those settlement phases determined by pollen analysis and ^{14}C datings as Neolithic with the Neolithic cultures as known from archaeological sources is a complicated matter. The oldest phases (SK-3, SR-3, SW-3) can certainly be correlated with the Funnel Beaker culture, settlements of which are known from several localities on Wolin Island.

The regeneration phases RK-1 and RR-1, recorded only in the Kołczewo and Lake Racze profiles, illustrate a decrease in human activity in the morainic area. These phases dated to 4600* – 4400*(4300*) BP, are concurrent with the so called "regeneration phase" reflected in numerous pollen diagrams from northwestern Europe (summarized by Göransson 1984). The problem of what pollen diagrams really represent in this phase and how they should be interpreted, is one of the main topics of several papers by Göransson (1982, 1984, 1986, 1987b, 1988). He suggests that the "regeneration phase" shows rather an intensification of the use of nature resources than a decrease in agriculture. According to this author, this phase illustrates changes in the forest structure due to coppicing, which caused the intensive flowering of all tree species and resulted in a false palynological picture resembling that of a "virgin forest". The same opinion is held by some archaeologists (for instance Bostwick-Bjerck 1988). Recently, climatic and hydrological changes have been suggested by Göransson (1991) as the cause of the change in land use. Other authors, however, interpret this phase as one of forest regeneration due to population changes caused by a cultural change from an agrarian back to a hunter-gatherer economy (Welinder 1981, Østmo 1988) or a complex set of relationships between ecological conditions, demography and the level of technology (Berglund 1988).

The results obtained in this study suggest that forest regeneration on fertile, low lying ground was caused by both a decrease in population and a change in the economy, connected with the appearance of the early Corded Ware culture peoples who mainly exploited higher ground. A further development of this culture is reflected in phases SK-4, SR-4, and maybe also in SK-5 phase, which coincides with the Neolithic/Bronze Age transition. These phases differ mainly by the intensity of human interference and illustrate activity typical of pastoral tribes practising small-scale cultivation.

A different picture of the late Neolithic can be drawn from the Wolin II diagram, because in phase SW-4 cereal cultivation was of greater importance. We are inclined to link this phase with the late Funnel Beaker culture rather than with Corded Ware culture.

This view receives support from the archaeological evidence, a settlement of Funnel Beaker culture having been discovered close to the investigation site (Cnotliwy 1961), with cereal remains present among the excavated material (Klichowska 1967a).

The Sw-5 phase from the Wolin II profile probably corresponds to the Corded Ware culture.

The correlation presented here accepts the view of some archaeologists (Wiślański 1969, 1983) that different Neolithic cultures could coexist in this region. It should be stressed, however, that the identification of individual settlement phases may be incorrect because of the inaccuracy of the ^{14}C datings and the relatively poor information about the cultural processes at that time.

THE BRONZE AGE

The Bronze Age is well represented only in the Kołczewo profile. From the Wolin II and Lake Racze diagrams we can assume nothing but that at that time human interference was relatively strong around these sites. A more detailed correlation is not possible because of the very low accumulation rate within the upper part of the Sw-6 phase in the Wolin II profile and the erosional disturbances in the SR-5 phase in the Lake Racze profile.

According to the pollen data from Kołczewo, human activity was really intensive during the Bronze Age. The most important phases were SK-6 (early Bronze Age) and SK-8 (late Bronze Age, Lusatian culture). The short period of settlement recession (RK-2 phase, ca. 3300*–3100* BP) could be the result of local over-exploitation of the environment in the preceding, SK-6 phase. Evidence of soil stabilization is also registered in the Lake Racze sediments: the intercalation of a fine detritus gyttja between two sandy layers dated at 3100±110 BP, indicates a temporary set-back in erosional processes due to a decline in human activity within the lake catchment. A comparison of the archaeological and pollen data shows a far reaching coincidence concerning the development of the Lusatian culture (SK-7, SK-8 and the uppermost parts of SR-5 and Sw-6 phases), but the earlier, very clear, SK-6 phase is not confirmed by excavations.

Only single finds of the early Bronze Age are known from Wolin Island and its environs (Cnotliwy 1966, Siuchniński 1983, Wesołowski 1983), which suggests that settlements were short-lived, indicating a pastoral economy. At the same time the SK-6 phase shows relatively intensive agriculture (including animal husbandry and small-scale cereal cultivation) preceded by deforestation and resulting in significant changes in the ground water-table and an increase in soil erosion.

The late Bronze Age is much better known because numerous settlements dated to the Lusatian culture have been discovered on the island (Wojtasik 1958). The most important of them was still fully developed at the beginning of the early Iron Age and did not collapse before the Hallstatt D period, which coincides with the end of the Sw-6 phase in the Wolin II profile.

The down-fall of the Lusatian culture and the contemporary Nordic culture widespread in Scandinavia, has been largely discussed elsewere. Climatic deterioration is generally quoted as the most important factor responsible (Hensel 1980, Bukowski 1981).

Palaeoecological and palaeohydrological studies from western Europe, as well as from northern Poland and Wolin Island itself, indicate that between 3000 BP and about 2500 BP rainfall increased (see discussion on p. 227). It is not clear if the increased humidity was synchronous with a distinct cooling. According to palaeoclimatic data from the northern Netherlands (Dupont 1985), between 2800 and 2500 BP the mean annual temperature increased to almost 11°C, i.e. it was 1.5°C higher than that of today, and the subsequent temperature fall did not occur before 2000 BP. On the other hand, isotope ^{18}O studies from Polish lake profiles (Różański 1987, Różański et al. 1988) show a slight gradual temperature decrease in the sections which can be related to the time under discussion. More distinct fluctuations suggesting remarkable cooling, have been observed in only a few cores.

An increasing wetness of climate together with the hydrological changes caused by large-scale deforestation, could, of course, result in the flooding of settlement situated at the lake's shores or on the lake's islands and peninsulas. However, the reasons for the down-fall of this culture were probably more complex and include various environmental factors as well as demographic, inter-cultural and level of technology problems. A considerable increase in population and intensive land-use over large areas with a short-cycle rotation system, caused a degradation of the environment and a decrease in production below the survival limit (Ostoja-Zagórski 1974, Kristiansen 1978). Pollen-analytical and lithological evidence from the Kołczewo and Lake Racze profiles fully confirm the hypothesis of the over-exploitation of natural resources during the time of the Lusatian culture. Among the most important negative factors, intensive soil erosion took place around these sites.

THE IRON AGE

In the diagrams from the morainic area, all the data from the sections corresponding to the Iron Age, (Fig. 26, 27 and 28) show a considerable decline in human interference (SK-9 phase). However, it is certain that continuity of habitation was maintained until ca. 1800*–1600* BP (RK-3, RR-2 phase), i.e. to the Migration Period. In the Kołczewo diagram a very clear SK-10 phase, radiocarbon dated to the pre-Roman period, has been described. It can be correlated with the activity of the Jastorf tribes (Wołągiewicz, oral inf.). The following, SK-11 phase is generally much weaker, but the frequency of *Cerealia* pollen increases. This phase belongs chronologically to the late pre-Roman and the Roman periods. During the Roman period Germanic tribes, Rügens (Gustow group), lived on Wolin Island (Wołągiewicz 1981, 1986). The same pattern as at Kołczewo can be identified in the Lake Racze diagram, although phase SR-6 is not divided in full detail and is not well established chronologically.

In both profiles evidence of human impact disappears completely, or almost completely, in the sections dated to the Migration Period while in the Lake Racze diagram this process took place later (?). Anthropogenic indicators reappear abundantly in the levels dated to ca. 1300*–1200* BP, i.e. in the early Middle Ages.

The information derived from the Wolin II profile is insufficient to enable clear conclusions to be drawn about settlement development during the Iron Age. The Sw-7 phase can be only broadly correlated with the Iron Age, but the sharp increase in *Secale* suggests that the Roman period is mainly represented here. The development of cereal cultivation was the main feature of this period but, at the same time, patches of *Calluna* heath became partly overgrown by pine, which reflects their restricted exploitation. This pollen diagram shows no definite cessation of settlement, moreover, human activity increased in this area probably as early as 1520±90 radiocarbon years BP. This continuity of settlement is also suggested by pollen diagrams from the Szczecin Lagoon (Wypych 1980). These problems have been discussed in two earlier papers (Latałowa, in print a, b).

A comparison of the pollen analytical results with archaeological data shows a good concurrence. Following the decline of the Lusatian culture, only single occupation points (mainly burial grounds) of the Iron Age are known (Fig. 4). Some of these are located in the vicinity of the sites presented in this study. However, the occurrence of settlements and cultivated fields have unequal chances of being checked by pollen analysis. In the morainic area settlements were situated on terrain covered mostly by woodland, where pollen dispersal was very poor, and this resulted in a restricted representation of the anthropogenic flora in the Kołczewo and Lake Racze profiles. The situation in the vicinity of the Wolin II site was different. The land was already mostly deforested and human activity was well reflected in the pollen diagram. Palynological data fully confirms archaeological opinion (Wołągiewicz 1986, Godłowski 1989) that in north-western Poland (Pomerania) settlement already began to decline in the 2nd century AD, while in the Migration Period the economic recession was not uniformly expressed over the area. A total cessation of settlement took place in the morainic part of Wolin Island ca. 5–7th century AD, but, in the vicinity of the Dziwna crossing, a small settlement probably survived. The new occupation phase started about 6–7th century AD, but the main rise in settlement took place in the 9–11th centuries AD (Filipowiak 1985, 1988).

The settlement decline during the late Iron Age is a well known phenomenon in pollen diagrams from northwestern Europe, although it is not synchronous and locally evidence of uninterrupted inhabitation is also recorded.

In the diagrams from northern Poland there are clear signs of a settlement recession which, on the basis of several ^{14}C dates, started around the 3–4th century AD and lasted generally up to the 7–8th century AD with the deepest phase being ca. 5–7th century (summarized by Latałowa, in prep.). Only a few exceptions, which probably indicate continuity of settlement along the Baltic coast during the Migration Period, are known so far. In the diagrams from the Szczecin Lagoon (Wypych 1980), Kluki (Tobolski 1982, 1987) and Wolin II (if the stratigraphical interpretation is correct) there are slight traces of reforestation concurrent with a rise in the *Cerealia* pollen frequency, which should probably be interpreted as an increase in the role of cultivation in the small, scattered settlements surviving at that time.

This settlement recession phase can be seen in most of the pollen diagrams from south Scandinavia, but its appearance is metachronous (4–6th century)(Berglund 1969). Moreover in some areas, such as Scania, only slight forest regeneration and a fairly small decrease in human impact is recorded (Berglund 1969, Gaillard & Berglund 1988, Regnéll 1989). Forest regeneration, due to a decline in anthropogenic interference, is also known from Jutland and north Germany (Behre 1976, Aaby 1986, 1988, Müller-Wille et al. 1988, Dörfler 1989), where it began slightly later, mostly in the 5–6th century and lasted about 200–300 years. On Rügen the situation was probably similar to that on Wolin Island. In some pollen diagrams from this area, settlement indicators are lacking for the late Iron Age while in others continuity of human occupation is recorded (Lange et al. 1986).

FINAL COMMENTS

A comparison of the human impact pattern documented by the pollen diagrams from Wolin Island with palynological data from other sites in the Baltic coastal zone of Poland northeastern Germany and south Scandinavia cannot be entirely successful. Only the Scandinavian diagrams (e.g. Gaillard 1984, Aaby 1986, 1988, Regnéll 1989, Göransson 1991) illustrate a full, well developed and chronologically reliable history of human impact on the natural environment. The diagrams from eastern Germany are not, or only poorly, radiocarbon dated (Lange et al. 1986) or contain in adequate data of the anthropogenic flora (Fukarek 1961, Kolp 1976). Pollen diagrams from the area of Kosel, now in preparation (Dörfler 1988, 1990), will be of great importance for future comparison. Four radiocarbon dated sites are known from the Polish Baltic coastal zone (Latałowa 1982, 1985, 1989a, Tobolski 1982, 1987), but evidence of Neolithic husbandry, in particular, is rather weak, mainly due to the low peat accumulation rate in the profiles investigated.

Wolin Island lies in a transitional area as far as human impact on vegetation is concerned, being exposed to both western and eastern influences, a fact which is also in agreement with the archaeological data (Kozłowski 1981). During the Neolithic the expansion/regression pattern (Berglund 1986) was very similar to that of southern Scandinavia (Berglund 1988) and northeastern Germany (Lange et al. 1986). In the Bronze and early Iron Ages, the development of settlements of the Lusatian culture, and in consequence, the strong devastation of the environment, resembles rather the situation existing in the area farther to the east (Latałowa 1982, 1985). In the pre-Roman and Roman periods Wolin Island, although being under the influence of western, Germanic tribes, shows relatively weak human influence. This is also a characteristic picture for the eastern Baltic coastal zone, where the general settlement intensity was much lower (Latałowa 1982, 1985, unpubl.) than in the western Baltic coastal zone (Lange et al. 1986) or in southern Scandinavia (Berglund 1988). In the late Iron Age settlement history was relatively similar over a large area, which is seen in the pollen diagrams from the eastern Baltic coastal zone of Poland as well as from the western Baltic coast and southern Scandinavia.

This comparison is much simplified mainly due to the author's view that one should only compare that which is comparable. The diagrams from Wolin Island demonstrate that significant differences can exist between sites lying very close each other, and how important a ^{14}C chronology is for any correlation. A survey of the history of human activity within the Polish Baltic coastal zone is the main topic of a paper at present in preparation (Latałowa).

PREHISTORIC ECONOMY AS REFLECTED IN THE POLLEN DIAGRAMS

FOREST CHANGES IN THE MESOLITHIC

Since the 70's, increasingly detailed palynological analyses have allowed many assumptions about man-environment relationships in the Mesolithic. The traditional view of a dense mixed-deciduous forest limiting the occurrence of Mesolithic tribes because of a shortage of nutritional resources and difficulties with hunting (Iversen 1941, 1973) has been critically debated by some authors (Rowley-Conwy 1982, Göransson 1984, 1988). These authors suggest that Mesolithic man did not adapt himself passively to environmental conditions, but was constantly changing the forest structure for his own purposes.

Numerous papers from the British Isles link changes in the vegetation with the activities of Mesolithic man. The development of blanket mires in some areas (Caseldine & Maguire 1986, Robinson 1987), the survival of the chalk-grasslands of south England during Boreal and Atlantic times (Bush 1988), the delay in the upward extension of forest in uplands area (Tallis & Switsur 1990) and even woodland recessions (Simmons et al. 1983, Caseldine & Maguire 1986, Innes & Simmons 1988) have all been put down (at least in part) to the impact a Mesolithic man.

In this context, forest disturbance by fire is widely discussed. It is generally accepted, that the majority of forest fires during the Mesolithic were man-induced rather than natural (Rakham 1988, Innes & Simmons 1988). In European temperate woodlands natural fires are extremely rare even during periods of extensive drought (Chandler et al. 1983, after Bennet et al. 1990). Moreover, pine is the only native combustible tree species in Britain (just as on Wolin Island) which can burn when struck by lightening. Other trees, even in forest communities mixed with pine, are rather resistant to fire (Rakham 1988a). Therefore, most of the charcoal layers in lake and peat deposits and the dispersed charcoal dust which occurs abundantly in the pollen slides, are usually interpreted as the result of fires actively started by man (Jacobi et al. 1976, Simmons et al. 1983, Sturludottir & Turner 1985, Caseldine & Maguire 1986, Innes & Simmons 1988, Chambers et al. 1988). All these authors accept as possible a hypothesis given by Jacobi et al. (1976) that Mesolithic hunter populations practised a kind of woodland management by regular and recurrent burning to encourage the browse for wild animals, particularly red deer. These forest disturbances were predominantly on a local scale, however, in some areas intensively penetrated by Mesolithic tribes, changes could be more extensive. Innes & Simmons (1988) report 28 palynologically investigated sites within the relatively small area of northeastern Yorkshire, which record vegetation disturbances of the Mesolithic age. On such areas Mesolithic people may have had a significant influence upon the landscape.

Recently, a new opinion of the evidence of fire in pollen diagrams covering the Mesolithic period has been presented by Bennet et al. (1990). They suggest that most of the English post-glacial charcoal records should be explained as evidence of domestic fires rather than the natural or anthropogenic burning of woodland. However, more investigations are needed to develop this discussion.

Pollen and charcoal data, which can be correlated with the activity of Mesolithic man, are known from other areas of northern Europe, too. Generally, however, the evidence is rather slight, and mainly includes the presence of some indicator species, for example *Pteridium aquilinum*. It is frequently ignored or shortly commented as a possible sign of the occurrence of Mesolithic tribes (Hjelmroos-Ericsson 1981, Gaillard 1984, Lange et al. 1986, Regnéll 1989, Miotk-Szpiganowicz 1992).

The opposite arguement is presented by Göransson (1982, 1984, 1986). According to him vegetational changes, especially during the late Mesolithic, were much more widespread and far reaching than is usually reported. He presents a forest management theory, which assumes that trees were girdled by Mesolithic man and that on small areas below them, branches and twigs were later burnt. This procedure could have several advantages: 1- the "lowering" of the tree canopy, which became more accessible to browsing animals, 2- the creation of better light conditions facilitating the development of herb and undergrowth layers, important for browsing and grazing animals, and 3- the possibility of garden cultivation of cereals below girdled trees.

Interesting results are presented by Kloss (1987, 1990). In the pollen diagrams from several Mesolithic sites in northeastern Germany, a rich anthropogenic flora is described, which suggests considerable man-made changes in the vegetation, including the development of small patches of heathland. According to this author, changes in the sedimentation rate and the deposition of sand layers were determined by palynological and archaeological methods as also being caused by early Mesolithic settlements.

How do the pollen diagrams from Wolin Island look against this background ? The sections, which can be correlated with the Mesolithic (8000*–5800* BP), are badly developed in the Kołczewo and Lake Racze profiles, but in the Wolin II profile the youngest phase of this period (ca. 6300*–5800* BP) is relatively well represented. In all the diagrams a high content of charcoal is found. The scale of the vegetational changes illustrated by the pollen diagrams suggests that these high charcoal values are not only the result of local domestic fires but also of burnings in the woodland. Forest disturbances took place mainly on poor habitats, where *Pinus-Quercus-Betula* forests dominanted, and resulted in the *Pinus* decline, the increasing role of *Quercus* the development of a very rich herb layer with *Pteridium aquilinum*; and the spread of patches of light demanding herb communities typical of sandy soils with *Calluna, Melampyrum* and *Rumex acetosella*. The regularly repeated burning probably affected pine which is not a fire resistant tree and the very dense *Pteridium* layer would have prevented its regeneration from seedlings.

It is, of course, impossible to ascertain whether the trees were girdled at that time or not. From the archaeozoological data it is known, however, that red deer, roe deer and aurochs were the most important animals for the Mesolithic people living in this part of

Europe (Lepiksaar 1986, Kozłowski 1989). The roe deer is a typical browsing animal while red deer is a browsing-grazing species (Groenman-van Waateringe 1986). Both of them, thus, needed a rich undergrowth or shrub-like trees as fodder. This could force humans to adapt the forest structure to their needs. Aurochs (*Bos primigenius* Bojanus), the remnants of which are very abundant in Maglemose sites in Denmark (Aaris-Sørensen & Brinch Petersen 1986), are also known from Mesolithic sites in Poland (Kozłowski 1989), including those of the Ertebølle culture (Ilkiewicz 1989). This animal, just as to-day's cattle, was a grazing species, which demanded patches of open grassland or at least open, woodland with a rich herb layer (Lepiksaar 1986). Intensive burning of the herb layer and the undergrowth, which led to their abundant regeneration and a thinning of the forests, could then be practised to maintain the herds of aurochs.

The above speculations cannot be proved, they are, however, supported by the high intensity of changes recorded in the pollen diagrams, especially from the Wolin II site. This intensity is no surprise considering the fact that Ertebølle settlements were in use throughout the whole year and have sometimes been inhabited for centuries (Vang Petersen 1984).

THE *ULMUS* DECLINE

The first distinct decline in the *Ulmus* curve in the Holocene diagrams from northern Europe is the problem which has been most discussed since the papers of Iversen (1941, 1944, 1960) and Troels-Smith (1953, 1960) appeared. Current opinions have been summarized by several authors (e.g. Garbett 1981, Rowley-Conwy 1982, Groenman-van Waateringe 1983, 1988, Hirons & Edwards 1986, Birks 1986a, Molloy & O'Connell 1987, Edwards 1988, Scaife 1988). Mostly, anthropogenic factors combined with climatic (e.g. Göransson 1986, 1991) or edaphic changes (e.g. Sturludottir & Turner 1985) or disease (e.g. Birks 1986a, Girling 1988) are taken into consideration. The phenomenon has also been attributed exclusively to disease (Molloy & O'Connell 1991) and to climatic change (Göransson 1991). It seems, however, that the question still remains open.

