Laboratory of Palaeoecology and Archaeobotany

Department of Plant Ecology
University of Gdańsk

25th Bog Excursion

North-west Poland

Part I: Wolin Island and Drawa National Park
(1-4 September 2001)

Excursion Guide

Gdańsk - 2001
edited by Małgorzata Latałowa

CONTENTS

INTRODUCTION

The 25th Bog Excursion will traverse through northwestern Poland. Its first part will include the Wolin Island and the Drawa National Park. Both areas are situated in the young postglacial landscape, north of the maximum extent of the Vistulian glaciation (Fig.1). The Wolin Island lies north, while the Drawa National Park south of the Pomeranian stage (c. 15.2 ky BP) of this glaciation.

During the excursion we will present our already published results and those that are still in current elaboration being a part of the actually ongoing projects. The main focus will be palaeoecology and palaeogeography of the visited areas, but also the most interesting recent vegetation problems and archaeological information will be presented during the meeting.

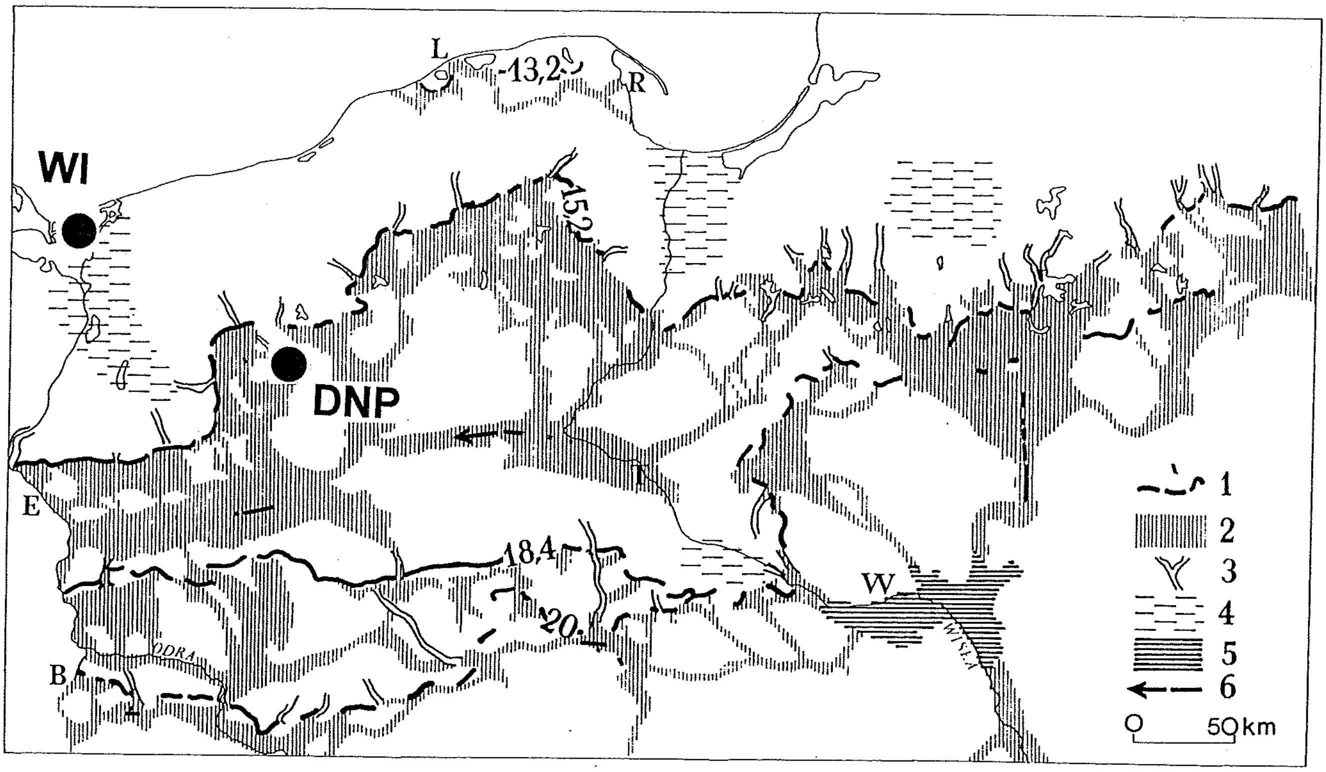

Fig. 1. The Vistulian glaciation in the area of northern Poland (from Mojski 1993) and location of the excursion areas; 1- maximum extent of the Vistulian ice-sheet and its main phases, 2-outwash plains and alluvial plains, 3- more important channels, 4- end depressions, 4- periglacial ice-dammed lakes, 6- direction of melt-water drainage; WI – Wolin Island, DNP- Drawa National Park

The editor is indebted to the authors who sent their contributions, especially to Professor Ryszard K. Borówka and his team, Professor Władysław Filipowiak and Dr Jolanta Kujawa Pawlaczyk. The particular thanks are due to Dr. Joanna Jarosińska who helped in the technical preparation of this guide.

Gdańsk, 25 August 2001

Małgorzata Latałowa

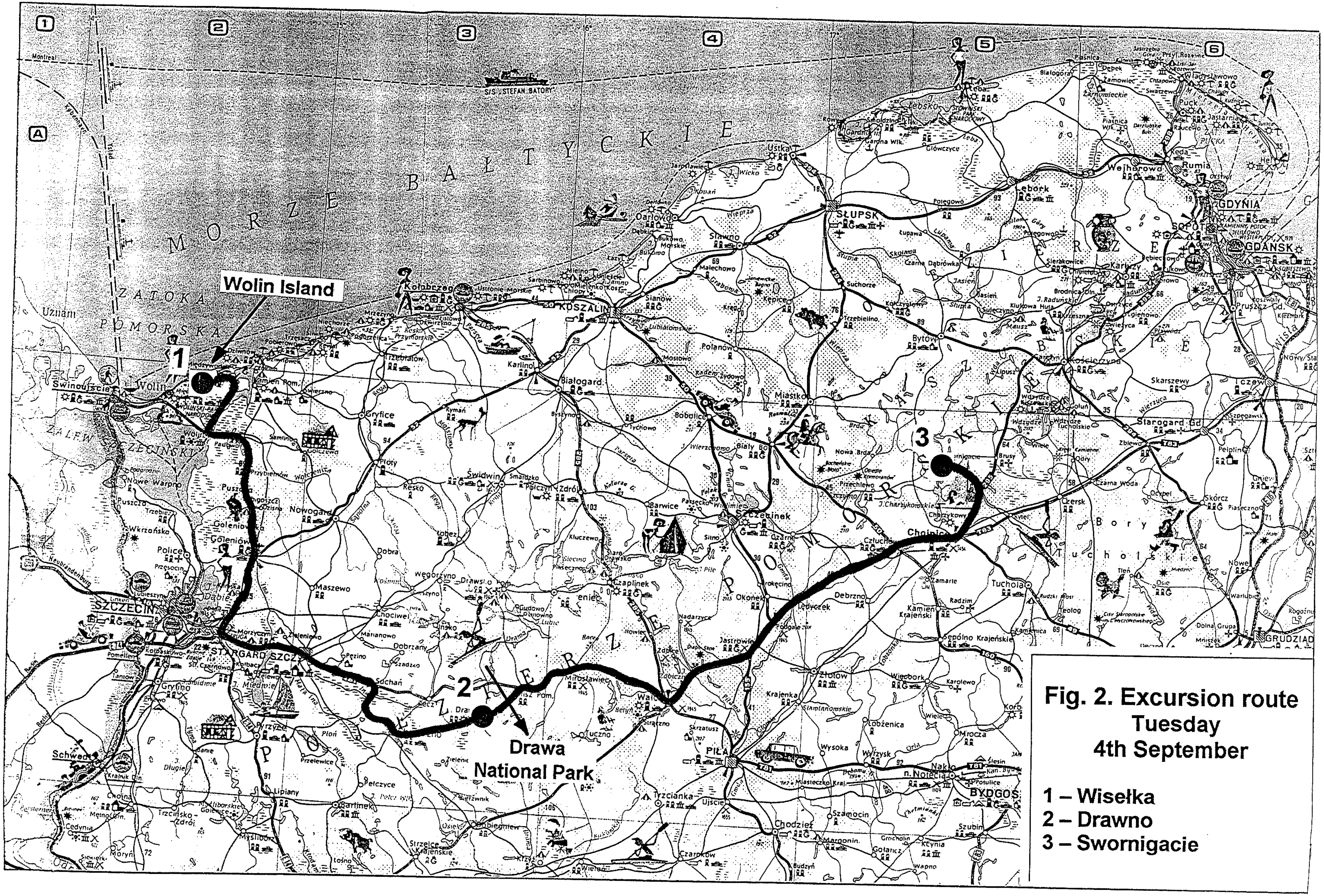

Fig. 2. Excursion route
Tuesday
4th September

1 – Wisełka
2 – Drawno
3 – Swornigacie

I. WOLIN ISLAND

1. The general information on the area

1. 1. AN OUTLINE OF GEOLOGY AND GEOMORPHOLOGY OF WOLIN ISLAND

Ryszard K. Borówka, Tomasz Duda, Michał Lorenc
Szczecin University, Department of Natural Sciences, Marine Research Institute

The Wolin Island is one of two islands separating the Szczecin Lagoon from the Baltic Sea. Its eastern border is the Dziwna Channel together with the Kamieński Lagoon, and western border is the Świna Channel.

The island consists of two basic parts differentiating both on the subject of morphology, structure, as well as the age of the Quaternary deposit cover. The eastern part of the island is mainly a fragment of the Pleistocene morainic plateau of the Western Pomeranian coastal plain. However, the western part is a fragment of the Holocene barrier – Świna Barrier, separating the Szczecin Lagoon from the Pomeranian Bay. There is also a similar Holocene barrier – Dziwna Barrier, situated in the north-western edge of the island.

Geology
Sub-Cenozoic bottom

Nearly entire Wolin Island lays within the Pomeranian Anticlinorium, only its south-western part is situated in the area of the Szczecin Synclinorium (Szczecin Basin). There can be distinguished two tectonic blocks on the island – Gryfice Block and Wolin Block – separated from each other by a dislocation zone of Kamień Pomorski (Fig. 3), which is oriented meridionally (Dadlez 1970).

The Gryfice Block embraces only a small, north-eastern part of the island – Dziwna Barrier, and a fragment of the Kodrąb Lowering, clinging directly to the banks of Dziwna River and Kamieński Lagoon. The Wolin Block, which lays on the western side of Kamień Pomorski's dislocation zone, is lowered in comparision to the Gryfice Block. It is bounded in the west by a Świnoujście-Drawsko-Złocieniec dislocation zone, separating the Pomeranian Anticlinorium from the Szczecin Synclinorium. The main structural element of Wolin Block is a flat Wisełka Syncline, situated in the central part of the island and

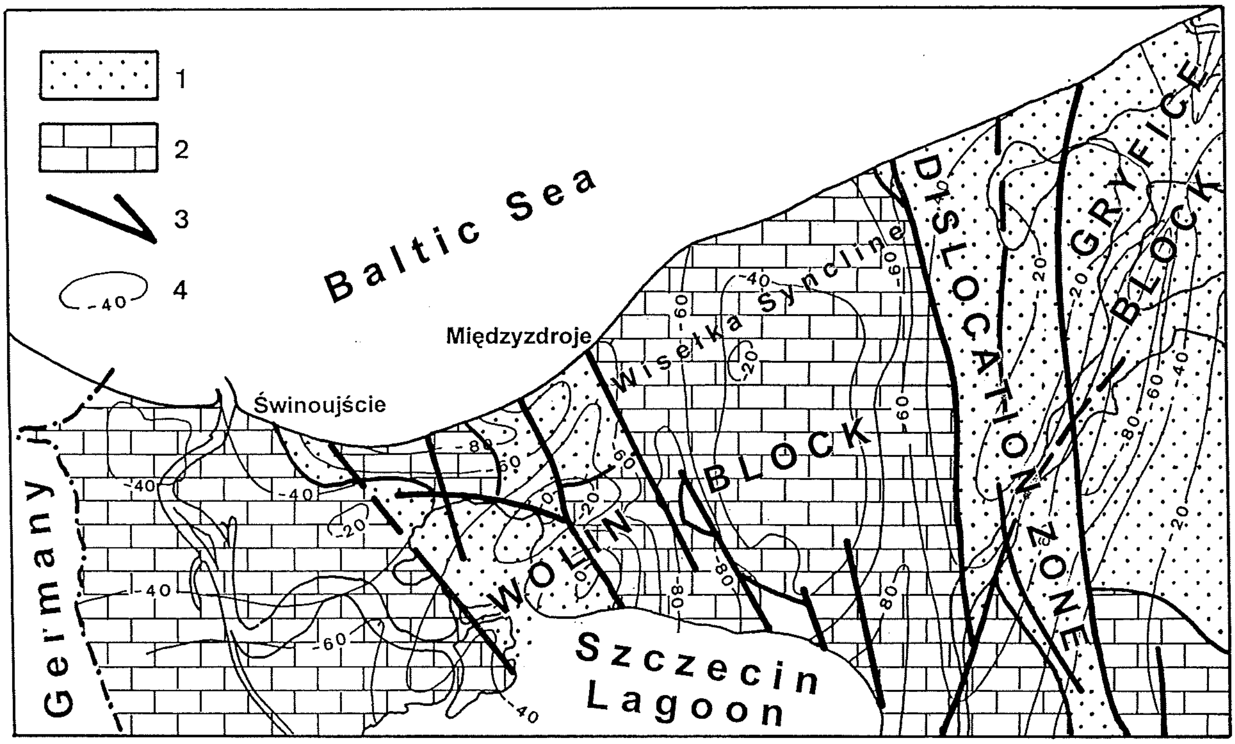

Fig. 3. Tectonic map od Wolin Island vicinity (after Ruszała, Wdowiak 1977; Ruszała et al. 1979)

extending towards north to the Baltic Sea. There can be distinguished secondary tectonic structures in the south and west from the Wisełka Syncline – hemianticlines of Dargobądz, Wapnica and Międzyzdroje (Dadlez 1970; Jaskowiak-Schoeneichowa 1969).

The tectonic structures of this area were formed during the alpine orogenesis. Some vertical movements of the individual tectonic blocks, which appeared along discontinuity zones, marked there. Directions of these displacements were various, what caused in consequence to differentiation of sedimentary conditions and unequal distribution of rock complexes thickness. That is why succeeded there an unequal load of zechstein salts series, and afterwards their activation and movement in the direction of reduced-pressure areas of rock complexes. The halokinetic processes were significant in the development of tectonic structures, causing additional perturbations in the configuration of the rock layers. For the great part of Mesozoic, till the Upper Cretaceous, marked here only slow tectonic movements. Their intensity increased during the Upper Cretaceous and the oldest Tertiary.

The sub-Quaternary surface of Wolin constitutes, first of all, Jurassic and Cretaceous rocks. The anticline of Kamień Pomorski and hemianticlines of Wapnica and Międzyzdroje are built of Jurassic rocks. Cretaceous marles and limestones appear within the Wisełka Syncline and in the most western part of the island, situated on the border between the Wolin Block and the Szczecin Synclinorium. The Tertiary sediments appear only within the vicinity of Dargobądz, where they reach thickness of 40 meters. They infill a fossil valley form cut out in Mesozoic rocks to the depth of 80-90 m b.s.l. (Matkowska et al. 1977; Ruszała, Wdowiak 1977; Ruszała et al. 1979).

Pleistocene deposits

The Quaternary deposits of the Wolin Island are mainly connected with an activity of Scandinavian glacial sheets, whose streams were determined by rock elevations of Bornholm and Rügen Island. That is the reason the glacial sheets were able to arise from the Bornholm Basin (NNE direction), or from Arkona Basin (NW-N directions). They eroded strongly the ground, especially within the elevated Pomeranian Anticlinorium. Numerous rafts of Jurassic and Cretaceous rocks, which appear among the Quaternary deposits on the island itself and its nearest vicinity, evidence it (Deecke 1907; Petersen 1924; Alexandrowicz 1966).

The stratigraphy of Eopleistocene and Mesopleistocene Quaternary deposits of Wolin is still recognised just a little. There have not been found any sites with biogenic interglacial sediments, which could perform as biostratigraphic "key sites". Neopleistocene sediments are known much better because they excavate on cliffs, which develop along the coasts of Pomeranian Bay and Szczecin Lagoon. Only among those sediments some sites have been recently documented, which contain some traces of Eemian series with marine mollusks (Borówka et al. 1999). Moreover, there has been found sediments dating from Interplenivistulian (Grudziądz Interglacial) (Borówka et al. 1998, 2000) and also from Late Glacial (Borówka et al. 1982, 1986).

Syntetic profiles of Neopleistocene sediments (Fig. 2, 3), strongly disturbed as a result of glaciotectonic processes, present as follows:

- Cretaceous marls (embedded as glaciotectonic scales and rafts amongst Quartenary formations);
- glacial grey till, in some parts also brown;

- sandy series amongst which appear the marine malakofauna characteristic of Eemian sea (Borówka et al. 1999);
- interplenivistulian sandy-silty series which sporadically feature intercalations of organic matter and very rarely the lumps of gravel with sparse boulders (Borówka et al. 2000).

The glaciotectonically disturbed formations might reach nearly up to the very hilltops, in particular in their elevation zones. In such locations they are often covered with a thin layer of brown glacial till with a thickness of strata up to a few metres. In the bottom part of glacial till numerous structures characteristic of dynamic contact with lower lying deposits are observed.

A series of glaciotectonically perturbed formations and the youngest layer of glacial till are usually significantly eroded (Fig. 4, 5). Above this discontinuity area the following might appear:

- covers of slope deposits;
- deflational pavement;
- trisectional cover of aeolian sands within which the intercalations of two fossil soils commonly appear; the older one has the features of poorly developed tundra soil of Usselo type and originates from the Alleröd period, whereas the younger one was already forming during the Holocene period (Borówka et al. 1982).

Taking into account the litostratigraphic data it is safe to say that the perturbations described formed between the Eemian Interglacial and the Late Vistulian Interglacial. The marine malacofauna found in disturbed sandy series near Świętoujść (Borówka et al. 1999) dates from the Eemian Interglacial, whereas the oldest cover of aeolian deposits dates from the Late Glacial and more accurately from the Pre-Alleröd period.

Holocene deposits

Holocene deposits are famous mostly from Świna Barrier and Dziwna Barrier (Fig. 6). There are:

- marine sediments, connected with the Atlantic transgression of the Baltic Sea,
- fluvio-marine sediments, deposited as a result of the development of Świna and Dziwna rivers back-deltas,
- eolian coastal deposits, occupying the biggest surfaces in the Świna Barrier.

Grodno - Gosań

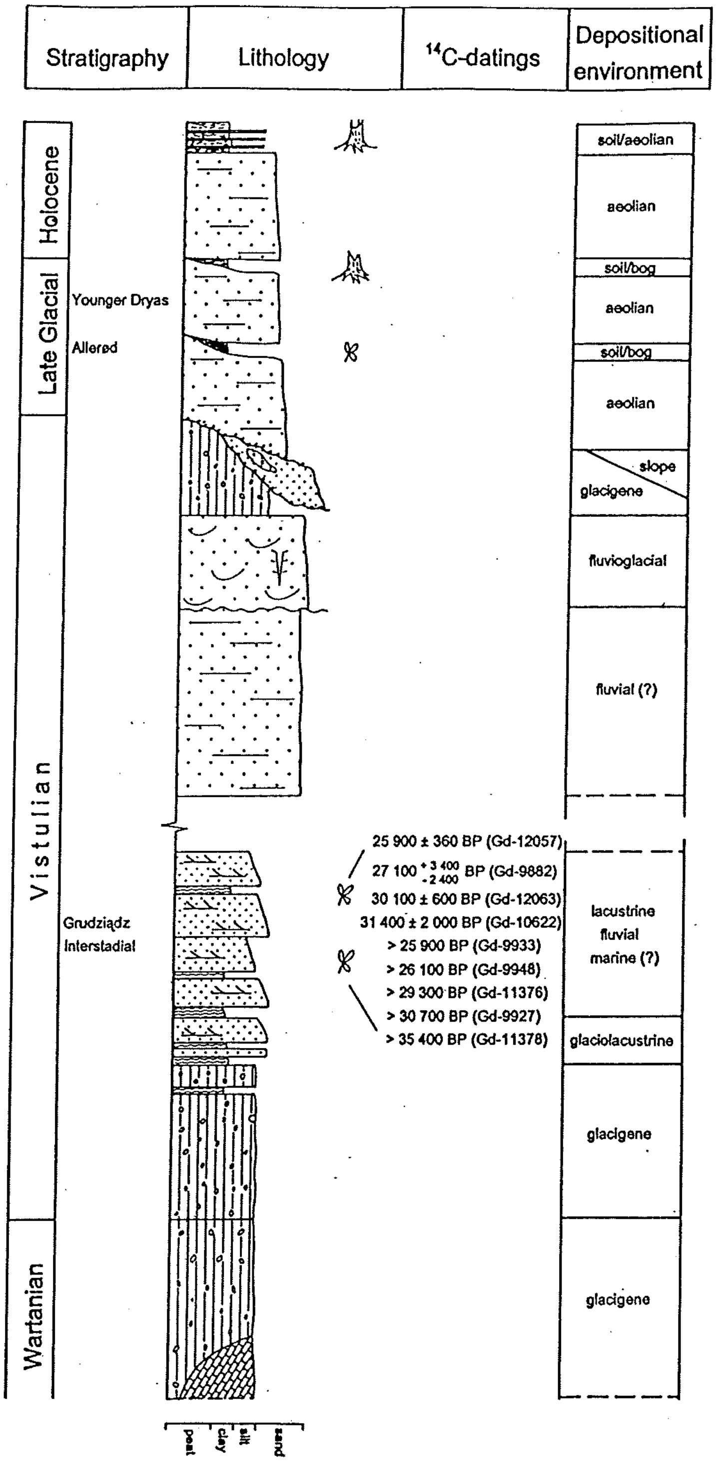

Fig. 4. Generalised lithostratigraphic log from Wolin End Moraine – Grodno Site (after Borówka et al. 2000)

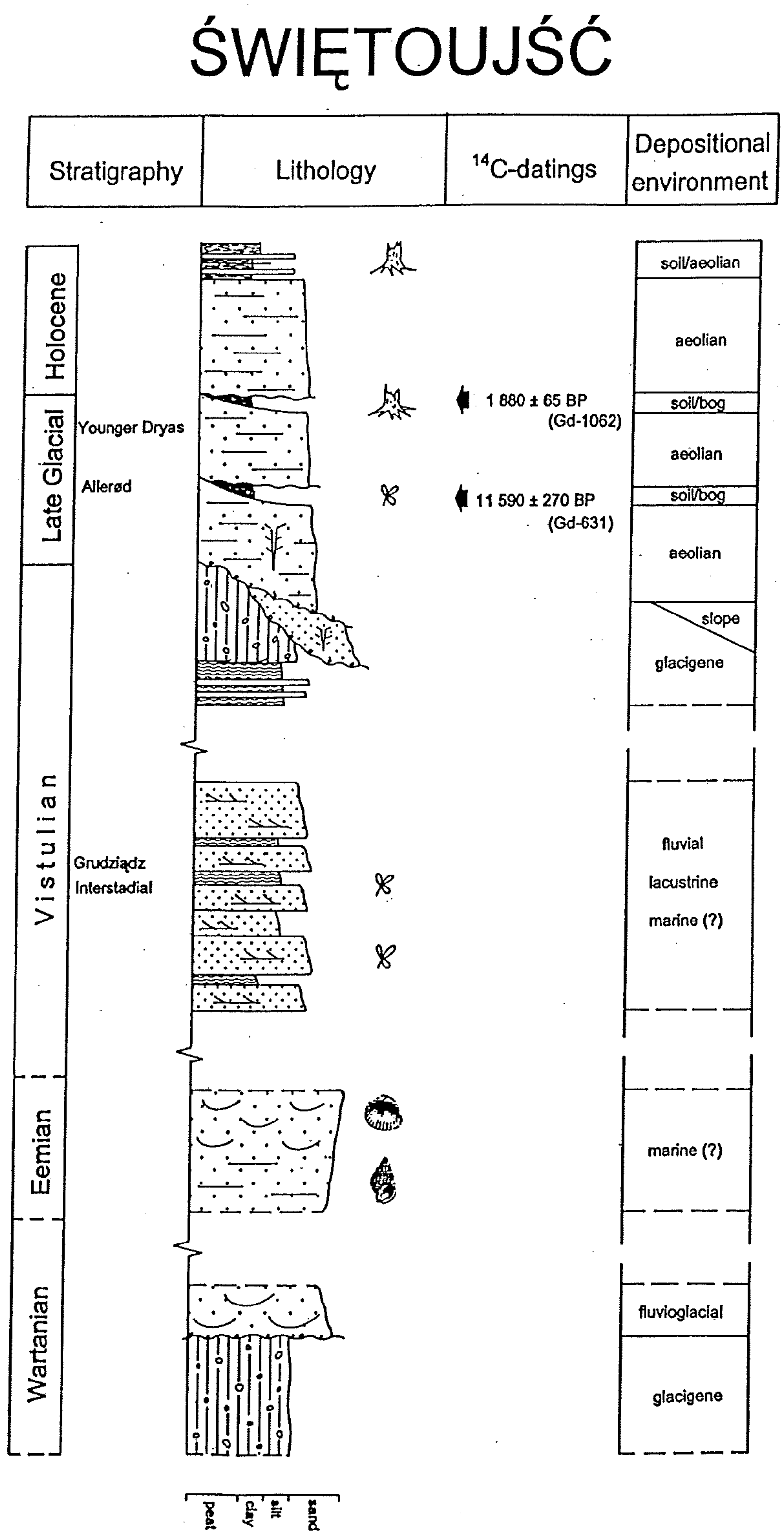

Fig. 5. Generalised lithostratigraphic log from Wolin End Moraine – Świętouść Site(after Borówka et al. 2000)

Within the Świna Barrier thickness of marine sediments reaches to about 20 m. They are known from numerous searching and hydrogeological cores. However, they have not been yet a subject of detailed sedimentological researches. The sediments of Świna back-delta are also recognised only a little. There is some more information about dune forms developed on the surface of Świna Barrier.