The main reason for the debate is the apparent synchroneity (ca. 5100–5000 BP) of the phenomenon. However, with the increasing number of radiocarbon dated pollen diagrams, it is clear that the age of the elm decline in northern Europe ranges through up to more than 1000 radiocarbon years, e.g. 5970±70 BP (Hofstede et al. 1989) and 4570±120 BP (Turner 1965). Differences of several hundreds years are known even from smaller regions (Hirons & Edwards 1986, Aaby 1986b, Molloy & O'Connell 1987, Scaife 1988). These data do not change the fact, that the majority of the radiocarbon dates fall around 5100–5000 BP.

The first elm decline is dated to 5820±130 BP in the Kołczewo profile and to 5860±120 BP (the minimum *Ulmus* values) in the Wolin II profile. It has the same features in both diagrams from the morainic part of the island but differs in the diagram from the Wolin II site (Tab. 5). Unfortunately, a thorough analysis and interpretation of this event is limited by the very low accumulation rate in the Kołczewo and Lake Racze profiles. Even a hiatus cannot be excluded (cf. Göransson 1991). However, the early ^{14}C

dates for the *Ulmus* fall seem to be reliable in respect of their occurrence in two such different profiles.

Table 5. The main features of the *Ulmus* falls in the diagrams from Wolin Island

Site	*Ulmus* fall	^{14}C BP	Decrease %	Duration yr	Associated events in the pollen diagrams
Kołczewo	1st	5.820±130	5 → 1	1.300	increase in *Quercus*, *Corylus*, *Tilia*; decrease of *Hedera*, *Plantago lanceolata* appears; increase of aquatic plants
	2nd	4.170±120	7 → <1	400	increase in *Corylus*, beginning of *Carpinus* and *Fagus* curves; decrease in *Fraxinus*, *Hedera*, *Quercus*; increase in *Pteridium*, *Artemisia*, *Plantago lanceolata*
Lake Racze	1st	> 5.500*	4 → 1	>900	increase in *Quercus*, *Corylus*, *Tilia*, increase in *Populus*; single pollen grain of *Plantago media*, *P. lanceolata* slightly above this level
	2nd	> 4.100*	5 → 1	(?) 400	sharp increase in *Corylus*, beginning of *Fagus* curve and regular occurence of *Carpinus*; decrease in *Fraxinus*, *Hedera*, *Quercus*; *Plantago lanceolata* curve present, first *Cerealia* slightly above this level
Wolin II	1st	> 5.860±120	3 → 1	200	*Fraxinus* decline, increase in *Calluna*, *Rumex coll.*, *Urtica*; first pollen grain of *Plantago lanceolata* slightly above this level
	2nd	5.400*–5.300*	5 → <1	200	*Fraxinus*, *Pinus* decline, increase in *Quercus*, *Corylus*, *Rumex coll.*, *Artemisia*, *Urtica*; *Plantago lanceolata* 1.2%, first *Cerealia* slightly above this level
	3rd	4.130±60	1.5 → <1	<200	*Fraxinus*, *Tilia* decline, *Pinus* increase, beginning of *Carpinus* and *Fagus* curves; sharp rise in *Calluna* and *Rumex* coll., increasing frequency of *Cerealia* slightly above this level

In all the profiles the *Ulmus* curve regains or exceeds its earlier values. At Kołczewo and Lake Racze this is achieved after ca. 1300 years, while at Wolin II, where the decrease is not so pronounced, the curve rises again after ca. 200 years. In the Wolin II profile, the second, more prominent *Ulmus* fall is dated to ca. 5400*–5300* BP. In all the diagrams the *Ulmus* curve remains low at ca. 5000 BP; the next, synchronic elm decline is dated to 4170±120 BP at Kołczewo, 4130±60 BP at Wolin II and 4100* BP at Lake Racze.

On Wolin Island, the elm decline is always associated with evidence of human impact. It is also important, that even the first *Ulmus* decline was preceded by a long period of clear anthropogenic interference. It is possible, that ca. 5800* BP economic changes took place, which enabled the introduction of new methods of woodland exploitation. This date lies within the limits accepted for the beginning of the younger phase of the Ertebolle culture (Gramsch 1978, Schwabedissen 1981, Vang Petersen 1984, Ilkiewicz 1989), people of which could have been present in the investigated area. In this phase, animal husbandry and even small-scale cereal cultivation were probably practised

(Schwabedissen 1981). Thus, the *Ulmus* decline could result from the over-exploitation of elm trees due to intensive pollarding (Troels-Smith 1953, 1960). This does not exclude, however, the elm disease as a possible, but secondary cause. Climatic, edaphic and hydrological causes, if they played any role in this case, are not confirmed by the results obtained so far.

COPPICE WOODS IN THE EARLY AGRICULTURAL LANDSCAPE

Long sections of the pollen diagrams from Wolin Island, reflecting the period from ca. 5800* to ca. 3400* BP, are interpreted as giving evidence of coppicing. The following features of the diagrams warrant such an opinion:

1- the very high percentage and concentration values of *Corylus* and *Quercus*, as well as the high or very high total AP influx indicate very good light conditions in forests; the great amount of *Corylus* pollen can be explained by the fact that hazel begins to flower again more rapidly after coppicing than any other underwood species (Rakham 1980); the increase in *Quercus* pollen maybe result from a specialized use of oaks: in coppice woods, where a lowering of tree-canopy generally occurred, oak was probably treated mostly as a timber or mast tree (Rakham 1980), in which case it was taller than other coppiced trees and, in such open conditions, produced a full pollen output.

2- in some sections of the diagram, the concurrent increase in the pollen of both shade-tolerant and light-demanding trees suggests the exploitation of different tree species by coppicing and pollarding, thus causing their vigorous flowering.

3- the low NAP values associated with the above mentioned indications of very good light conditions in the forests, could be the result of an effective filtering of herb pollen by the dense structure of the coppice woods (Göransson 1982). Moreover, the over-production of AP usually leads to the underrepresentation of NAP in pollen diagrams (Aaby 1988).

4- among the NAP, typical anthropogenic indicators, including *Plantago lanceolata* and *Cerealia*, play the most important role; this shows relativelly strong human activity within the area covered by woodland.

The creation and maintenance of coppice woods was a widespread method of forest management both in prehistory and in historical times (Rakham 1980, 1988b), and in some areas it has been practised up until the present day (Rakham 1980, Pott 1986, Austad 1988). In such woods smaller trees were probably felled, which allowed them to grow again from stools or suckers thus giving an important crop of underwood. Other trees were pollarded or shredded for leaf fodder and bark was peeled for winter and early spring fodder (Austad 1988). These woods were probably partly utilized as wood-pastures, where the good light supply enabled the development of herbs. Girdling and coppicing had a manuring effect by supplying the soil with the released nutrients, which was also of importance in enriching the vegetation (Romell 1964, after Görassson 1988). Small patches of coppice woods were put under corn cultivation (Pott 1986, 1990, Göransson 1988). The shoots of coppiced trees were utilized for different purposes. Hazel shoots were of importance in fencing fields and pastures (Malmros 1986, Rakham 1988b). A dendrological analysis of the elm wood fragments from the Alvastra pile-dwelling site (Göransson 1982) shows that elms were coppiced. Also the Neolithic trackways discovered for example in Somerset (Rakham 1980) and in Tibirke (Malmros 1986) were constructed from different tree species, which had been previously coppiced or sometimes pollarded. These finds give evidence of at least a Neolithic age for anthropogenic changes in the forest structure.

In those sections of the Wolin diagrams, which reflect coppicing, the *Tilia* pollen curve does not follow those of the other trees. This suggests that lime was managed in a different way. The *Tilia* curves rise sharply just before the first *Ulmus* fall and, then, they remain at this high level and fluctuate very slightly until ca. 3500* BP. They also reach very high values in the period dated at ca. 3100*–2900* BP.

Lime (mainly *T. cordata*) was almost certainly one of the most important trees on Wolin Island. It found especially good habitat conditions on the sandy-clayey soils of the slightly undulated morainic area, which is shown by its rising to values of 10% in the pollen diagram from Lake Racze. It is difficult to find an unequivocal answer to the question – why did *Tilia* gain rather than suffer as a consequence of Neolithic activity? It could be explained in two ways: 1- special management and protection of *Tilia* trees, 2- limited human interference in the forest communities dominated by lime.

Andersen (1988a) describes an early Neolithic settlement phase which is characterized by a distinct fall in the pollen values of all the deciduous trees except *Tilia*, and suggests that at that time woodland was destroyed but lime was saved as the most important leaf-fodder tree. It was not coppiced or pollarded but shredded which does not destroy trees but stimulates their vigorous flowering. Such methods of lime exploitation are known from many European areas.

Another interpretation is based on Rowley-Conway's (1982) suggestion that patches of lime forests could have been protected for hunting because of their poorly developed undergrowth. Considering development of coppicing suggested above, we can imagine that successful hunting was difficult in these transformed forests, therefore pure stands of lime would have provided more favourable conditions.

The pollen data from Wolin Island clearly demonstrate forest management during the time which is probably referable to the late Ertebølle culture and to the Neolithic and early Bronze Age, with a maximum in the settlement phases Sk-5 and Sw-5 dated to the Neolithic/Bronze Age transition. This does not mean, however, that coppicing, pollarding and other technics were not practised earlier or later. The most speculative, of course, are the suppositions on forest management in the Mesolithic, though anthropogenic changes to the forest structure by local burning do seem to be documented. In the late Bronze Age and in the Iron Ages, as well as in historical times, woodland resources were certainly exploited in different ways, including coppicing. In the sections of the pollen diagrams related to those times, however, the evidence of deforestation is clearest.

ANIMAL HUSBANDRY AND CULTIVATION

It is usually difficult to determine the exact beginning of agriculture, by pollen analysis. Animal husbandry can only be identified by the presence of pollen of plants which are typical apophytes of grazed forests and pastures, but these pollen grains may also be derived from natural habitats (Behre 1981). The situation seems to be better with regard to the first signs of cultivation, because the pollen grains of cereals can be determined. However, the chance of recovery of pollen grains from the self-pollinated *Triticum* and *Hordeum*, which were the earliest cereals and which grew in small fields scattered in the woodland area, is very accidental. In addition, pollen of *Triticum* and *Hordeum* types or *Cerealia indet.* may include some wild grasses (Beug 1986).

In the pollen diagrams from Wolin Island changes referable to the first presumed signs of agriculture (Fig. 29) are connected with the SK-2, SR-2 and SW-2 settlement phases which, especially in the Wolin II profile, seem to be correlated with the late Ertebolle culture. At that time pollarding and tiny woodland pastures were the primary basis for animal husbandry. Small-scale cereal cultivation was probably also practised, as evidenced in the pollen diagram from the Wolin II site in the samples dated to ca. 5400*–5300* BP.

This first evidence of agriculture, distinctly earlier than the typical Neolithic culture in this area, are significant. It supports the earlier ideas (Troels-Smith 1953, Iversen 1973, Schwabedissen 1980, Jennbert 1988) of the farming practices of the late Ertebolle people, which justifies the use of the term "proto-Neolithic" for this culture (Wiślański 1979a, Schwabedissen 1981). Judging from the Wolin II pollen diagram, which in this case gives the clearest picture, there was a continuity of settlement from the late Mesolithic Ertebølle culture through to the Funnel Beaker culture, which represents the early Neolithic in this area. It seems that some traditional woodland management practices were continued during this time, as for example regular burning of the *Pinus-Quercus-Betula* forests, which resulted in the development of *Calluna* heath. Both animal husbandry and small-scale cultivation were probably introduced gradually to complement earlier activities.

The above hypothesis is in agreement with the theory of neolithization accepted by archaeologists for the areas settled by the Ertebølle people. According to it, the Ertebølle culture developed on an earlier Mesolithic background and gradually adopted methods of animal husbandry and cultivation from the Neolithic tribes of the Linear Pottery culture (Wiślański 1979). Jennbert (1988) supposes that grain and cattle arrived by way of exchanged gifts and were introduced as a luxury goods, not necessary for human survival. The scattered archaeological artifacts of the Linear Pottery culture found on Wolin Island itself and in its surroundings (Wiślański 1969) are probably evidence of the direct contact between these tribes and the Ertebølle people. This is not surprising because a large settlement area of the Linear Pottery culture (Pyrzyce region) lies only some tens of kilometers to the south of Wolin Island (cf. Fig. 3).

The further development of agriculture was connected with the Funnel Beaker culture which, in this area, probably came into existence on the basis of the Ertebølle culture (Wiślański 1979), as it did in southern Scandinavia (Jennbert 1988).

Pollen diagrams from Wolin Island show that the keeping of livestock was the major land use during the Neolithic, Bronze Age and early Iron Age. This probably changed in the Roman Iron Age, but a clearly strong increase in cultivation is documented only for the early Middle Ages. To some extent, this could be a false picture resulting from the natural underrepresentation of cultivated plants in the pollen diagrams, but, on the other hand, it agrees well with the archaeological data concerning the prehistoric economy in

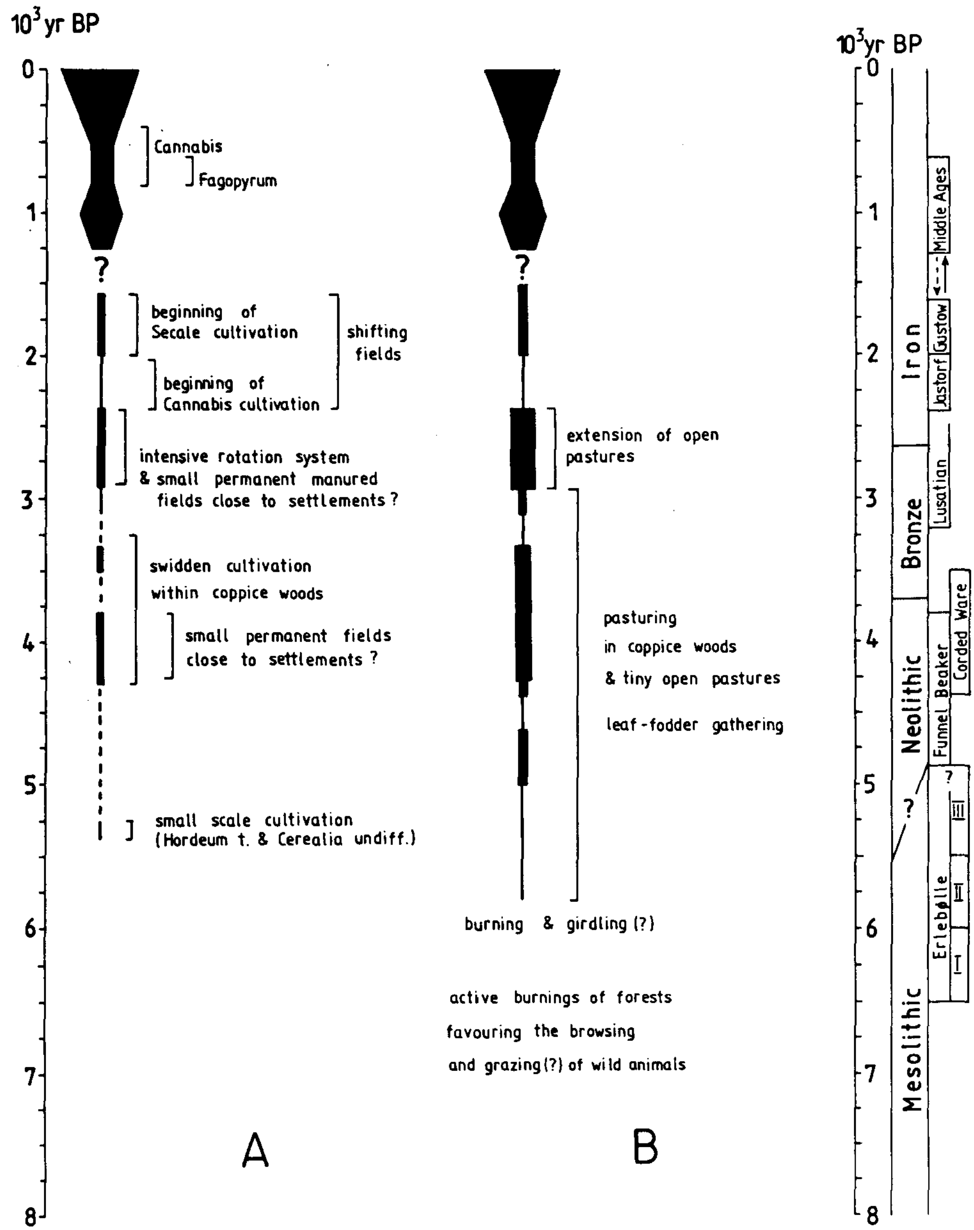

Fig. 29. A synthetic compilation on the development of farming on Wolin Island: A – cultivation; B – animal husbandry

northwestern Poland (Wiślański 1969, 1979, Wesołowski 1983, Wołągiewicz 1983) and in the investigated area itself (Cnotliwy 1961, 1966).

In the Neolithic and early Bronze Age livestock was probably pastured mainly in coppice woods and leaf-fodder was of importance but more open woodland pastures and even patches of open pasture and heathlands were also in use. This can be assumed, not only from the pollen diagrams in which *Plantago lanceolata* and graminids play an important role, but also from the archaeozoological data of domestic animals from excavations in northwestern Poland (Wiślański 1969). In this material the bones of cattle predominate and it is well known that these animals eat herbs and grasses rather than lignoses (Haeggström 1990). Patches of *Calluna* heath in the vicinity of the Wolin II site could have been of special importance in the effective feeding of sheep and goats (cf. Gimingham 1972).

The development of extensive open pastureland was certainly connected with the middle and late Bronze Age, i.e. with the Lusatian culture, and then, with the early Middle Ages. During these periods a considerable opening up of the landscape took place, which resulted in increased soil erosion. The extent of deforestation in the late Lusatian culture was probably comparable to that of early Medieval times.

Information about cultivation can be inferred primarily from the pollen of cultivated plants and field weeds. With respect to the Neolithic, the best evidence comes from the Wolin II diagram, which illustrates a well developed cultivation phase, probably of the late Funnel Beaker culture. At that time, *Triticum* and *Hordeum* were grown in the vicinity of the site. This is confirmed by the macrofossil records from a settlement close to the investigated fen (Klichowska 1967a). Unfortunately, these data are very poor and include only one *Triticum sp.* and five *Hordeum vulgare* imprints on the pottery. Two pollen grains of *Secale* found in the Wolin II profile probably represent the rye-weed (cf. Behre 1981).

An interesting list of plants, which are to-day typical weeds of arable land, is established on the base of the palynological data reflecting this cultivation phase. It includes several annuals such as *Centaurea cyanus, Scleranthus annuus, Polygonum aviculare, Papaver rhoeas* (?) and *Lapsana* (*communis* ?). All these plants are known from macrofossils from the Neolithic of northwestern Poland (Klichowska 1972) or the neighbouring countries (Jensen 1985). Some of them, for example *Centaurea cyanus*, are very rare in the early agricultural layers (cf. p. 140) and to-day grow mostly among winter cereals. Since winter sowing was probably not practised in prehistoric times, at least not before the Roman period (Groenman-van Waateringe 1979), the presence of this rather rich complex of weed species could be explained as the result of permanent cultivation, which possibly took place on the small fields close to the settlement, as has been suggested for the Funnel Beaker settlement in southern Sweden (Larsson 1989 after Reqnéll 1989).

There is only very poor evidence for Neolithic cultivation in the morainic part of the island; it includes single pollen grains of *Cerealia undiff.* and *Triticum* type, appearing rather late, in the settlement phases corresponding probably to the Corded Ware culture. It is very probable that at that time swidden cultivation was practised, as has been demonstrated by Andersen (1988b) for the Neolithic of Denmark, because of the very clear palynological evidence of coppicing associated with the middle and late Neolithic settlement phases in all the diagrams from Wolin Island.

According to the archaeological data slash-and-burn cultivation continued during the Bronze Age but, especially during the time of the Lusatian culture other methods were probably also developed (Gardawski 1979). This is confirmed by the palynological data from Wolin Island. The high charcoal content, the evidence of coppicing and the only scattered pollen of *Cerealia* suggest slash-and-burn cultivation as the main method at least up until the Lusatian culture phase. However, in the Lusatian culture, the presence of more permanent fields, especially in the close vicinity of settlements cannot be excluded. In the Kołczewo profile the evidence of soil erosion (mineral layer) is not accompanied by a distinct increase in macroscopic charcoal particles in the peat. Moreover, the cereal pollen frequency rises together with the appearance of numerous taxa indicating a rich weed flora typical of arable fields (Fig. 29), whereas the swidden technique somewhat prohibited the development of weed communities (Andersen 1988b). The great amount of pollen of *Chenopodium album* (cf. p. 141) and the presence of its seeds in the peat deposit may indicate, that at least some fields were manured at this time, as has already been discussed by Regnéll (1989) for settlements of a similar age in the Ystad area (S. Sweden).

During the Iron Age, human impact on Wolin Island, as a whole, declined, but in a reduced number of settlements cultivation rose in importance. In the diagram from Kołczewo (Fig. 7), the sharp fluctuations in the *Fagus* and *Pinus* curves may illustrate a series of small-scale deforestations and forest regeneration phases on fallow land, which may be indicative of shifting fields. Also in this diagram, which is the best developed, two different periods of farming are illustrated.

During the pre-Roman Iron Age (Jastorf culture) the indications of animal husbandry are much stronger than those of cereal cultivation. This agrees with the characteristic features of the Jastorf culture economy given by Lange (1971). It is interesting to note, that in this phase *Cannabis* was cultivated, which is a relatively early record (see the discussion below).

The Roman Iron Age (Gustow group) was a time of increasing cereal cultivation and the introduction of rye mono-cultures (cf. Lange 1975). In the pollen diagrams the *Secale* pollen frequency exceeds that of other cereals for the first time. This confirms the generally accepted opinion that, in Poland, rye gradually spread as a weed, especially in crops of barley, from Neolithic times, but was not sown as a separate crop earlier than in the Roman period (Wasylikowa 1983, Wasylikowa et al. 1991). The relatively small proportions of field-weeds in the pollen diagrams show that large-scale permanent cultivation was not established at that time, which is a characteristic feature of areas of poor soil (Wielowiejski 1981).

The increase in the acreage of arable land took place in the early Middle Ages, in connection with the development of numerous settlements and the early Medieval town (cf. p. 131). The increased population density on the island and its surroundings resulted in the extension of arable fields, probably even onto the poorest soils. It is also possible that some cereals were imported to supplement local food resources. This can be deduced from the archaeobotanical finds of several weed species foreign to the Wolin flora, in the archaeological layers of the early Medieval port (Latałowa, in print).

The palynological data give only limited information about the full richness of the cultivated species. Many of them are not identifiable by their pollen, for example *Panicum miliaceum*, which is important in the archaeobotanical material (Klichowska 1961, Latałowa in print), or several members of the *Cruciferae* or *Leguminosae* families. It is also impossible to draw reliable conclusions of the real proportions between the cultivated cereals (cf. p. 187). It seems, however, that *Secale* although an important crop, was not a dominant one, because barley and millet are more abundant among the macrofossil remains (Klichowska 1961).

The pollen diagrams illustrate the rich weed-flora typical of arable land. *Centaurea cyanus* was one of the most important weeds showing that the winter sowing of *Secale* and probably also of *Hordeum* (cf. Lange 1975) was practised. The development of weed communities is evidence of cultivation in permanent fields. The poor soils of Wolin Island probably needed intensive manuring. The abundance of nitrophilous weeds with *Chenopodiaceae* and *Cruciferae* may indicate the existence of field-weed communities of the *Eu-Polygono-Chenopodietea* class, nowadays typical of summer cereals and root crops, if the soil is well manured.

The diagrams from Wolin Island contain interesting data on the cultivation of hemp. Pollen grains determined as belonging to cf. *Cannabis* (cf. p. 141) appear in the Kołczewo profile in samples dated to the pre-Roman Iron Age, which suggests that this plant was already used by people of the Jastorf culture.

In most cases the beginning of *Cannabis* cultivation in Europe is linked with the expansion of the Romans, i.e. the time after the birth of Christ (Hopf & Zohary 1988). Earlier finds are rather rare. However, in archaeobotanical material from southeastern and central Europe (Hungary, Romania, Czekoslovakia) single records dated to the La Tène period are known (Wasylikowa et al. 1991). A pre-Roman find of *Cannabis* is also reported by Wesołowski (1981) from Wyciąże near Kraków (southern Poland) but, according to Wasylikowa et al. (1991), this record has not been verified. All these finds derive from areas under Celtic influence. Wolin Island lies beyond the extent of the Celtic culture. It is possible, however, that this important fiber, oil and drug plant was introduced to the area by way of trade.

Hemp was also cultivated in the Roman period and in the early Middle Ages, but the best data come from the Lake Racze sediments and are dated to ca. 640±60 BP. The great amount of cf. *Cannabis* pollen is evidence of hemp retting in fiber processing. Such data are known from many sites in northern Europe (Szczepanek 1972, Bradshaw et al. 1981, Påhlsson 1981, Andersen 1984, Gaillard & Berglund 1988).

PLANTAGO LANCEOLATA AS AN ANTHROPOGENIC INDICATOR IN THE LIGHT OF PALYNOLOGICAL DATA FROM WOLIN ISLAND

Plantago lanceolata is unquestionably one of the best indicators of prehistoric farming (Behre 1981, 1988). It is mostly regarded as an indicator for fresh meadows and pastures in all the diagrams from northern and central Europe where traces of human impact have been investigated. Lange (1971, 1975, 1986) goes even further and uses the *Cerealia : Plantago lanceolata* ratio as an index of the proportion of tillage to stock farming, and she recommends its application to the whole husbandry system. Recently, some authors have shown that such an interpretation is oversimplified and, thus, misleading.

According to Behre (1981, 1986) *Plantago lanceolata* is also an important diagnostic species of fallow land, especially in early agricultural systems. Groenman-van Waateringe (1986) discusses in detail the palaeobotanical data from the Netherlands, which indicate that this species was particularly common as a weed on arable land during the Neolithic and Iron Ages. Its role as an indicator of prehistoric cultivated fields has also been pointed out by Regnéll (1989).

In the diagrams from northern Poland, *Plantago lanceolata* pollen does not appear before the first man-made forest disturbances, in spite of the fact that it probably belonged to the natural Holocene flora, as it did in England (Godwin 1975) and Denmark (Andersen 1984). In the Wolin diagrams *Plantago lanceolata* appears above the first *Ulmus* fall and in the earliest settlement phases is treated mainly as an indicator of tiny pastures, because it is rather difficult to speculate about arable land when only single cereal pollen are found. It cannot, however, be excluded that the pollen grains of *P. lanceolata* are partly derived from the fields and that their better representation than that of the cereals is due to their better pollen production and dispersal. The highest pollen frequency of *P. lanceolata* was found in the Kołczewo profile in the layers dated at the Lusatian culture. Since this species is usually underrepresented in pollen rain (Berglund et al. 1986), it is quite probable that the greater part of this pollen was eroded from a cultivated field located close to the peatbog.

The pollen diagrams from Wolin Island illustrate clearly the relationship between the *Plantago lanceolata* pollen frequency and the soil conditions of the area. In the diagrams from the more fertile morainic part of the island *P. lanceolata* is one of the best anthropogenic indicators and fluctuations in its curve are adequate to suggest changes in the intensity of human impact on the vegetation, whereas in the diagram from the poor sandy area (Wolin II) its role is rather restricted. In the Wolin II diagram *Calluna vulgaris* (starting from the Neolithic) and *Juniperus* (from the Middle Ages) are indicative mostly of a pastoral economy. In the upper part of this diagram the *P. lanceolata* curve drops distinctly, while the other indicators of land utilization, especially of cultivation increase sharply. In the same section the pollen curves of *Juniperus* and other plants typical of acid sandy pastures rise. As has been shown already (Latałowa, in print) this part of the diagram does not illustrate a decrease in stock farming, but rather soil impoverishment or a shift of pastures onto the poorest habitats.

The data discussed above provide additional arguments for Behre's (1981) reservations against the oversimplified interpretation of anthropogenic indicators, especially of *Plantago lanceolata*.

THE HISTORY OF SELECTED PLANT COMMUNITIES

THE BEECH FORESTS

Different forest communities dominated by beech or with a significant proportion of beech are the most typical feature of the present day vegetation in the morainic part of Wolin Island. They occupy a variety of habitats, but large patches of nearly pure stands of beech (*Luzulo pilosae-Fagetum*), which represent the poorest association, are the most common and develop mostly on the tops and slopes of terminal moraine hills where strongly podzolized acid brown earths and podzols, developed from the sandy clayey substrate, and a very deep ground water table shape the edaphic conditions. Acid oak-beech forest (*Fago-Quercetum*) is, spatially, also of importance occuring mainly on the lower parts of slopes. Phytocoenoses of the rich *Melico-Fagetum* association are of very restricted significance while patches of *Cephalantero rubrae-Fagetum* form a narrow zone on the top of the sea cliffs which are overblown by sand (Piotrowska & Olaczek 1976, Piotrowska in print).

The synthetic compilation (Fig. 30), based on the pollen diagrams from Kołczewo and Lake Racze, illustrates the development of beech forests in the morainic landscape (characterized by poor brown soils and podzols), where the *Luzulo pilosae-Fagetum* and *Fago-Quercetum* associations grow to-day. However, distinct differences between these diagrams due to slightly different habitat conditions (cf. Fig. 5) are also of interest. Patches of more clayey substrate are more frequent close to Lake Racze which is well expressed in the much lower participation of pine and the higher values of the more demanding trees throughout the whole pollen diagram from this site.

The first *Fagus* pollen grains appear in the samples somewhat older than 5000* BP in both profiles, while the start of the low (%) continuous pollen curve is dated to ca. 4200* BP. The curves exceed 2% values at the levels dated to 2860±110 BP (Kołczewo) and >3100±110 BP (Lake Racze) which, according to Huntley and Birks (1983), suggests that, at least locally, beech was sparsely represented in the forest communities growing around the sites. This initial establishment of *Fagus* was contemporary with the man-made disturbances in the *Tilia* and *Tilia-Quercus* forests as is well demonstrated by a clear negative correlation between the *Tilia* and *Fagus* pollen curves. A similar relationship has been observed by other authors (Andersen 1984, Aaby 1986).

The real beech expansion on Wolin Island took place in consequence of the nearly total extinction of *Tilia* due to the intensive exploitation of woodland resources during the period of the Lusatian culture. Pollen diagrams from the sites under consideration seem to illustrate three successional stages which led to the *Fagus* dominated forests and which reflect the competition between pine, oak and beech under different types and degrees of anthropogenic pressure.

Following the relative decline of human activity at the turn of the Bronze and Iron Ages (since ca. 2700* BP) beech, together with oak, gradually increased in importance, although pine and birch were the most important trees to invade the abandoned farmland (*Pinus* forest). During the next ca. 500 years pine, as a light-demanding tree, become gradually suppressed by the broad-leaved trees (*Quercus-Fagus* forest), especially on

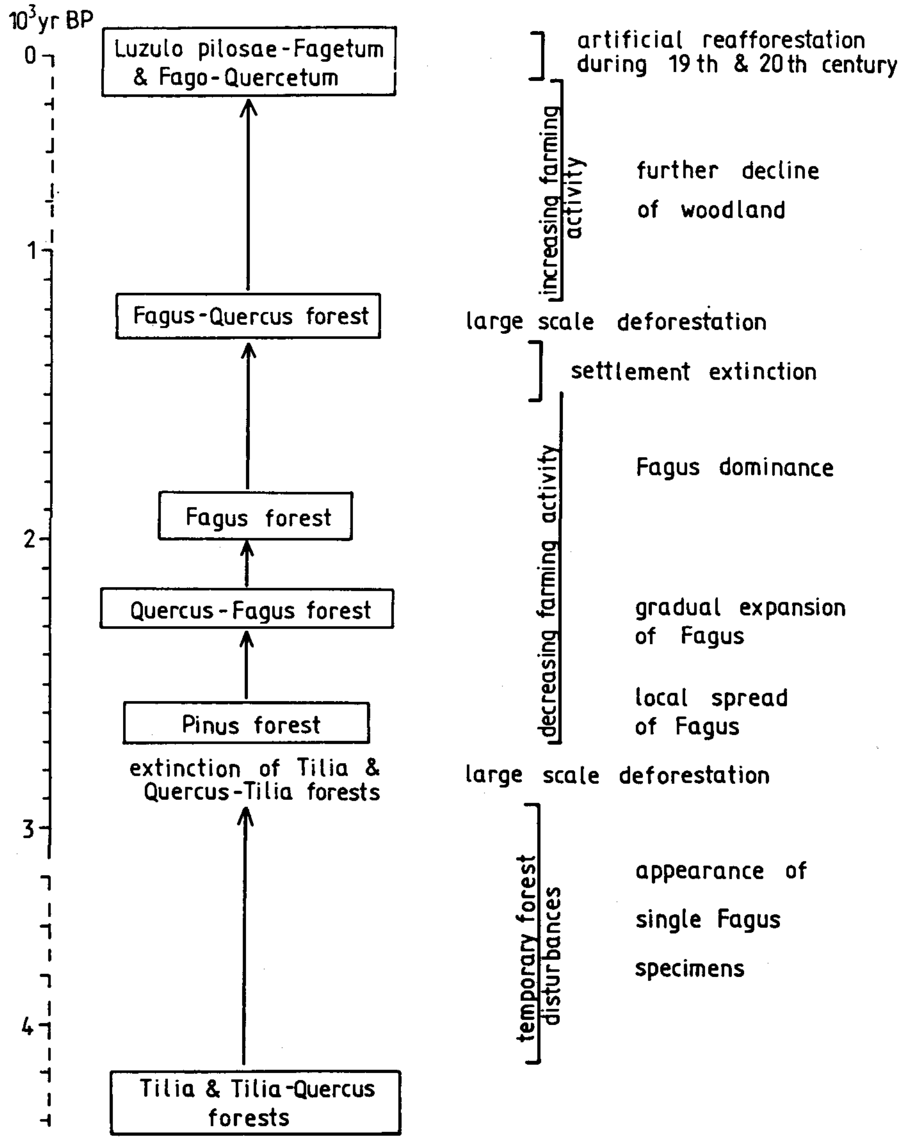

Fig. 30. A synthetic compilation on the history of beech forest on the poor moraine habitats of Wolin Island

the more clayey soils. Both these forest succession stages underwent different but generally rather slight human influence. For the period dated to 1820±60 – 1300±60 BP very weak farming activity is documented by the pollen diagrams with a total cessation in settlement by the end of this phase. At this time *Fagus* became a dominant tree on all suitable habitats in the morainic part of the island (*Fagus* forest). It replaced *Quercus* to a considerable extent, but oak became more important again with the beginning of early Medieval forest management.

The *Fagus* forest succession described above certainly depended on various ecological factors, the most important of which was probably competition, at first between lime and beech, and then between pine, oak and beech.

Where *Tilia* occurred as the main tree on rather poor, well drained soils in the morainic area, *Fagus* was unable to invade the natural or only slightly disturbed forests. As has been shown by Rakham (1980), Aaby (1983) and Andersen (1984), locally in such areas *Tilia* was even able to persist as the dominant tree long time after the immigration of *Fagus*, if the forest was not disturbed. However, once the natural ecological equilibrium had been unsettled by man, *Tilia* could not compete successfully with *Fagus*, especially on acid soils. One of the most important causes was the intensive formation of a thick acid humus layer immediately after the invasion of beech trees (Aaby 1983). The climatic factor was probably of secondary significance.

The competition between pine, oak and beech in invading fallow land and followed by their regeneration ability under different light conditions forms the basis of the further *Fagus* forest succession.

It is clear that pine was the first invader of fallow land as its light seeds propagate easily and, under full illumination, it grows well. It spreads very fast and, under favourable conditions, after 15 years it already germinates every 2–4 years. It does not, however, regenerate when its seedlings or saplings are overshadowed (Tomanek 1966, Obmiński 1970). It was, thus, hampered by oak and beech when they became more frequent in the forest.

Oak and beech have rather heavy fruits and they do not spread as fast, despite the fact that they are largely disseminated by animals. Admittedly, *Quercus* (in this case probably *Q. petraea*) had a better chance of effective invasion because it was well established in the area before deforestation, it germinates more frequently than beech (Tomanek 1966, Dzwonko 1990) and easily regenerates from seeds on well illuminated sites (Andersen 1984). Beech spreads slowly but once established, it is a strong competitor changing both the light and the edaphic conditions in the forest. Its shade practically eliminates the juvenile specimens of other trees, whereas its own saplings are independent of light conditions (Andersen 1984). In *Fagus* stands, litter composed of leaves very resistant to decay accumulates and, in consequence, a deep acid humus layer is formed which accelerates podsolization. The nature of the soil under *Fagus* trees and especially the surficial mats of its roots, impede the rejuvenation of oak and also of beech itself. Rejuvenation of *Fagus* is much better under *Quercus* trees or in the openings within the forest (Andersen 1984). Undoubtedly, this strong competitive character of *Fagus* caused the expansion of nearly pure beech forests, when human influence ceased. The increasing participation of *Quercus* is thus an indication of destruction on the acid *Fagus* forest habitats.

Pollen diagrams from Wolin Island illustrate the slow initial *Fagus* spread and its later rapid expansion, which is characteristic of northern Europe (Iversen 1973, Huntley & Birks 1983). The beach expansion was connected with the preceding forest disturbances. As in Denmark (Aaby 1986, 1988) and southern Scania (Regnéll 1989), it was locally present from about 3000* BP, which is relatively early in comparison with other

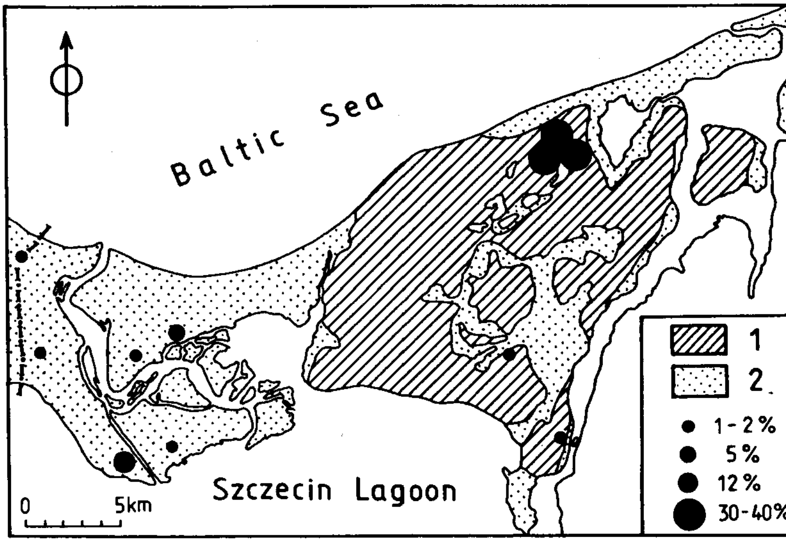

Fig. 31. Maximum *Fagus* percentage values in the pollen diagrams from Wolin Island ca. 1.500 BP according to Orwat (1958), Prusinkiewicz & Noryśkiewicz (1966) and Latałowa (this paper): 1 – Pleistocene deposits, 2 – Holocene deposits

sites in the Baltic coastal zone of Poland (Latałowa 1989a, Latałowa & Tobolski 1989). Unequivocally, the further spread of beech was a result of a decrease in the intensity of human impact after serious destruction of the former woodland. The same relationship has been documented by Aaby (1986, 1988) for Denmark. The anthropogenic factor was certainly decisive in the expansion pattern of *Fagus*. Favourable climatic conditions (recently emphasized by Huntley 1988) probably reinforced its competativeness with respect to other trees, but played a rather minor role in the *Fagus* invasion.

When considering all the pollen data from Wolin Island for the time of maximum beech expansion (Fig. 31), the local character of its pollen representation is obvious. This well known phenomenon (Andersen 1970) is stressed here to show the danger of over-simplification, even in large-scale reconstructions, if habitat conditions are not taken into consideration. According to the Huntley's isopollen maps (1988) beech was never of importance in northwestern Poland, northeastern Germany and Denmark. For 2000 BP a 2% isopollen line is drawn for this area, whereas in several pollen diagrams (Andersen et al. 1984, Aaby 1986, Lange et al. 1986, Orwat 1958) the *Fagus* curve exceeds 20% in the layers of that age, and in the slightly younger (200–300 years) spectra it has a maximum exceeding 40%. It seems that, among others, pollen data from sites into which beech practically has never expanded, were used for the construction of these isopollen maps.