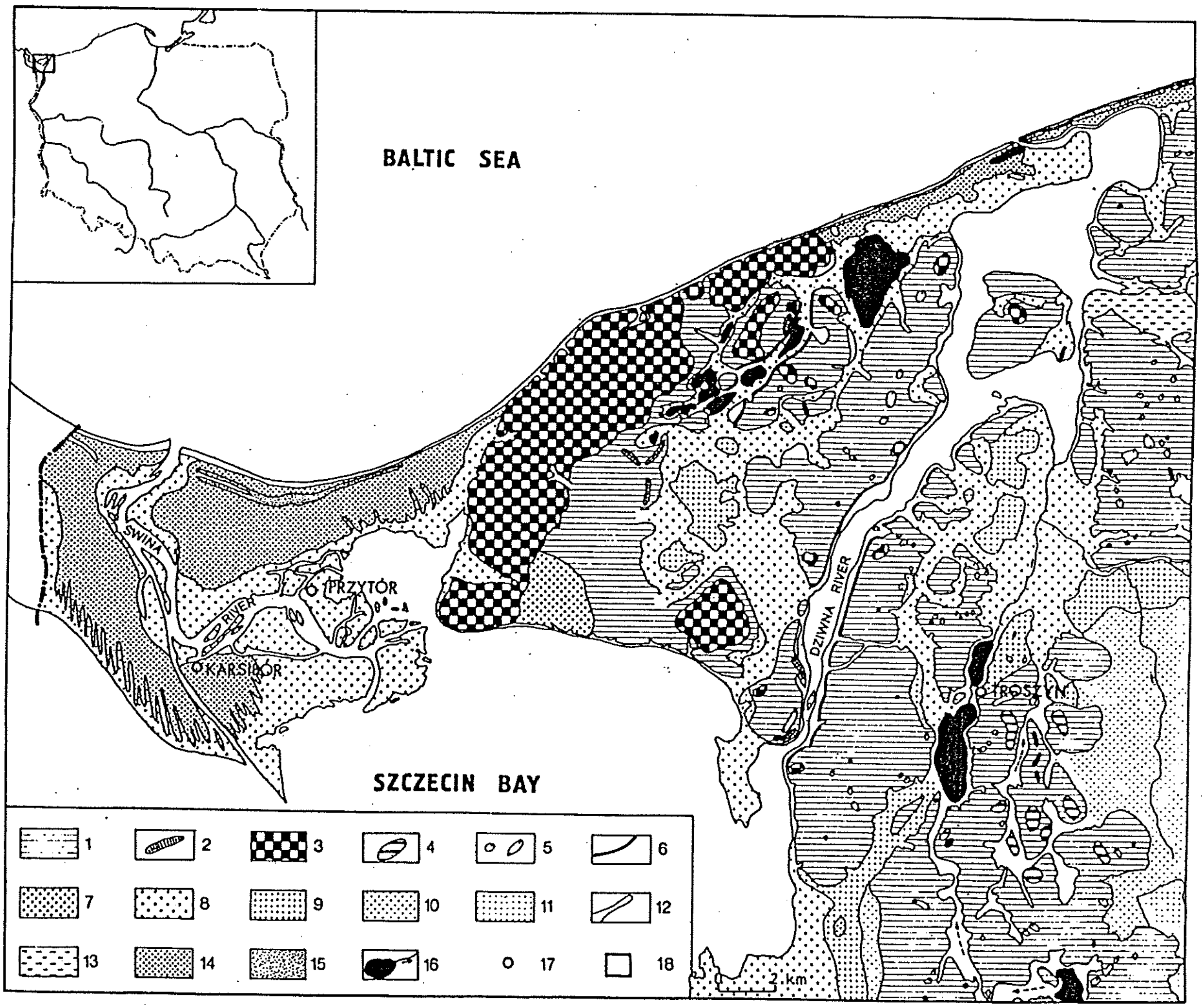

Fig. 6. Geomorphological map of Wolin Island (after a manuscript by A. Karczewski, 1968); 1 – morainic plateau; 2 – eskers; 3 – end moraines; 4 – kames; 5 – melt-out depressions; 6 – scarps; 7 – outwash plains; 8, 9, 10, 11 – terraces of Lower Odra Valley; 12 – erosional-denudative valleys; 13 – ice marginal valleys; 14, 15 – inland and coastal dunes; 17 – lakes and streams; 17 – research sites; 18 – location of Wolin Island

Geomorphology

On the Wolin Island, in agreement with a Marsz's (1967) proposition, there can be distinguished some microregions as follows, differing virtually on the respect of geomorphology (Fig. 7):

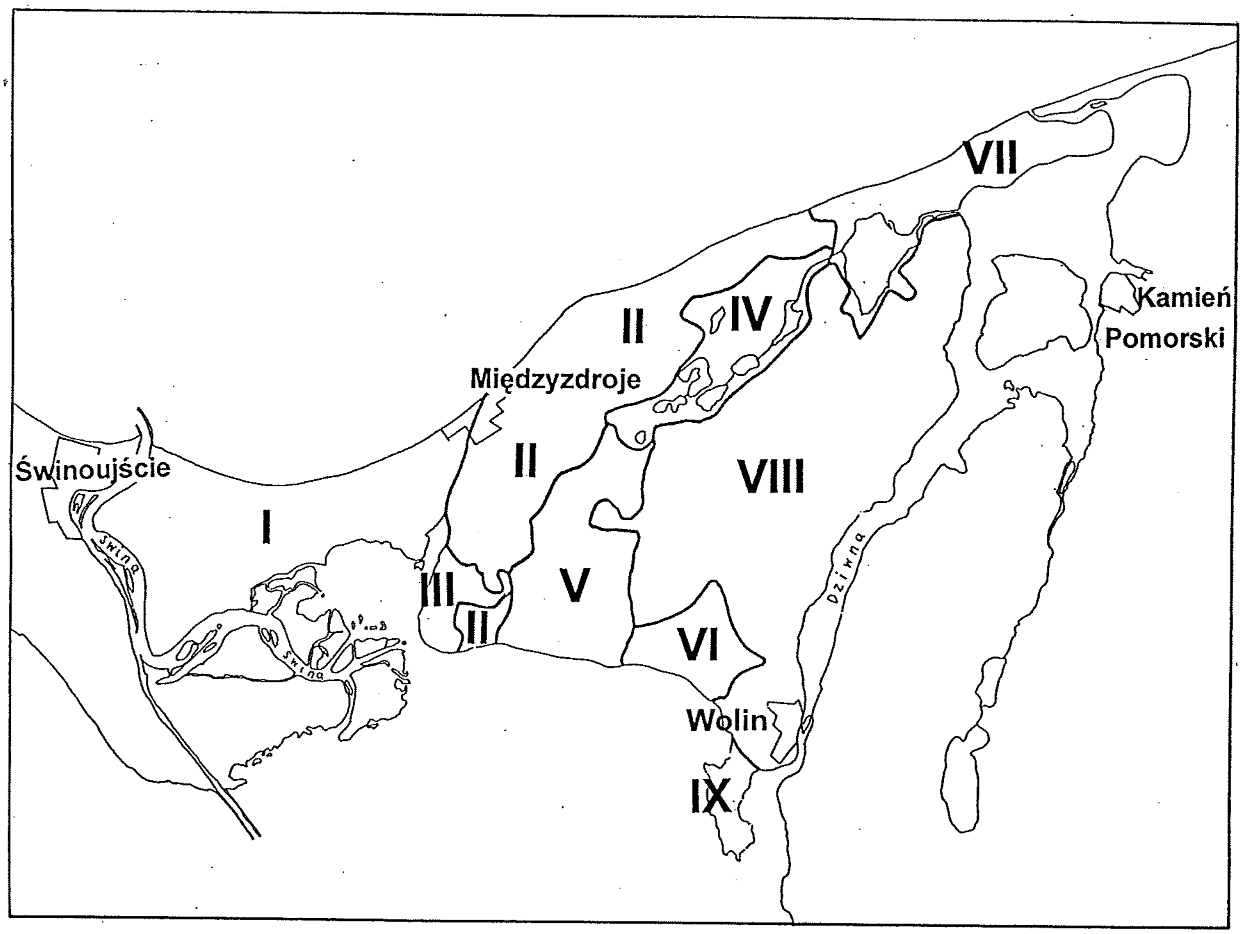

Fig. 7. Microregions of the Wolin Island (after Marsz 1966); I – Świna Barrier (Świna Gate), II – Wolin Hills, III – Lubin-Wapnica Hills, IV – Wolin Lakeland, V – Dargobądz Plain, VI – Mokrzyce Hills, VII – Dziwna Barrier, VIII – Kodrąb Lowering, IX – Rów Peninsula

- Wolin Hills (II)) with Lubin-Wapnica Hillocks (III) extend from Lubin village in the south through Międzyzdroje to Świętoujść in the north-eastern part of the Wolin Island. They constitute a big end moraine form, developed during the Wolin Phase of last glaciation. They reach the relative heights of several dozen metres and the maximum height is about 115 m a.s.l. Since at least 6000 years the morainic hills are strongly abraded by marine waters.

- Wolin Lakeland (IV) lays in the north-central part of the island and comprises the area of channel lakes. 8 little lakes appear there. The lakes are accompanied with numerous kame and esker forms.
- Dargobądz Plain (V), embracing the sand outwash surface determined by the Wolin Hills in the north and west, and to the east extending to the meridian at Warnowo village. There are numerous small dunes and kettle-holes.
- Mokrzyce Hills (VI), morainic elevation reaching the height of 90 m a.s.l., which are situated in the south part of the island.
- Kodrąb Lowering (VIII), the biggest microregion of the Wolin Island. It occupies the whole eastern part of the island, and arises to maximum 20 m a.s.l. The region is a fragment of little-undulated morainic plateau. The central part of the lowering is covered with peat layers with the maximum depth of few metres.
- Dziwna Barrier (VII) in the northern part is consisted of few foredune forms, and its southern part play as a swampy plain, clinging to Koprowo Lake and Kamieński Lagoon.
- Świna Barrier (I) consists of numerous elongated dune forms in the northern and western parts and a flat surface of Świna River back-delta in the south.
- Rów Peninsula (IX) is a swampy plain lying about a 1 m a.s.l. There are some peat layers with the thickness of few meters.

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1. 2. **CLIMATE** (M. Latałowa)

Wolin Island belongs to the region of Baltic climates, i.e. climates influenced by the sea. In the general atmospheric circulation of this area the oceanic air masses play an especially big part. The average annual temperature is 7.5^{0}C to 8.0^{0}C. Winters are relatively mild with an average January temperature between 0 ^{0}C and -0.6^{0}C, while summers are rather cool with an average July temperature between 17.0 ^{0}C and 17.5 ^{0}C. The annual precipitation is rather moderate, 550-650 mm in average. Strong winds from the west are frequent (Młodzikowski 1986).

1. 3. **SOILS** (M. Latałowa)

The varied origin of substrates influenced differentiation of soil pattern. The soils of Wolin Island are generally rather poor. Acid brown soils in various stages of podzolization and podzols dominate in the area of the terminal moraine upland. Large areas of the ground moraine are covered mostly with loose, slightly clayey podzols formed in sands.

The similar, poor soil types developed on kames and outwash-plains. Podzols are formed on dune sands. A chalk outcrop in the south-west of the island is the only place where the more fertile brown soils occur. The relatively extensive areas are covered with boggy soils, which developed on peaty substrates (Borowiec 1969).

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1. 4. THE MAIN FEATURES OF THE PRESENT-DAY VEGETATION AND ITS PHYTOGEOGRAPHICAL CHARACTER

Małgorzata Latałowa

Lab. of Palaeoecology and Archaeobotany, Dept. of Plant Ecology, University of Gdańsk

The specific characters of climate, the considerable variety of habitats and human activity are responsible for the present-day Wolin Island vegetation. Its the most characteristic phytogeographical feature is the presence of a number of the so called „Atlantic" species and communities with a western-type range (Fig. 8) (Piotrowska 1966, Matuszkiewicz 1980).

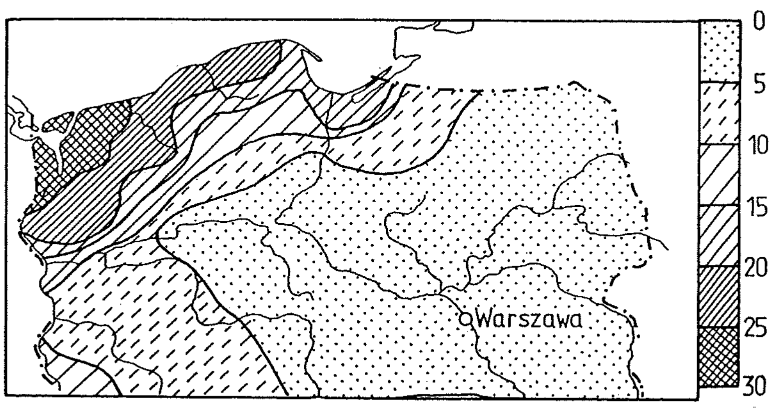

Fig. 8. Number of Atlantic and sub-Atlantic plant associations in N Poland (Matuszkiewicz 1980)

Forests

Woodland dominates on the elevated, central part of the island, now protected as the Wolin National Park. This is an area of potential domination of beech and mixed forest with beech (Fig. 9). *Fagus sylvatica* belongs to the strongest and the most expansive species in this region. In this area mainly acidophilous forest communities are present with acid beechwood (*Luzulo pilosae-Fagetum*) and oak-beech forest (*Fago-Quercetum*) being the most important; in places patches of pine-oak forest (*Pino-Quercetum*) also occur. The mesophilous forest communities are spatially unimportant and include very rare, small fragments of fertile beech forest (*Melico-Fagetum*) - only within the range of the cretaceous outcrop, beech forest with orchids (*Carici-Fagetum*) - along the maritime cliff belt, termophilous elm forest (*Violo odoratae-Ulmetum campestris*) - at the southern cliff, as well as patches of oak-birch forest (*Betulo-Quercetum*).

The dune-covered sandbars are partially overgrown by coastal pine forest (*Empetro nigri-Pinetum*) being now in a recession. In the waterlogged depressions between the dunes alder swamps (*Ribo nigri-Alnetum*) are found, while on more oligotrophic organic substrata marshy pine forest (*Vaccinio uliginosi-Pinetum*) and very rare marshy birch woods (*Betuletum pubescentis*) are present. Alluvial forests (mainly of *Circeo-Alnetum*) are scarce (Piotrowska 1996, Piotrowska & Olaczek 1991, Piotrowska 1983 (85), Piotrowska et al. 2000).

Open dry land vegetation

The large areas of Wolin Island, especially its eastern part, have been almost totally deforested. The anthropogenic open-land vegetation - meadows, pastures and arable fields dominates on former woodland habitats.

In the result of the prevalence of poor acid soils, the field weeds vegetation almost exclusively represents acidophilous communities. In corn-fields associations of *Arnosero-Scleranthetum*, *Vicietum angustifoliae-hirsutae* and *Papaveretum argemones* are present, while in root crops *Echinochloo-Setarietum* is the most common (Nowiński 1964, Piotrowska 1966).

Wet meadows on peaty soils (Molinietalia), which developed due to reclamation of wetlands are more common than those developing on fertile fresh soils (Arrhenatheretalia). The *Corynephoretum canescentis* association is widespread on the

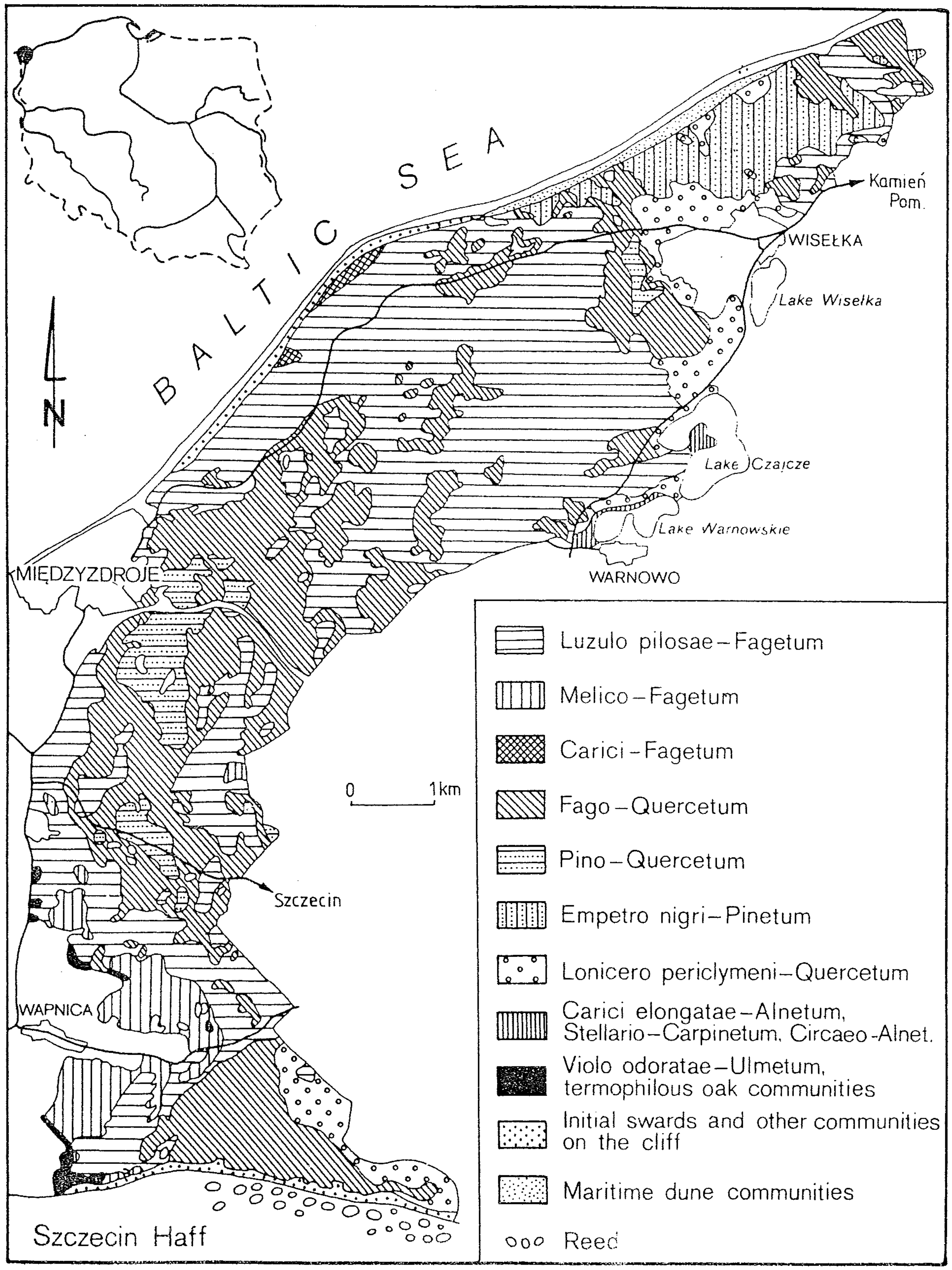

Fig. 9. Potential natural vegetation of the Woliński National Park (within the former boundaries) – from Piotrowska, Olaczek 1991).

dry sandy formations of the gently undulating ground moraine. In some areas, patches of semi-natural termophilous dry grasslands with *Armeria maritima* subsp. *elongata*, representing Armerion elongate alliance are present.

Natural dry swards of different character develop on northern cliffs overlooking the sea and on south-facing cliff bordering with Szczecin Lagoon. On the sea-cliffs grasslands of Kelerion albescentis alliance with *Trifolium pratese* subsp. *maritimum*, *Anthyllis vulneraria* subsp. *maritima*, *Lathyrus pratensis* subsp. *velutinus*, *Festuca rubra* subsp. *arenaria* and *Artemisia campestris* subsp. *sericea* (*Trifolio-Anthyllidetum*) are the most typical. Patches of this association border with the specific for this situation the sea-buckthorn (*Hippophae rhamnoides*) scrub community. On the warm, south-facing cliff, where the substrate is exceptionally rich in calcium carbonate, the xerothermic swards of continental character representing Koelerion glaucae alliance and termophilous grasslands of Festuco-Brometea belong to the most interesting. Several rare species grow here: *Stachys recta*, *Orobanche caryophyllacea*, *Silene otites*, *Vincetoxicum hirundinaria*, *Koeleria glauca*, *Anthericum liliago*, *Achillea pannonica*, *Potentilla nemanniana* and *Asparagus officinalis*. The another plant community typical for the southern cliff slopes are natural as well as anthropogenic termophilous shrubs of Prunetalia with *Prunus spinosa*, *Rhamnus catharticus*, *Crategus monogyna*, *Euonymus europaea, Ligustrum vulgare* and *Berberis vulgaris* (Piotrowska, Celiński 1965, Markowski et al. 2000).

Wetlands

Wetlands and swamps are very important in the Wolin Island landscape. In some areas, due to reclamation, meadows and pastures represented mostly by phytocoenoses classified to the order of Molinietalia developed. The natural vegetation is present in inland stands, especially around numerous lakes, but it is particularly well developed and diversified along both rivers which overflow the island and along the coasts of Szczecin Lagoon. Among the numerous associations of the Magnocaricion alliance *Cladietum marisci* belongs to the most interesting, while *Caricetum ripariae* to the most frequent. *Myrica gale* forms large stands in the phytocoenoses of *Cladietum marisci.* On huge areas vegetation of Phragmition alliance spread. The most common association of *Phragmitetum australis* forms belts along rivers, ditches, lakes and lagoon; in shallow waters of the lagoon patches of *Scirpetum lacustris* create large, elevated holms. Periodic inflows of saline waters from the Baltic Sea to the Szczecin Lagoon, resulted in spread of the semi-halophilous and halophilos species. In coastal zone of the lagoon *Soncho-Archangelicetum litoralis* (with *Angelica archangelica* subsp. *litoralis, Sonchus palustris, Eupatorium cannabinum* and *Calystegia sepium*) and *Scirpetum maritimi* (with *Bulbochoenus maritimus* and *Schoenoplectus tabernaemontani*) developed. The halophilous meadow vegetation is represented mainly by *Juncetum gerardi* and *Puccinellio-Spergularietum salinae* (Piotrowska 1966).

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2. Description of sites

Sunday 2 September

2. 1. STOP 1 - Zielonka Hill - Evolution of Szczecin Lagoon

2. 1. 1. FEATURES OF SEDIMENTARY ENVIRONMENT OF THE SZCZECIN LAGOON (ZALEW SZCZECIŃSKI, ODERHAFF), POLAND-GERMANY

Andrzej Osadczuk

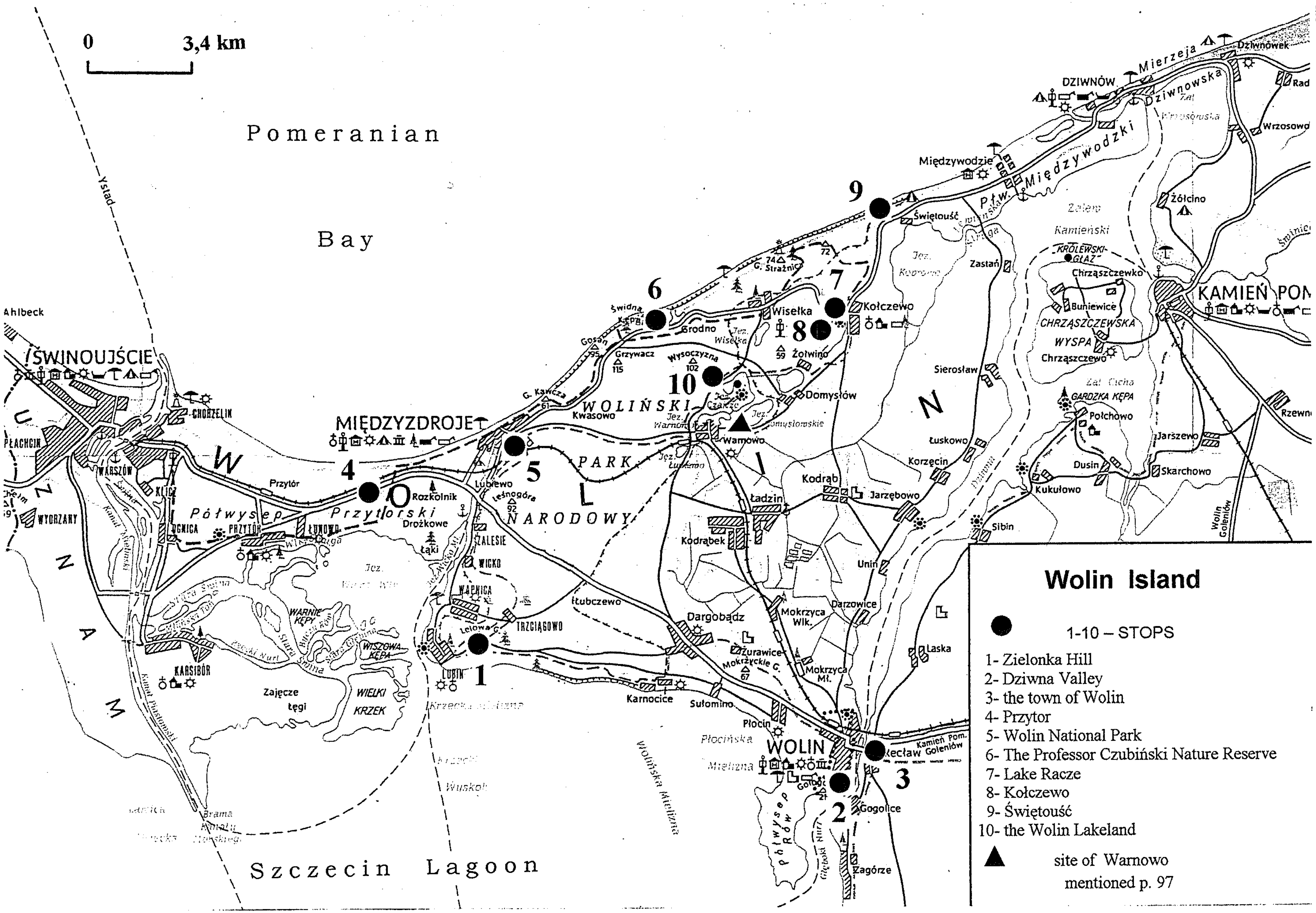
University of Szczecin, Institute of Marine Sciences, Felczaka 3A, 71-412 Szczecin, Poland,
E-mail: andros@univ.szczecin.pl

Characteristics of the sedimentary basin

The shape of a sedimentary basin, the relief of its bottom, its depth, as well as the location of a river mouth plays a very important role in the process of sedimentation. These factors significantly affect water circulation in the basin, and hence suspension movement as well as possible resuspension and redeposition of sediment. The circulation system may also be decisive for the facies variability of the sediment.

The Szczecin Lagoon (*Zalew Szczeciński* in Polish or *Oderhaff* in German) is a shallow water basin located in the Oder River mouth area (Fig. 10). Its natural depth does not exceed 8.5 m, and 95.8% of the bottom area lies at a depth of less than 6 m, while shallow water less than 2 m deep occupies more than 25% of its area. The basic part of its two regions is a relatively flat and featureless bottom at depths of 4-6 m (Fig. 11).

The significant elements of bottom morphology that affect water circulation in the Szczecin Lagoon include a trough-like depression between its two regions, eastern called the Small Lagoon and western called the Big Lagoon, and shoals in the north-eastern part of the Big Lagoon (Krzecki Wyskok and the Wolin Shoal). Across the western part of the basin runs a fairway for big ships. Its construction required a narrow trough 10-11 m deep to be dredged in the basin's natural bottom. The fairway was built in the years 1875-1880 when Kaiserfarht was dug on Usedom Island making a shortcut in the Świna waterway. Both these projects have undoubtedly changed the circulation system of the lagoon waters. The deeply incised, narrow trough of the fairway forms a kind of a stream channel for the penetration of the salt sea water into its southern part. Under favourable weather conditions, a developing density



0 3,4 km
Pomeranian
Bay
Szczecin Lagoon
ŚWINOUJŚCIE
MIĘDZYZDROJE
WOLIN
KAMIEŃ POM
DZIWNÓW
WOLIŃSKI PARK NARODOWY
Półwysep Przytorski
Międzywodzie
Świętouść
Wisełka
Kołczewo
Żołwino
Domysłów
Wapnica
Lubin
Karsibór
Warnowo
Wolin Island
1-10 – STOPS
1- Zielonka Hill
2- Dziwna Valley
3- the town of Wolin
4- Przytor
5- Wolin National Park
6- The Professor Czubiński Nature Reserve
7- Lake Racze
8- Kołczewo
9- Świętouść
10- the Wolin Lakeland
site of Warnowo mentioned p. 97

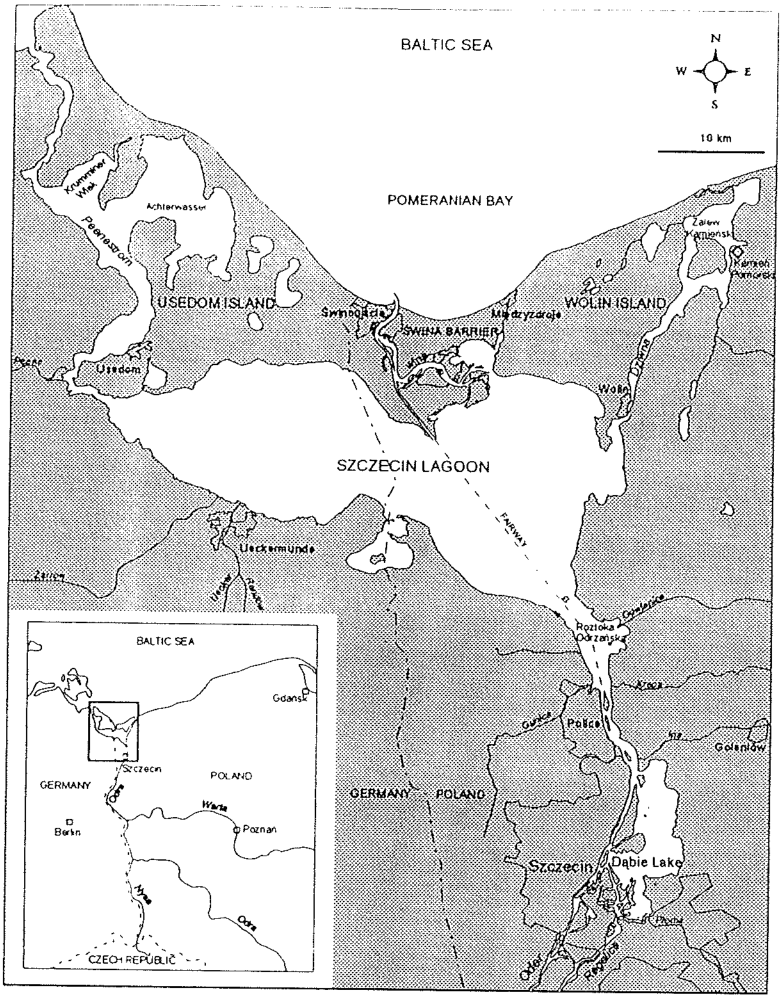


Fig. 10. Location map of the Oder river mouth.

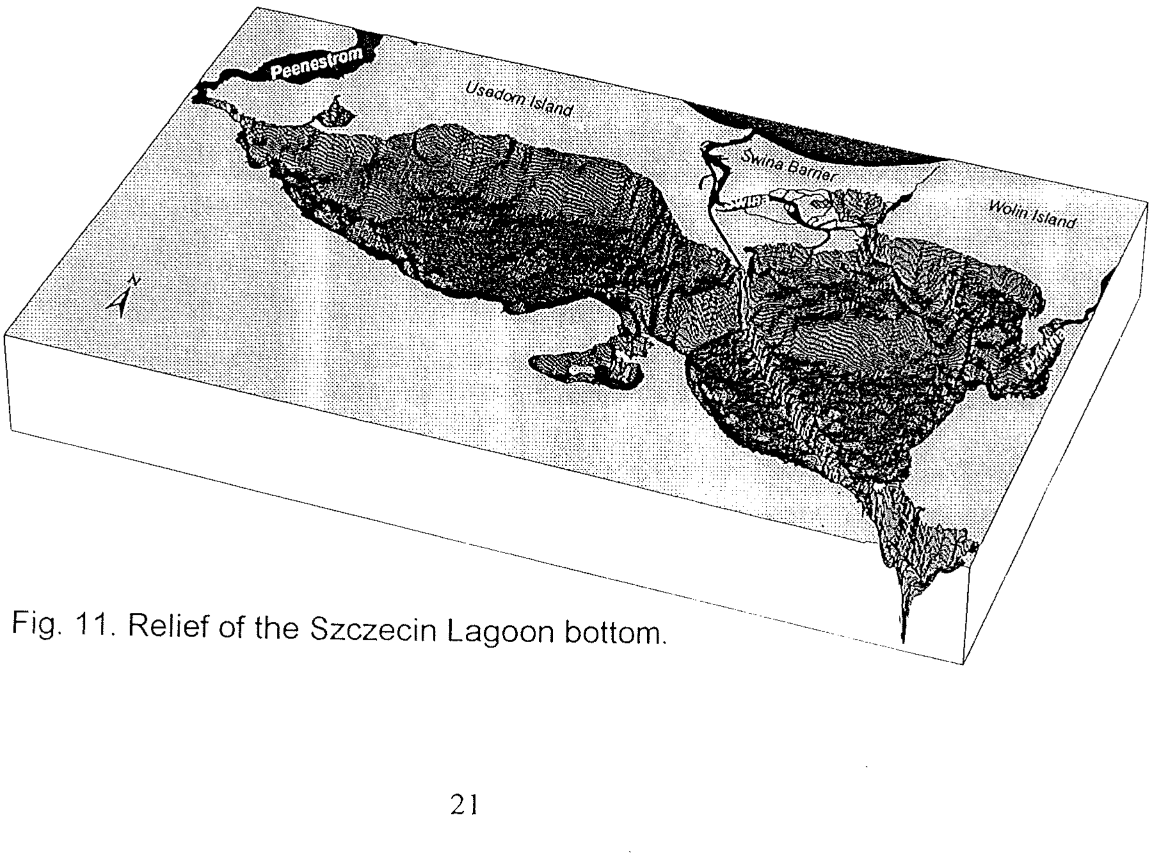


Fig. 11. Relief of the Szczecin Lagoon bottom.

compensation current can cause a near-bottom flow of salt water through the channel to the Oder, sometimes even as far landwards as Szczecin (Majewski 1972; Robakiewicz et al. 1993).

The waters of the Szczecin Lagoon are brackish. Their salinity varies seasonally and from area to area. The seasonal changes are connected with the flow cycle of river waters. Starting with an average salinity of 0.6-0.9 parts per thousand at the beginning of the year, the Lagoon waters freshen quickly in spring after the ice has melted and the volume of inflowing river water has increased. Changes in salinity, however, lag behind changes in the volume of river inflow. The salinity is usually at its minimum in May and June (0.2-0.5‰), to grow steadily in the summer and attain a maximum during November storms and their accompanying greater inflows of sea water. The salinity increases then on average to 0.8-1.3 parts per thousand. The highest levels are recorded in the immediate neighbourhood of the inlets, especially the Świna Inlet, and in the fairway trough and the depression between the Small and the Big Lagoon. During larger storm-surge inflows the salinity of near-bottom water in those areas can reach 6-7 parts per thousand (Majewski 1980).

The characteristic location of the Szczecin Lagoon in the Oder mouth system makes it a transition basin for river water as well as a periodic reception basin for sea water. That is why it is extremely difficult to fit it into one of the customary classifications of coastal basins. It does not display the properties of the typical estuary, which in the classical version is a funnel-shaped area where a river enters the sea, and where fresh and marine water mix freely producing a characteristic density circulation. A barrier separates the Szczecin Lagoon from the sea hence the mixing of fresh and sea water in the basin itself is restricted. The exchange of these two types of water takes place only *via* three long and narrow inlets. Because of the absence of tides, the inflows of seawater to the Lagoon are only observed during high storm surges in Pomeranian Bay. The factors controlling water circulation in the Szczecin Lagoon are the inflow of river water, the storm-surge inflow of sea water, and the blowing winds.

Granulometric properties of sediments

In terms of Shepard's (1954) classification, there are four lithological types of bottom sediment in the Szczecin Lagoon: silts, sandy silts, silty sands, and sands (Fig. A). Generally, silts occupy the deeper central parts of both basins, viz. the Big and the Small Lagoon. Towards the shores the admixture of coarser grains grows in them gradually and they become sandy silts, i.e. silts with more than 20% of the sand fraction. Further on towards the coastal shallows, where the proportion of the sand fraction exceeds 50%, sandy silts turn into silty sands. Silts and sandy silts cover a total of 54% of the Lagoon bottom area, of which silts 33.3% and sandy silts 20.7%. Silty sands take up 17.6%, and sands 28.4% of the bottom (Osadczuk 1999)

The silty sediments in all the parts of the Big Lagoon are generally sorted poorly ($?_I$ = 1-2 ?), and sometimes even very poorly ($?_I$ = 2-4 ?). Sands are poorly or medium sorted ($?_I$ = 0.5-1 ?), and it is only in the area of Krzecki Wyskok that their sorting is good ($?_I$ = 0.35-0.5 ?).

The deposition rate of silt sediments in Szczecin Lagoon was estimated by ^{210}Pb (Neumann et al. 1996) and pollen analysis (Müller, Janke, Lampe 1996) at about 1 mm per year.

Mineralogy and geochemistry of sediments

Among the mineral components of both sands and silts, quartz grains are predominant. There are significant mineral components of biogenic origin: crushed shells of molluscs, ostracods and diatoms. They contribute substantial amounts of calcium carbonate to the sediments (calcite or aragonite) and silica (opal). Silts with a small proportion of sand have the consistency of a jelly because of a considerable amount of highly decomposed amorphic organic matter. Their colour varies from brown-black to black. Only their top 0.5-1 cm layer is lighter - brown, often with a greenish tint. On being dredged to the surface they smell distinctly of hydrogen sulphide.

On the basis of X-ray reflex intensity, proportions of basic mineral components were estimated in sediment samples. They varied as follows: quartz, 10-25%; calcite, 1-10%; pyrite, 1-15%; feldspars, 1-5%; and dolomite, about 1%. Apart from trace minerals (below 1%), the rest of the composition is a mixture of organic matter with other amorphic phases (e.g., of silica) and possibly small quantities of clay minerals and manganese oxides (Osadczuk 1999). Such minerals as quartz, feldspars, calcite, dolomite, muscovite, chlorite, illite, kaolinite, gypsum, pyrite, hydrotroilite, apatite, and opal were also recorded in earlier studies (Nagler, Rzechuła 1976; Eidam et al. 1994).

From the chemical point of view, the principal component of the silt sediments are silica, which contributes some two thirds of their mass, calcium carbonate (up to as much as 32%), and organic compounds. The amount of organic matter expressed as the organic carbon content can even attain 12%.

The highest concentrations of organic matter are found in the silts of the south-western part of the Big Lagoon and near the belt separating it from the Small Lagoon; the lowest, in the north of the Big Lagoon. In the south, allogenic matter contributed by the Oder waters predominates in the sediment, while in the north and west there is a greater proportion of autogenic substances coming largely from the decomposition of the phyto- and zooplankton falling to the bottom in large quantities. In the sediments of the Small Lagoon the C_{org}/N ratio is usually lower than 8, while in the Big Lagoon it is generally larger than 9. The highest C_{org}/N values (10-11.5) are recorded near the area where the Oder enters the Lagoon (Fig. B).

According to Hansen (1959), the C/N ratio of less than 10 is characteristic of gyttja-like sapropel silts. The macroscopic features of the Szczecin Lagoon silts and the presence in them of large amounts of autochthonous organic matter justify calling them sapropel silts or gyttja.

Four geochemically different areas to be distinguished on the bottom of the Szczecin Lagoon (Osadczuk 1999):

1. The southern and western parts of the Big Lagoon, where the dominant type of sedimentation is that closely connected with the inflow of suspended and dissolved substances carried by the Oder River; its feature is a high proportion of organic matter and trace metals in sediments;
2. The north-eastern area of the Big Lagoon, where sea water plays a significant part in sedimentation; its sediments are characterised by a low content of organic matter, calcium carbonate and trace metals, and a higher proportion of sulphur and magnesium;
3. The Small Lagoon, where silt sediments exhibit the smallest geochemical differences, which is indicative of a relative stability of sedimentary processes caused by an equilibrium between the river and sea influences; in this area the sediments have a high proportion of calcium carbonate as a result of high primary production (500-700 g C m^2yr^{-1}) (Lampe 1998); and
4. A narrow strip of the bottom along the fairway running across the Lagoon; it is characterised by the highest phosphorus and manganese contents caused probably by frequent changes in the redox conditions due to the big ship traffic.

Depending on the wind-speed and direction, a characteristic cellular circulation of water can be observed in the Szczecin Lagoon. It seems the pattern of facies variability of sediments reflects this specific water circulation (Robakiewicz 1993).

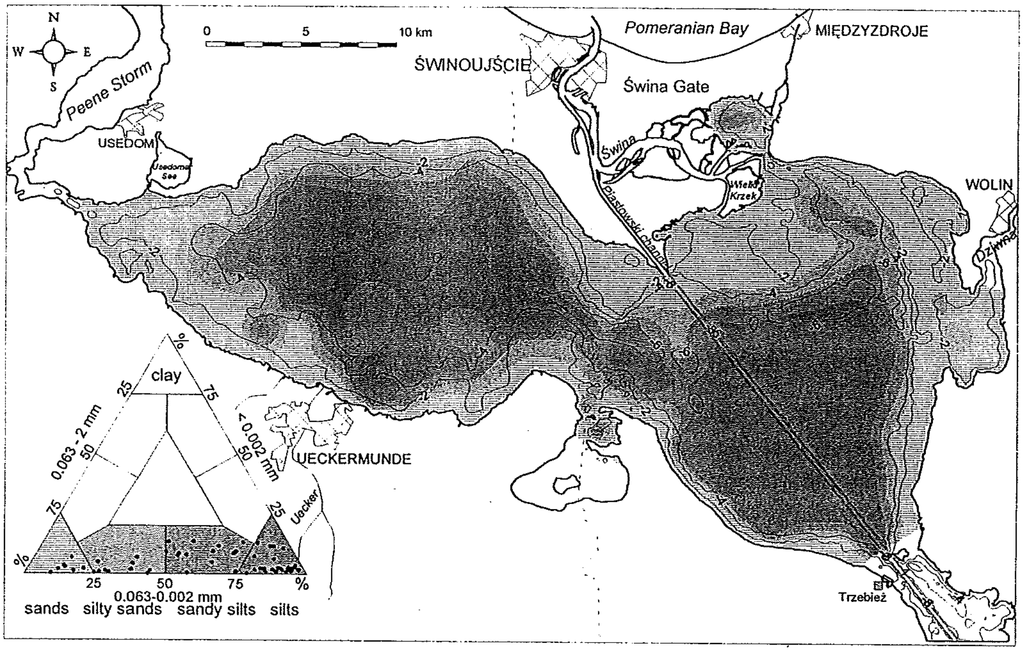


Fig. A. Distribution of granulometric types of sediments

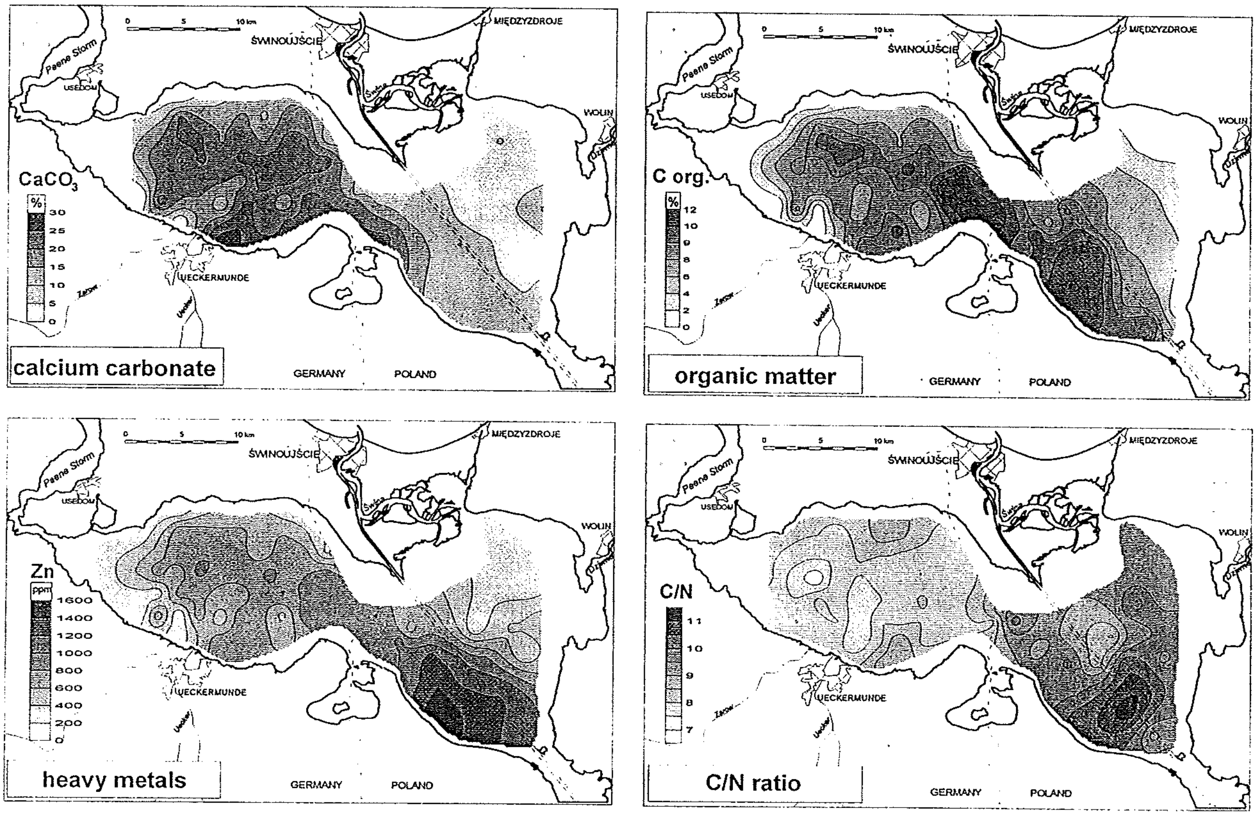


Fig. B. Geochemical variability of the Szczecin Lagoon bottom sediments

Conclusions

The Oder mouth displays much more features characteristic of coastal lagoons than of estuaries. The features include:

- the presence of a barrier separating it from the open sea and the connection with the sea *via* three long and narrow inlets performing a role similar to that of ebb and flood channels in classic lagoons;
- the formation of a sandy ingression delta in the sea-controlled zone;
- the shallowness of the sedimentary basin typical of lagoons;
- the dominant effect of wind on water circulation and no density stratification of water;
- high organic production, mainly of phytoplankton;
- the deposition of characteristic lagoon sediments, i.e., sapropel silts rich in organic matter.

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2. 1. 2. THE DEPOSIT SEQUENCES OF THE SZCZECIN LAGOON

Ryszard K. Borówka, Andrzej Osadczuk, Andrzej Witkowski,
Brygida Wawrzyniak-Wydrowska

Szczecin University, Department of Natural Sciences, Marine Research Institute

Introduction

Geological structure of the Zalew Wielki (Great Lagoon) was analysed from a board of the R/V „Doktor Lubecki". Seismoacoustic studies were done by means of bottom profiler „Seabed Oretech 3010-S" at 5 kHz. Alltogether 18 seismoacoustic profiles, 200 km in length were accomplished. Based on the preliminary results of the seismoacoustic profiling, 23 sites were chosen for vibrocoring (Fig. 12). Vibrocores were taken by means VKG-3 device, 4 m long and 9.1 cm of internal diameter. Particular cores 3-4 meters in length were cut into 1 m intervals and stored in 3-4°C temperature. In laboratory conditions all cores were photographically documented and their lithology was macroscopically described. In the description were included: colour of the sediment, structural and textural features, organic matter content and the presence of fossil macroremains. Subsamples for the following analyses were collected: granulometric, diatomological, palynological, malacological, geochemical and for ^{14}C dating.

Depositional sequences

The results of the former studies showed that the sedimentary infill of the Great Lagoon is composed of several depositional sequences. The best examples of their development and succession were observed in the following cores: 29/99; 35/99; 37/99; 39/99; 42/99 and 47/99 (Fig. 13-18). The following depositional series were distinguished in accordance with the stratigraphic order: fluvial, limnic-swampy, marine and lagoonary.

Fluvial series usually constitute basement of the organic deposits filling in the Great Lagoon basin. The bottom of this series was not penetrated at the area of the Great Lagoon by the coring equipment, therefore its total thickness was not accurately determined. The data from the older studies indicates that it reaches at least the depth of 24 m b. s. l., but in the sole part it shifts into fluvioglacial deposits. In the cores of the present study its thickness attained up 3.5 m. In the lower part
occurred usually fine- and medium-grained sands, sometimes with large scale diagonal bedding. In the uppermost (towards the roof) part of the series increased content of finer

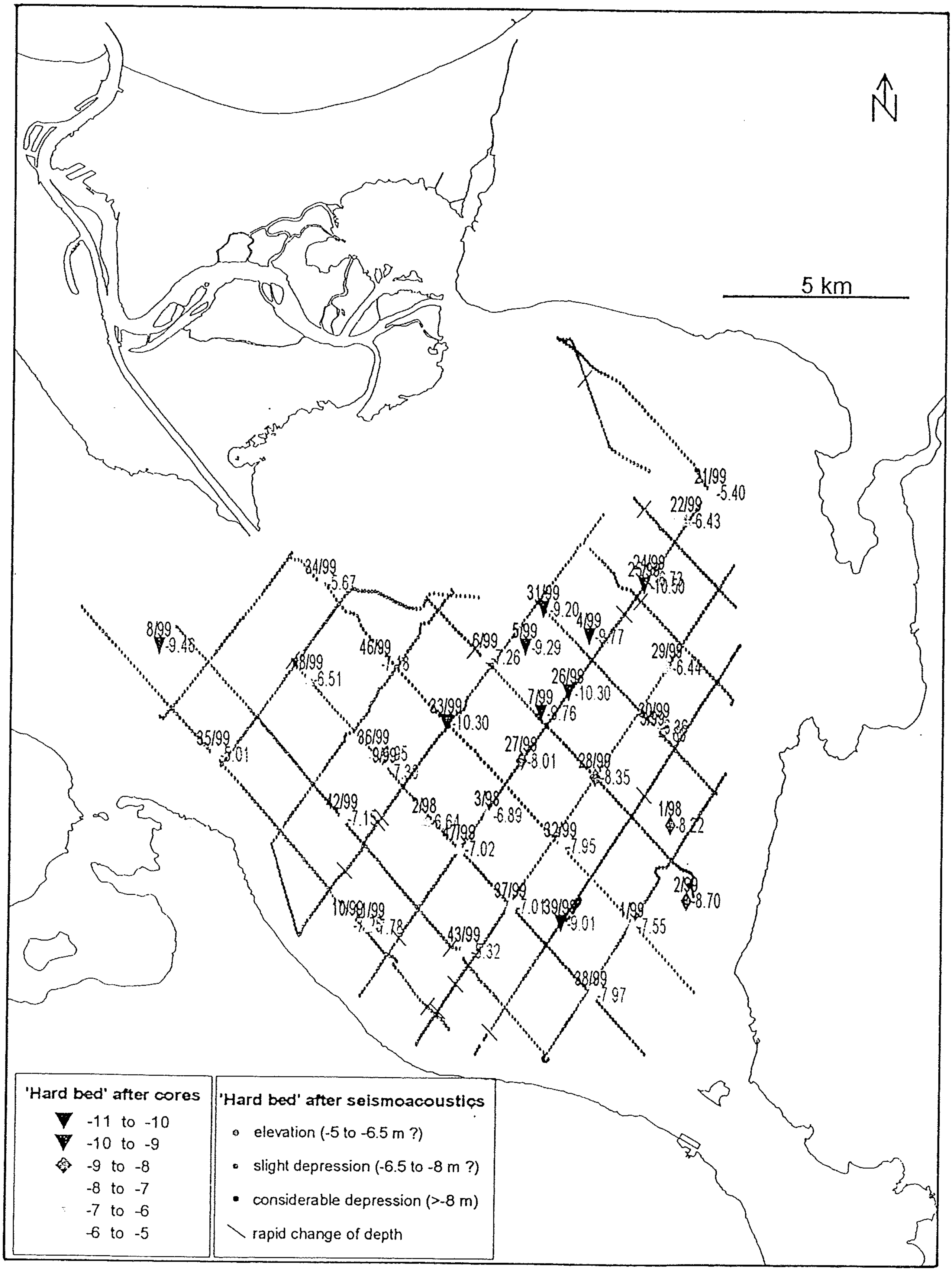


Fig 12. Szczecin Lagoon: distribution of the vibrocores and seismoacustic profiles