THE *CALLUNA* HEATH

On maps showing the distribution of lowland heathland in Europe (Gimingham et al. 1979), Wolin Island and, similarly, the whole of Poland, lies outside of its range

(Fig. 32), despite the favourable climatic conditions for the development of this vegetation type (Gimingham 1972). Indeed, the extensive heathlands, typical of large areas of western Europe are not present in Poland today. However, in many places, mainly in northwestern Poland, patches of heathland communities have been recognized (Pawłowski & Zarzycki 1972, Matuszkiewicz 1982). They represent three associations of the *Calluno-Ulicetalia* order:

– *Calluno-Genistetum*, subatlantic inland heathlands; the most typical phytocoenoses occur in the area south of the Szczecin Lagoon (Puszcza Wkrzańska), while those from the localities situated more to the east are devoid of several Atlantic species and include some others of a more boreal character (Markowski, oral inf.); this community occurs on the poor sandy or sandy-clayey soils, mainly after the retreat of pine forests, but also in openings in acid oak, beech or even hornbeam forests;

– *Salici-Empetretum nigri*, boreal-atlantic heathlands, which develop only on the moist dune sands of the Baltic coast;

– *Arctostaphylo-Callunetum*, subcontinental heathlands with a boreal type of distribution; this community occurs in northeastern and eastern Poland.

On Wolin Island, only the heath community with *Empetrum nigrum* and *Salix arenaria* is present today, occuring in patches on the dune sands. Farther inland *Calluna* heathlands do not occur on this area, but in places, the present vegetation composition indicates, that they probably existed there in the past. Patches of such a vegetation have been found in the neighbourhood of the Wolin II site (cf. p. 162), and the pollen diagram

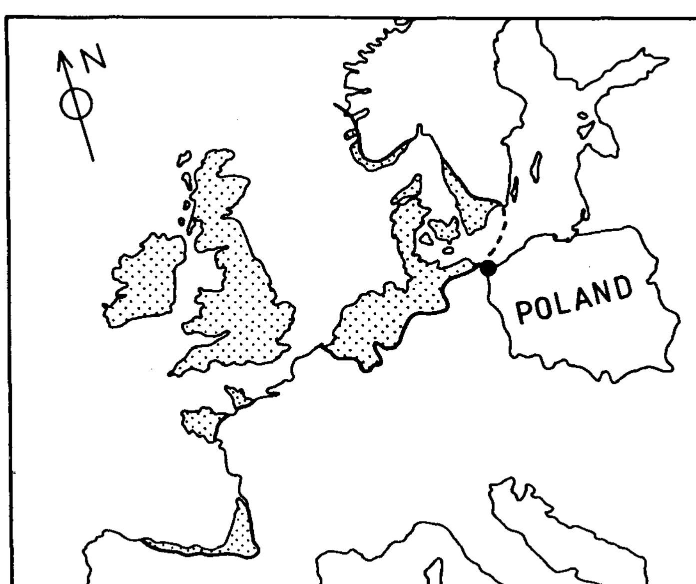

Fig. 32. Location of Poland and Wolin Island (black dot) with respect to the extent of lowland heathland vegetation in Europe (after Gimingham et al. 1979)

from this locality clearly illustrates the history of the local *Calluna* heath, which spread close to the investigation area.

As is shown by the palynological results (Fig. 33), *Calluna* heath developed in the Neolithic as a consequence of the exploitation of the *Pinus-Quercus-Betula* forests on the light, predominantly sandy soils. Since 6340±70 BP at least, regular burning and grazing by wild, and later domestic animals, certainly caused soil degradation and the

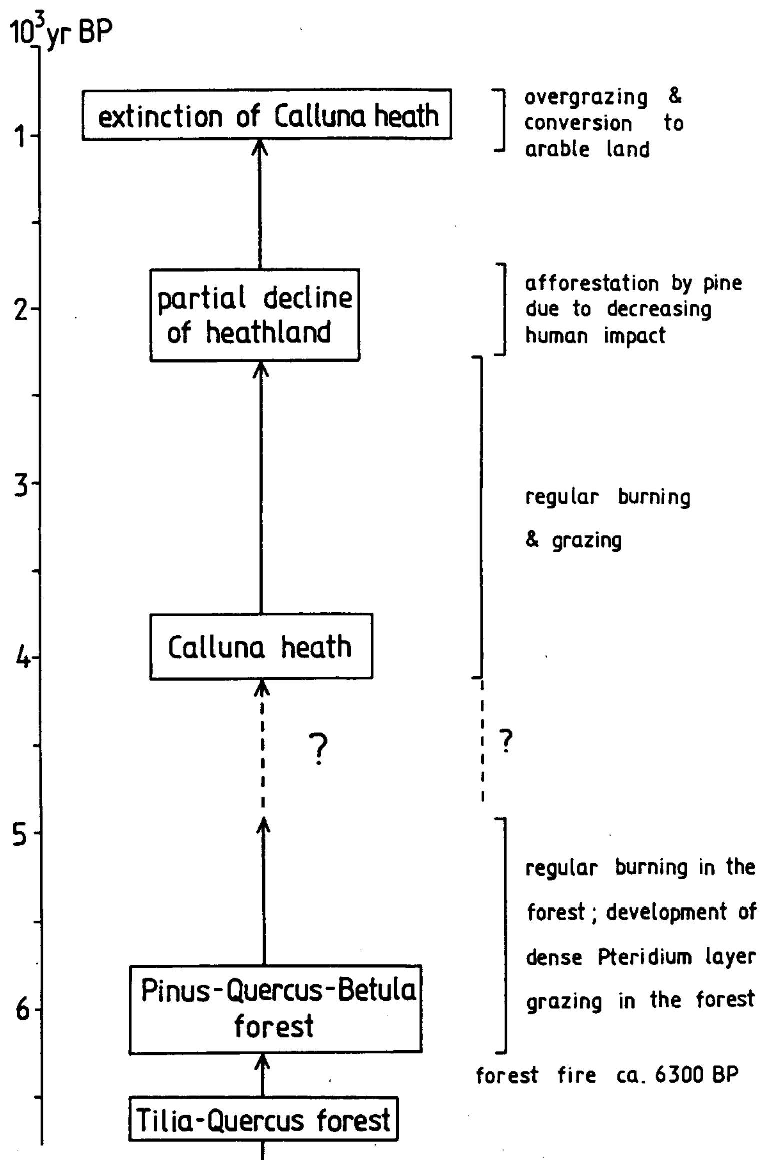

Fig. 33. A synthetic compilation of the history of *Calluna* heath on Wolin Island

strong expansion of *Pteridium aquilinum*, which hindered forest rejuvenation. In the Neolithic, regular stock farming started in this area, which was probably continuously inhabited throughout the whole of prehistoric time. As in western Europe (Behre 1988, Odgaard 1988), *Calluna* heath could be used for winter grazing because the climate of the island is ralativelly mild and, even today, the snow cover is only 5–10 cm thick in the coldest month and snow is present on only about 35 days in the whole winter. Winter temperatures are also relatively high with an average for the coldest month (February) of between -1.5 and -1.0°C, but only -0.6°C in January (Młodzikowski 1986). Taking into consideration the generally better climatic conditions in the Subboreal period, we can imagine that winter grazing was perfectly possible on Wolin Island during prehistoric times.

The *Calluna* heaths reached their optimum during the Neolithic, Bronze and early Iron Ages. They were regularly burnt (the very high charcoal content) and grazed (the evidences of permanent stock farming in the area) which, according to Gimingham (1972), is the necessary management for their maintenance. In the late Iron Age *Calluna* heath still existed but it probably became partly afforested by pine, due to the decreased human activity, while in the early Middle Ages it disappeared. It seems, that the pollen diagram indicates some of the possible causes of this disappearance. The most important one is documented by the great number of *Pteridium aquilinum* spores which increase again as the *Calluna* curve declines. It is a known fact, that *Calluna* is not resistant to heavy grazing, especially by sheep, and when weakened, *Pteridium aquilinum* is not only one of the main invaders, but also precludes the re-establishment of heather (Gimingham 1972). Such was probably the case with the heath on Wolin Island. In the early Middle Ages, when the town came into existence, its environs were certainly intensively exploited for farming. Sheep and goats were probably important as, for example, in early Medieval Szczecin (Leciejewicz & Wieczorowski 1983). It is also possible, that some of the *Calluna* heath area was converted into arable land. This idea is supported by the very sharp increase in cereal pollen. Among these pollen grains strongly corroded specimens are frequent, which indicates their erosional origin in the fields lying close to the investigation site, previously occupied by heath.

The history of Wolin's heath vegetation is comparable with records from numerous localities lying within the optimum areas for Atlantic heathlands, areas where these heathlands developed mostly after the retreat of acid oak woods *Betulo-Quercetum* and *Fago-Quercetum* (Pott 1988). Heathland expansion due to Neolithic forest exploitation has been recorded, for example, in western Norway (Kaland 1986), the Netherlands (Casparie & Groenman van Waateringe 1980), Germany (Behre & Kučan 1986) and Denmark (Odgaard 1988). In some localities heathlands disappeared after human impact ceased and re-expanded in later periods of increased settlement (Behre 1988). In others, heathlands have persisted until today having constantly declined, however, during historical times, due to intensive farming or afforestation (Behre 1988, Odgaard 1988). A Neolithic age for heathland expansion is not the earliest. In Britain (Robinson 1987) and in eastern Germany (Kloss 1990) evidence for their temporary spread due to the activities of Mesolithic man has been recorded.

In reviewing pollen diagrams from northern Poland it becomes clear, that only the Wolin II diagram contains unquestionable evidence of local heathland history. However, the pollen diagrams from Kołczewo and Lake Racze, as well as diagrams from Tuchola Forest (Hjelmroos-Ericsson 1981, Miotk-Szpiganowicz 1992) and Darżlubie Forest (Latałowa 1982), from areas of sandy soil, lying on the outwash plains in eastern Pomerania demonstrate the great role of *Calluna* in the past plant communities. For example, in the regional pollen diagrams from Lake Gacno (Hjelmroos-Ericsson 1981), this species, the pollen of which is usually badly dispersed, (see discussion by Thelaus 1989) forms continuous curves exceeding 1% from the levels dated to the early Boreal period, while from the late Atlantic time the curves clearly increase, oscillating around 3–5% of the total pollen sum, but in some sections the values even fluctuate between 10%. and 20%. In all these diagrams the rises in the *Calluna* curves are associated with palynological evidence of fire. *Calluna vulgaris* is an important component of different plant communities on open, dry oligotrophic habitats. In northern Poland, apart from heathlands, it is frequent in dry grasslands, in open pine forests, and in some of the acid deciduous forest glades; it also occurs in dry places on ombrotrophic peatbogs. This ability of *Calluna* to grow on different habitats, should warn us to be cautious in interpreting its curves in the pollen diagrams. It seems, however, that especially in the diagrams from the areas where heathland communities occur today, the higher *Calluna* curves may reflect the development of local heath. Thus, in the Tuchola Forest region local heath vegetation could have already occupied some areas in the Neolithic, whereas short episode of *Calluna* heath development probably took place in the Darżlubie Forest during the late Lusatian/Pomeranian cultures.

The reason for the scarcity of heathland vegetation in northern Poland today is probably complex. According to Markowski (oral communication), not only climate but also different farming methods and the large-scale afforestation, which has taken place since the 19th century, are behind its recent almost complete disappearance.

HUMAN ACTIVITY AND HYDROLOGICAL CHANGES

WATER LEVEL

Water has always been an important factor determining the location and development of settlements. On the other hand, at least since the Neolithic, man has influenced the hydrology by changing the forest structure and its composition. Different farming methods, as well as differences in their intensity, have resulted in various hydrological reactions.

A detailed reconstruction of palaeohydrological events on Wolin Island is not possible on the basis of data obtained so far. Three different basin types and various kinds of sediments give a variety of information on factors leading to fluctuations in the ground water table (lake sediments, rheogenic and minerogenic peats) or presumed climatic changes (ombrogenic peat) (Fig. 34), but all these data are, as yet, insufficient. Only a few, indirect data are related to fluctuations in the level of the Baltic Sea, which have undoubtedly been the most important factor shaping the water regime of the island.

The information, which can be inferred from the profiles investigated is as follows:

– Kołczewo – predominantly man-induced changes in the ground water table are recorded for the period 5820±130 – 2860±110 BP, and climatically conditioned ones for the period 3000*–800* BP;

– Lake Racze – the single profile from this rather deep, small, oligotrophic lake cannot form the basis for water level reconstruction; the clear evidence of erosional processes does not, in this case, necessarily indicate a lowering of the water table; only very restricted data are available from this locality;

– Wolin II – both, fluctuations in the Baltic Sea and farming activity have influenced changes in the ground water table which are reflected in this profile from ca. 7300* BP.

These data come mainly from different mire communities, and so water level rises are mostly regarded as hydrological events caused by external factors. The interpretation of drier phases is not so clear cut since autogenic processes are usually also of importance (Aaby 1976). However, phases of very low peat accumulation have been shown (Fig. 34) as supplementary data. The very slow peat (Kołczewo) and sediment (Lake Racze) growth recorded in the sections dated to ca. 8000*- 4700* years BP, as well as the low peat accumulation rate in the Wolin II profile (around 4900* BP) illustrate a well-known phenomenon occurring over large areas of Europe. This is generally explained as the result of a lowering of the ground water table caused by increased transpiration from woodland in which pine had been replaced by broad-leaved trees (see discussion by Ralska-Jasiewiczowa & Starkel 1988).

The best records of human induced hydrological changes come from the Kołczewo profile, where phases 1–4 and 6 (Fig. 34) showing a higher ground water level are always associated with clear evidence of increased settlement activity. It is interesting, that phase 1 (5820±120 BP) is concurrent with the first *Ulmus* decline, which has been interpreted as the result of intensive pollarding (maybe combined with disease) rather than forest clearance (cf. p. 207). Phase 6 (Lusatian culture) is the most striking. In this phase, the raised bog succession, which started about 100–150 years earlier, was interrupted by a rise in the ground water table. Ground water penetrated the ca. 60 cm thick ombrogenic peat layer and a small water body with eutrophic aquatic vegetation appeared once more. In the Wolin II profile phases 4 and 5 (concurrent with phases 3 and 4 in the Kołczewo profile) provide the best evidence for human influence on the ground water. In phase 4 (late Neolithic) the change was a result of disappearance of the local *Pinus-Quercus-Betula* forest and the development of *Calluna* heath, whereas in phase 5 (early Bronze Age) it was a consequence of the large-scale woodland disturbances on all kinds of habitats. The effects of human impact upon hydrological cycles have been efficiently discussed by Moore (1983, 1985, Moore et al. 1986) who stresses that even in prehistoric times forest clearances could seriously affect the water budget, changing several environmental features. He also supposes that some climatic changes may have been masked by alterations in the hydrology caused by prehistoric deforestation (Moore 1985).

In the pollen diagrams from Wolin Island, only a small amount of information seems to refer exclusively to climatic conditions. Data are derived mainly from the ombrogenic

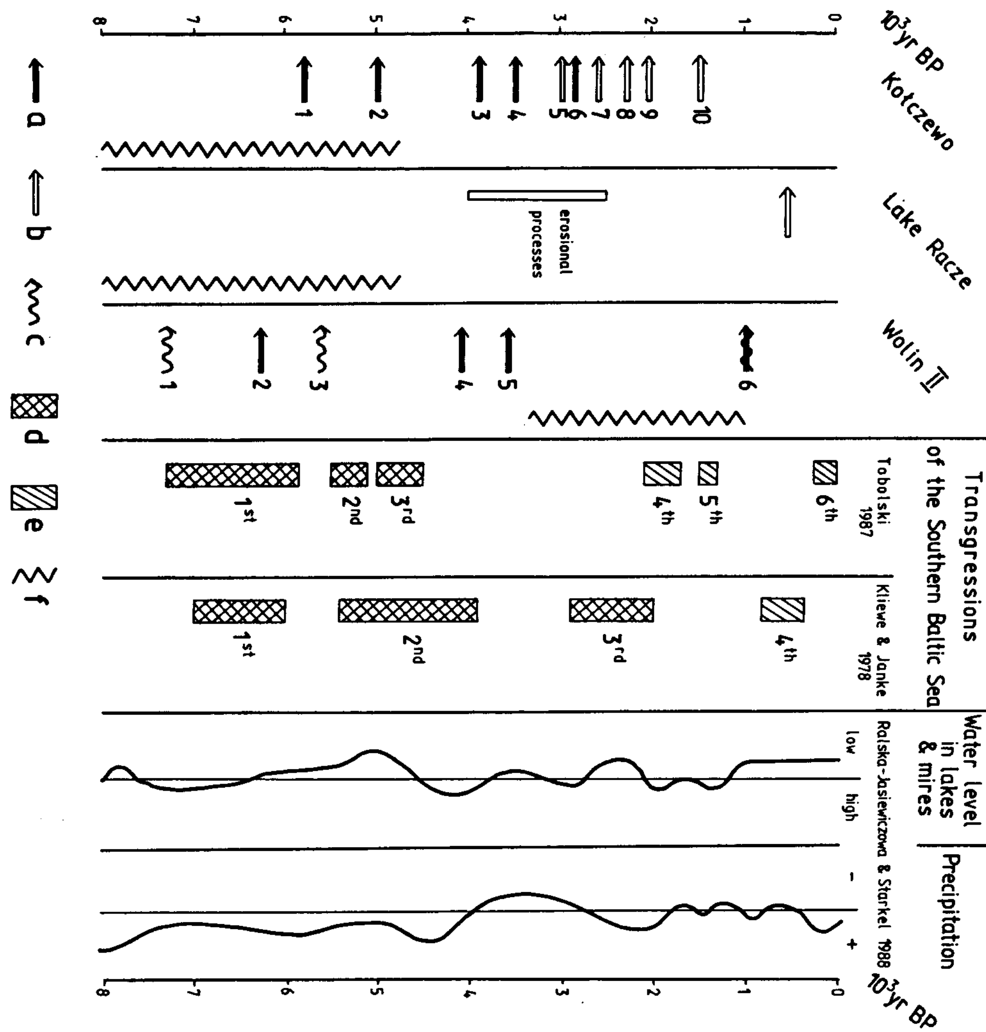

Fig. 34. Palaeohydrological events on Wolin Island against a background of the southern Baltic transgressions, water level changes in lakes and mires in northern Poland and inferred precipitation for Poland: a – rise in ground water table due to anthropogenic forest disturbance; b – climatically conditioned shifts towards wetter conditions; c - rise in ground water table probably caused by Baltic Sea transgressions; d – Littorina transgressions; e – post-Littorina transgressions; f – periods of very low accumulation rate observed in the profiles

peats deposited during the last 3000* years in the Kołczewo site. The evidence is certainly incomplete, because it comes from only the two profiles in which a correlation of dark and light peat layers (Latałowa unpubl.) and a tentative determination of the leading rhizopod genera noticed on the pollen slides was made. A good agreement has been observed between shifts from darker to lighter peat layers and the *Amphitrema* (*A. flavum*) curve (cf. p. 146 and Fig. 7), which are thought to be indicative of changes towards wetter conditions (Aaby & Tauber 1974, Aaby 1976, Barber 1981). *Assulina spp.* peaks are concurrent with those of *Amphitrema* in the lower part of the peat, while in the upper part, which is characterized by an extremely rapid peat growth, culminations of the curves appear in consecutive samples. The *Arcella* (mainly *A. cf. discoides*) and *Heleopera* (mainly *H. cf. petricola*) curves follow that of *Assulina*, while *Nebela* (mostly *N. collaris*) seems to be negatively correlated with *Amphitrema*. According to the autecological characteristics given by Tolonen (1986b), precise data on water conditions cannot be obtained on the basis of the above-mentioned taxa. It is however very probable that *Arcella, Heleopera* and *Assulina* indicate the wettest conditions, while *Nebela* the drier ones. The high *Nebela* peak in the lowest *Sphagnum* peat layer probably shows the initial, dystrophic phase of ombrogenic peat development.