Core 29/99

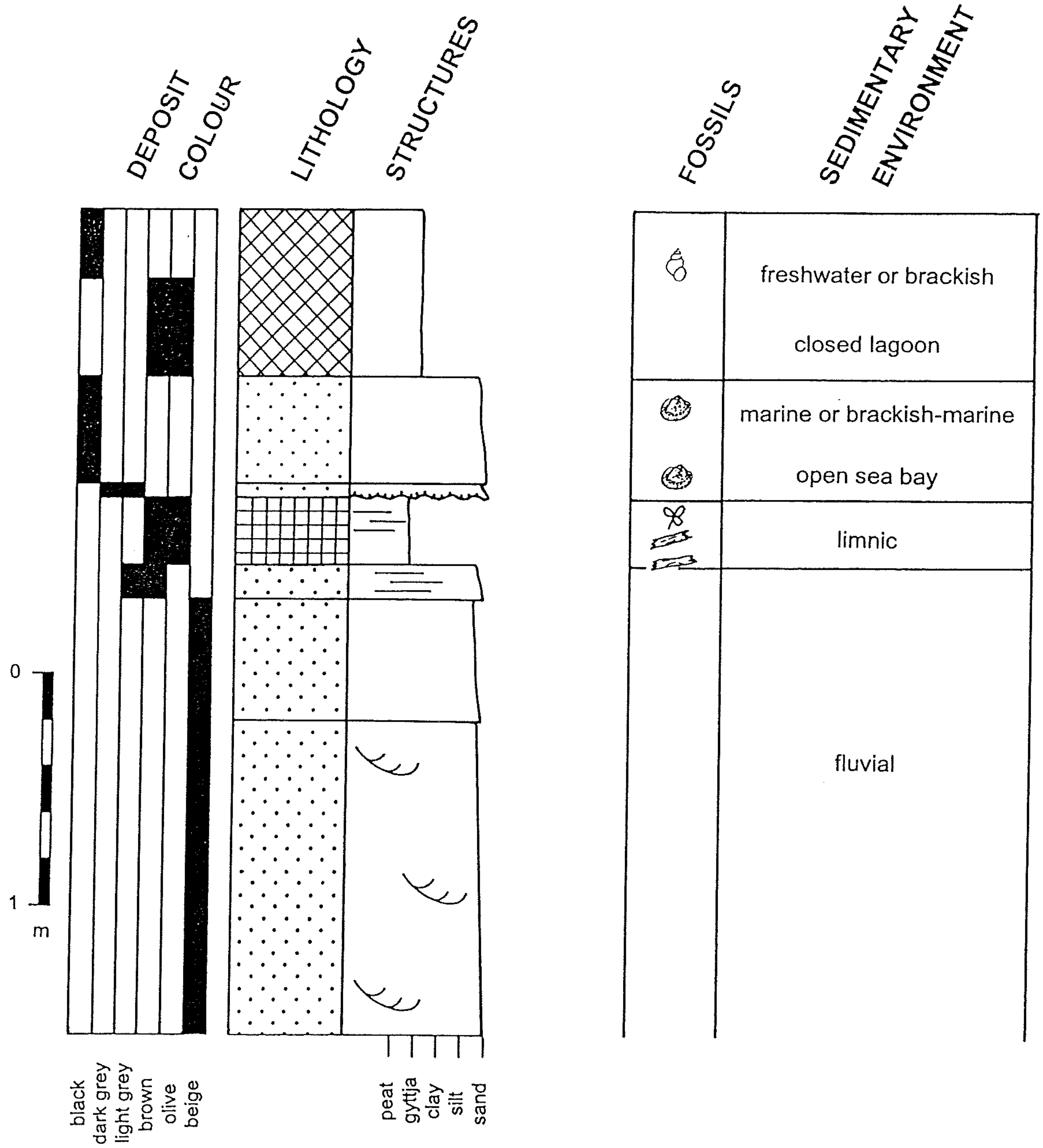


Fig. 13. Szczecin Lagoon; core 29/99 – lithology, structures Szczecin Lagoon; core 29/99 – lithology, structures and sedimentary environment reconstruction

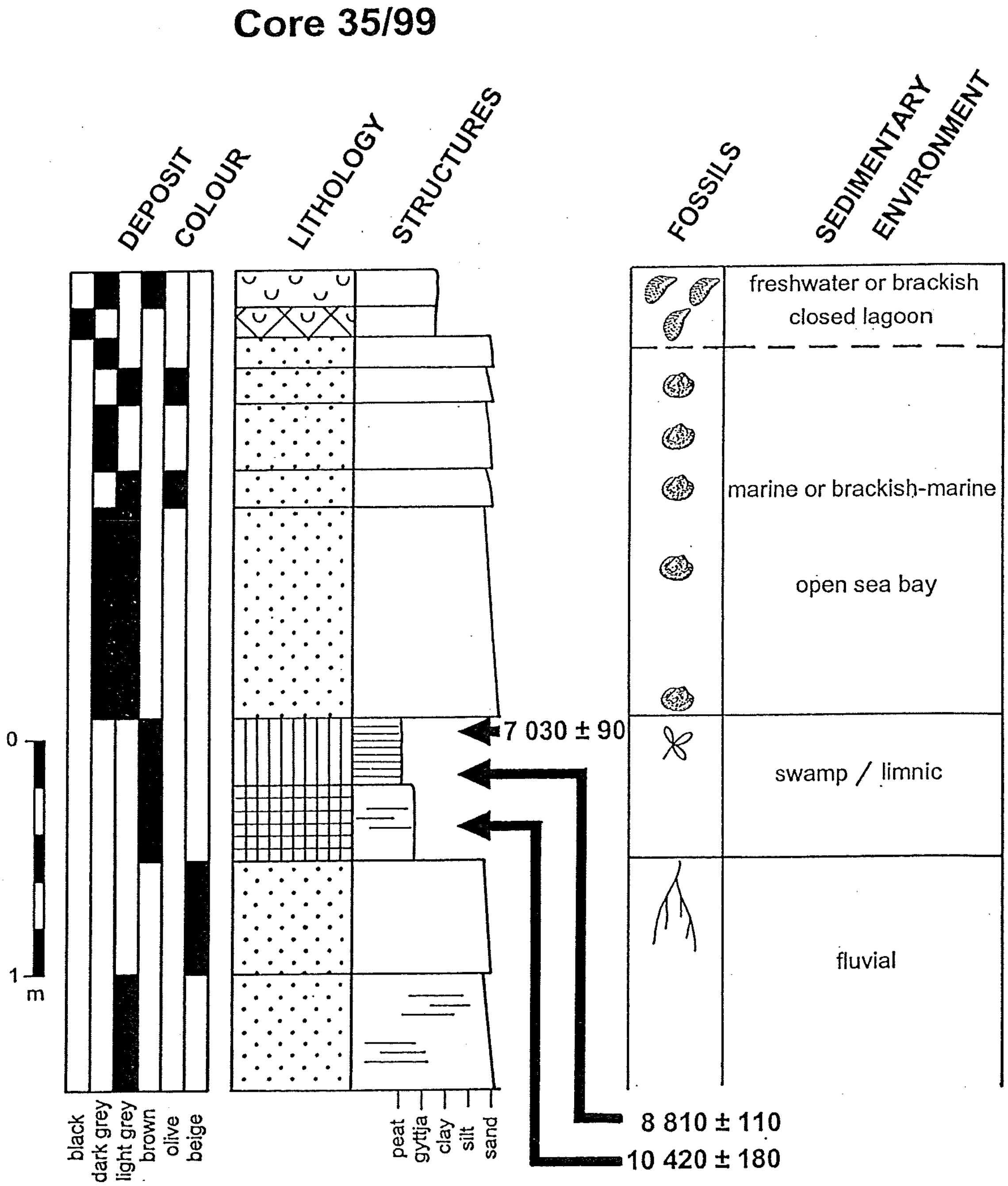


Fig. 14. Szczecin Lagoon; core 35/99 – lithology, structures, radiocarbon datings and sedimentary environment reconstruction

Core 37/99

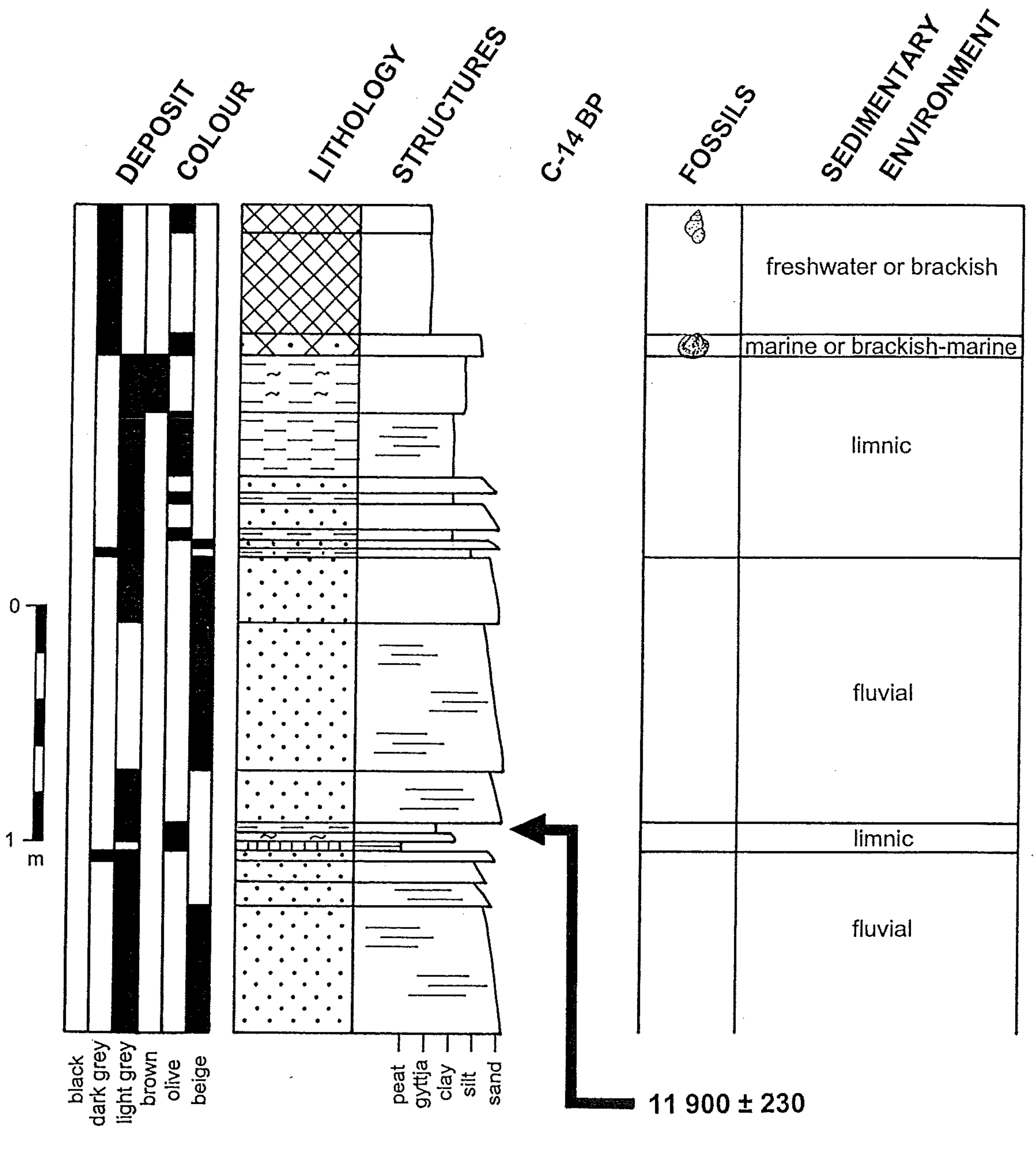


Fig. 15. Szczecin Lagoon; core 37/99 – lithology, structures, radiocarbon datings and sedimentary environment reconstruction

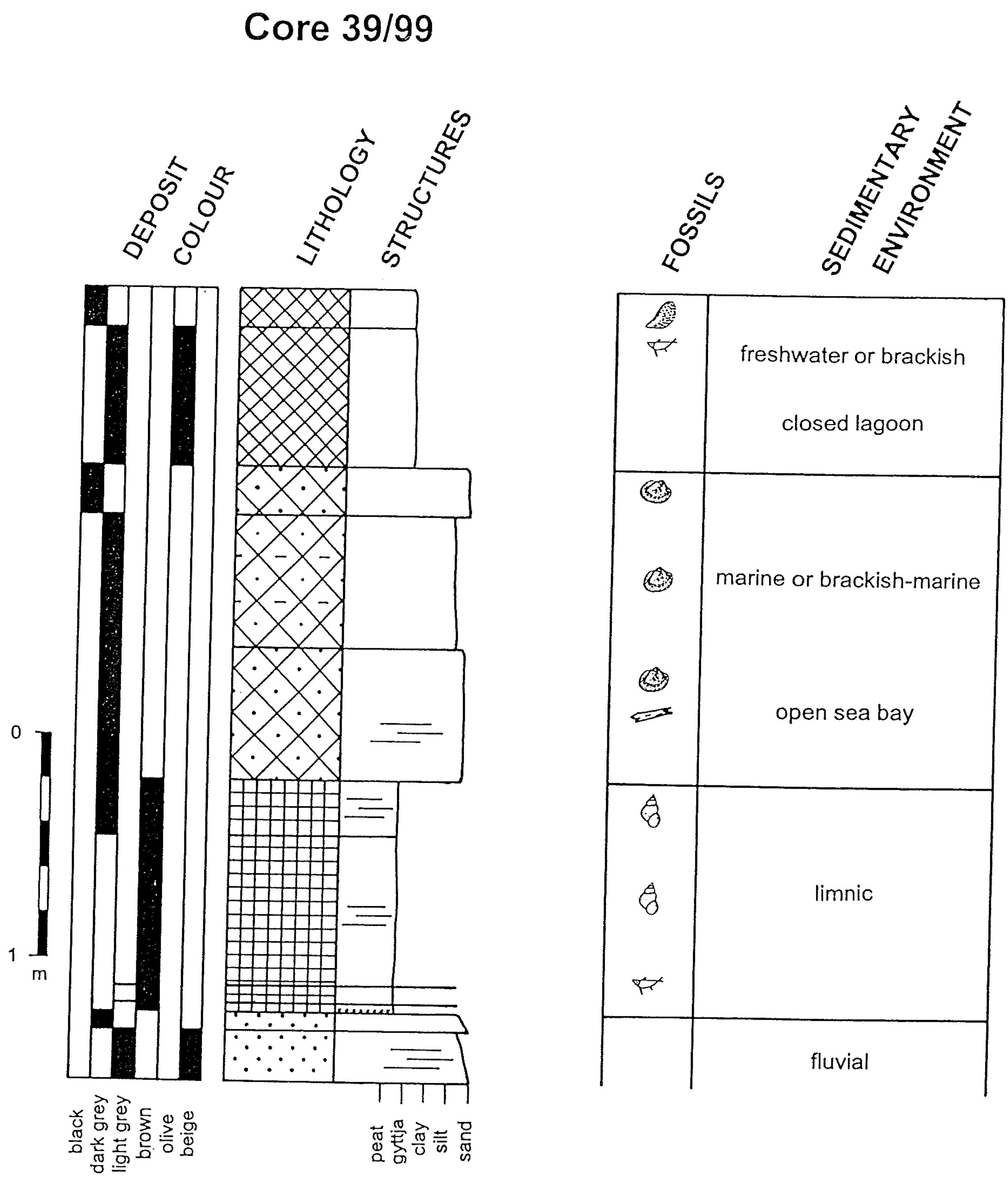


Fig. 16. Szczecin Lagoon; core 39/99 – lithology, structures and sedimentary environment reconstruction

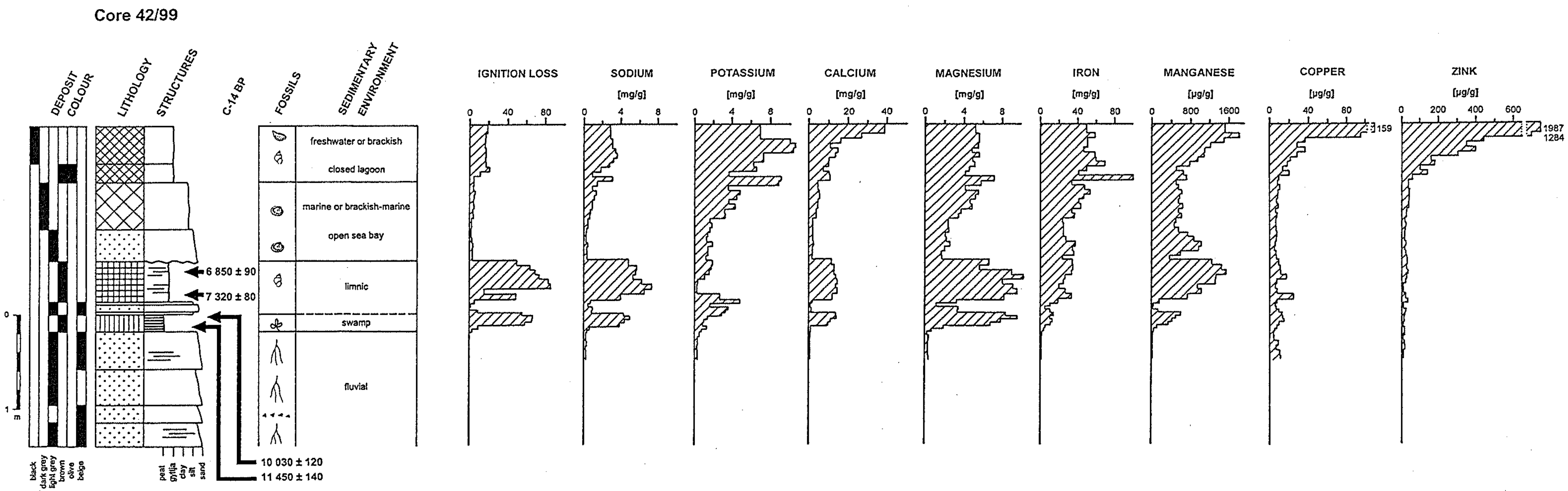


Fig. 17. Szczecin Lagoon; core 42/99 – lithology, structures, radiocarbon datings, sedimentary environment reconstruction and geochemical diagram

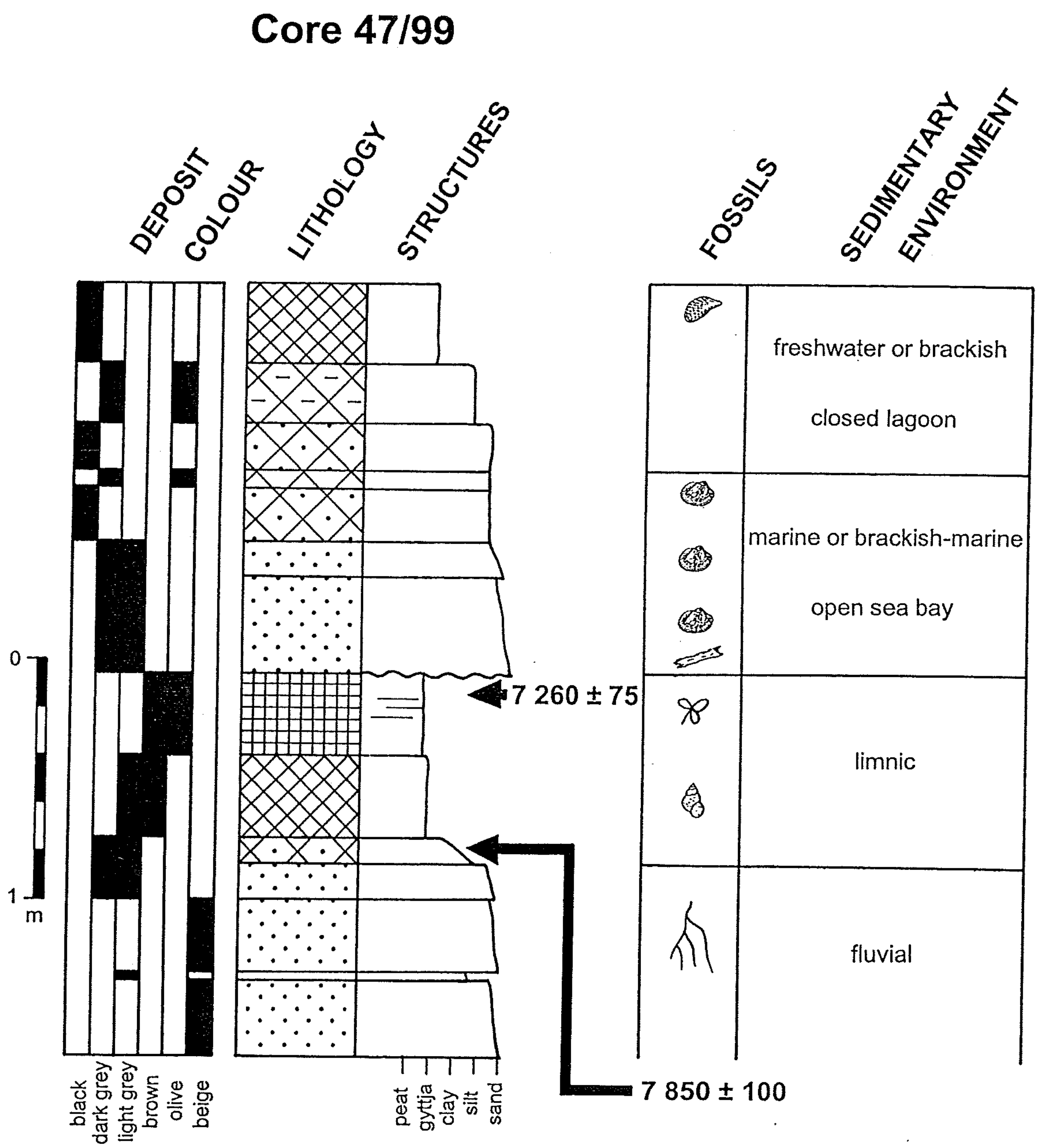


Fig. 18. Szczecin Lagoon; core 47/99 – lithology, structures, radiocarbon datings and sedimentary environment reconstruction

fractions followed by horizontal lamination. Sands of this series are characterised by well and very well sorting, and their mean grain diameter (Mz) usually ranged from 2.0 to 3.0 phi units (Fig. 19).

Within some of the cores (e.g. 35/99; 42/99 and 47/99) in the uppermost part of the fluvial series numerous traces of root levels and sometimes intercalations of sand with charcoal were observed. In the core (37/99) fluvial series were divided into two parts, the lower riverine sand was separated from the upper one by thin layer of limnic-swampy deposits of Alleröd age (Borówka et al. 2001).

The morphology of the roof surface of the fluvial series is variable (Fig. 20). Its deepest position was recorded in the middle part of the Great Lagoon, where it appears at the height of 10-11 m b. s. l. and in the north-western part, close to the border of the Little Lagoon (Mały Zalew = Kleines Haff). In the eastern part and along the western coast of the Lagoon the height of the roof increases to 6-7 m b.s.l. The analysis of the seismoacoustic data revealed the presence of relatively steep surfaces, within the roof surface of the fluvial series, with edges of the relative height up to ca. 3 m. These surfaces are interpreted as erosional cuts related to the lateral migration of the Pre-Odra River beds (Osadczuk & Borówka 2000).

Aleröd limnic-swampy series - its presence was recorded in three cores (i.e. 36/99; 37/99 and 42/99), which were located along the western coast of the Great Lagoon, at the area of fluvial series elevation. Its stratigraphic position has been based so far only on the litostratigraphic and chronostratigraphic analyses (Borówka et al. 2001). The total thickness of this series ranges from more than 10 cm to more than 20 cm and is composed of organic and clayey – muddy deposits. It appears within the fluvial series.

Holocene limnic-swampy series - it rather frequently constitutes lower part of the organic deposits filling in the sedimentary basin of the Great Lagoon. Its thickness ranges from more then 10 cm up to 2 m. However, in some locations it was absent. Spatial analysis of its thickness distribution revealed that this series fill in elongated depressions within the roof of the fluvial series, particularly in the middle part of the Great Lagoon (Fig. 20). They are interpreted most likely as past river beds of the Pre-Odra River.

The limnic-swampy series are predominantly composed of Early Holocene detritus gyttja, which sometimes are underlayed or overlayed by usually well decomposed peat with wood pieces. The organic matter content of this gyttja ranged from 20 to 80 %, with sometimes distinct share of $CaCO_3$ (Borówka 2000).