The following , climatically conditioned shifts towards wetter conditions have been observed in the Kołczewo profile: phase 5 (ca. 3000*–2900* BP), phase 7 (ca. 2600*–2500* BP), phase 8 (2300±100 BP), phase 9 (ca. 2000* BP) and phase 10 (ca. 1500*BP). Phase 5 is in agreement with the results obtained by Dupont and Brenninkmeijer (1984), which point to a climatic deterioration around 3000 BP. According to the tentative correlation proposed by Gaillard (1985), a tendancy of a rise in water-level after 3000 years BP manifests itself throughout the whole Europe. This fact speaks for climatic causes in spite of the strong human activity, which over large areas could obscure natural hydrological changes. The next three phases (7–9) coincide with similar phases detectable in Danish raised bogs (Aaby 1976) and cover the period of distinct alterations of water regime in northern Poland (see Fig. 34), during which climatic and anthropogenic factors (extensive deforestation) have been of importance. Phase 9 (ca. 2000* BP), best expressed in the Kołczewo profile, coincides with the time of highest Holocene water level in the Kujawy and Tuchola Forest regions in northern Poland (Niewiarowski 1987, Bogaczewicz-Adamczak 1990). Phase 10 (ca. 1500* BP) is contemporary with some of the strongest evidence for a rising water-table in the Scandinavian raised bogs (Aaby 1976, Berglund 1983). Climatic deterioration (including climatic cooling) in the middle of the first millennium AD, in the period known as the Dark Ages, is also assumed for the British Isles (Barber 1981, Blackford et al. 1991).

Fairly reliable evidence of climatic deterioration has been registered in the upper part of the Lake Racze profile. According to the palaeolimnological investigations of Rybak et al. (1987) (see also Fig. 35) the formation of the pelagic zone in this small lake started when the planktonic forms, represented mainly by *Cyclotella comta*, showed a gradual increase. This rise in the lake water level can be regarded as being generated by climatic change rather than by human impact, because the lake catchment, as well as its surroundings, had already been cleared of forest some hundreds of years earlier. This level in the profile is situated above the horizon radiocarbon dated to 630±80 BP and, thus, it corresponds to the beginning of climatic deterioration during the so called Little Ice Age, known both from Poland (Starkel 1977) and other north-European countries (Lamb 1977).

Another kind of palaeohydrological evidence comes from the Wolin II site. Peat deposits from this locality lying close to the river Dziwna, which joins Szczecin Lagoon with the Baltic Sea, should, at least partially, illustrate Baltic Sea level fluctuations. In fact, peat accumulation started here about 7320±520 BP (phase 1) as a result of the first phase of the Littorina transgression of the southern Baltic. The 7300 BP date is also quoted by Tobolski (1987) as the beginning of this transgression and an age of 7200±105 BP was obtained for the uppermost peat layer covered by the lacustrine sediments in the Pomorska Bay, north of the Wolin Island (Kotliński 1991). The 2nd phase of increased water level on the mire was probably initiated by a man-made forest fire in the vicinity of the site (peak of *Potamogeton* pollen). Later, water level decreased only slightly (*Cladium* dominance), probably due to the generally high water table during the first phase of the Littorina transgression, which according to Tobolski (1987) lasted until about 5.850 BP; in the Wolin II profile the *Cladium* community declined ca. 5860±110 BP, as in the Kluki profile.

The rapid change (phase 3), which took place ca. 5700*–5600* BP can, with all probability, be linked with the second and then, the third Littorina transgression phases (acc. to Tobolski 1987). The rush vegetation with *Cladium*, which previously accumulated about 50 cm of peat, was replaced by a vegetation which may be compared with the *Thelypteridi-Phragmitetum* association of today. Admittedly, both, *Cladium* and *Thelypteris palustris* communities, tolerate a wide range of water table fluctuations (Podbielkowski & Tomaszewicz 1979), however the sharp change, without any sign of a hiatus (see pollen concentration, Fig. 18) must indicate a rising of the water level rather than a lowering.

It is interesting that the fourth and fifth phases of the Baltic Sea transgression (Post-Littorina transgression acc. to Tobolski) as well as the third Littorina transgression (acc. to Kliewe & Janke 1978) are not expressed in the Wolin II peat deposits. The very low peat growth or even the possibile occurrence of hiatuses suggest instead a regression or stagnation of the Baltic Sea, which is particularly well pronounced in the section dated to 1520±90 – 980±60 BP.

A new, distinct rise in ground water level (phase 6) is radiocarbon dated to 980±60 BP and could be the result of both an increase in the level of the Baltic Sea and the total deforestation of the area. There are several arguments for the assumption, that the sea level rise has been of importance here. Archaeological investigations carried out in the early Medieval port in Wolin town have shown (Filipowiak, oral information[1]) that three times during the 10th century AD the wharf was shifted towards a more inland position because of inundation. Evidence for the direct influence of sea water is given by the occurrence of euhalobic and halofilous diatoms in the peat accumulations of this wharf (Bogaczewicz-Adamczak unpbl.). The data quoted above suggest that the contemporary Baltic Sea transgression started much earlier than was assumed by Tobolski (1987) and samewhat earlier than was calculated by Kliewe and Janke (1978).

The data presented in this chapter clearly indicates the importance of this source of information for palaeohydrological reconstructions. Each of the three sites registered

---

[1] the view presented in the lecture entitled "The early medieval port and shipping on Wolin Island", given on 16th of May 1991 in the Geological Institute, Sopot; according to this in the 10th century the water level of the Dziwna river was ca. 160 cm below its present-day level.

different facts in the hydrological history of the area. The hydrological peculiarity of mires which are under the influence of sea water should be stressed while, on the other hand, the isolation of kettle-holes situated in the morainic area from sea level fluctuations is also noticeable.

TROPHIC CONDITIONS

Past human influence on the trophic status of surface waters, which can be detected by sedimentological changes, is one of the most thoroughly discussed problems in recent palaeolimnological and palaeoecological investigations (Alhonen 1987). Two opposing processes are responsible for these changes. Eutrophication is caused by the in-wash of nutrients from settlements and fertilized arable land or even by more primitive disturbances of a soil cover containing calcium carbonate (Huttunen & Tolonen 1975, Bogaczewicz-Adamczak 1990). Acidification arises as a result of human induced changes in vegetation on poor soils (e.g. spread of heathlands) or in recent times, as a consequence of acid precipitation (e.g. Tolonen & Jaakkola 1983, Birks et al. 1990).

Palaeoecological data from Wolin Island include several indications of changes in trophic conditions due to human interference.

In the Kołczewo profile very clear evidence of eutrophication is recorded in the section related to the Lusatian culture. The renewed contact with the ground water and extensive soil erosion resulted in a spectacular phenomena: the development of a shallow water body, with *Nuphar, Nymphaea, Ceratophyllum* and *Pediastrum*, on a former raised bog.

In the Wolin II profile the opposite process is registered. In the section illustrating the spread of *Calluna* heath on dry ground, a decrease in pH on the mire surface can be assumed from the appearance of *Sphagnum* and *Lycopodiella inundata* spores (Fig. 16) and sclerenchymatic spindles of *Eriophorum vaginatum* (Latałowa unpubl.). This change could be the result of progressive podzolization under *Calluna* heath, which led to the acidification of drainage water in the catchment. To some extent, however, the appearance of the above-mentioned taxa could also be associated with the natural succession on the bog; fen vegetation dominated by *Thelypteris palustris* sometimes develops into more minerotrophic communities (Podbielkowski & Tomaszewicz 1979).

In the Lake Racze profile, the evidence of eutrophication appears as early as the section described as the first anthropogenic phase (SR-1), which is distinguished by the beginning and then sharp increase of the *Pediastrum* curve. Throughout prehistoric times, the *Pediastrum* content of this originally oligotrophic lake, fluctuated with changes in farming intensity within the lake catchment.

The most interesting data come from the upper part of the Lake Racze profile. The palaeoecological investigation of this lake was originally planned as a joint palaeobotanical and palaeolimnological study. However, the palaeolimnological aspect has been limited to the examination of the upper 1 m of sediment and the results have been published without reference to the palynological data (Rybak 1987, Rybak et al. 1987). In presenting the different aspects of human interference on the environment of Wolin Island here, I find it necessary to bring these papers into critical discussion and to reinterpret certain results.

The diagram (Fig. 35) illustrating selected pollen (Latałowa, this paper), diatom and chemical data (Rybak et al. 1987) shows the very clear relationship between the degree of deforestation within the lake catchment or a specific human activity (retting of hemp) and the trophic conditions in the lake itself. Four limnological zones illustrating changes in the lake have been distinguished by the present author. The first zone (I) reflects the state of the lake before deforestation. Beech forest had its optimum development at that time and human impact on this part of the island was very weak if at all (cf. p. 179). The influx of terrigenous material into the lake was very low (high organic matter (OM) and low Si, Mg, Al and Fe content). Lake productivity was relatively high. This is expressed in such indices as the high values of total Kjeldhal nitrogen (TKN) or the epiphasic to hypophasic carotenoids ratio (EC:HC), which indicates the development even of a blue-green algal population (Rybak et al. 1987). This relatively high trophic status could result firstly, from the calcium carbonate input which, although generally very low throughout the whole core section, shows maximum values in these two samples, and secondly, from the good oxygen conditions (low Fe:Mn ratio).

The second zone (II) illustrates continued lake development under conditions of rather rapid deforestation. Arable land and pastures were created within the lake catchment. Increased leaching (calcium carbonate decrease) and soil erosion (a rise in Si, Al, Fe and Mg content) as well as a better light supply and probably a rising water level produced new ecological conditions in the lake, and enabled the development of diatom communities dominated by *Stauroneis* (mostly *S. anceps*) and *Navicula* (mostly *N. vulpina*). A slight increase in water trophy can be inferred, mainly from decrease of some acidobiontic and acidophilous forms, for example *Eunotia pectinalis* var. *minor* fo. *intermedia* (Rybak et al. 1987).

The third zone (III) is associated with clear palynological evidence of hemp retting in the lake. All indicators of erosional processes (SiO_2, MgO, Al_2O_3, Fe_2O_3) and increased trophy (P_2O_5, OM:TKN, EC:HC) attain high values. According to Rybak et al. (1987) the increase in the Fe:Mn ratio and the lowering of the CD:TC ratio points to a period of high anoxic conditions in the lake, which is supported by the development of *Gleotrichia echinulata* which also appears abundantly in the pollen slides. The hypolimnetic oxygen depletion in this zone has been interpreted by these authors (p. 178) as the result of the presence of a forest curtain which would prevent hypolimnetic water from mixing. This interpretation is incorrect because palynological data indicate an earlier total deforestation of the lake catchment.

The same authors describe, though with some reservations, (p. 177) a sudden drop in water pH in this zone, as inferred from the diatom data. This calculation is based mainly on the dominant position of *Tabellaria flocculosa* var. *flocculosa* which is included in the acidobiontic, planktonic forms. This is also an erroneous interpretation. Battarbee (1986) pleads for care when interpreting diatom life-forms and gives *Tabellaria flocculosa* as an example of a taxon, which may occur in the plankton as well as in the periphyton. Round (1985) reports that *Tabellaria flocculosa* var. *flocculosa* is an epiphyte

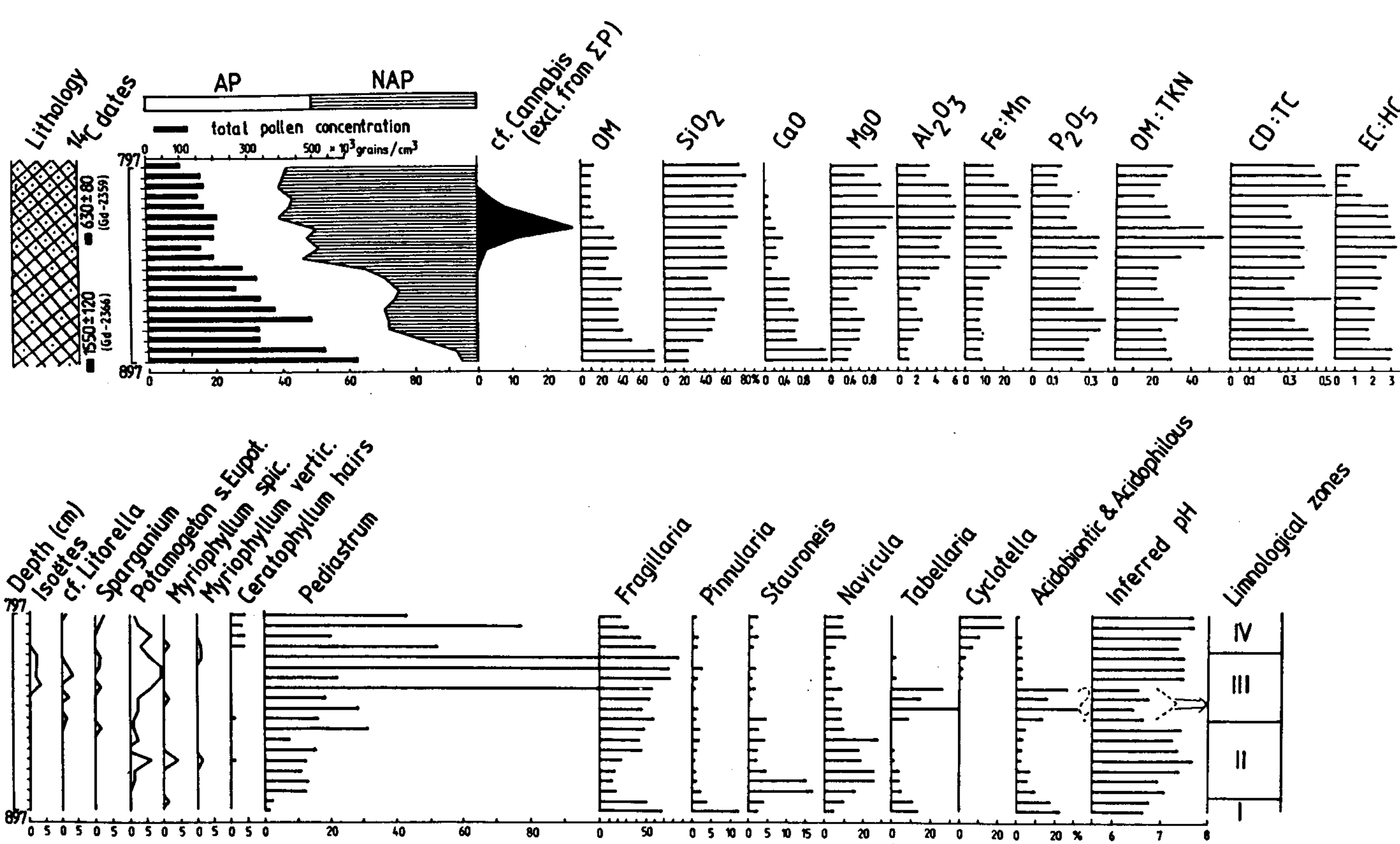

Fig. 35. A compilation of selected palynological (Latałowa, this paper) and palaeolimnological (Rybak 1987) data for the uppermost sediments of Lake Racze: OM – organic matter, TKN – total Kjeldhal nitrogen, CD – chlorophyll derivatives; TC – total carotenoids; EC – epiphasic carotenoids; HC – hypophasic carotenoids; the question mark, arrow and division into limnological zones according to the present author

which produces chains of cells extending outwards from the place of attachment and is, therefore, an organism which can form a much larger population than could be achieved solely by adnate specimens. The chains of cells are easy burst and when removed from its epiphytic site the cells can remain members of the pseudoplankton for some time. For this very reason *Tabellaria flocculosa* is often found in the central part of lakes. With regard to the pH requirements of this diatom, it is, in fact, generally classified as an acidobiontic form with an optimum pH of ca. 5.5 (Cholnoky 1968, Kalbe 1980), but many diatomists (e.g. Knudsen 1954) put it in the "indifferent" group. It has also been found as an epiphyte on *Cladophora glomerata* in the Skawa river, where the pH was between 7 and 8 (Chudyba 1968).

According to the opinion of the present author, most of the *Tabellaria flocculosa* valves come from the periphyton. Just like *Fragillaria*, which is dominant in this part of the profile and represented by *F. pinnata* and *F. pinnata* var. *subrotunda* (Rybak et al. 1987), *Tabellaria* could overgrow aquatic macrophytes, which at that time appeared in greater number (e.g. *Potamogeton* s. *Eupot.*, *Isoëtes*, cf. *Litorella uniflora*, *Myriophyllum ssp.*), not to mention the hemp steams sinking in the lake. The high proportion of periphyton forms in the profile was probably the result of both their more abundant development and the better possibilities for their displacement towards the central part of the lake, because of the intensive water mixing in the course of hemp retting.

Water eutrophication due to retting has been reported in several papers. In Lake Likolampi (Grönlund et al. 1986) the oxygen deficiency and eutrophication were manifested in both the sediment stratigraphy and in the disappearance of *Drepanocladus fluitans*, while in Bussjösjön (Regnéll 1989) a black sulphide gyttja was deposited due to oxygen depletion. A very strong eutrophication has also been recorded in numerous other Scandinavian lakes, for example Lake Lovojärvi (Huttunen & Tolonen 1975) or Bjaresjö (Gaillard & Berglund 1988). These data, as well as the results of the chemical analyses from Lake Racze itself, imply an opposite conclusion to that presented by Rybak et al. (1987) concerning changes in the pH values. This statement is supported by the fact that if we exclude *Tabellaria flocculosa* var. *flocculosa* from the acidobiontic forms we obtain a completely different graph of pH changes with a sharp pH increase in the zone under discussion. This unsound pH reconstruction has also influenced the following paper by Rybak (1987), in which a fossil chrysophycean cyst flora from the Lake Racze sediments has been described in terms of its ecological requirements. Some cyst's morphotypes, which have their optimum together with *Tabellaria flocculosa*, have been related to a lowering of pH values.

In the uppermost part of the Lake Racze profile (zone IV), the increase in planktonic forms, represented mainly by *Cyclotella comta*, shows the development of a pelagic zone, while the CD:TC and Fe:Mn ratios indicate an improvement in the hypolimnetic oxygen conditions (Rybak et al. 1987). A rise in the lake water table can be assumed. In this zone, representing the last 400–500 years, the lake trophic status decreased from that of the preceding period in which hemp retting was practised (zone III) and attained only a slightly higher level than in zone II.

It is interesting that the trophic status of Lake Racze has changed only slightly in more than 1000 years (apart from the period of hemp retting) despite the strong increase in farming activity around the site. This is probably the result of the specific ratio between the small catchment and the relatively large water volume of the lake together with a very low content of calcium carbonate in the surrounding soils.

In conclusion, the results of anthropogenic influence on the trophic conditions of the sites investigated have been differentiated. They are dependent on the character of the basin, features of its catchment and the intensity of human impact. With regard to the discussion and reinterpretation of the palaeolimnological results it should be emphasized that a thorough interpretation of this kind of data is not possible without the pollen analytical background.

SUMMARY AND FINAL CONCLUSIONS

Pollen diagrams (supplemented by charcoal particles and ash content data) from three sites are presented to show the considerable diversity of the landscape of Wolin Island in the past. This diversity was shaped by the ecological features of the area and the different anthropogenic pressures around the investigation sites. Pollen data from these relatively small (ca. 4–5 ha) basins illustrate mainly local changes, but the great similarity in the diagrams from the morainic part of the island (Kołczewo and Lake Racze), and the chronological accordance of most of the independently distinguished local pollen assemblage zones and anthropogenic phases, permit more general conclusions.

The various types of sediments investigated and their different growth rates forms the base of the discussion concerning the reliability of the palynological and chronological data. The interpretation of the nature and degree of human impact on the vegetation was influenced by differences in the accuracy of the pollen record caused by variations in the growth rate of the deposits. The best data come from the ombrogenic peat accumulated at the Kołczewo site during the last 3000 years.

Five stages of forest history have been described, primarily on the basis of the pollen profiles from the morainic part of Wolin Island (Kołczewo and Lake Racze): 1 – (8000* – ca. 5800* BP) development of forest communities dominated by mesophilous trees in which local disturbances by fire were probably initiated by Mesolithic people; 2 – (ca. 5800*–3400* BP) widespread coppicing of woodlands changed their structure as well as their species composition – *Quercus*, *Corylus* and *Tilia* were most important; limited clearances were also made; 3 – (ca. 3400*–2700* BP) large-scale deforestation on all kinds of habitat caused the disappearance of *Ulmus*, *Fraxinus* and *Tilia*, the restriction of *Corylus* and the spread of *Pinus* and *Betula* as well as gradual expansion of *Carpinus* and *Fagus* onto fallow land; 4 – (ca. 2700*–1300* BP) reforestation under conditions of decreasing human impact – succession towards forest communities dominated by beech or pine; 5 – since ca. 1300* BP general deforestation and gradual formation of the present-day cultural landscape.

The most striking vegetation feature in the sandy area of the southeastern part of the island (Wolin II profile) was the development of *Calluna* heath as a result of regular burning and probably also grazing of the *Pinus-Quercus-Betula* forest habitats. This vegetation type was maintained by active management from the Neolithic to the early Middle Ages.

An attempt has been made to compare the anthropogenic phases distinguished in the pollen diagrams with archaeological data. It seems clear that local man-made forest changes already took place in the Mesolithic. It is also assumed that in the late Mesolithic and at the Mesolithic/Neolithic transition, Ertebølle people probably lived on Wolin Island. Evidence of farming by Funnel Beaker and Corded Ware culture tribes in the Neolithic has been discussed. Fairly intense human activity has been recorded in the early Bronze Age (3500*–3300* BP), while in the late Bronze Age (Lusatian culture, 2900* – 2700* BP), the island's landscape was completely changed due to the very dense settlement. In the Iron Age human influence on vegetation, in general, began to decline, but settlement phases of the Jastorf culture (pre-Roman) and Gustow group (Roman) were identified in the Kołczewo diagram. A very good concurrence has been found between the pollen data and archaeological opinion concerning the Migration Period and the occupation of the early Middle Ages. In the morainic part of the island an economic recession started as early as the 2nd century AD while a total breakdown of farming activity occurred between ca. 5th and 7th century AD. However, in the southeastern part of the island in the vicinity of the crossing of the river Dziwna a continuity of habitation was highly probable. The development of numerous early medieval villages and the town of Wolin is clearly expressed in all the diagrams in which evidence of large-scale deforestation and the increasing role of cultivation have been recorded.

Different aspects of the prehistoric economy reflected in the pollen diagrams have been described. It is suggested that man has been actively changing woodland since the Mesolithic, creating better conditions for game and easier hunting. The first signs of farming activity have been indicated for the time corresponding to the late Ertebolle culture. The *Ulmus* decline, which in the diagrams from Wolin Island has been radiocarbon dated to ca. 5800* BP, seems to have been caused mainly by human interference. Despite the early appearance of cultivation (the first cereal pollen grains have been dated at ca. 5400*–5300* BP), animal husbandry was of prime importance during the Neolithic and Bronze Age. The role of cultivation increased somewhat at the Bronze/Iron Age transition (Lusatian culture) and in the Iron Age, but the real extension of arable land did not take place until the early Middle Ages.

The pollen diagrams from Wolin Island contain several indications of palaeohydrological events. The rises in the ground water table recorded in the Kołczewo (5820±130, 4730±100, 3900* BP, 3440±120, 2860±110 BP) and Wolin II profiles (ca. 6340±70, 4130±60, 3500* BP) were a consequence of anthropogenic changes to the forest cover. Climatically conditioned shifts towards more humid conditions on the Kołczewo raised bog have been dated to 3000*–2900*, 2600*–2500*, 2300±100, 2000* and 1500* BP; a probable climatic cause was also assumed for the rise in water level in Lake Racze after 630±80 BP. The following rises in the ground water table at the Wolin II site have been regarded as a result of fluctuation in the level of the Baltic Sea: 7320±520, 5700*- 5600* and 980±60 BP.

Changes in the trophic status caused by human interference have been discussed. The most interesting data come from the Lake Racze sediments in which evidence of hemp retting is clearly associated with considerable changes in the limnological properties of the former lake.

The pollen data presented in this paper indicate both the common features and the clear discrepancies in the vegetation history and palaeohydrology of the individual areas of Wolin Island. Dissimilarities in the woodland and cultural landscape development were noticed not only between relatively distant and strongly differentiated sites. It was also possible tc show rather clear differences in the the forest succession around the Lake Racze and Kołczewo sites, both of which lie in the morainic part of the island, at a distance of ca. 600 m from each other. These facts which are no surprise to botanists, draw our attention to the fact that the reconstruction of the past environment on a regional scale is a complex matter and should be based on a sufficient number of detailed and well dated pollen diagrams. This consideration stimulates further investigations, which include pollen analysis of the sediments of a large lake lying in the morainic area, farther to the west (Lake Czajcze). A so called "regional diagram" is expected from this site which, being devoid of the strictly local features which were the main advantage in terms of the present study, should help us to obtain a more regional picture of the dynamic development of the vegetation on Wolin Island and allow a more reliable correlation of these processes through the Baltic coastal zone of Poland.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to Professor Hanna Piotrowska and Professor Krystyna Wasylikowa for valuable and inspiring discussions and to Prof. Kazimierz Tobolski for his encouragement and stimulating advice, especially at the initial stage of this work.

I am greatly indebted to Professor Björn Berglund who made the lake corings possible and to Thomas Persson, Dr. Magnus Thelaus and Dr. Joachim Regnéll for doing them. Dr. Marie-José Gaillard-Lemdahl helped me complete some bibliographic details.

I am greatly grateful to M.Sc. Małgorzata Sajkowska for preparing settlement maps and Dr. Tadeusz Galiński and M.Sc. Ryszard Wołągiewicz for the discussion concerning prehistoric settlement in northwestern Poland.

I would like to thank all my colleagues at the Department of Plant Ecology and Nature Protection, University of Gdańsk but especially Dr. hab. Wiesław Fałtynowicz and M.Sc. Krzysztof Goss for help with the field work and peat borings, and Dr. Maria Herbichowa and Dr. Ryszard Markowski for valuable discussions in the field concerning problems of the present day vegetation. All the figures were drawn by M.Sc. Magdalena Jąkalska, while M.Sc. Jolanta Miądlikowska helped me with some of the laboratory work.

I am especially indebted to Dr. Sheila Hicks for the revision English language.

Finally I would also like to thank my husband Dr. Adam Latała who patiently prepared the manuscript and helped me with some work at the computer.

The study has been financially supported by MR-II-2 PAN and CBP 04.04 B.V.3 PAN Project Programmes.

REFERENCES

AABY B. 1976. Cyclic climatic variations in climate over the past 5.500 yr reflected in raised bogs. Nature, 263 (5575): 281–284.

— 1979. Characterization of peat and lake deposits. In: Berglund B.E. (ed.). Palaeoecological changes in the temperate zone in the last 15.000 years: Subproject B, lake and mire environments, Project guide vol. I, Dept. Quat. Geol., Lund University.

— 1983. Forest development, soil genesis and human activity illustrated by pollen and hypha analysis of two neighbouring podzols in Draved Forest, Denmark. Danm. Geol. Unders., 2: 1–114.

— 1986 a. Palaeoecological studies of mires. In: Berglund B. E. (ed.). Handbook of Holocene palaeoecology and palaeohydrology. J. Wiley & Sons Ltd, Chichester-New York.

— 1986 b. Trees as anthropogenic indicators in regional pollen diagrams from eastern Denmark. In: Behre K.-E. (ed.). Anthropogenic indicators in pollen diagrams. Balkema, Rotterdam-Boston.

— 1988. The cultural landscape as reflected in percentage and influx pollen diagrams from two Danish ombrotrophic mires. In: Birks H. H., Birks H. J. B., Kaland P. E. & Moe D. (eds). The cultural landscape – past, present and future. Cambridge Univ. Press.

— & TAUBER H. 1974. Rates of peat formation in relation to degree of humification of local environment, as shown by studies of raised bog in Denmark. Boreas, 4: 1–17.

AARIS-SØRENSEN K. & BRINCH PETERSEN E. 1986. The Prejlerup aurochs – an archaeozoological discovery from Boreal Denmark. Striae, 24: 111–117.

ADAMS S. N. 1975. Sheep and cattle grazing in forest. A review. The Journal of Applied Ecology, 12: 143–152.

ALHONEN P. 1987. Anthropogenic sedimentological changes during the Holocene: northern Europe. Striae, 26: 13–19.

AMMANN B. 1988. Palynological evidence of prehistoric anthropogenic forest changes on the Swiss Plateau. In: Birks H. H., Birks H. J. B., Kaland P. E. & Moe D. (eds). The cultural landscape – past, present and future. Cambridge Univ. Press.

ANDERSEN S. T. 1970. The relative pollen productivity and pollen representation of North European trees and correction factors for tree pollen spectra determined by surface pollen analyses from forests. Danm. Geol. Unders. II, 96.

— 1979. Identification of wild grass and cereal pollen. Danm. Geol. Unders., Årbog 1978: 69–92.

— 1984. Forest at Lövernholm, Djursland, Denmark, at present and in the past. Biol. Skr. Dan. Viol. Selsk., 24 (1): 1–210.

— 1988 a. Changes in agricultural practices in the Holocene indicated in a pollen diagram from a small hollow in Denmark. In: Birks H. H., Birks H. J. B., Kaland P. E. & Moe D. (eds). The cultural landscape – past, present and future. Cambridge Univ. Press.

— 1988 b. Pollen spectra from the Double Passage-Grave, Klekkendehoj, on Mon. Evidence of swidden cultivation in the Neolithic of Denmark. Journal of Danish Archaeology, 7: 77–92.

—, AABY B. & ODGAARD B. 1983. Environment and man. Current studies in vegetational history at the Geological Survey of Denmark. Journal of Danish Archaeology, 2: 184–196.

AUSTAD I. 1988. Tree pollarding in western Norway. In: Birks H. H., Birks H. J. B., Kaland P. E. & Moe D. (eds). The cultural landscape – past, present and future. Cambridge Univ. Press.

BARBER K. E. 1981. Peat stratigraphy and climatic changes. A palaeoecological test of the theory of cyclic peat bog regeneration. Balkema, Rotterdam.

BATTARBEE R. W. 1986. Diatom analysis. In: Berglund B. E. (ed.). Handbook of Holocene palaeoecology and palaeohydrology. Wiley & Sons Ltd., Chichester-New York.

BEHRE K.-E., 1981. The interpretation of anthropogenic indicators in pollen diagrams. Pollen et Spores, 23 (2): 225–245.

— 1988. The role of man in European vegetation history. In: Huntley B. & Webb III T. (eds). Vegetation history. Kluwer Acad. Publ., Dordrecht-London.

— & KUČAN D. 1986. Die Reflektion archäologisch bekannter Siedlungen in Pollendiagrammen verschiedener Entfernung – Beispiele aus der Siedlungskammer Flögeln, Nordwestdeutschland. In: Behre K.-E. (ed.). Anthropogenic indicators in pollen diagrams. Balkema, Rotterdam-Boston.

BENNET K. D., SIMONSON W. D. & PELGAR S. M. 1990. Fire and man in Past-Glacial woodlands of eastern England. Journal of Archaeological Science, 17: 635–642.

BERGLUND B. E. 1969. Vegetation and human influence in South Scandinavia during prehistoric time. Oikos Suppl., 12: 9–28.

— 1983. Palaeoclimatic changes in Scandinavia and on Greenland, a tentative correlation based on lake and bog stratigraphical studies. Quaternary Studies in Poland, 4: 27–44.

— 1985. Early agriculture in Scandinavia: research problems related to pollen-analytical studies. Norw. Arch. Rev., 18 (1–2): 77–90.

— 1986. The cultural landscape in a long-term perspective. Methods and theories behind the research on land-use and landscape dynamics. Striae, 24: 79–87.

— 1988. The cultural landscape during 6000 years in south Sweden – an interdisciplinary study. In: Birks H. H., Birks H. J. B., Kaland P. E. & Moe D. (eds). The cultural landscape – past, present and future. Cambridge Univ. Press.

—, EMANUELSSON U., PERSSON S. & PERSSON T. 1986. Pollen/vegetation relationship in grazed and mowed plant communities of south Sweden. In: Behre K.-E. (ed.). Anthropogenic indicators in pollen diagrams. Balkema, Rotterdam-Boston.

— & RALSKA-JASIEWICZOWA M. 1986. Pollen analysis and pollen diagrams. In: Berglund B. E. (ed.). Handbook of Holocene palaeoecology and palaeohydrology. J. Wiley & Sons Ltd, Chichester-New York.

BEUG H. J. 1961. Leitfaden der Pollenbestimmung. Gustav Fischer Verlag, Stuttgart.

— 1986. Vegetationsgeschichtliche Untersuchungen łber das Frłche Neolithikum im Untereichsfeld, Landskreis Göttingen. In: Behre K.-E. (ed.). Anthropogenic indicators in pollen diagrams. Balkema, Rotterdam-Boston.

BINKA K., CIEŚLA A., ŁĄCKA B., MADEYSKA T., MARCINIAK B., SZEROCZYŃSKA K. & WIĘCKOWSKI K. 1991. The development of Błędowo Lake (Central Poland) – a palaeoecological study. Studia Geologica Polonica, 100.

BIRKS H. J. B. 1973. Past and present vegetation of the Isle of Sky – a palaeoecological study. Cambridge Univ. Press, London.

— 1986a. Late-Quaternary biotic changes in terrestial and lacustrine environments, with particular reference to north-west Europe. In: Berglund B. E. (ed.). Handbook of Holocene palaeoecology and palaeohydrology. J. Wiley & Sons LTD, Chichester-New York.

— 1986b. Numerical zonation, comparison and correlation of Quaternary pollen-stratigraphical data. In: Berglund B. E. (ed.). Handbook of Holocene palaeoecology and palaeohydrology. J. Wiley & Sons Ltd, Chichester-New York.

— BERGE F., BOYLE J. F. & CUMMING B. F. 1990. A palaeoecological test of the land-use hypothesis for recent lake acidification in South-West Norway using hill-top lakes. Journal of Paleolimnology 4: 69–85.

— & BIRKS H. H. 1980. Quaternary palaeoecology. Edward Arnold, London.

—, LINE J. M. & PERSSON T. 1988. Quantitative estimation of human impact on cultural landscape development. In: Birks H. H., Birks H. J. B., Kaland P. E. & Moe D. (eds). The cultural landscape – past, present and future. Cambridge Univ. Press.

BLACKFORD J. J. & CHAMBERS F. M. 1991. Proxy records of climate from blanket mires: evidence for a Dark Age (1400 BP) climatic deterioration in the British Isles. The Holocene 1 (1): 63–67.

BOGACZEWICZ-ADAMCZAK B. 1990. Paleolimnologia jezior Borów Tucholskich w świetle badań kopalnych okrzemek (summary: The paleolimnology of the Bory Tucholskie (Tuchola Forest) lakes in the light of studies of fossilized diatoma). Zeszyty Naukowe, Rozprawy i monografie, 150. Uniwersytet Gdański, Gdańsk.

BOROWIEC S. 1969. Zagadnienia gleboznawczo-siedliskowe WoliNskiego Parku Narodowego, Szczecin. Tow. Nauk., Wydz. Przyr.-Roln., 31(3): 3–59.

BOROWIK-DĄBROWSKA M. 1985. Uwagi botanika na marginesie pracy J. Kruka, Gospodarka w Polsce południowo-wschodniej w V-III tysiącleciu p.n.e., (summary: A botanists remarks on the margin of J. Kruk's work, Economy in south-eastern Poland in the fifth to third millenia B. C.). Archeologia Polski, 30 (2): 411–434.

BOSTWICK-BJERCK L. G. 1988. Remodelling the Neolithic in southern Norway: another attack on a traditional problem. Norw. Arch. Rev., 21 (1): 21–33.

BRADSHAW R. H. W., COXON P., GREIG J. R. A. & HALL A. R. 1981. New fossil evidence for past cultivation and processing of hemp (Cannabis sativa L) in eastern England. New Phytol., 89: 503–510.

BUKOWSKI Z. 1981. Europa od połowy II do połowy I tysiąclecia p.n.e. In: Kozłowski S. K. (ed.). Kultury i ludy dawnej Europy. PWN, Warszawa.

BUSH M. B. 1988. Early Mesolithic disturbance: a force on the landscape. Journal of Archaeological Science, 15: 453–462.

CASELDINE C. J. & MAGUIRE D. J. 1986. Lateglacial/early Flandrian vegetation change on northern Dartmoor, south-west England. Journal of Biogeography, 13: 255–264.

CASPARIE W. A. & GROENMAN-VAN WAATERINGE W. 1980. Palynological analysis of Dutch barrows. Palaeohistoria, 22: 7–65.

CELIŃSKI F. 1962. Zespoły leśne Puszczy Bukowej pod Szczecinem (summary: The forest communities of the Puszcza Bukowa near Szczecin). Monogr. Bot., 13, Suppl. : 3–208.

CHAMBERS F. M., KELLY R. S. & PRICE S.-M. 1988. Development of the late-prehistoric cultural landscape in upland Ardudwy, north-west Wales. In: Birks H. H., Birks H. J. B., Kaland P. E. & Moe D. (eds). The cultural landscape – past, present and future. Cambridge Univ. Press.

CHOIŃSKI A., KOWALSKI G., ŚWIRKO A. & ZIMMER A. 1978. Stosunki wodne wyspy Wolin. In: Kostrzewski A. (ed.). Studia z geografii fizycznej i ekonomicznej wyspy Wolin. Studenckie Koło Geografów im. S. Pawłowskiego, Uniw. A. Mickiewicza w Poznaniu, Poznań.

CHOLNOKY T. J. 1968. The ecology of diatom in inland waters. I, Cramer, Lehre.

CHUDYBA H. 1968. Cladophora glomerata i glony towarzyszące w rzece Skawie. Rozmieszczenie i warunki występowania (summary: Cladophora glomerata and concomitant algae in the river Skawa. Distribution and conditions of appearance). Acta Hydrobiol., 10 (1–2): 39–84.

CNOTLIWY E. 1961. Wyniki archeologicznych badań ratunkowych na Wzgórzu Wisielców w Wolinie w 1959 r. Materiały Zachodniopom., 7: 181–292.

— 1966. Powiat kamieński w starożytności. Muzeum Pomorza Zachodniego, Szczecin.

CZARNECKI M. 1983. Początki zasiedlania w paleolicie i mezolicie. In: Filipowiak W. & Labuda G. (eds). Pradzieje Szczecina. PWN, Warszawa-Poznań.

CZUBIŃSKI Z. 1950. Zagadnienia geobotaniczne Pomorza. Bad. Fizjogr. Pol. Zach., 2 (4): 439–658.

DIGERFELDT G. & LETTEVALL U. 1969. A new type of sediment sampler. Geol. Fören. Stockh. Förhandl., 91: 399–406.

DOMAŃSKA G. & WOŁĄGIEWICZ R. 1981. Kultura jastorfska. In: Wielowiejski J. (ed.). Prahistoria ziem polskich. Vol. V. Późny okres lateński i okres rzymski. Ossolineum, Wrocław-Gdańsk.

DÖRFLER W. 1988. Einige Aspekte zur Anwendung der Pollenanalyse in der Ur- und Frühgeschichtsforschung. Archäeologische Informationen 11 (1): 32–38.

— 1989. Polenanalytische Untersuchungen zur Vegetations- und Siedlungsgeschichte im Süden des Landkreises Cuxhaven, Niedersachsen. Problems der Küstenforschung im südlichen Nordseegebiet, 17: 1–75.

— 1990. Palynological investigations in area of Kosel. In: Behre K.-E. (ed.). Environment and settlement history in the N. German coastal region. Excursion Guide. Niedersächsisches Institut für historische Küstenforschung, Wilhelmshaven 13–20 Sept. 1990.

DUPONT L. M. 1985. Temperature and rainfall variation in a raised bog ecosystem; a palaeoecological and isotope-geological study. Thesis, Universiteit van Amsterdam, pp. 1–162.

— & BRENNINKMEIJER C. A. M. 1984. Palaeobotanic and isotopic analysis of late Subboreal and early Subatlantic peat from Engbertsdijksveen VII, The Netherlands. Review of Palaeobot. Palynol., 41: 241–271.

DZWONKO Z. 1990. Ekologia. In: Białobok S. (ed.). Buk zwyczajny – Fagus sylvatica L. Nasze drzewa leśne, vol. 10, PWN, Warszawa – Poznań.

EDWARDS K. J. 1988. The hunter-gatherer/agricultural transition and the pollen record in the British Isles. In: Birks H. H., Birks H. J. B., Kaland P. E. & Moe D. (eds). The cultural landscape – past, present and future. Cambridge Univ. Press.

ERDTMAN G., , BERGLUND B. E. & PRAGLOWSKI J. 1961. An introduction to a Scandinavian pollen flora. Almqvist & Wicksell, Stockholm.

FAEGRI K & IVERSEN J. 1975. Textbook of pollen analysis. Munksgaard, Copenhagen.

FILIPOWIAK W. 1973. Wyspa Wolin w prahistorii i we wczesnym średniowieczu. In: Białecki T. (ed.). Z dziejów Ziemi wolińskiej. Inst. Zachodniopom. w Szczecinie, Stow. Kult. Ziemi Wolińskiej w Świnoujściu, Szczecin.