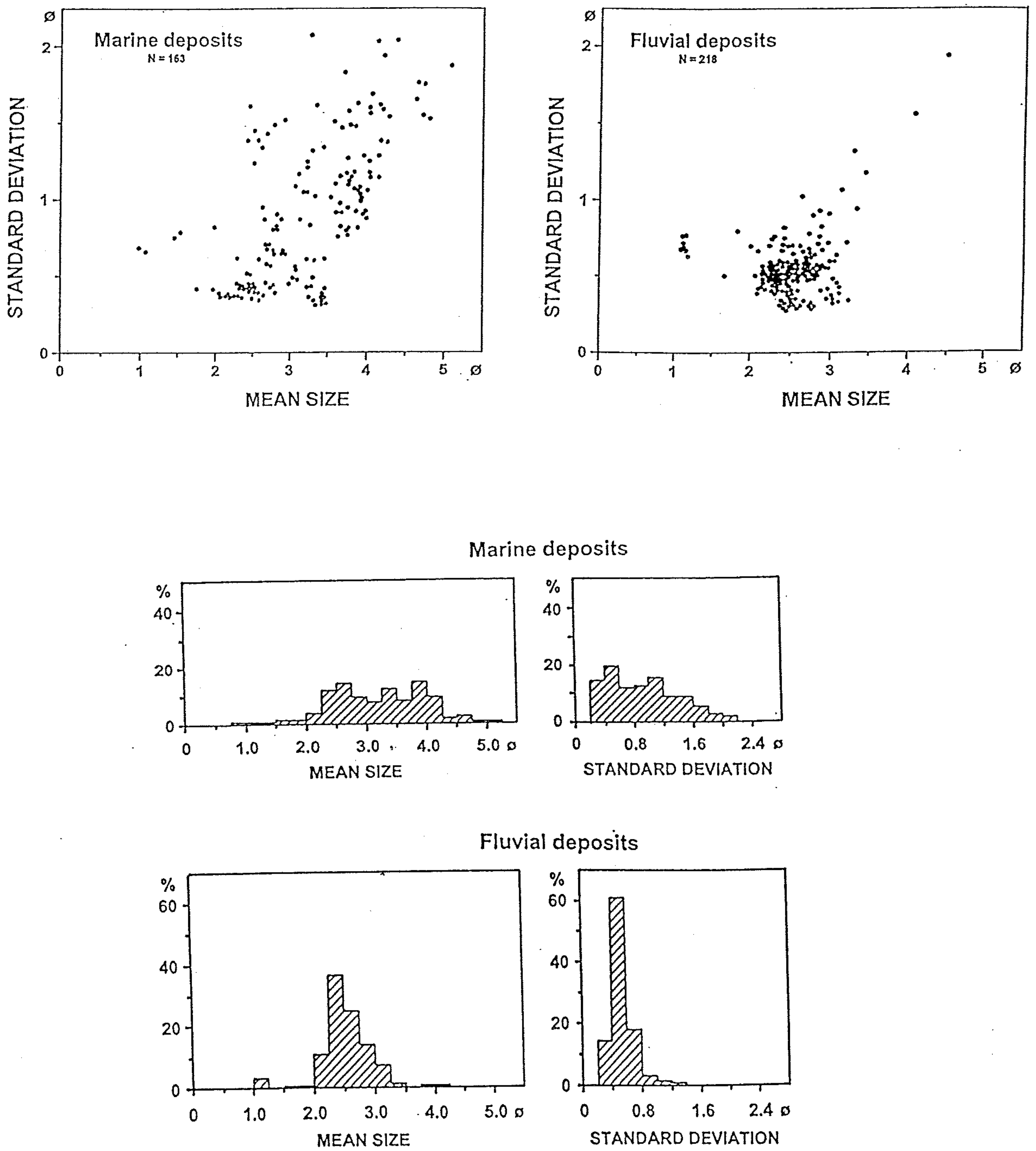


Fig. 19. Szczecin Lagoon – grain size distribution parameters of the fluvial and marine deposits

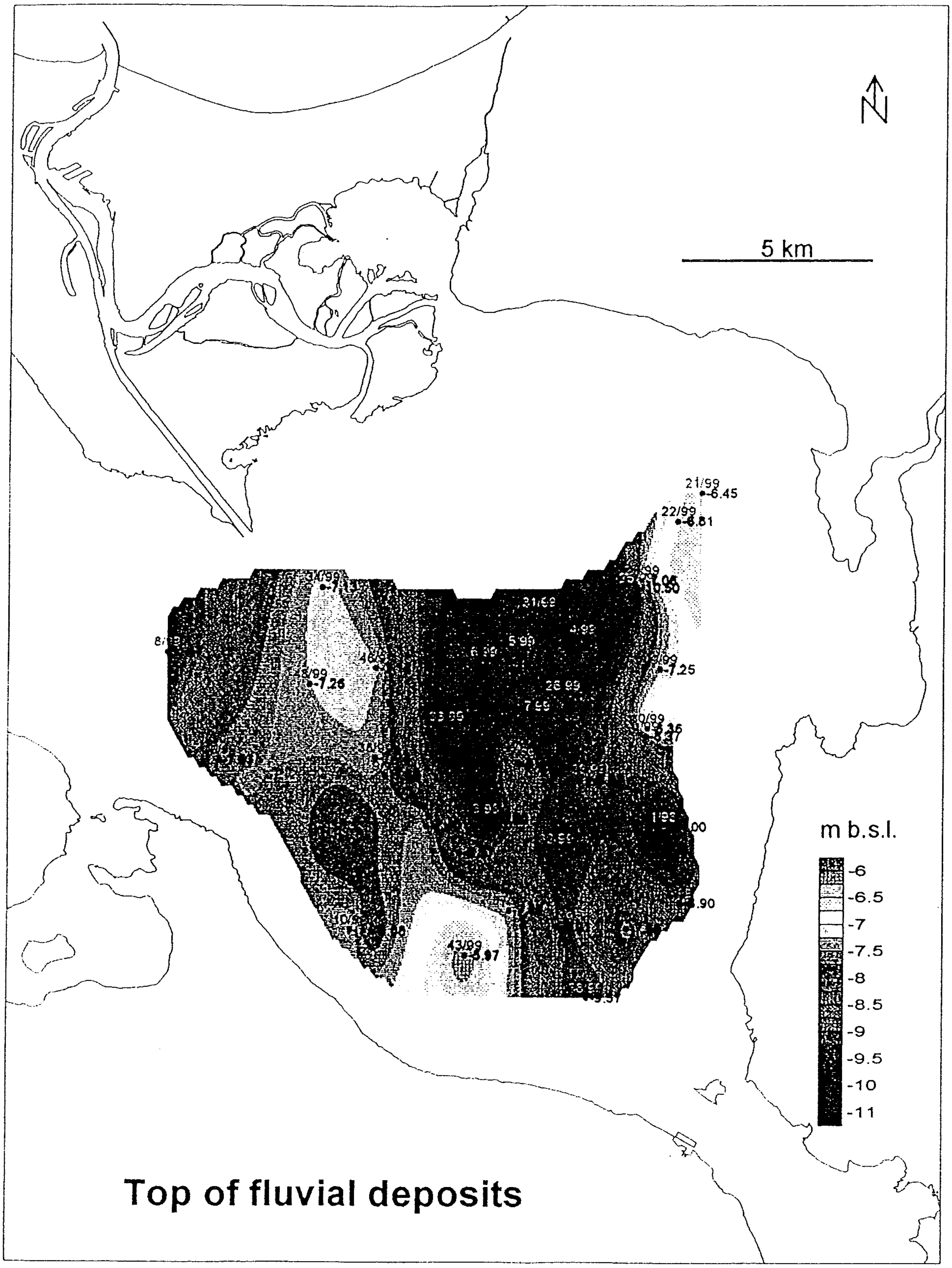


Fig. 20. Szczecin Lagoon – morphology of the top surface of the fluvial deposits

In the detritus gyttja commonly occurs freshwater molluscan fauna, among which dominant were taxa characteristic for small lacustrine basins (Fig. 21), e.g. *Bithynia tentaculata, Valvata piscinalis, Lymnaea* sp. oraz *Pisidium* sp. (Borówka et al. 2000). Sporadically, some fish remnants were also encountered.

In these series abundant diatom flora was recorded. This was predominantly epiphytic taxa pointing out to an existence of shallow water bodies with abundant occurrence of macroplants. Simultaneously, domination of benthic taxa indicates shallow water environment with good light conditions (Fig. 22, 23, 24, 25, 26).

In the zone of higher terrace levels, e.g. in Skoszewska Bay and in Dąbie Lake, the series of Holocene limnic-swampy deposits are only represented by peat covers composed of different peat types. These were *Carex* and *Carex*-reedy peat in the sole part of the profile and woody and woody-*Carex* peat in the roof. Its thickness attained up to ca. 2 m.

The duration of the deposition of the limnic-swampy series is determined from the beginning of Holocene up to ca. 6200 y BP (Borówka et al. 2001). The hitherto obtained data points out to its formation in conditions of rather distinct isolation from influences of the Pre-Odra River waters. Only in one core (43/99) the presence of ca. 1-m thick layer of fluvial sands within the Holocene limnic-swampy series was recorded. In the remaining cores these deposits did not include more distinct interlayerings of fluvial sediments.

Marine series - it occurred in almost all cores analysed which were taken from the deep water part of the Great Lagoon. Its sole is marked by a distinct erosional discontinuity at which sandy sediments were deposited. They are characterised by increased content of coarse fraction and relatively well degree of sorting. The floor surface of this series is not well marked and its uppermost boundary is only possible to be determined based on the malacological analysis.

Thickness of the marine series is variable, but it rarely exceeds 1.5 m. Its highest thickness was recorded in the northern part of the area analysed (Fig. 20. In the core 31/99 it attained ca. 3 m and was not penetrated to the bottom The presence of marine series was not encountered in the area of higher terraces level i.e. in Skoszewska Bay and Dąbie Lake.

Marine series are very well distinguished based on malacological analysis (Borówka et al. 2000). The molluscs fauna of the sandy sediments is dominated by *Cardium glaucum*, which forms here well developed populations with shell size larger than in recent Pomeranian Bay. It was accompanied by *Hydrobia ventrosa*, *H. ulvae* and *H. balthica*.

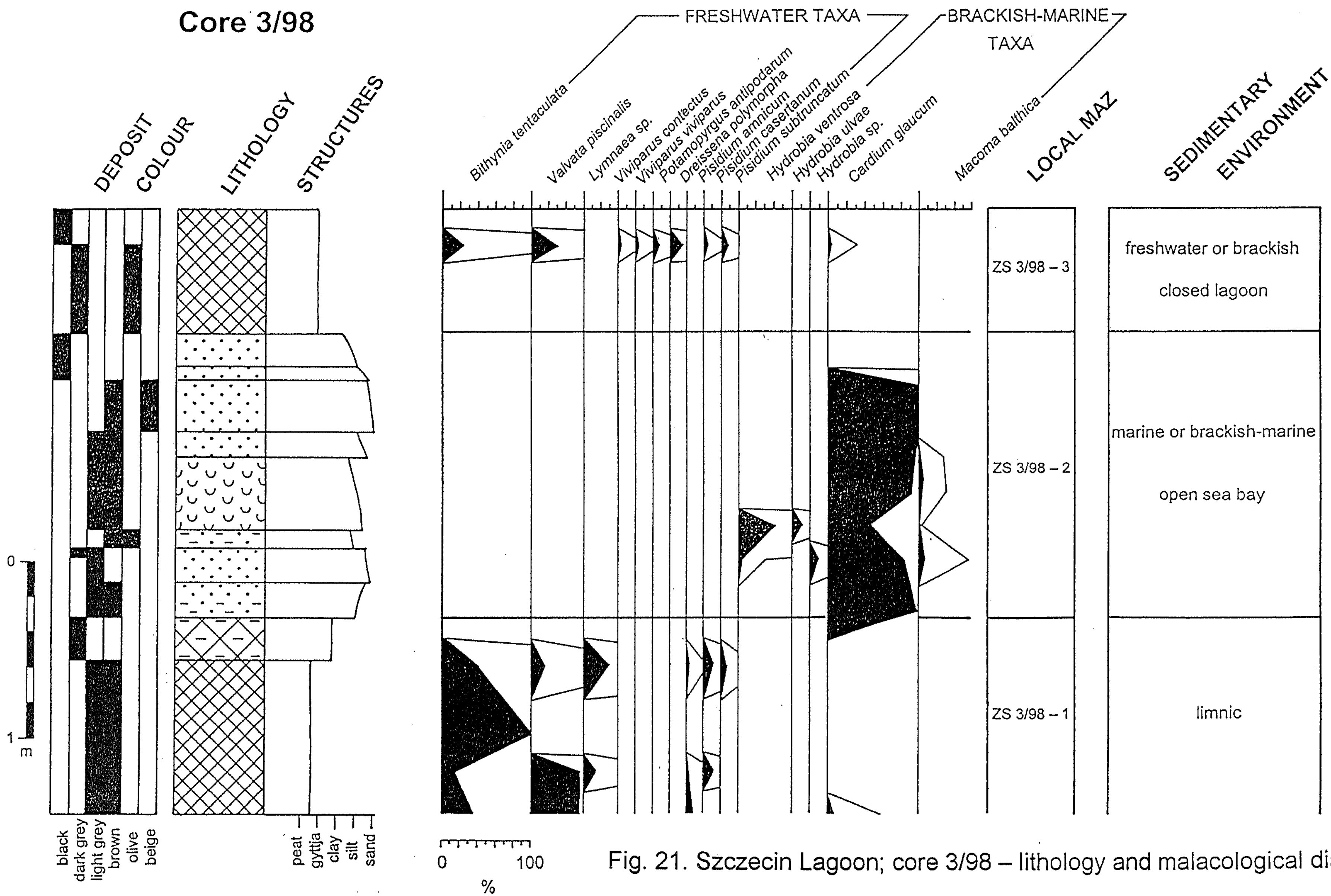


Fig. 21. Szczecin Lagoon; core 3/98 – lithology and malacological diagram

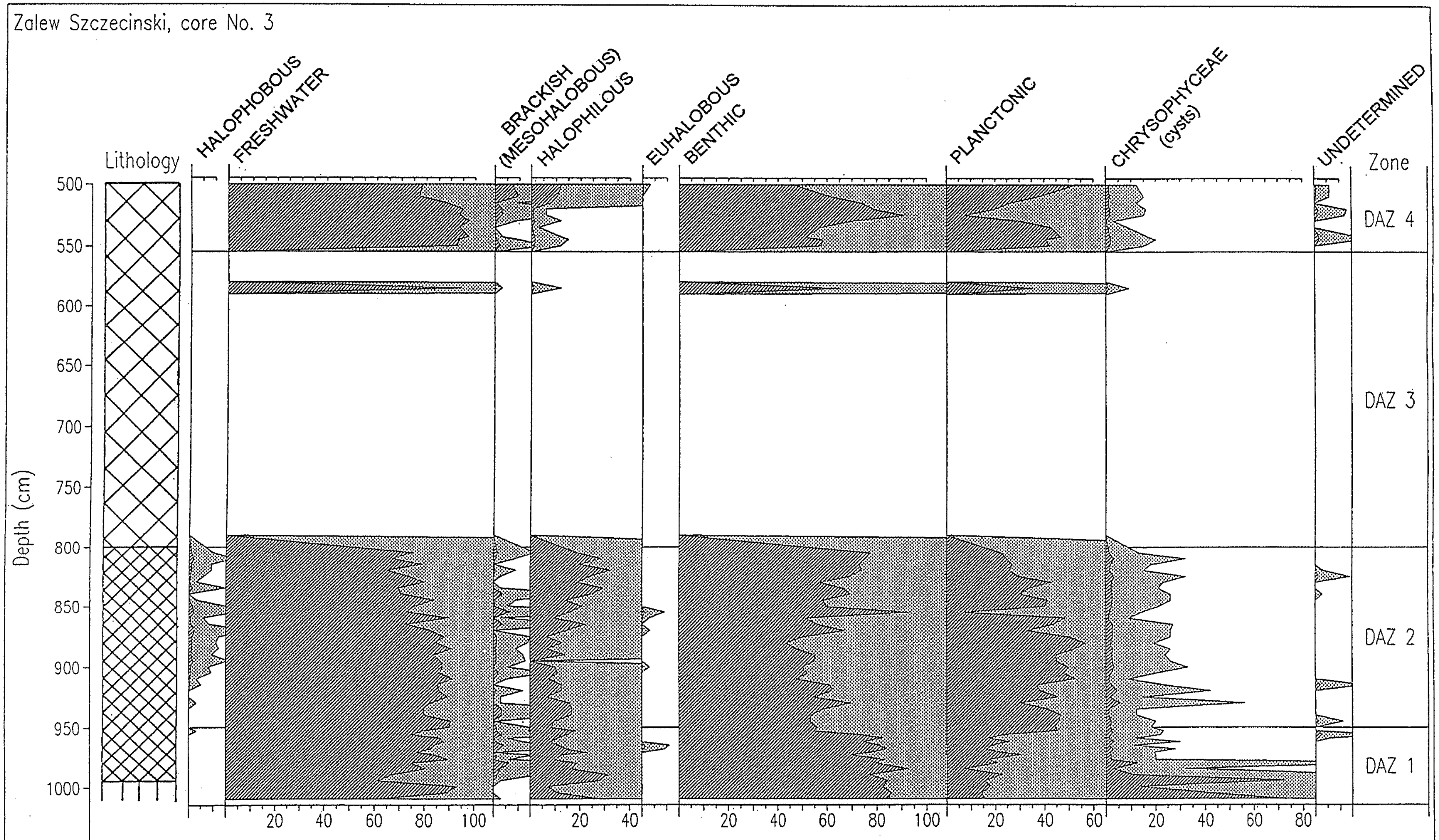


Fig. 22. Szczecin Lagoon; core 3/96 – diatomological diagram (after Borówka et al. 1999)

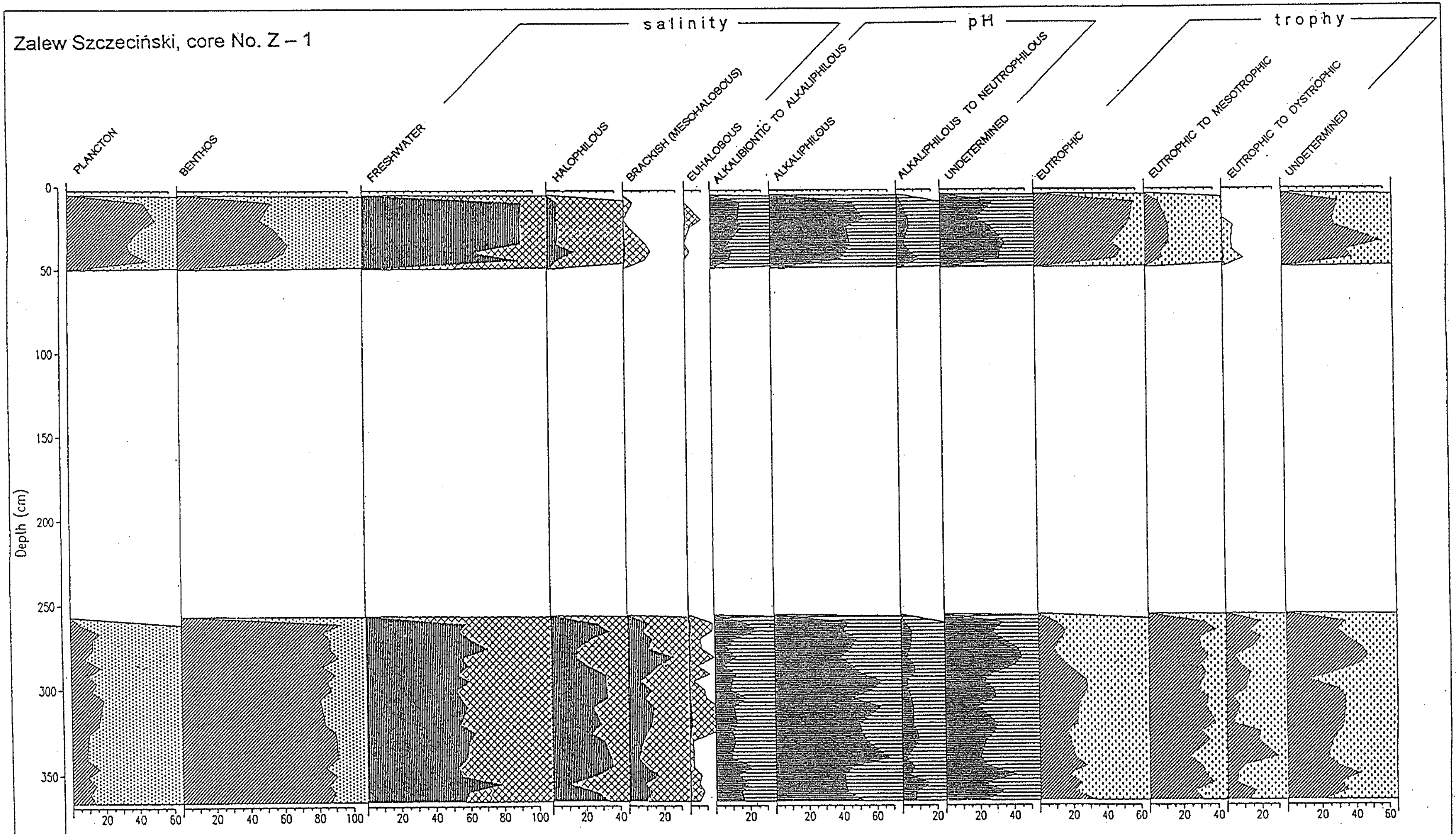


Fig. 23. Szczecin Lagoon; core 1/98 – diatomological diagram

Analysis Krystyna Kowalczyk, 2000.

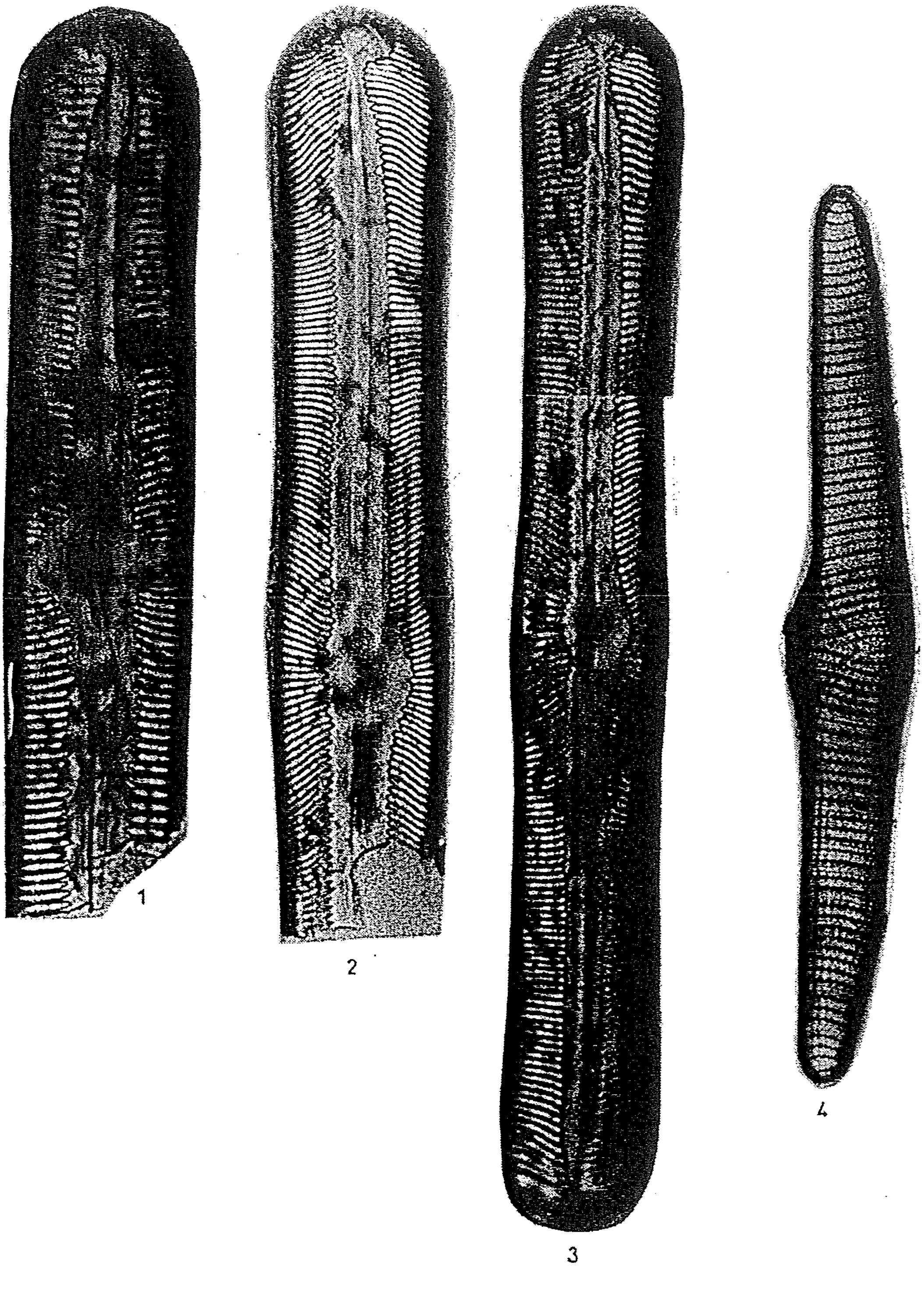


Fig. 24. Szczecin Lagoon; selected species of diatomea
1 – *Pinnularia cardinalis*, 2, 3 – *Pinnularia nobilis*, 4 - *Epithemia turgida* (initial cell)

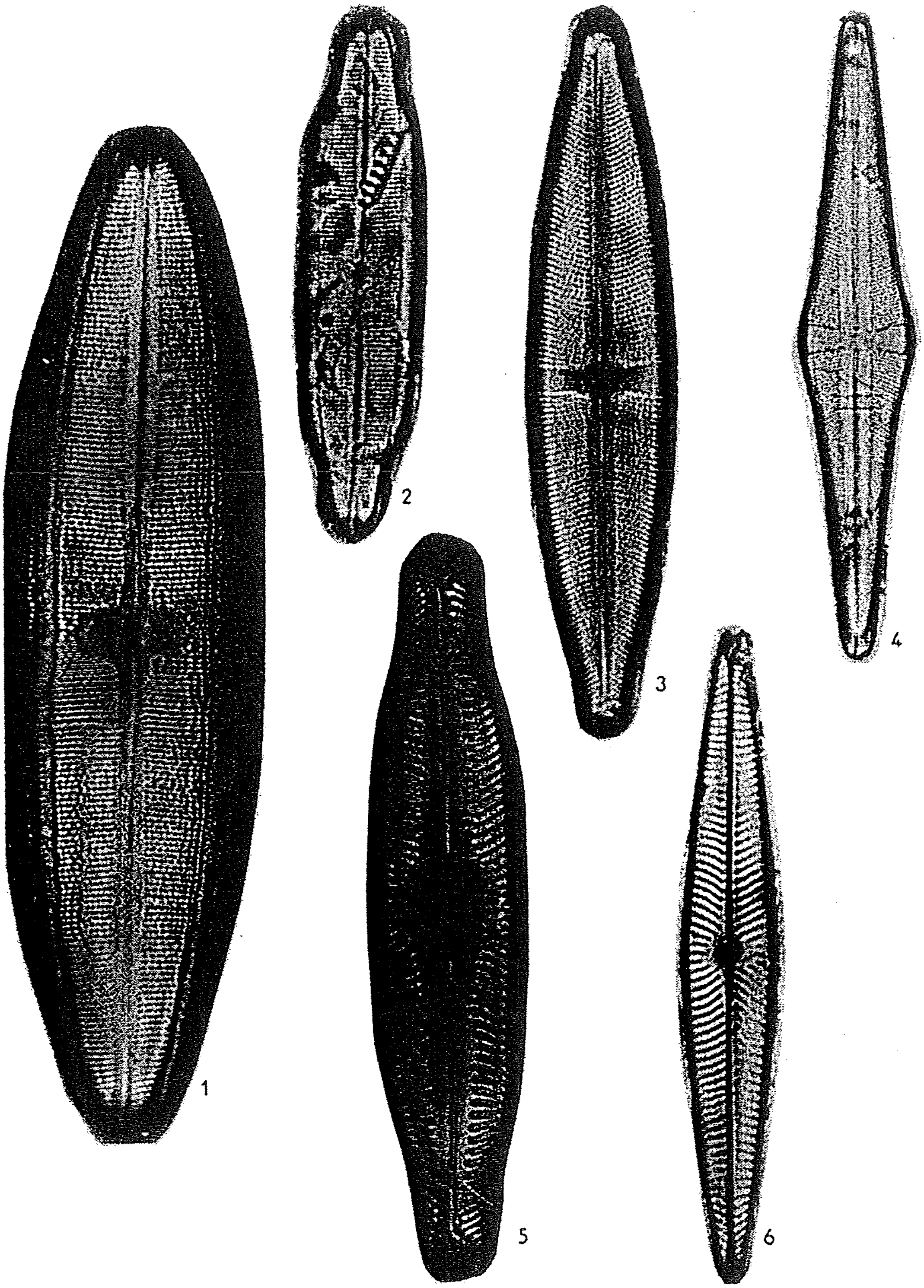


Fig. 25. Szczecin Lagoon; selected species of diatomea

1 – *Neidium sp.* 2 – *Neidium cf. Ampliatum,* 3 – *Stauroneis gracilis,* 4 – *Stauroneis acuta,* 5 – *Pinnularia divergens var. decrescens,* 6 – *Navicula radiosa*