— 1985. Słowiańskie początki "uprawy" morza. Z otchłani wieków, 3–4: 189–199.

— 1986. Vineta. Ausgrabungen in einer versunkenen Stadt. Kulturhistorishes Museum Rostock DDR, Ostsee-Druck Rostock.

— 1988. Handel und Handelsplätze an der Ostseeküste Westpommerns. In: Oldenburg – Wolin -Staraja Ladoga – Novgorod – Kiev. Handel und Handelsverbindungen im südlichen und östlichen Ostseeraum während des frühen Mittelalters. Bericht der Römisch – Germanischen Komm., 69: 690–719.

FLORIN M.-B. 1969. Late-Glacial and Pre-Boreal vegetation in central Sweden. I. Records of pollen species. Sv. Bot. Tidskr., 63 (1): 143–187.

FUKAREK F. 1961. Die Vegetation des Darss und ihre Geschichte. Pflanzensoziologie 12: 1–321.

GAILLARD M.-J. 1984. A palaeohydrological study of Krageholmssjön (Scania, South Sweden). Lundqua, Report 25.

— 1985 Postglacial palaeoclimatic changes in Scandinavia and central Europe. A tentative correlation based on studies of lake level fluctuations. Ecol. Medit., 11 (1): 159–175.

— & BERGLUND B. E. 1987. Land-use history during the last 2700 years in the area of Bjäresjö, S. Sweden. En arbetsrapport fran Kulturlandskapet under 6.000 ar, ett project stött av Riksbankens jubileumsfond. Växtekologiska Institutionen. Lunds Universitet, pp. 36.

— & BERGLUND B. E. 1988. Land-use history during the last 2700 years in the area of Bjäresjö, southern Sweden. In: Birks H. H., Birks H. J. B., Kaland P. E. & Moe D. (eds). The cultural landscape – past, present and future. Cambridge Univ. Press.

GALIŃSKI T. in print. Zespoły typu Tanowo. Zachodniopomorski ekwiwalent ugrupowania Ertebølle-Ellerbek-Lietzow. Materiały Zachodniopom., 33.

GARBET G. G. 1981. The elm decline: the depletion of a resource. New Phytol., 88: 573–585.

GARDAWSKI A. 1979. Podstawy gospodarki. In: Dąbrowski J. & Rajewski Z. (eds). Prahisroria ziem polskich, vol. IV, Od środkowej epoki brązu do środkowego okresu lateńskiego. Ossolineum, Wrocław – Gdańsk.

GEEL VAN B., BREGMAN R., MOLEN VAN DER P. C., DUPONT L. M. & DRIEL-MURRAY VAN C. 1989. Holocene raised bog deposits in the Netherlands as geochemical archives of prehistoric aerosols. Acta Bot. Neerl., 38 (4): 467–476.

GIMINGHAM C. H. 1972. Ecology of heathlands. Science Paperbacks, Chapman & Hall, London.

—, CHAPMAN S. B. & WEBB N. R. 1979. European heathlands. In: Specht R. L. (ed.). Heathlands and related shrublands, ecosystems of the world, Elsevier Scientific Publishing Company, Amsterdam-New York.

GIRLING M. A. 1988. The bark beetle Scotylus scotylus (Fabricius) and the possible role of elm disease in the early Neolithic. In: Jones M. (ed.). Archaeology and the flora of the British Isles. Oxford University Committee for Archaeology, 14: 34–38.

GODŁOWSKI K. 1989. Ziemie polskie w okresie wędrówek ludów. Problem pierwotnych siedzib Słowian. Barbaricum, Wyd. Uniw. Warszawskiego, Warszawa.

GODWIN H. 1975. History of the British Flora. Cambridge University Press, Cambridge.

GÖRANSSON H. 1982. The utilization of the forests in north-west Europe during early and middle Neolithic. PACT, 7: 207–221.

— 1984. Pollen analytical investigations in the Sligo Area. In: Burenhult G. (ed.). The Archaeoecology of Carrowmore. Theses and papers in North-European archaeology, 14: 154–187.

— 1986. Man and forests of nemoral broad-leafed trees during the Stone Age. Striae, 24: 143–152.

— 1987 a. Neolithic man and the forest environment around Alvastra pile dwelling. Theses and papers in North-European archaeecology, 20: 1–90.

— 1987 b. Comments on early agriculture in Scandinavia. Norw. Arch. Rev., 20 (1): 43–45.

— 1988. Comments on remodelling the Neolithic in soutern Norway. On pollen analytical myths. Norw. Arch. Rev., 21 (1): 33–37.

— 1991. Vegetation and man around Lake Bjärsjöholmssjön during prehistoric time. Lundqua Report, 31: 1–44.

Gramsch B. 1978. Die Lietzow-Kultur Rügnes und ihre Beziehungen zur Ostseegeschichte. Petermanns Geogr. Mitt., 122: 155–164.

GROENMAN-VAN WAATERINGE W. 1979. The origin of crop weed communities composed of summer annuals. Vegetatio, 41 (2): 57–59.

— 1983. The early agricultural utilization of the Irish landscape: the last word on the elm decline? BAR, British Ser., 116: 217–232.

— 1986. Grazing possibilities in the Neolithic of the Netherlands based on palynological data. In: Behre K.-E. (ed.). Anthropogenic indicators in pollen diagrams. Balkema, Rotterdam-Boston.

— 1988. New trends in palynoarchaeology in northwest Europe or the frantic search for local pollen data. In: Esmée Webb R. (ed.). Recent developments in environmental analysis in Old and New World archaeology, BAR Int. Ser., 416: 1–19.

GRÖNLUND E., SIMOLA H. & HUTTUNEN P. 1986. Paleolimnological reflections of fiber-plant retting in the sediment of a small clear-water lake. Hydrobiologia, 143: 425–431.

HAEGGSTRÖM C.-A. 1990. The influence of sheep and cattle grazing on wooded meadows in Aland, SW Finland. Acta Bot. Fennica 141: 1–28.

HEGI G. 1965. Illustrierte Flora von Mitteleuropa, Vol. 5 (1). Carl Hauser Verl., München.

HENSEL W. 1980. Polska starożytna. Ossolineum, Wrocław – Gdańsk.

HERSE J. 1982. Szczegółowa uprawa roślin. PWN, Warszawa.

HICKS S. 1975. Variations in pollen frequency in a bog at Kangerjoki, N. E. Finland during the Flandrian. Commentationes Biologicae, 80: 1–28.

— 1988. The representation of different farming practices in pollen diagrams from northern Finland. In: Birks H. H., Birks H. J. B., Kaland P. E. & Moe D. (eds). The cultural landscape – past, present and future. Cambridge Univ. Press.

HIRONS R. K. & EDWARDS K. J. 1986. Events at and around the first and second Ulmus declines: palaeoecological investigations in Co. Tyrone, Northern Ireland. New Phytol., 104: 131–153.

HJELMROOS-ERICSSON M. 1981. Holocene development of Lake Wielkie Gacno area, northwestern Poland. Lund University. Dept. of Quat. Geol., Thesis 10.

HOFSTEDE J. L. A., BERENDSEN H. J. A. & JANSSEN C. R. 1989. Holocene palaeogeography and palaeoecology of the fluvial area near Maurik (Neder-Betuwe, The Netherlands). Geologie en Mijnbouw, 68: 409–419.

HUNTLEY B. 1988. Europe. In: Huntley B. & Webb III T. (eds). Vegetation history. Kluwer Academic Publ., Dordrecht-London.

— & BIRKS H. J. B. 1983. An atlas of past and present pollen maps for Europe: 0–13.000 years ago. Cambridge University Press. Cambridge.

HUTTUNEN P. & TOLONEN K. 1975. Human influence in the history of Lake Lovojärvi, S. Finland. Finskt Museum, 1975: 68–105.

ILKIEWICZ J. 1989. From studies on cultures of the 4th millenium B. C. in the central part of the Polish coastal area. Przegl. Archeol., 36: 17–55.

INNES J. B. & SIMMONS I. G. 1988. Disturbance and diversity: floristic change associated with pre-elm decline woodland recession in north east Yorkshire. In: Jones M. (ed.). Archaeology and the flora of the British Isles. Oxford University Committee for Archaeology, 14: 7–20.

IVERSEN J. 1941. Land occupation in Denmark's Stone Age. Danm. Geol. Unders., II, 66: 1–65.

— 1944. Viscum, Hedera and Ilex as climatic indicators. Geol. För. Förh., 66(3): 463–483.

— 1960. Problems of the early Postglacial forest development in Denmark. Danm. Geol. Unders., IV, 4 (3): 1–32.

— 1973. The development of Denmark's nature since the last glacial. Danm. Geol. Unders., V, 7-C: 1–126.

JACOBI R. M., TALLIS J. H. & MELLARS P. A. 1976. The soutern Pennine Mesolithic and the ecological record. Journal of Archaeological Science, 3: 307–320.

JACOBSON G. L. JR. & BRADSHAW R. H. W. 1981. The selection of sites for palaeovegetational studies. Quaternary Research, 16: 80–96.

JANKOWSKA D. 1983. Kultury pucharów lejkowatych i amfor kulistych na Pomorzu. In: Malinowski T. (ed.). Problemy epoki kamienia na Pomorzu. Wyższa Szkoła Pedagogiczna w Słupsku, Słupsk.

JENBERT K. 1988. Der Neolithisierungsprozess in Südskandinavien. Praehistorische Zeitschrift 63 (1): 1–22.

JENSEN H. A. 1985. Cataloque of late- and post- glacial macrofossils of Spermatophyta from Denmark, Schleswig, Scania, Halland and Blekinge dated 13.000 B.P. to 1.536 A.D. Danm. Geol. Unders., Ser. A, 6.

KALAND P. E. 1986. The origin and management of Norwegian coastal heaths as reflected by pollen analysis. Behre K.-E. (ed.). Anthropogenic indicators in pollen diagrams. Balkema, Rotterdam – Boston.

KALBE L. 1980. Kieselalgen in Binnengewässern. A. Zimsen Verlag, Wittenberg Lutherstad.

KALIS A. J. 1980. Papaveraceae. In: Punt W. & Clarke G. C. S. (eds). The Northwest European pollen flora. Vol. II. Elsevier Sci. Publ. Comp., Amsterdam – New York.

KLICHOWSKA M. 1961. Wczesnośredniowieczne szczątki roślinne odkryte w Wolinie na stanowisku wykopaliskowym 4 w latach 1953–1955. Mat. Zachodniopom., 7: 457–461.

— 1967 a. "Wzgórze Wisielców" w Wolinie Pomorskim w świetle badań botanicznych. Mat. Zachodniopom., 11 (1965): 571–576.

— 1967 b. Szczątki roślinne ze stanowiska archeologicznego Wolin-Młynówka. Mat. Zachodniopom., 11 (1965): 577–579.

— 1972. Rośliny naczyniowe w znaleziskach kulturowych Polski północno-zachodniej (summary: Vascular plants in archaeological excavations of north-western Poland from the Neolithic to the early Middle Ages). Pozn. Tow. Przyj. Nauk, Wydz. Mat.-Przyr., Prace Kom. Biol., 35 (2): 3–74.

KLIEWE H. 1960. Die Insel Usedom in ihrer spät- und nacheiszeitlichen Formenentwicklung, Neuere Arb. Z. Mecklenburg. Küstenforschung 5, Berlin.

— & JANKE W. 1978. Zur stratigraphic und Entwicklung des nordöstlichen Küstenraumes der DDR. Pettermanns Geogr. Mitt., 122: 81–92.

KLOSS K. 1987. Pollenanalysen zur Vegetationsgeschichte, Moorentwicklung und mesolithisch-neolithischen Besiedlung im Unteren Rhinluch bei Friesack, Bezirk Potsdam. Veröffentlichungen des Museums für Ur- und Frühgeschichte Potsdam, 21: 101–120.

— 1990. Anthropogenic indicators in early Mesolithic vegetation in north-east Germany. Abstracts of lectures and posters, Symposium 15–17.09.1990 in Wilhelmshaven, INQA-Commission for the Study of the Holocene, Working group: Impact of Prehistoric and Medieval Man on Vegetation, pp. 2.

KNUDSEN B. M. 1954. The ecology of the diatom genus Tabellaria in the English Lake District. J. Ecol., 42: 345–358.

KOLP O. 1976. Submarinen Uferterrassen der südlichen Ost- und Nordsee als Marken des holozänen Meeresanstiegs und der Überflutungsphasen der Ostsee. Pettermanns Geogr. Mitt., 120: 1–23.

KOTLIŃSKI R. 1991. Sediments of the Southern Baltic Sea, their deposition and lithostratigraphy. Kwartalnik Geologiczny, 35 (1): 81–106.

KOZŁOWSKI J. K. & KOZŁOWSKI S. K. 1981. Europa do V tysiąclecia p.n.e. In: Kozłowski S. K. (ed.). Kultury i ludy dawnej Europy. PWN, Warszawa.

KOZŁOWSKI S. K. (ed.). 1981. Kultury i ludy dawnej Europy. PWN, Warszawa.

— 1989. Mesolithic in Poland. A new approach. Uniwersytet Warszawski, Warszawa.

KRISTIANSEN K. 1978. The consumption of wealth in Bronze Age in Denmark. A study in the dynamics of economic processes in tribal societies. In: Kristiansen K. & Paludan-Müller C. (eds). New directions in Scandinavian archaeology. National Museum of Copenhagen, Copenhagen.

KRUK J. 1980. Gospodarka w Polsce południowo-wschodniej w V-III tysiącleciu p.n.e. (summary: Economy in south-eastern Poland in the 5th–3th centuries B.C.). Ossolineum, Wrocław-Gdańsk.

KRYGOWSKA L. & KRYGOWSKI B. 1965. Kilka spostrzeżeń dotyczących struktury klifu w Grodnie na Wolinie. Bad. Fizjogr. Pol. Zach., 15: 167–170.

LAMB H. H. 1977. Climate: present, past and future. Methuen & Co., London.

LANGE E. 1971. Botanische Beiträge zur mitteleuropäischen Siedlungsgeschichte. DAW, Schrift. z. Ur- u. Frühgeschichte 27, 142 pp. & Figs.

LANGE E. 1975. The development of agriculture during the first millenium A.D. Geol. Förh., 97: 115–124.

— 1986. Pollenanalytische Untersuchungen von Burggrabensedimenten aus der nordwestlichen Niederlausitz – Ein Beitrag zu methodischen Fragen der Auswertung von Pollendiagrammen und zur slawischen Landwirtschaft. In: Behre K.-E. (ed.). Anthropogenic indicators in pollen diagrams. Balkema, Rotterdam-Boston.

—, JESCHKE L. & KNAPP H. D. 1986. Die Landschaftsgeschichte der Insel Rügen seit dem Spätglazial. DAW, Schrift. z. Ur- u. Frühgeschichte 38, pp. 175 & Figs.

LARSSON M. 1989. The Funnel Beaker culture during early and middle Neolithic. Economic and social changes. Acta Archeol. Ludensia, ser. 4.

LATAŁOWA M. 1982. Postglacial vegetational changes in the eastern Baltic coastal zone of Poland. Acta Palaeobot., 22 (2): 179–249.

— 1985. Warunki przyrodnicze osadnictwa prahistorycznego w okolicach jeziora Żarnowieckiego w świetle badań paleobotanicznych (summary: The natural conditions of prehistoric settlement in the area of Lake Żarnowiec in the light of palaeobotanical studies. Archeologia Polski, 30 (2): 261–286.

— 1989 a. Type region P-t: Baltic Coastal Zone. In: Ralska-Jasiewiczowa M. (ed.). Environmental changes recorded in lakes and mires of Poland during the last 13.000 years. P. III., Acta Palaeobot., 29 (2): 103–108.

— 1989 b. Type region P-u: Baltic Shore, W part Wolin Island. In: Ralska-Jasiewiczowa M. (ed.). Environmental changes recorded in lakes and mires of Poland during the last 13.000 years. P. III., Acta Palaeobot., 29 (2): 115–120.

— in print a. Forest changes at the Mesolithic/early Neolithic transition and in the Migration Period on Wolin Island (NW Poland). Proceedings of the ESF Workshop on "Evaluation of land surfaces cleared from forests by prehistoric man in early Neolithic times and the time of migrating germanic tribes", Mainz, March 1990, Palaeoklimaforschung.

— in print b. The last 1.500 years on Wolin Island in the light of the palaeobotanical studies. Festchrift prof. van Zeist, Review of Palaeobot. Palynol.

— & TOBOLSKI K. 1989. Type region P-u: Baltic Shore. In: Ralska-Jasiewiczowa M. (ed.). Environmental changes recorded in lakes and mires of Poland during the last 13.000 years. P. III., Acta Palaeobot., 29 (2): 109–114.

LECIEJEWICZ L. & WIECZOROWSKI T. 1983. Wczesne średniowiecze do czasu ukształtowania się miasta (VI-X wiek). In: Filipowiak W. & Labuda G. (eds). Pradzieje Szczecina. PWN, Warszawa-Poznań.

LEPIKSAAR J. 1986. The Holocene history of theriofauna in Fennoscandia and Baltic countries. Striae, 24: 51–70.

LINKOLA K. 1916. Studien über den Einfluss der Kultur auf die Flora in den Gegenden nördlich vom Ladogasee I. Allgemeiner Teil. Acta Soc. Fauna Flora Fennica, 45 (1): 1–429.

LUCAS C. 1860. Flora der Insel Wollin. Verh. d. Bot. Ver. f. d. Prov. Brandenburg u. d. angrenzenden Länder. 2, Berlin.

MALMROS C. 1986. A Neolithic road built of wood at Tibirke, Zealand, Denmark. Contribution to the history of coppice management in the Sub-Boreal period. Striae, 24: 153–156.

MARKOWSKI R. 1971. Regeneracja acidofilnych zbiorowisk leśnych na porębach wysp Wolina i południowo-wschodniego Uznamu (summary: Regeneration of acidophilous forest communities on clearings of the island Wolin and south-eastern Uznam). PTPN, Wydz. Mat.- Przyr., Prace Kom. Biol., 35 (1): 1–29.

— 1982. Sukcesja wtórna roślinności na porębach lasów liściastych (summary: Secondary succession of vegetation on clear cuttings in deciduous forests). PTPN, Wydz. Mat.- Przyr., Prace Kom. Biol., 61: 1–77.

MATUSZKIEWICZ W. 1982. Przewodnik do oznaczania zbiorowisk roślinnych Polski. PWN, Warszawa.

MIDDELDORP A. A. 1982. Pollen concentration as a basis for indirect dating and quantifying net organic and fungal production in a peat bog ecosystem. Review Palaeobot. Palynol., 37: 225–282.

MIOTK-SZPIGANOWICZ G. 1992. The history of the vegetation of Bory Tucholskie and the role of man in the light of palynological investigations. Acta Palaeobot., 32 (1): 39–122.

MŁODZIKOWSKI Z. 1986. Klimat Wolińskiego Parku Narodowego. In: Kostrzewski A (ed.). Woliński Park Narodowy, Monografia Geograficzna. Studenckie Koło Naukowe Geografów im. S. Pawłowskiego, Uniw. A. Mickiewicza w Poznaniu, Poznań.

MOLLOY K. & O'CONNELL M. 1987. The nature of the vegetational changes at about 5000 BP with particular reference to the elm decline: fresh evidence from Connemara, western Ireland. New Phytol., 106: 203–220.

— & O'CONNELL M. 1991. Palaeoecological investigations towards the reconstruction of woodland and land-use history at Lough Sheeauns, Connemara, Western Ireland. Review Palaeobot. Palynol., 67: 75–113.

MONOSHON M. K. 1973. Opredelitel' pyl'tsy vidov semeistva marevykh. Izd. Nauka, Moskwa.

MOORE P. D. 1983. Palynological evidence of human involvement in certain palaeohydrological events. Quaternary Studies in Poland, 4: 97–105.

— 1985. Forests, man and water. Intern. J. Environmental studies, 25: 159–166.

— 1988. The development of moorlands and upland mires. In: Jones M. (ed.). Archaeology and the flora of the British Isles. Oxford University Committee for Archaeology, 14: 116–122.

—, EVANS A. T. & CHATER M. 1986. Palynological and stratigraphic evidence for hydrological changes in mires associated with human activity. In: Behre (ed.). Anthropogenic indicators in pollen diagrams. Balkema, Rotterdam-Boston.

—, MERRYFIELD D. L. & PRICE M. D. R. 1984. The vegetation and development of blanket mires. In: Moore P. D. (ed.). European mires. Academic Press, London.

MÜLLER-WILLE M., DÖRFLER W., MEIER D. & KROLL H. 1988. The transformation of rural society, economy and landscape during the first millenium A.D.: Archaeological and palaeobotanical contributions from northern Germany and southern Scandinavia. Geogr. Ann. 70B (1): 53–68.

NIETSCH H. 1934. Waldgeschichtliche Untersuchungen im westlichen Ostpommern und in der angrezenden Neumark. Dohrniana, 13: 3–137. Niewiarowski W. 1987. Development of Lake Strażym (Brodnica Lake District) during the Late-Glacial and Holocene. Acta Palaeobot., 27 (1): 251–268.

NOWIŃSKI M. 1964. Chwasty segetalne wyspy Wolin. Pozn. Tow. Przyj. Nauk, Prace Kom. Biol., 22 (6): 3–39.

OBMIŃSKI Z. 1970. Zarys ekologii. In: Białobok S. (ed.). Sosna zwyczajna – Pinus silvestris L. Nasze drzewa leśne, Vol. 1, PWN, Warszawa – Poznań.

ODGAARD B. V. 1988. Heathland history in western Jutland, Denmark. In: Birks H. H., Birks H. J. B., Kaland P. E. & Moe D. (eds). The cultural landscape – past, present and future. Cambridge Univ. Press.

OINONEN E. 1967. Sporal regeneration of bracken (Pteridium aquilinum (L.) Kuhn.) in Finland in the light of the dimensions and the age of its clones. Acta Forestalia Fennica 83 (1): 1–96.

ORWAT F. 1958. Wyniki analizy pyłkowej dwu torfowisk na wyspie Wolin (summary: The results of pollen analysis of two peatbogs on the Island of Wolin). Bad. Fizjogr. Pol. Zach., 4: 253–264.

OSTOJA-ZAGÓRSKI J. 1974. From studies on the economic structure at the decline of the Bronze Age and the Hallstatt period in the north and west zone of the Odra and Vistula Basins. Przegl. Archeol., 22: 123–150.

ØSTMO E. 1988. Comments on remodelling the Neolithic in southern Norway. Norw. Arch. Rev., 21 (1): 44–46.

PÅHLSSON J. 1981. Cannabis sativa in Dalarna. Striae 14: 79–82.

PAWLIKOWSKI M., RALSKA-JASIEWICZOWA M., SCHÖNBORN W., STUPNICKA E. & SZEROCZYŃSKA K. 1982. Woryty near Gietrzwałd, Olsztyn Lake District, NE Poland – vegetational history and lake development during the last 12000 years. Acta Palaeobot., 22 (1): 85–116.

PAWŁOWSKI B. & ZARZYCKI K. 1972. Zespoły łąkowe i wrzosowiskowe. In: Szafer W. & Zarzycki K. (eds). Szata roślinna Polski. Vol. I, PWN, Warszawa.

PIOTROWSKA H. 1966 a. Rośliny naczyniowe wysp Wolina i południowo- wschodniego Uznamu. Pozn. Tow. Przyj. Nauk, Wydz. Mat.-Przyr., Prace Kom. Biol., 30 (4): 1–282.

— 1966 b. Stosunki geobotaniczne wysp Wolina i południowo-wschodniego Uznamu (summary: Geobotanical study of the Wolin and South-East Uznam Isles). Monogr. Bot., 22: 3–157.

— & CELIŃSKI F. 1965. Zespoły psammofilne wysp Wolina i południowo-wschodniego Uznamu. Bad. Fizjogr. Pol. Zach., 16: 123–170.

— & OLACZEK R. 1976. Inwentaryzacja fitosocjologiczna wraz z kartowaniem zbiorowisk roślinnych Wolińskiego Parku Narodowego. M. S. Uniwersytet Gdański – Uniwersytet Łódzki.

— & OLACZEK R. 1987. The application of the theory of phytocoenosis degeneration to studies of the vegetation in the Wolin National Park. M. Luther-Universität Halle-Wittenberg Wissenschaftliche Beitr., 1987/46 (P31), 3: 175–186.

PODBIELKOWSKI Z. & TOMASZEWICZ H. 1979. Zarys hydrobotaniki. PWN, Warszawa.

POEL L. W. 1961. Soil aeration as a limiting factor in the growth of Pteridium aquilinum (L.) Kuhn. J. Ecol., 49 (1): 107–111.

POST VON L. 1924. Das genetische System der organogenen Bildungen Schwedens. Comite Intern. de Pédologie. IV Commision, 22: 287–304.

POTT R. 1984. Pollenanalytische Untersuchungen zur Vegetations- und Siedlungsgeschichte im Gebiet der Borkenberge bei Haltern in Westfalen. Abhandl. Westfälischen Museum für Naturkunde, 46 (2): 3–28.

— 1986. Der pollenanalytische Nachweis extensiver Waldbewirtschaftungen in den Haubergen des Siegerlandes. In: Behre K.-E.(ed.). Anthropogenic indicators in pollen diagrams. Balkema, Rotterdam – Boston.

— 1988. Entstehung von Vegetationstypen und Pflanzengesellschaften unter dem Einfluss des Menschen. Düsseldorfer Geobot. Kolloq., 5: 27–54.

— 1990. Die Haubergswirtschaft im Siegerland. Wilhelm-Münker-Stiftung, 28: 4–41.

PRUSINKIEWICZ Z. & NORYŚKIEWICZ B. 1966. Zagadnienie wieku bielic na wydmach brunatnych Mierzei Świny w świetle analizy palynologicznej i datowania radiowęglem ^{14}C (summary: Problem of age of podzols on brown dunes of Bay Bars of River Świna in the light of a palynological analysis and dating by radiocarbon ^{14}C). Zesz. Nauk. UMK Toruń, Nauki Mat-Przyr., 14, Geografia V: 75–88.

PUNT W. & MALOTAUX M. 1984. Cannabaceae, Moraceae and Urticaceae. In: Punt W. & Clarke G. C. S. (eds). The northwest European pollen flora, IV. Elsevier Science Publishers B. V., Amsterdam.

RACKHAM O. 1980. Ancient woodland, its history, vegetation and uses in England. E. Arnold, London.

— 1988 a. Wildwood. In: Jones M. (ed.). Archaeology and the flora of the British Isles. Oxford University Committee for Archaeology, 14: 3–6.

— 1988 b. Trees and woodland in a crowded landscape – the cultural landscape of the British Isles. In: Birks H. H., Birks H. J. B., Kaland P. E. & Moe D. (eds). The cultural landscape – past, present and future. Cambridge Univ. Press.

RALSKA-JASIEWICZOWA M. 1981. Wpływ zasiedleń prahistorycznych na kształtowanie się szaty roślinnej okolic Worytów w ciągu ostatnich 5000 lat (wyniki analizy pyłkowej)(summary: Impact of prehistoric settlements on natural vegetation of Woryty region during the last 5000 years). In: Dąbrowski J. (ed.). Woryty, studium archeologiczno-przyrodnicze zespołu osadniczego kultury łużyckiej. Ossolineum, Wrocław-Łódź.

— 1983. Isopollen maps for Poland: 0–11.000 years B. P. New Phytol., 94: 133–175.

— 1989. The South-Baltic Coastal Zone. In: Ralska-Jasiewiczowa (ed.). Environmental changes recorded in lakes and mires of Poland during the last 13.000 years. P. III. Acta Palaeobot., 29 (2): 101.

— & LATAŁOWA M. in print. Synthesis of palaeoecological events in Poland. In: Berglund B. E., Birks H. J. B., Jasiewiczowa M. & Wright H. (eds). Palaeoecological events in Europe during the last 15.000 years – patterns, processes and problems. J. Wiley & Sons.

— & STARKEL L. 1988. Record of the hydrological changes during the Holocene in the lake, mire and fluvial deposits of Poland. Folia Quat., 57: 91–127.

RANDALL R. E., ANDREW R. & WEST R. G. 1986. Pollen catchment in relation to local vegetation: Ceann Ear, Monach Isles N. N. R., Outer Hebrides. New Phytol., 105: 271–310.

REGNÉLL J. 1989. Vegetation and land use during 6000 years. Palaeoecology of the cultural landscape at two lake sites in southern Skane, Sweden. Lundqua Thesis 27: 1–62.

ROMER E. 1949. Regiony klimatyczne Polski. Prace Wrocł. Tow. Nauk., Ser. B, 16:1–26.

ROBINSON D. E. 1987. Investigations into the Aukhorn mounds, Keiss, Caithness: pollen, plant macrofossil and charcoal analysis. New Phytol., 106: 185–200.

— & DICKSON J. H. 1988. Vegetational history and land use: a radiocarbon-dated pollen diagrams from Machrie Moor, Arran, Scotland. New Phytol., 109: 223–251.

ROSA B. 1984. Rozwój brzegu i jego odcinki akumulacyjne. In: Augustowski B. (ed.). Pobrzeże Pomorskie. GTN, Ossolineum, Wrocław-Łódź.

ROUND F. E. 1985. The ecology of algae. Cambridge Univ. Press, Cambridge.

ROWLEY-CONWY P. 1982. Forest grazing and clearance in temperate Europe with special reference to Denmark: an archaeological view. In: Bell M. & Limbrey S. (eds). Archaeological aspects of woodland ecology. BAR, Int. Ser., 146: 199–215.

RÓŻAŃSKI K. 1987. The ^{18}O and ^{14}C isotope investigations of carbonate sediments from the Lake Strażyn (Brodnica Lake District). Acta Palaeobot., 27 (1): 277–282.

—, WCISŁO D., HARMATA K., NORYŚKIEWICZ B & RALSKA-JASIEWICZOWA M. 1988. Palynological and isotope studies on carbonate sediments from some Polish lakes – Preliminary results. In: Lang G. & Schlüchter Ch. (eds). Lake mire and river environments. Balkema, Rotterdam.

RYBAK M. 1987. Fossil chrysophycean cyst flora of Racze Lake, Wolin Island (Poland) in relation to paleoenvironmental conditions. Hydrobiologia 150: 257–272.

—, RYBAK I. & ZADROŻNA M. 1987. Paleolimnology of a small oligotrofic lake on Wolin Island, Baltic Sea, Poland. Hydrobiologia 146: 169–179.

SAJKOWSKA M. 1987, 1991. Mapa osadnicza wyspy Wolin. M. S.

SCAIFE R. G. 1988. The elm decline in the pollen record of south east England and its relationship to early agriculture. In: Jones M. (ed.). Archaeology and the flora of the British Isles. Oxford University Committee for Archaeology, 14: 21–33.

SCHWABEDISSEN H. 1981. Ertebolle/Ellerbek – Mesolithicum oder Neolithicum? Veröffentl. Mus. Ur- u. Frühgesch. Potsdam, 14/15: 129–142.

SIMMONS I. G., RAND J. I. & CRABTREE K. 1983. A further pollen analytical study of the Blacklane peat section on Dartmoor, England. New Phytol., 94: 655–667.

SIUCHNIŃSKI K. 1972. Klasyfikacja czasowo-przestrzenna kultur neolitycznych na Pomorzu Zachodnim, II. Opracowanie analityczne. Muzeum Narodowe, Szczecin.

— 1983. Stosunki kulturowe u ujścia Odry w neolicie i początkach epoki brązu. In: Filipowiak W. & Labuda G. (eds). Pradzieje Szczecina. PWN, Warszawa-Poznań.

SKARŻYŃSKA B. 1965. Palaeohydrological research in the territory of ancient Poland. Part I, II. Bull. Acad. Pol. Sci., s. Geol.-Geogr., 8 (3): 237–247.

STARKEL L. 1977. Paleogeografia holocenu. PWN, Warszawa.

STOCKMARR J. 1971. Tablets with spores used in absolute pollen analysis. Pollen et Spores 13 (4): 615–621.

STURLUDOTTIR S. A. & TURNER J. 1985. The elm decline at Pawlaw mire: an anthropogenic interpretation. New Phytol., 99: 323–329.

SZCZEGÓŁOWA MAPA GEOLOGICZNA POLSKI 1:50.000. 1978. Wyd. Geol., Warszawa.

SZCZEPANEK K. 1971. Kras staszowski w świetle badań paleobotanicznych (summary: The Staszów karst in the light of palaeobotanical studies – south Poland). Acta Palaeobot., 12 (2): 60–140.

TALLIS J. H. & SWITSUR V. R. 1990. Forest and moorland in the south Pennine uplands in the Mid-Flandrian period. II. The Hillslope forests. Journal of Ecology, 78: 857–883.

TAUBER H. 1965. Differential pollen dispersion and the interpretation of pollen diagrams. Danm. Geol. Unders., II, 98.

THELAUS M. 1989. Late Quaternary vegetation history and palaeohydrology of the Sandsjön – Arshult area, south-western Sweden. Lundqua, Thesis 26.

TOBOLSKI K. 1982. Anthropogenic changes in vegetation of the Gardno-Łeba Lowland, N. Poland. Preliminary report. Acta Palaeobot., 22 (1): 131–139.

— 1987. Holocene vegetational development based on the Kluki reference site in the Gardno-Łeba plain. Acta Palaeobot., 27 (1): 179–222.

TOLONEN K. 1986 a. Charred particle analysis. In: Berglund B. E. (ed.). Handbook of Holocene palaeoecology and palaeohydrology. J. Wiley & Sons Ltd, Chichester-New York.

— 1986 b. Rhizopod analysis. In: Berglund B. E. (ed.). Handbook of Holocene palaeoecology and palaeohydrology. J. Wiley & Sons Ltd, Chichester-New York.

— & JAAKKOLA T. 1983. History of lake acidification and air pollution studied in sediments in south Finland. Ann. Bot. Fennici, 20: 57–78.

TOMANEK J. 1966. Botanika leśna. PWRiL, Warszawa.

TROELS-SMITH J. 1953. Ertebolle Culture – Farmer Culture. Results of the past ten years excavations in Aamosen Bog, West Zeland. Aarboger Nordisk Oldkyndighed og Historie, 1953, 5–62.

— 1955. Karakterisering af lose jordarter. Danm. Geol. Unders. IV, 3 (10): 1–73.

— 1960. Ivy, mistletoe and elm: climatic indicators – fodder plants. Danm. Geol. Unders., Ser. IV, 4 (4): 1–32.

— 1984. Stall-feeding and field-manuring in Switzerland about 6.000 years ago. In: Lerche G., Fenton A. & Steensberg A. (eds). Tools & Tillage. Vol. V, 1, National Museum of Denmark, Copenhagen.

TURNER J. 1965. A contribution to the history of forest clearance. Proc. R. Soc., B, 161: 343–354.

UOTILA P. 1974. Pollen morphology in European species of Chenopodium sect. Chenopodium, with special reference to C. album and C. sueciccum. Ann. Bot. Fennici 11: 44–58.

VANG PETERSEN P. 1984. Chronological and regional variation in the late Mesolithic of eastern Denmark. Journal of Danish Archaeology, 3: 7–18.

VORREN K. D. 1986. The impact of early agriculture on the vegetation of Northern Norway. A discussion of anthropogenic indicators in biostratigraphical data. In: Behre K.-E. (ed.). Anthropogenic indicators in pollen diagrams. Balkema, Rotterdam-Boston.

VUORELA I. 1970. The indication of farming in pollen diagrams from southern Finland. Acta Bot. Fenn., 87: 1–40.

— 1973. Relative pollen rain around cultivated fields. Acta Botanica Fennica 102: 2–27.

— 1980. Microspores of IsoÐtes as indicators of human settlement in pollen analysis. Memoranda Soc. Fauna Flora Fennica 56: 13–19.

— 1983. Field erosion by wind as indicated by fluctuation in the ash content of Sphagnum peat. Bull. Geol. Soc. Finland, 55 (1): 25–33.

— 1986. Palynological and historical evidence of slash-and-burn cultivation in South Finland. In: Behre K.-E. (ed.). Anthropogenic indicators in pollen diagrams. Balkema, Rotterdam – Boston.

WASYLIKOWA K. 1983. Fossil evidence for ancient food plants in Poland. In: Zeist van W. & Casparie W. A. (eds). Plants and ancient man. Studies in palaeoethnobotany. Balkema, Rotterdam.

— 1989. Palaeoecological characteristics of the settlement periods of the Linear Pottery and Lengyel cultures at Cracow-Nowa Huta (on the basis of plant material). Przegl. Archeol., 36: 57–87.

—, CARICIUMARU M., HAJNALOVĆ E., HARTYÁNYI B. P., PASHKEVICH G. A. & YANUSHEVICH Z. V. 1991. East-Central Europe. In: van Zeist W., Wasylikowa K. & Behre K.-E. (eds). Progress in Old World palaeoethnobotany. Balkema, Rotterdam-Brookfield.

WELINDER S. 1981. The disappearance of a hunting-gathering economy. Veröffentl. Mus. Ur- u. Frühgesch. Potsdam, 14/15: 151–163.

WESOŁOWSKI S. 1983. Plemiona kultury łużyckiej na terenie Szczecina (od XII do IV wieku p.n.e.). In: Filipowiak W. & Labuda G. (eds). Pradzieje Szczecina. PWN, Warszawa – Poznań.

WHITTINGTON G. & GORDON A. D. 1987. The differentiation of the pollen of Cannabis sativa L. from that of Humulus lupulus L. Pollen and Spores 29 (1): 111–120.

WIELOWIEJSKI J. 1981. Produkcja rolno-hodowlana. In: Wielowiejski J. (ed.). Prahistoria ziem polskich. Vol. V. Późny okres lateński i okres rzymski. Ossolineum , Wrocław-Gdańsk.

WIŚLAŃSKI T. 1969. Podstawy gospodarcze plemion neolitycznych w Polsce północno zachodniej (summary: Economic basis of Neolithic tribes in north-western Poland). Ossolineum, Wrocław-Kraków.

— 1979 a. Kształtowanie się miejscowych kultur rolniczo-hodowlanych. Plemiona kultury pucharów lejkowatych. In: Hensel W. & Wiślański T (eds). Prahistoria ziem polskich. Vol. II, Neolit, Ossolineum, Wrocław – Gdańsk.

— 1979 b. Dalszy rozwój ludów neolitycznych. Plemiona kultury amfor kulistych. In: Hensel W. & Wiślański T. (eds). Prahistoria ziem polskich. Vol. II, Neolit, Ossolineum, Wrocław – Gdańsk.

— 1983. Rola Pomorza w młodszej epoce kamienia. In: Malinowski T. (ed.). Problemy epoki kamienia na Pomorzu. Wyższa Szkoła Pedagogiczna w Słupsku, Słupsk.

WOJTASIK J. 1958. Pozostałości kultury łużyckiej na wzgórzu "Młynówka" na Wolinie. Materiały Zachodniopom., 4: 49–104.

WOŁĄGIEWICZ R. 1981. Grupy kulturowe na pograniczu kręgu nadłabskiego. In: Wielowiejski J. (ed.). Prahistoria ziem polskich. Vol. V. Późny okres lateński i okres rzymski. Ossolineum, Wrocław-Gdańsk.

WOŁĄGIEWICZ R. 1983. U schyłku starożytności – okres przedrzymski i rzymski. In: Filipowiak W. & Labuda G. (eds). Pradzieje Szczecina. PWN, Warszawa-Poznań.

— 1986. Stan badań nad okresem rzymskim na Pomorzu. In: Godłowski K. & Madyda-Legutko R. (eds). Stan i potrzeby badań nad młodszym okresem przedrzymskim i okresem wpływów rzymskich w Polsce. Mat. z konferencji Kraków, 14–16 listopad 1984, Uniw. Jagielloński, Kraków.

WRIGHT H. E. 1967. A square-rod piston sampler for lake sediments. J. Sedimentary Petr., 37: 975–976.

WYPYCH K. 1980. Powstanie i rozwój Zalewu Szczecińskiego. In: Majewski A. (ed.). Zalew Szczeciński. Inst. Met. Gosp. Wod., WKŁ, Warszawa.

ZAJĄC A. 1979. Pochodzenie archeofitów występujących w Polsce. Rozprawy habilitacyjne UJ, 29: 1–213.

ZARZYCKI K. 1979. Zarys ekologii. In: Białobok S. (ed.). Brzozy – Betula L. Nasze drzewa leśne, Vol. 7, PWN, Warszawa – Poznań.

— 1984. Ekologiczne liczby wskaźnikowe roślin naczyniowych Polski. Instytut Botaniki PAN.

ZOHARY D. & HOPF M. 1988. Domestication of plants in the Old World. Clarendon Press, Oxford.