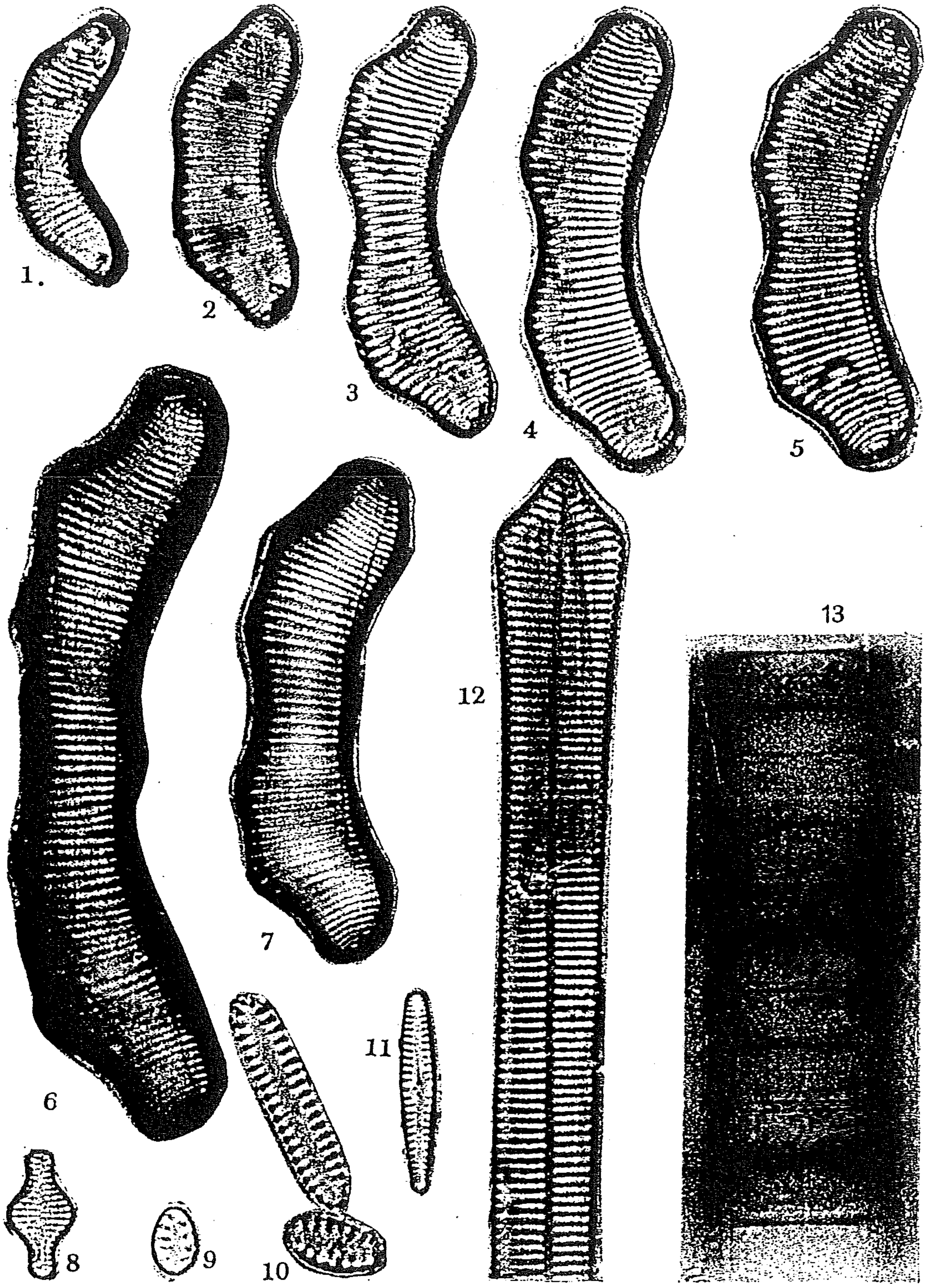
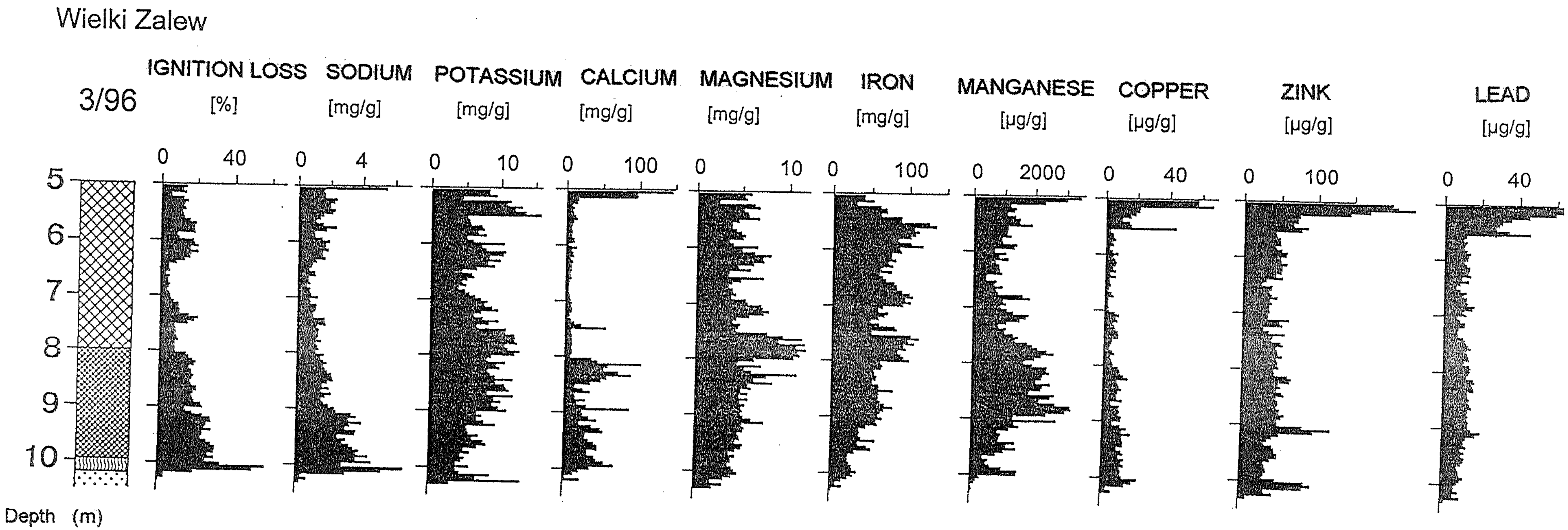


Fig. 26. Szczecin Lagoon; selected species of diatomea

1-7 – *Eunotia sp (nov.)*, 8 – *Fragilaria construens*, 9, 10 – *Fragilaria lapponica*, 11 – *Gromphonema pumilum*, 12 – *Fragilaria dilatata*, 13 – *Ellerbeckia arenaria*



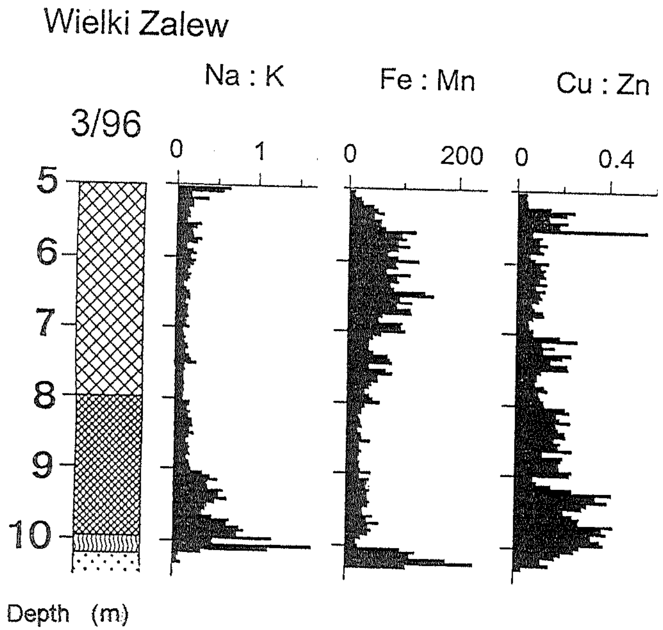


Fig. 27. Szczecin Lagoon; core 3/96 – geochemical diagram (after Borówka et al. 1999)

One of the characteristic features of the marine series is an absence of the diatom flora (Wypych 1980; Borówka et al. 1999). This phenomenon might be related to sedimentation rate of the sandy sediments and due to current and waves action.

With respect to lithology marine series shows distinct bipartition. It is composed from sandy and muddy-sand lithofacies, another factors of diversification are: organic matter, Na, K, Ca, Mg and Fe contents (Borówka 2000). Sediments of the marine series show distinct variability with respect to grain-size composition comparing to the fluvial series (Fig. 19). They have much finer grain-size and worse sorting, particularly in the eastern part of the area analysed.

Lagoonary series it differs from marine series with respect to higher content of organic matter, chemical composition (Borówka 2000), and also the species composition of molluscan fauna. Its thickness was recorded in the middle part of the study area, sometimes exceeding 2 m. On the contrary the very low thickness of the lagoonary series was characteristic for the western part of the Great Lagoon (Fig. 20).

The subfossil malacofauna of the lagoonary series is predominantly composed of freshwater taxa including *Bithynia tentaculata, Valvata piscinalis, Viviparus* sp., *Pisidium* sp., *Unio* sp., and *Dreissena polymorpha.* The latter species on some localities of the Great Lagoon bottom forms extensive colonies (e.g. core 35/99).
The period of lagoonary series deposition is marked by the presence of the diatom flora, which is predominated by freshwater planctonic taxa. Within the youngest deposits again halophilous and brakish-water taxa appeared.

The lagoonary series show a distinct bipartition with respect to geochemical analyses (Borówka 2000). Their upper part, up to a half meter in thickness, is characterised by increased concentrations of heavy metals and: Zn, Pb, Cu and Mn. In comparison to the lower part in the uppermost part 9-fold increase in Zn and almost 5-fold increase in Cu contents were observed (Fig. 17, 27).

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2. 1. 3. POLLEN AND MACROFOSSIL CONTENT OF THE SELECTED PROFILES FROM SZCZECIN LAGOON

Małgorzata Latałowa and Joanna Święta
Lab. of Palaeoecology and Archaeobotany, Dept. of Plant Ecology, University of Gdańsk

Several pollen diagrams were elaborated from the profiles taken in Szczecin Lagoon in its Polish (Mianowska and Zachowicz, in Wypych 1980; Sikorski 2000) and German (unpublished materials) area. However none of them presents undisturbed pollen sequence. Evidently, hydrological processes that took place in this area caused destruction of sediments.

Two new profiles were selected from the large set of borings made by K. Borówka team. The selected cores are characterised by relatively well developed and litologically differentiated organogenic sections of sediments. The main aims of the palaeoecological work (pollen and macrofossils – Figs. 28 and 29) is to reconstruct environmental condition in this area prior to the sea transgression and to complement data on the ecological changes during this process.

In the bottom part of the Z/42 core (see Fig. 17) accumulation of the Late Vistulian sediments is documented. The pollen picture obtained so far is not clear and should be supplemented in the feature research. The very low pollen frequency makes a serious limitation here. Local development of sedges delivering an extra large portion of *Carex* pollen affords another problem to the interpretation of this section of the diagram. It seems that at the very bottom of the profile one sample of the pre-Allerod age can be distinguished; sediments of the Allerod and Younger Dryas age contain several late glacial indicators identified by pollen or/and by macrofossils: e.g.: *Selaginella selaginoides, Dryas octopetala, Saxifraga spp., Helianthemum, Rubus chamaemorus*. Few remains of *Potamogeton*, *Lemna, Najas minor, Nymphaea alba,* cocoons of Oligochetae, gemmulae of Spongiae and remains of *Botryococcus* indicate shallow body of water surrounded by wet habitats in which *Menyanthes trifoliata* and *Selaginella selaginoides* were very common. Macrospores of the last species occur in great numbers (tens of specimens!). In the upper part, at the depth of 193-185 cm, the late glacial sequence is covered by a layer of sand.

In the next section (185-144 cm) the Holocene sequence, starting not earlier than about 8 ths years, developed. Pollen of *Pine* dominate in the diagram, but there are also

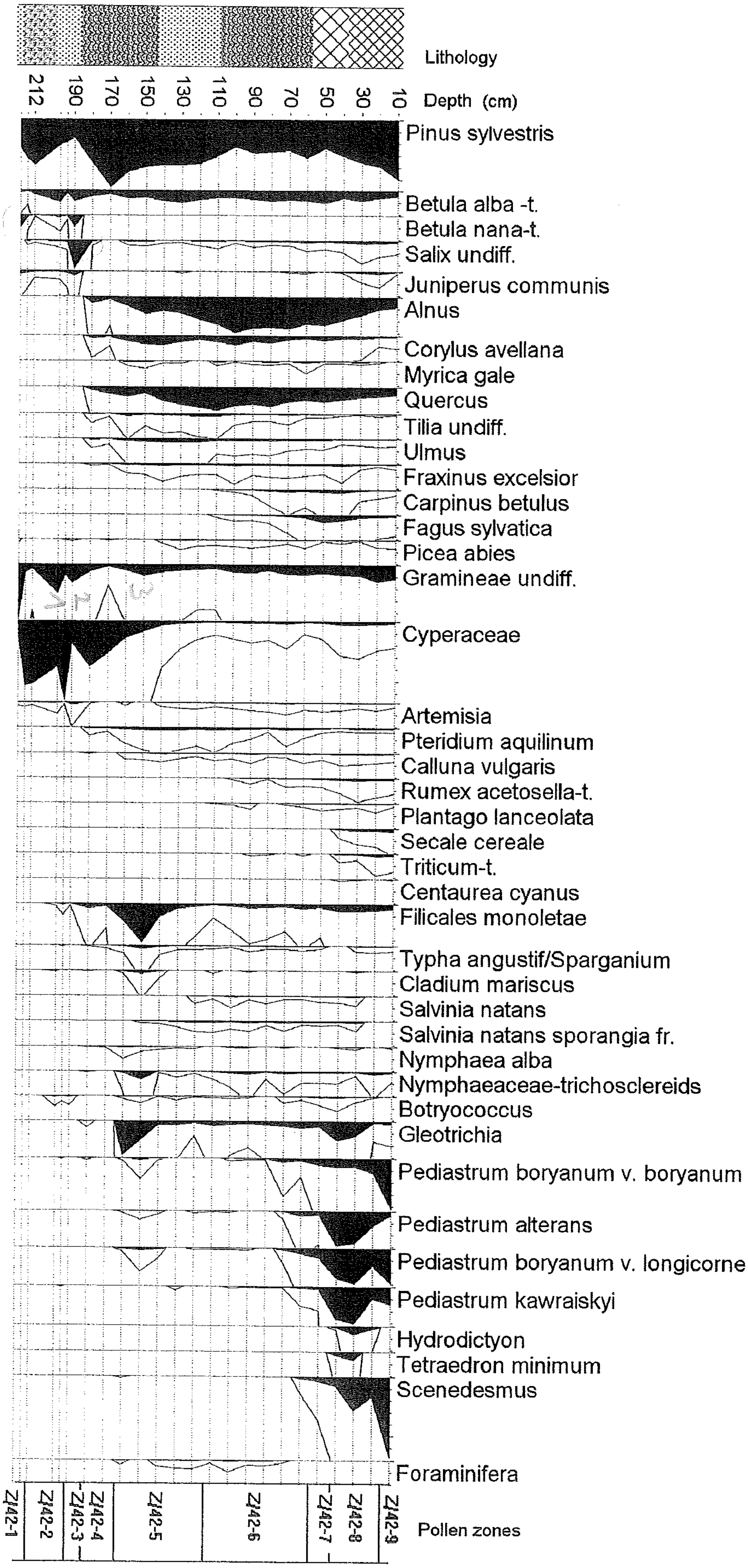

Fig. 28. Selected pollen and algae curves from Szczecin Lagoon (core 42)

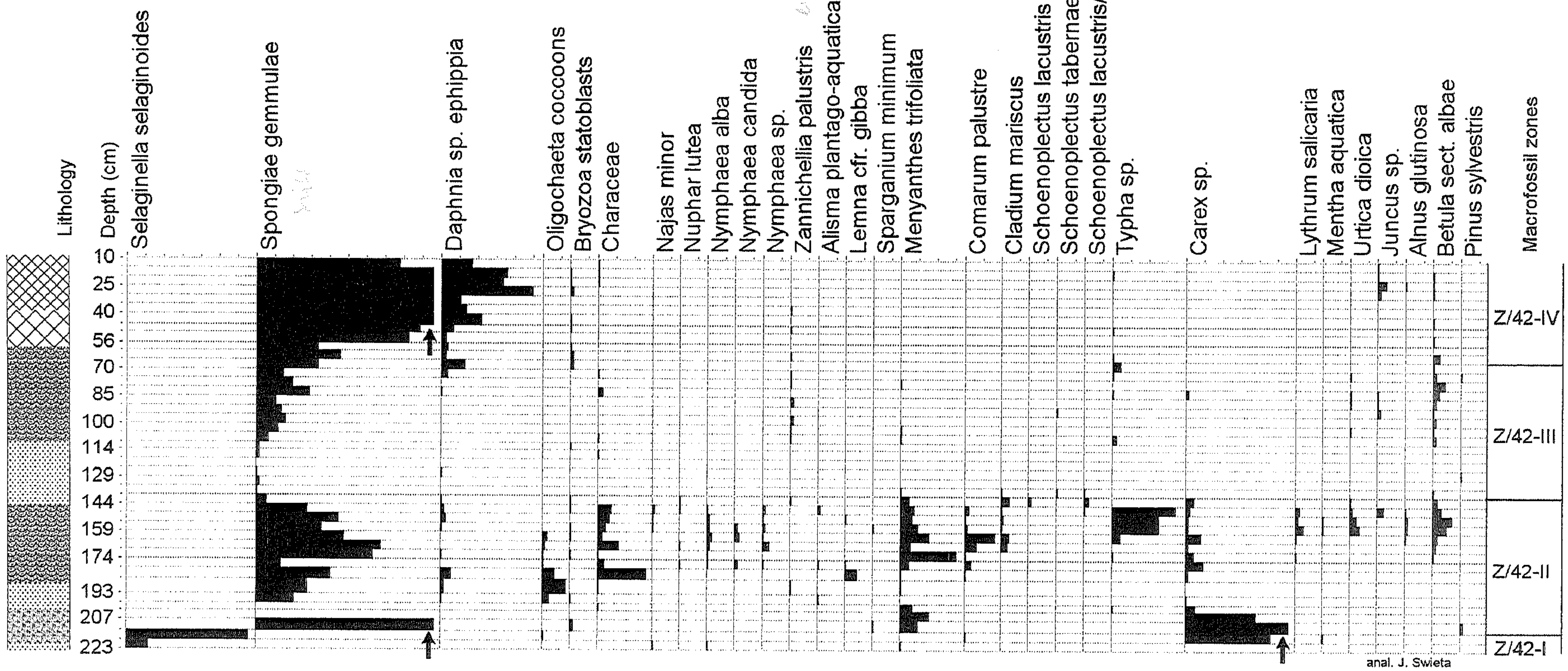

Fig. 29. Selected macrofossil data from Szczecin Lagoon (core 42)

evidences of the development of mesophilous forests. Locally, swamps with *Thelypteris palustris*, *Cladium mariscus, Comarum palustre. Menyanthes trifoliata* and several species of sedges spread. With the gradual increase in the water level water plants as *Nymphaea alba, Nuphar luteum, Potamogeton* spp., *Lemna, Salvinia natans, Sparganium spp.*, Characeae, and especially blue-green algae of *Gleotricha*, gained in importance.

In the section of 144-105cm further development of mesophilous forest is illustrated. Constant presence of charcoal particles, *Calluna vulgaris* pollen and *Pteridium aquilinum* spores document anthropogenic disturbances in woodland. Changes in the local environment can be learned from pollen and macroremains of water organisms. Remains of plants forming swamps at the margins of the lagoon decreased in importance what illustrates enlargement of the area occupied by open waters. Nympheids were still important constituents of rather shallow waters. *Salvinia natans* was widespread in the surface of water. Presence of blue-green algae point to the high trophic status of the basin environment. Inflow of marine waters is documented by presence of Foraminifera shells.

In the section 105-65 cm changes in the vegetation in the area surrounding the Lagoon are observed. The age of the lower limit of this section is about 3 ths uncal. years BP. In that time *Fagus* and *Carpinus* started to spread in woodland. The clear evidence of the developing agriculture is illustrated by the increase in anthropogenic indicators pollen curves. The local conditions in the Lagoon were similar as in the previous zone.

At the depth of c. 65 cm remains of several species of freshwater green algae and those of spongiae and *Daphnia* increase in number indicating change in the local ecological conditions. This process was especially intensive in the period illustrated in the uppermost part of the profile, which at the level of c. 40 cm can be dated to the beginning of the early middle ages, because, with great certainty, the sharp increase in the curves of indicators of agriculture is linked with the development of the town of Wolin.

The palaeoecological data from the Z/39 core illustrate environmental changes from about 8 ths years BP only. But the general scheme reflecting local hydrological processes as well as changes in the surrounding woodland is similar to that described from the Z/42 core. In this core the phase of the dominance of *Thelypteris palustris* is more prominent.

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2. 1. 4. PALAEOGEOGRAPHY AND PALAEOECOLOGY OF SZCZECIN LAGOON

Ryszard K. Borówka[1], Małgorzata Latałowa[2], Andrzej Osadczuk[1],
Joanna Święta[2], Andrzej Witkowski[1]

[1]Szczecin University, Department of Natural Sciences, Marine Research Institute
[2]Lab. of Palaeoecology and Archaeobotany, Dept. of Plant Ecology, University of Gdańsk

Late Glacial and Holocene stages of the Szczecin Lagoon development

The analysis of stratigraphical and spatial variability of the Great Lagoon sedimentary infilling enable the distinction of several stages of the development of this depositional basin (Fig. 30). Their preliminary chronostratigraphic position was based on numerous radiocarbon datings of limnic-swampy deposits (Borówka et al. 2001).

The ***Pre-Alleröd stage*** is represented by series of fluvial sediments, the origin of which is related to the development of the ower Odra River valley from the end of the last glaciation to the distinct climate amelioration during the Alleröd. Within this period a complex of six terrace levels in the area of recent Odra River valley and the Szczecin Lagoon was formed. The highest of them is raised up to ca. 20 m a.s.l., whereas the lowest one at ca 10 m b.s.l. (Karczewski 1968; Duda 1999). The age of particular terraces has not been determined yet. However, it has been already documented that at the height of ca. 8 m b.s.l., within fluviatile deposits, thin intercalations of limnic-swampy deposits appear, which are dated to the Alleröd. It can not be excluded that we deal with the sediments deposited at the surface of flood terrace of the contemporary Odra River.

Nowadays, it is hard to reconstruct the contemporary bottom of the Odra River Valley and the spread of the river bed itself. Based on the palaeohydrological studies (Kozarski & Rotnicki 1977; Kozarski 1983; Rotnicki 1983, 1991) carried for the Odra River's catchment area and some of its tributaries it is known that during the Late Glacial, within the bottom of some contemporary valleys, large meandering channels were

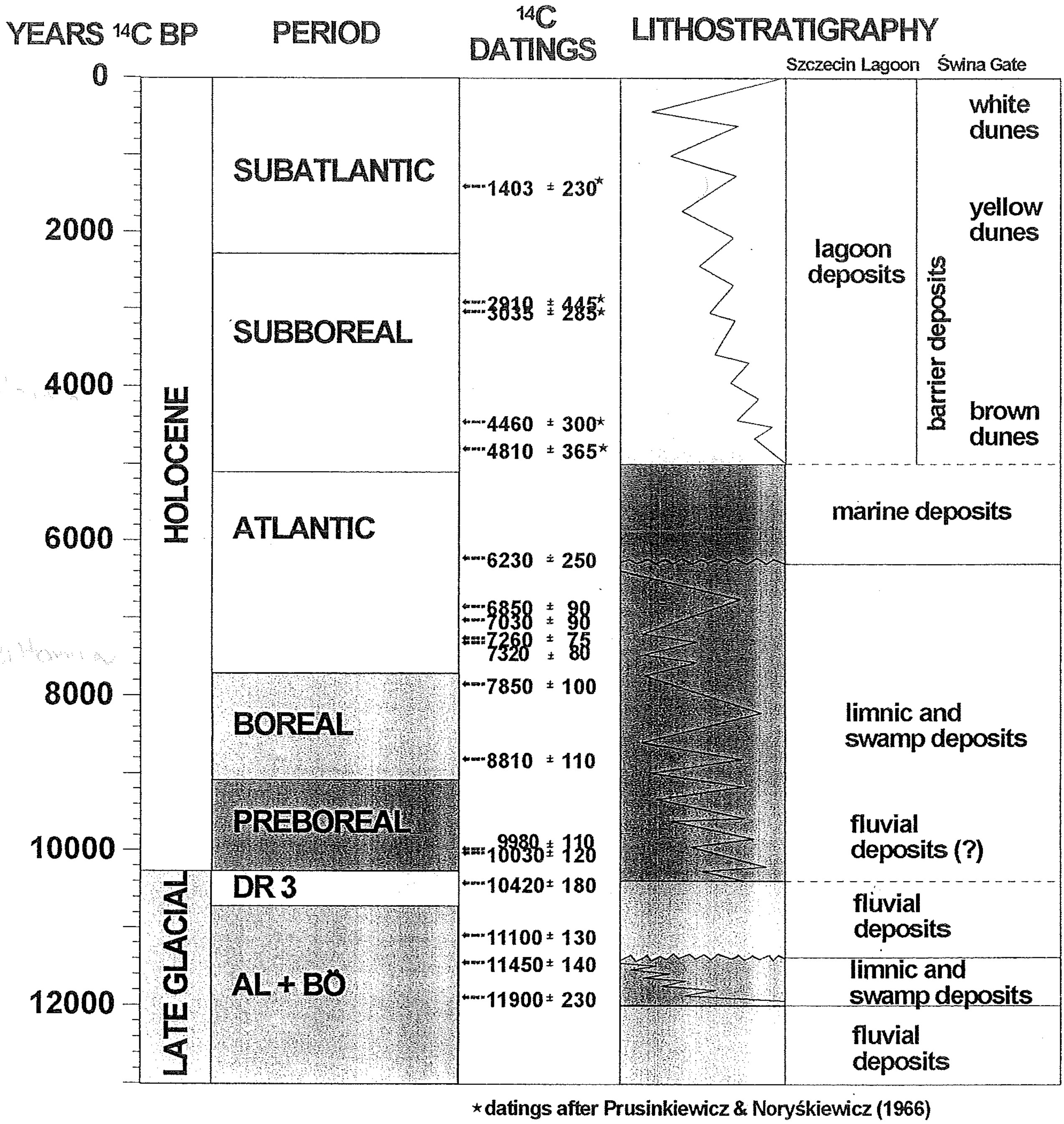

Fig. 30. Szczecin Lagoon – lithostratigraphy and chronostratigraphy of the infilling deposits.

formed. Comparing to the Early and Middle Holocene period they discharged several fold higher magnitudes of water (Rotnicki 1983, 1991). However, it can not be excluded that at the same time the lower Odra was a braided river, similarly to the other rivers draining northern slope of the Pomerania (Florek 1991). This problem remains unsolved and its resolution will be possible after detailed studies of the whole fluvial sediments deposited during that period.

The ***Alleröd stage*** is still poorly documented. It is already known that during this period some parts of the Szczecin Lagoon were filled in with shallow water bodies and covered by bogs and swamps. At that time, in the surroundings of the Szczecin Lagoon pine birch and pine forests developed. Patches of heliophilous vegetation were rather common and included tundra elements. This is evidenced not only by results of the palaeobotanical analyses (Latałowa 1989, 1999, Latałowa & Święta 2001), but also by the well- developed and widely distributed covers of fossil soils on the Wolin Island (Borówka et al. 1982, 1986).

The ***Younger Dryas Stage*** is marked in the area of the Great Lagoon by a distinct acceleration of fluvial processes, and particularly by aggradation of sandy deposits at earlier developed covers of Alleröd limnic-swampy deposits. In cores 36/99 and 37/99 the post-Alleröd fluvial deposits attain thickness exceeding to 1,5 m. This situation was probably related to deterioration of climatic conditions in the Younger Dryas. At that time, open-land vegetation spread at the cost of forest communities, soil erosion processes accelerated (Latałowa 1999) and also periglacial and aeolian processes became more intensified (Borówka et al. 1999a,b, Latałowa 2001). Probably during that period the quantity of sediments load transported in traction and in suspension by Odra River showed distinct increase. At the present stage of research it is not known how these processes affected the middle part of the Great Lagoon, where the Late Glacial fluvial deposits are recognised at the extremely little extent.

The ***Early- and Middle-Holocene stage*** encompasses the time span from the beginning of the Preboreal to the second half of the Atlantic period. (~10 250 – 6 200 y BP). The Great Lagoon area was predominantly filled in with limnic-swampy deposits. In large areas swamps with *Thelypteris palustris* and *Cladium mariscus* developed. Patches of water plants with nymphaeids as the dominant component, commonly occurred Latałowa, Święta 2001). It is very likely that during that time Pre-Odra was an anastomosing river, which flew through swamps and reedy areas, similarly to the recent lower Odra. In such cases there is observed a distinct stability of river beds and the limnic-swampy deposits are accumulated at the swampy flood terrace (Gradziński et al. 2000).

The ***Late Atlantic stage*** marked the Great Lagoon area with a large marine transgression (the Littorina transgression). Almost whole the Great Lagoon constituted at that time an open marine bay extending southward into the lower Odra River valley up to a place, where Szczecin is located (Borówka & Duda 2001). It also penetrated mouth areas of small valleys reaching the Szczecin Lagoon - e.g. Uecker Valley in the area of Ueckermünde (Bramer 1975). The contemporaneous water salinity was higher than in the recent the Pomeranian Bay as indicated by preserved shells of *Cerastoderma glaucum,* reaching size characteristic for waters with salinity values higher than 6-7 ‰ (Borówka et al. 2000). At the Lagoon margins water plants with *Salvinia natans, Nymphaea alba* and *Nuphar luteum* formed vegetation belts Latałowa & Święta 2001).

The duration and the rate of this transgression in the area of the Pomeranian Bay and Szczecin Lagoon has not been satisfactorily recognised yet. It can not be excluded that it was a disastrous event as was suggested by Rosa (1963). It might has been that during extremely strong storms a sandy bar existing in the area of Odra Bank and extending further eastward up to the region of Kołobrzeg was disrupted and destroyed (Mojski, ed. 1995; Kramarska 1999). Radiocarbon datings of limnic-swampy deposits from the Pomeranian Bay (Kramarska 1999) and from the Szczecin Lagoon (Wypych 1980; Borówka et.al. 2001), show very similar ages of the deposits in both areas, indicate relative fast rate of this transgression.

The ***Late-Holocene stage*** encompasses the Subboreal and Subatlantic periods, and has begun along with isolation of the Szczecin Lagoon from the direct marine influences. Intensified abrasion processes at high morainic shores of the Uznam and Wolin Islands caused rapid growth of spits and the development of a sand barrier in the area of recent Świna Barrier (Kailhack 1911; Prusinkiewicz & Noryśkiewicz 1966). Simultaneously, Świna back-delta has begun to develop behind the barrier formation. Its submerged part of the so called, Wyskok Krzecki extends far into the lagoon interior and dips with a relatively steep slope to the depth of 6.5-7 m.

The isolation of the Great Lagoon from direct marine influences resulted in a change of ecological conditions and the deposition processes. Content of organic matter rises up, and marine molluscs are replaced by freshwater taxa (Borówka et al. 2000).

Lagoonary series deposited during that time contain also predominantly freshwater diatom flora and the large quantity of the green and blue-green algae remains (Borówka et al. 1999, Latałowa & Święta 2001). The accumulation of the type of deposits continues in the Great Lagoon until nowadays. However, its sedimentation rate is highly variable and ranges from ca. 20 cm during the last century in the Little Lagoon (Leipe et al. 1995) to ca. 50 cm in the eastern part of the Great Lagoon (Borówka 2000). The lowest deposition rate, and perhaps even its lack, is characteristic for regions neighbouring with western coast of the Great Lagoon, which are located on a distinct elevation of the fluvial series top.

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2. 1. 5. DUNES OF THE ŚWINA BARRIER SPIT

Krystyna Osadczuk

University of Szczecin, Institute of Marine Sciences, Felczaka 3A, 71-412 Szczecin, Poland, E-mail: osadczuk@univ.szczecin.pl

The Świna barrier spit is situated in the Odra river mouth. It is a barrier between two Pleistocene push moraines of Uznam (Usedom in German) and Wolin islands. This barrier separates the waters of the Szczecin Lagoon from the Baltic Sea and consists of two sandy spits adjoining the morainic cores of those islands. The barrier origins are related to processes accompanying the Littorina transgression. It is a classical example of gradual growth of sand spits in lateral and longitudinal direction by successive accretion of beach ridges or dune chains thereby infilling an open bay between two opposed marginal basement cores.

The Świna barrier spit (Fig. 31) is composed of marine, fluvial and aeolian sand as well as swamp peat similarly as the other spits. The spit marine basement is covered by system of dune ridges (Fig. 32 and 33), which form the most characteristic relief of the barrier. Four generations of dune ridges can be identified in the area. They differ in size, orientation morphological axes, and extent of soil cover.

The oldest dune, called "brown" due to their brown illuvial horizon, form long and narrow ridges from 1 to 8 m heights, of a generally meridional orientation. They are straight and free-ending on the Uznam spit and curved on the Wolin spit, as a result of waves refraction. The ridges reflect the coastline changes in Subboreal period. The brown dunes represent a succession of parallel beach ridges transformed into coastal foredunes. Peat-filled hollows separate particular ridges of the brown dunes. The radiocarbon dates on bottom peat deposits as well as palynological data indicated that the brown dunes were formed during the Subboreal and the earlier part of the Subatlantic Period, at about 5000 to 1800 years BP (Prusinkiewicz & Noryśkiewicz, 1966).

The second generation of dunes, called „yellow", reflects the next stage of the Świna barrier development. The yellow dunes are formed as parallel ridges, too, but they discordantly abut on the brown dunes. The parallel-oriented yellow dunes from 3 to 10 m in relative height are covered by weakly developed podzols with a yellow illuvial horizon. The discordance implies a sudden change of the coastline, related to another phase of the transgression, followed by a gradual regression of the sea.

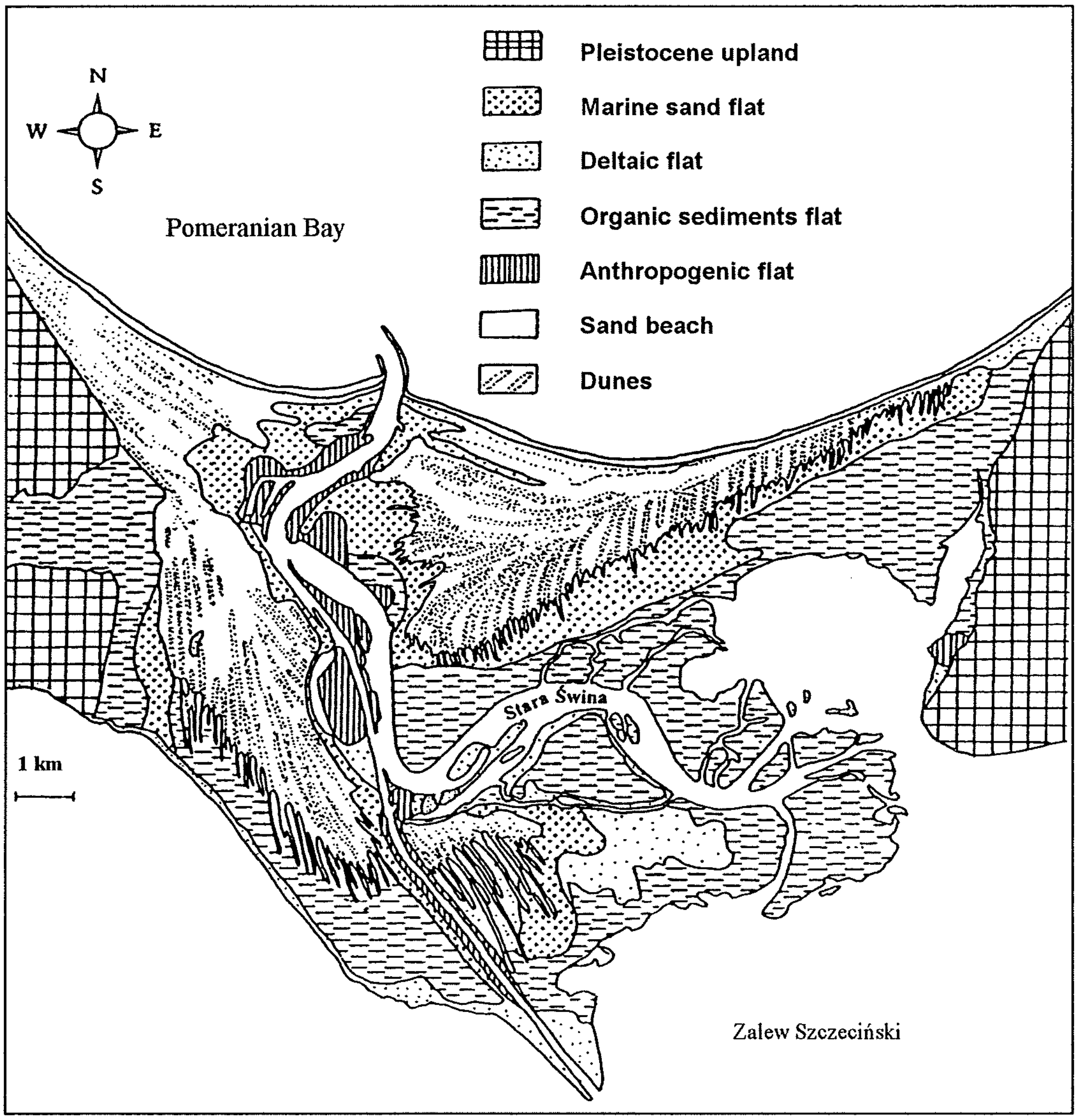

Fig. 31. Geomorphologic map of the Świna Barrier (after Matkowska et al. 1977, modified).

Third type of dunes is represented by a formation of transgressive dunes (called "white I"), invading the yellow dunes. They are the highest dunes, up to 22 m high. As opposed to previously described generally straight ridges they are sinuous in shape. These dunes are only about 300 years old. Keilhack (1912, 1914) estimated their age on the study of Swedish maps of 1694. Such transgressive dunes were formed as result of foredune erosion facilitated depleted vegetation.

The youngest coastal dunes ("white II") reflect the most recent and contemporary stage of the Świna Barrier development. The relative height of these forms is about 7 m.

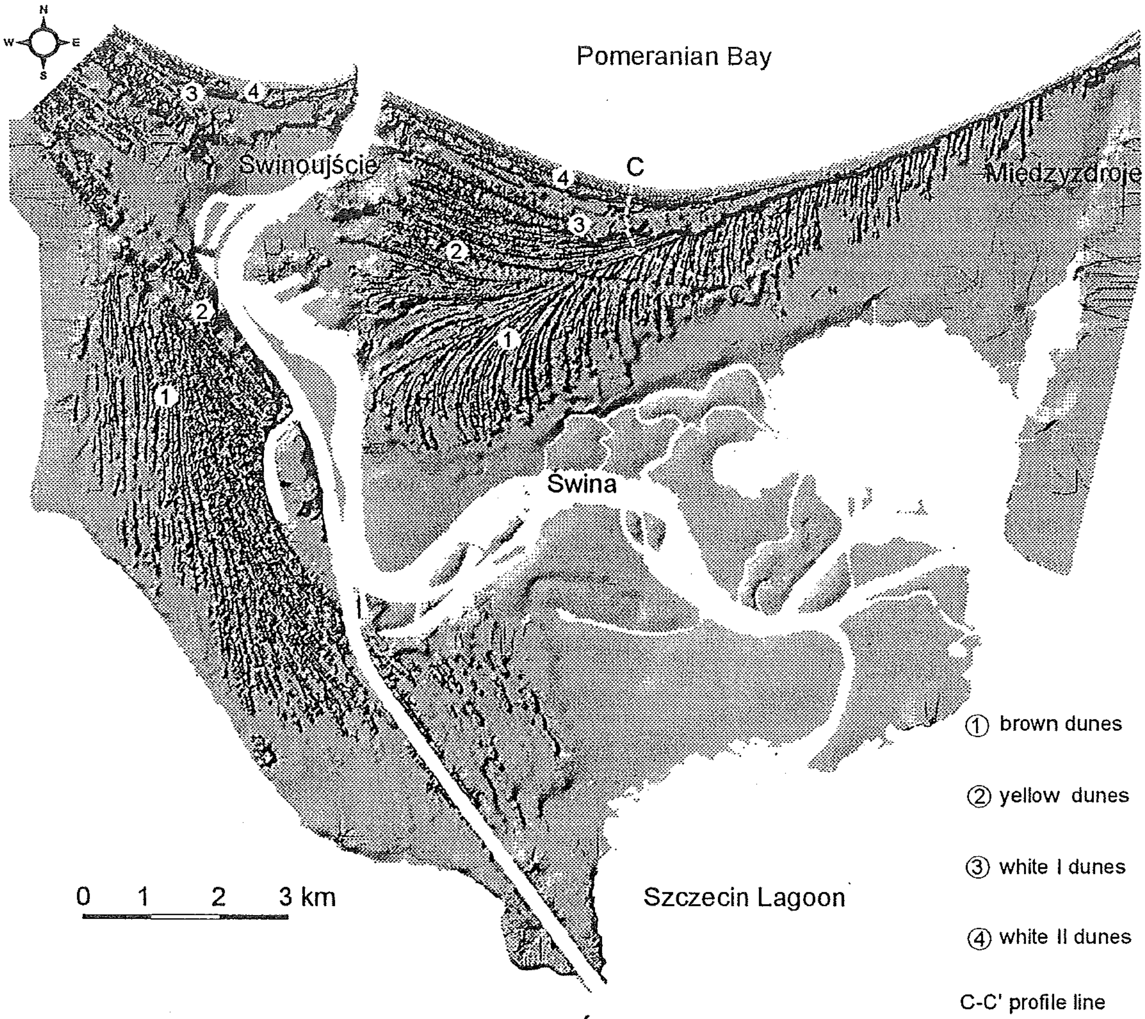

Fig. 32. Shaded-relief map of the Świna Barrier dunes.

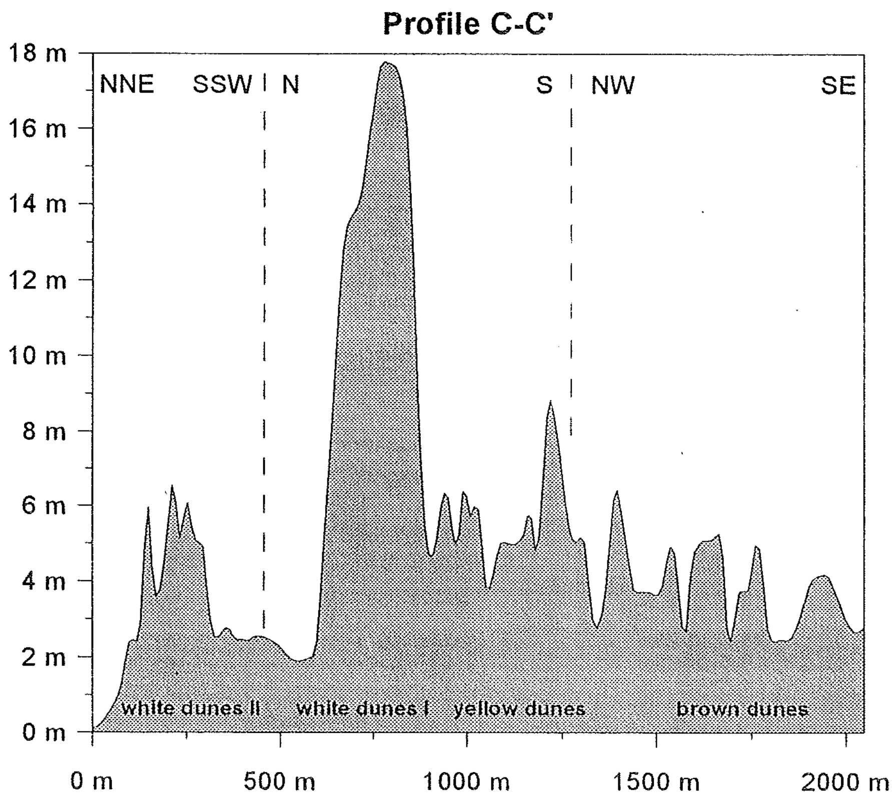

Fig. 33. Morphological profile of the Świna Barrier dunes.

Sedimentological studies were based on granulometric analyses showed the dunes to differ in grain size of the dune sands. In general, sands of younger dunes are finer grained and better sorted. Probably the differences in extent of soil cover development of brown dunes and yellow it is result of differences in sandy material. The brown dunes with a brown illuvial horizon, partially cemented by iron oxides are composed of medium sand (more than 70 %). The yellow dunes are composed of fine sand (almost 70 %).

Remote-sensing studies carried out in ninetieth years have made it possible to compare archival and contemporary aerial photographs taken of the Świna Barrier spit area (Musielak et al., 1991). The picture of the spatial dynamics of the coastline thus obtained revealed wide differences in the present processes of abrasion and accretion, even along neighbouring sections of the coast. While is a general tendency for the western coast of Poland to retreat at a rate varying from 0,35 m to 1,2 m per year, a single section of the coast has been observed in the Świna mouth area has shown a constant dominance of accretion over a period of many years. The widening of the barrier proceeds here at a maximum of 1,5 to 2,0 m per year.

At the back of the barrier, on its Szczecin Lagoon side, a well-developed back-delta (storm delta) of the Świna can be observed. Its development is evidence of intensive surges of sea water through the Świna strait during violent storms. It formed in its basic shape during the 17th and 18th centuries. The building of the Piastowski Canal (Kaiserfahrt) arrested its growth at the close of the 19th century (Musielak, Osadczuk, 1995).

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2. 2. STOP 2 - Dziwna valley
Environmental changes in the Dziwna valley and its surroundings due to hydrological changes and prehistoric human impact

2. 2. 1. GEOLOGY OF DZIWNA VALLEY IN THE VICINITY OF THE TOWN OF WOLIN

Ryszard K. Borówka
Szczecin University, Department of Natural Sciences, Marine Research Institute

The Dziwna Valley links the northern-eastern part of Szczecin Lagoon (Skoszewska Bay) with the Baltic Sea. The Dziwna River drains off to the Baltic about 20 % of water flowing the Lower Odra River to the Szczecin Lagoon. During the marine high-water states in the Pomeranian Bay the Dziwna's waters flow towards south to the Szczecin Lagoon. As a result of this there dominate currently brackish conditions in the Dziwna Valley.

The Dziwna Valley is very narrow in the town of Wolin vicinity (Fig. 34), reaching the width of about 80 to 100 meters. It is cut to about 10 m into the morainic plateau surface. From the west, the Dziwna Valley is limited by an esker rampart, which is built of sandy-gravel fluvioglacial deposits. This elongated form extends with some interruptions from Unin village to the south, till the Rów Peninsula, and reaches its maximum height of 21 m a.s.l. at the Wisielców Hill (Hanged-men Hill). There are some archeologic traces of Early Medieval settlement of Wolin and also cementaries connected to the old town, which lay on the surface of the form and among the Dziwna's bank.

The newest geological researches, carried on Recław-Wolin cross-section (Fig. 35), show that the Dziwna Valley is most probably a valley inherited from an old glacial channel. It is indicated by limnic and swampy deposits (detritus gyttja, algae gyttja and calcareous gyttja), which are covered with a thin layer of sandy-silty fluvial deposits. Nowadays, an extension of limnic deposits is not well known in the Dziwna Valley. However, it is understood that they appear under little islands situated within the Dziwna Channel, where theirs lowest parts lay about 8 m below sea level (Fig. 36).

In the western bank of Dziwna the thick covers of peats lay on the limnic deposits, as so on the fluvioglacial sediments. They are usually developed as *Carex* or *Carex-Phragmites* peats, which contain various admixtures of mineral matter. Within the peat deposits there are currently being excavated some traces of old harbour constructions of the early Medieval Wolin.

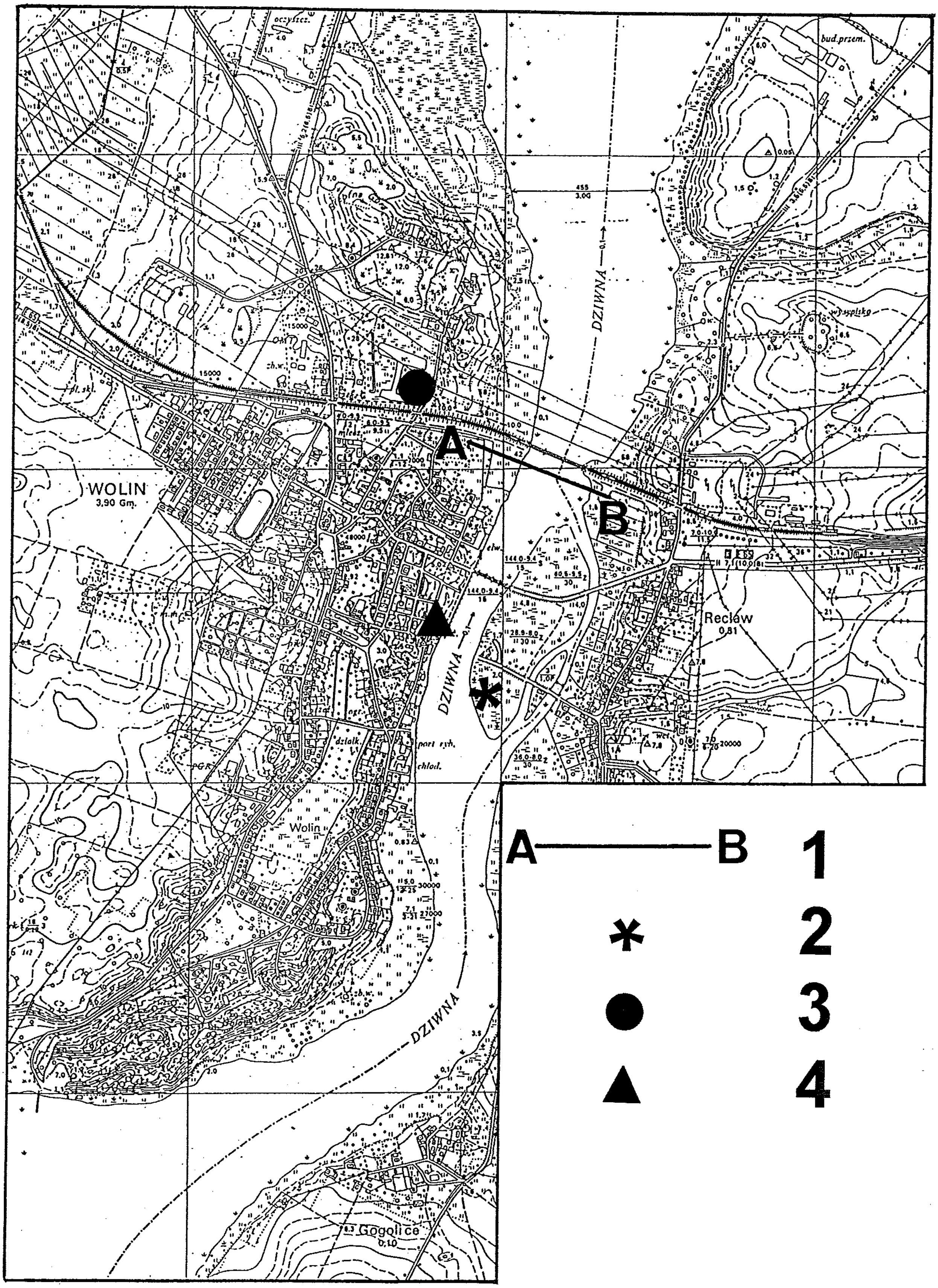

Fig. 34. Topographic map of the town of Wolin vicinity; 1 – location of the geological cross-section "Wolin-Recław", 2 – location of the core 510/00, 3 – location of the palaeobotanical profile "Wolin II", 4 – location of the palaeobotanical profile "Wolin I" (excavation in the early medieval port)

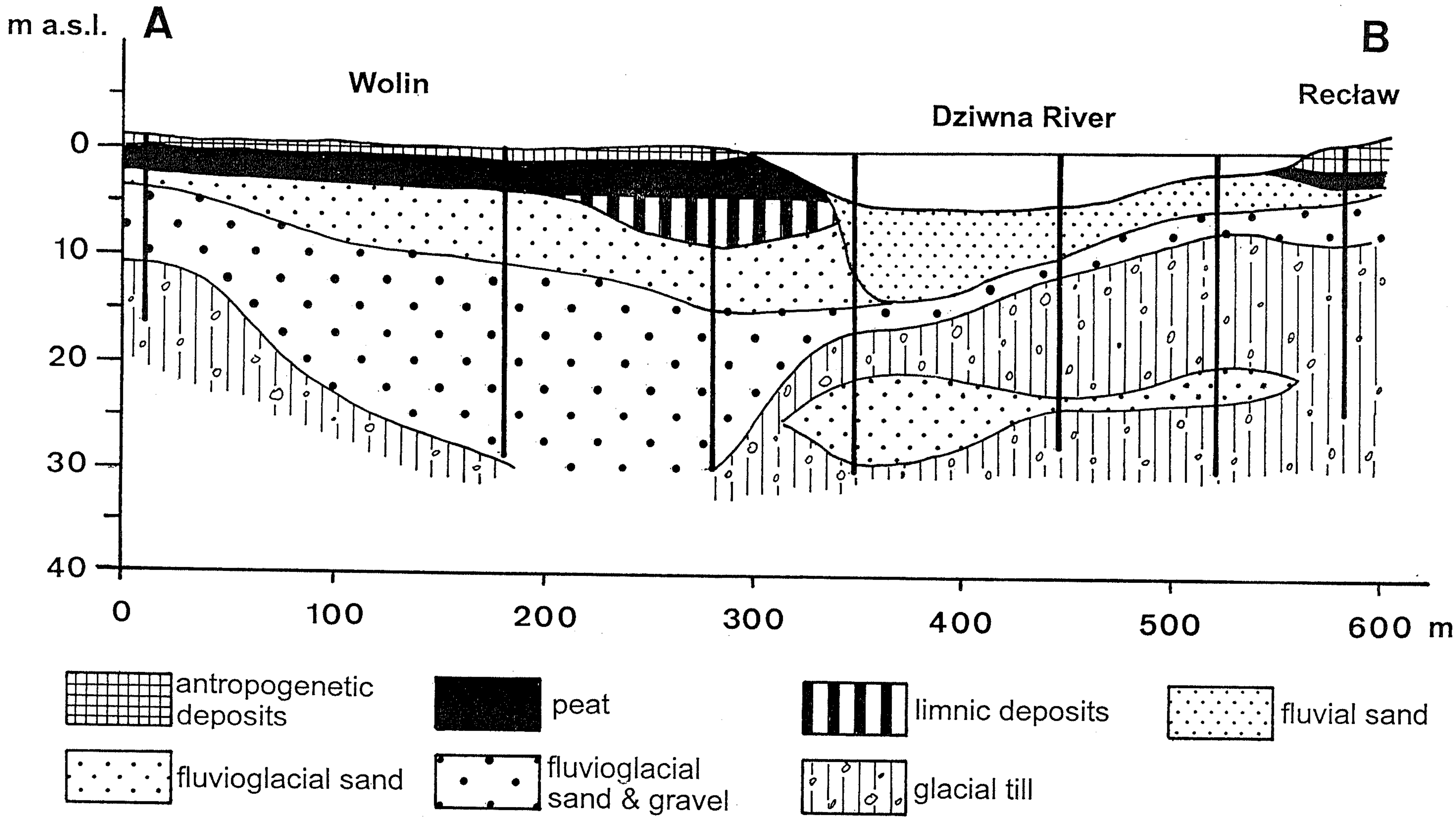

Fig. 35. Cross-section of the Dziwna valley between Wolin and Recław

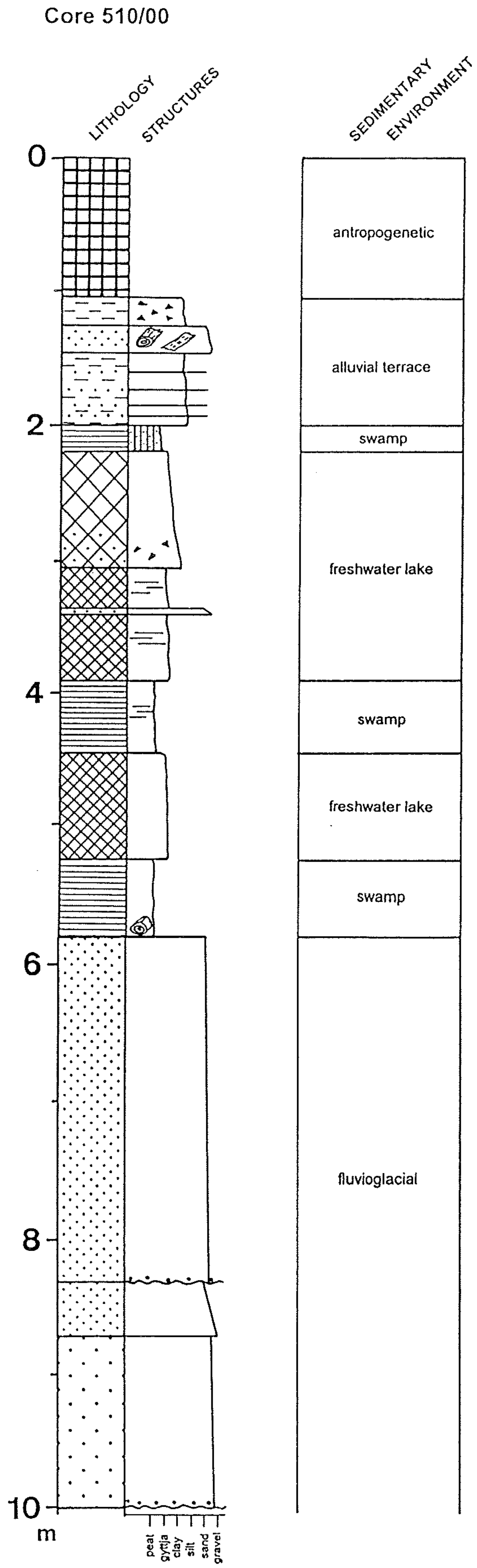

Fig. 36. Dziwna valley; core 510/00 – lithology

2. 2. 2. THE PRESENT-DAY VEGETATION IN THE VICINITY OF THE TOWN

Małgorzata Latałowa

The south-eastern part of the island where the town of Wolin is located, has been completely deforested. Acid meadows and pastures are dominant on the reclaimed wetlands; arable land prevails on mineral soils. The small hills near the town are covered with thickets of *Rhamnus catharticus, Ligustrum vulgare, Ulmus laevis,* different species of *Crataegus* and alien to the flora, introduced shrubs. On their slopes, on the more open places, patches of dry swards are present with such species as *Armeria elongata, Jasione montana, Thymus serpyllum, Helichrysum arenarium, Sedum sexangulare, Ranunculus bulbosus, Pulsatilla pratensis, Pimpinella saxifraga, Acinos arvensis* and *Corynephorus canescens.* This type of vegetation, as well as the occasional patches of Calluna *vulgaris* indicates, that heathland, replacing the original oakwoods, may once have existed here.

Wetlands dominated by beds of *Phragmites australis, Typha latifolia, T. angustifolia, Glyceria maxima, Equisetum limosum* and others form a large belt along the Dziwna river valley.

2. 2. 3. THE WOLIN II SITE - HISTORY OF VEGETATION

Małgorzata Latałowa

The site of Wolin II lies north of the town (Fig. 34) in a pocket-like form filled with peats. At this site organogenic sediments started to accumulate at about 7 ths years BP (Fig. 37).

Woodland and heath

In the middle Holocene, 7320±520 ^{14}C conv. years BP, [ca. 6150 ^{14}C cal. years BC], on the more elevated mineral grounds, especially on light soils, mixed forest communities with large participation of *Tilia* and other with predominance of *Pinus* were common; *Quercus* and *Corylus* made an admixture. In forest glades, patches of heliophilous vegetation with *Calluna vulgaris, Pteridium aquilinum* and *Melampyrum* were present. As shown by high participation of charcoal dust in the pollen slides, this area have been constantly visited by man.

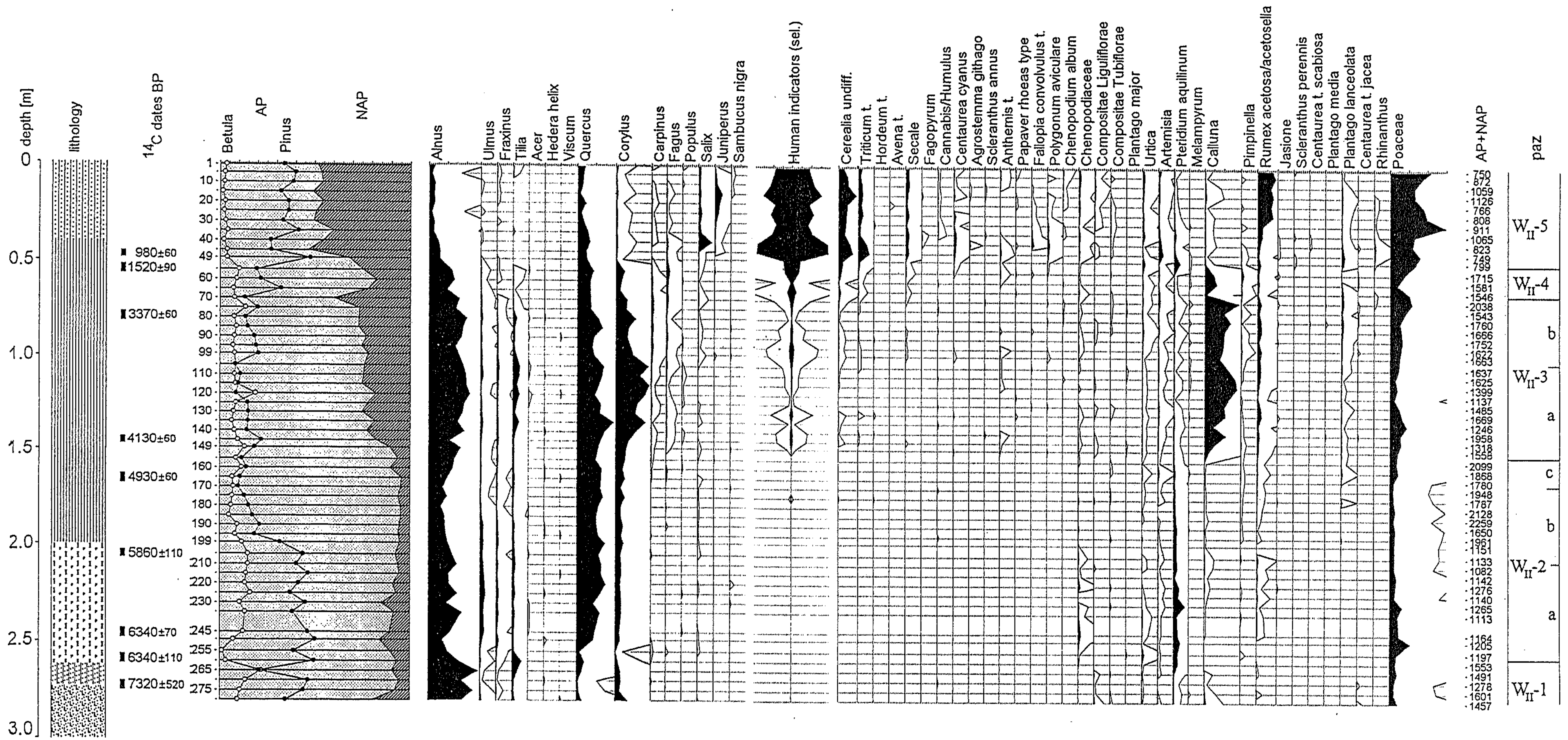

Fig. 37. Wolin II – simplified pollen diagram (selected curves); sum of pollen indicators includes pollen of cultivated plants and most important segetal weeds; 1- sand with silt, 2- sand with decomposed herbaceous peat, 3- *Cladium-Phragmites* peat, 4- herbaceous peat, 5- amorphic peat, 6- *Carex-Phragmites* peat with sand (from Latałowa 1999)

Large numbers of charcoal fragments in the sample dated to 6340±70 ^{14}C conv. years BP [ca. 5230 ^{14}C cal. years BC] and badly preserved, partly burnt pollen, help to understand further succession of vegetation surrounding the bog, which was certainly initiated by a fire. Pine, as the first, spread into disturbed habitats previously occupied by the *Tilia-Quercus* woodland, afterwards *Quercus* and *Betula* gradually replaced it. The soil erosion after the fire is documented (comp. Fig. 40) by the appearance of large number of sclerotia of *Coenococcum geophilum* in the peat deposit (Latałowa 1999).

The *Pinus-Quercus-Betula* forest was of a rather open structure and its herb layer was dominated by *Pteridium aquilinum*. During the next about two thousands years its undergrowth probably was regularly burnt and grazed, first by wild and later by domestic animals. This suggestion is supported by constant presence of charcoal and since at least 5860±110 ^{14}C conv. years BP [ca. 4680 ^{14}C cal. years BC] anthropogenic indicators related to animal husbandry. This type of forest management on the light, sandy soils caused the gradual degradation of habitats. Spontaneous renewal of pine was restricted both by regularly repeated fires and spread of *Pteridium aquilinum*.

As a result of exploitation of the *Pinus-Quercus-Betula* forest, between 4930±60 ^{14}C conv. years BP [ca. 3670 ^{14}C cal. years BC] and 4130±60 ^{14}C conv. years BP [ca. 2660 ^{14}C cal. years BC], the *Calluna* heath started to expand onto the mineral ground in the immediate vicinity of the Wolin II site, what is evidenced by presence of *Calluna* flowers, seeds and corroded pollen clumps in the peat deposit, which probably reached the mire by being washed out of the mineral soils. Soil erosion is shown again by the presence of *Coenococcum geophilum* (comp. Fig. 40). Due to regular burning and grazing during the next about two thousands years, the heath developed (Fig. 38), what is illustrated by:

(1) the high, constant presence of macroscopic charcoal in the sediments,

(2) high values of charcoal dust (Latałowa 1992)

(3) pollen of anthropogenic indicators suggesting the permanent stock farming in the area.

During the period of ca. 2300* - ?1520±90 ^{14}C conv. years BP [ca. 590 ^{14}C cal. AD] heathland certainly declined in importance, but because of the not enough detailed pollen evidence (the very low accumulation rate in the appropriate part of the profile) it is not possible to present comprehesively its history of that time. The negative correlation between the *Pinus* and *Calluna* curves suggests, that probably exploitation of heathland

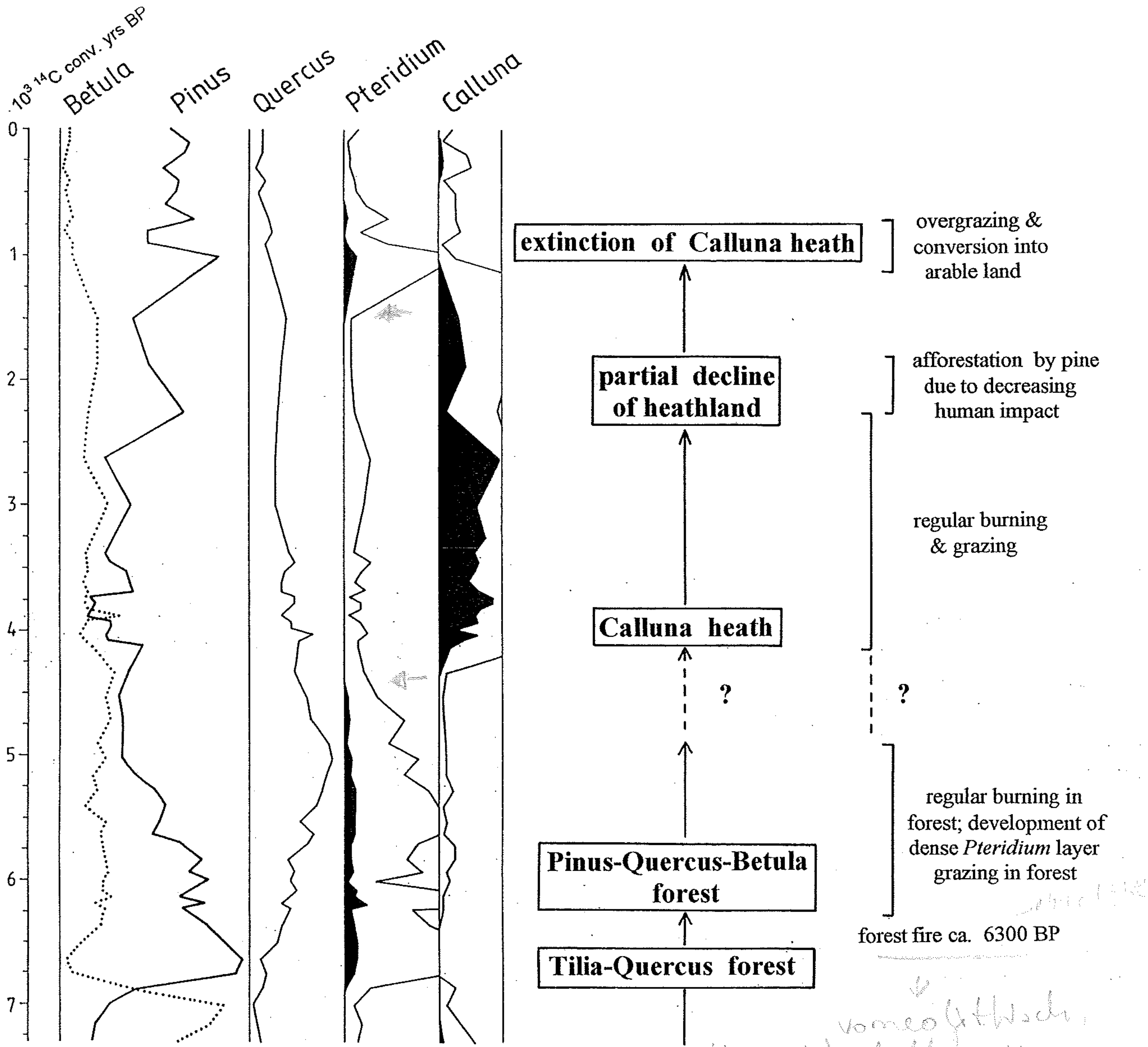

Fig. 38. History of *Calluna* heath on Wolin Island (from Latalowa 1999)

temporarily ceased, what allowed pine to encroach. Unfortunately, it is impossible to point out more exactly the time, in which this process took place.

The fairly low percentages of *Ulmus* and *Fraxinus* in the diagram indicate that forest communities with elm and ash were always scarce in the area. The first, clearly marked disturbances in this type of forests, caused probably by human activity, started before 5860±110 ^{14}C conv. years BP [ca. 4680 ^{14}C cal. years BC], (the first *Ulmus* fall) and then ca. 5400*-5300* ^{14}C conv. years BP (the second *Ulmus* decline). Both of elm declines (Fig. 39) are linked with a drop in the *Fraxinus* and *Tilia* curves and appearance of pollen of anthropogenic indictors, including *Plantago lanceolata* (both cases) and the first pollen grains of cereal type (the second case). The above, as well as the later fluctuations of these tree pollen curves, probably reflect intensive pollarding and other coppicing techniques developing with increasing animal husbandry. In places, small patches of pastures with Plantago *lanceolata* developed already before the 5 thousands years BP.

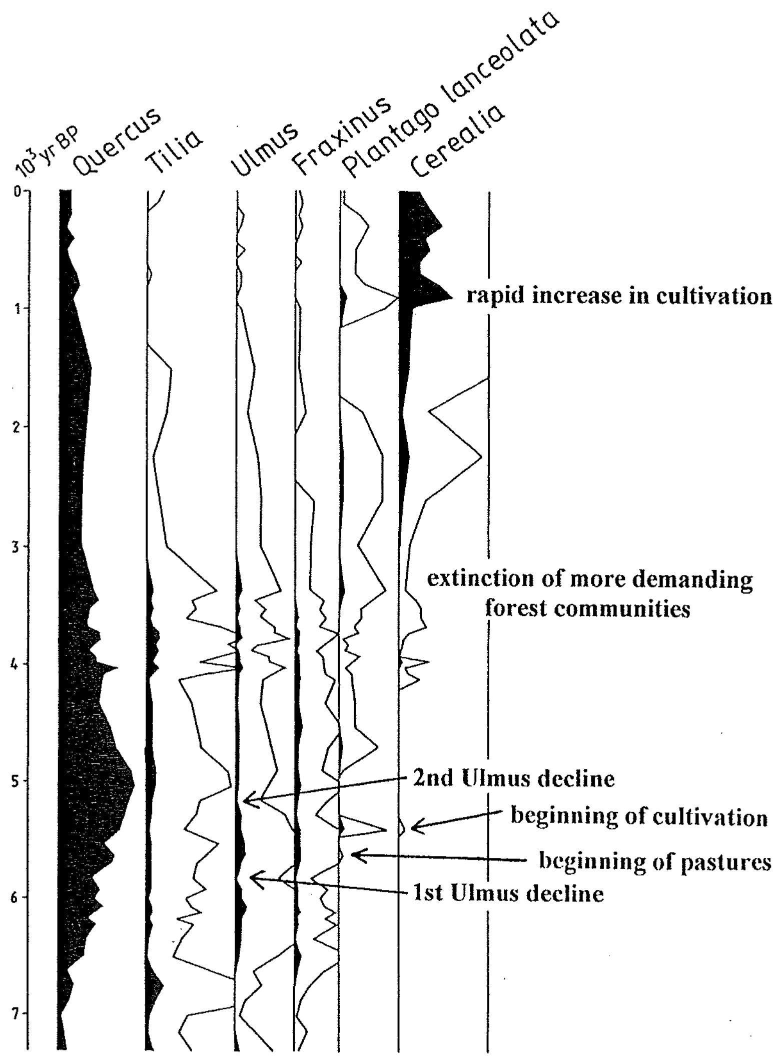

Fig. 39. Selected events resulting from human impact recorded in the Wolin II profile (from Latałowa 1999)

The time of final destruction of forests with *Ulmus, Fraxinus* and *Tilia* is indicated by the date 3370±60 ^{14}C conv. years BP [ca. 1590 ^{14}C cal. years BC]. This kind of habitats was used for pastures and then, for cultivated fields. The secondary woodland with pine expanded on the abandoned deforested areas. *Carpinus* and especially *Fagus,* which at that time started to play an important role in forest communities of the northern, morainic part of Wolin Island (Latałowa 1992), may have been at least an insignificant admixture in woodland in the discussed area. The final deforestation started between 1520±90 ^{14}C conv. years BP [ca. 590 ^{14}C cal. AD] and 980±60 ^{14}C conv. years BP [ca. 1130 ^{14}C cal. AD].

Prehistoric settlement and development of agriculture

The environmental conditions in the south-eastern part of Wolin Island must have been favourable for prehistoric man. The pollen diagram as well as constant presence of charcoal particles in the peat deposit indicate, that this area was frequently visited or settled by man since at least the Late Mesolithic.

The first settlement phase dated to 6340±70 ^{14}C conv. years BP [ca. 5230 ^{14}C cal. years BC] - 5860±110 ^{14}C conv. years BP [ca. 4680 ^{14}C cal. years BC] probably reflects activity of the Ertebölle tribes. This hypothesis presented in the earlier papers (Latałowa 1992a, 1994) should be confirmed by archaeological data. According to the oral information by K. Kruk, the Director of the Archaeological Museum in Wolin, some years ago, in course of the earth-works in the Dziwna valley, the large quantity of tools characteristic for the Ertebölle complex has been discovered; however, these data are not confirmed by more systematic investigations. At that time people regularly induced burning in woodland, probably to facilitate hunting and - maybe - to enrich undergrowth being a source of fodder for herds of wild animals. This kind of management caused thinning of woodland and gradual degradation of poor habitats.

During the next phase dated to 5860±110 ^{14}C conv. years BP [ca. 4680 ^{14}C cal. years BC] - 4930±60 ^{14}C conv. years BP [ca. ^{14}C 3670 cal. years BC] people of the Erteböllle culture continued the earlier type of forest management on the light, sandy soils, which resulted in further destruction of woodland. Probably at that time the new forms of economy started to develop. The leaf fodder gathering could produce the two following elm, ash and lime declines, which are evident in this phase. Peaks in *Plantago lanceolata,* which suggest presence of tiny pastures, also show the beginning of animal husbandry. The first slight evidences of cereal cultivation appear at the end of this period. This evidence of agriculture, distinctly earlier than the development of the first typical Neolithic culture (the Funnel Beaker culture) in this area, is especially interesting. It has been discussed in more detail in M. Latałowa (1992, 1994).

During the Neolithic - 4930±60 ^{14}C conv. years BP [ca. 3670 ^{14}C cal. years BC] - ca. 3600* ^{14}C conv. years BP, keeping of livestock was the major form of land use. Herds were probably pastured mainly in coppice woods and leaf-fodder was of importance, but more open woodland pastures and even patches of open pasture and heathland were also in use. Patches of *Calluna* heath could be of special importance for the feeding of sheep and goats. Cultivation was of minor importance. *Triticum* and *Hordeum* were used in the settlement of the Funnel Beaker culture, which developed directly in the area now occupied by the town of Wolin. This is confirmed both by pollen analysis and macrofossil data (Klichowska 1967a). Two pollen grains of *Secale* found in the Wolin II profile probably represent the rye-weed. On the basis of rich pollen flora for weeds present in the above pollen zone, including such annuals as *Centaurea cyanus, Scleranthus annuus, Polygonum aviculare, Papaver* (*rhoeas?*), permanent cultivation of small fields close to the settlement has been suggested. Especially the people of the Corded Ware culture practised swidden cultivation within coppice woods in a large scale.

The economic pressure on the natural environment increased rapidly in connection with the middle and especially the late Bronze Age and at the beginning of the Iron Age, i.e. with development of the Lusatian culture. Unfortunately this period is badly represented in the Wolin II diagram, because of the very low accumulation rate in the corresponding section of the profile. However, it is clear from this diagram that it was a time of continued increase in farming. Both, cultivation and animal husbandry were intensive. The archaeobotanical data (Klichowska 1967a,b) from two sites located within the present-day town of Wolin shows, that Lusatian people grew cereals (*Panicum miliaceum, Triticum aestivum, Hordeum vulgare*) and pulses (*Vicia faba, Pisum sativum*); two imprints of *Secale cereale* grains should be probably interpreted as presence of rye-weed.

The later part of the Iron Age is badly illustrated in the Wolin II diagram because of the same reason as in the case of the Lusatian culture.

During the Migration Period the general fall down in settlement occurred in the region, but the economic recession was not uniformly expressed over the area. According to Filipowiak (1986, 1988) in the vicinity of the Dziwna crossing, a small settlement probably survived. During that time woodland recovered on the large areas of the Island. In the northern, morainic part of the Island mainly beech forests spread, while on more light grounds pine and mixed oak-pine forests developed. Alder invaded damp, organogenic soils (Latałowa 1992).

The top part of the diagram illustrates environmental changes that started at the time of the development of the early medieval town of Wolin.

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2. 2. 4. HYDROLOGICAL CHANGES IN THE DZIWNA VALLEY IN THE LIGHT OF MACROFOSSIL AND POLLEN ANALYSES

Małgorzata Latałowa

The Wolin II macrofossil diagram supplemented by some of palynological data (Fig. 40) illustrates the history of wetlands, which spread along the Dziwna river close to the town.

Phase - 1. At around 7320±520 ^{14}C conv. years BP [ca. 6150 ^{14}C cal. years B.C], on the inundated ground vegetation dominated by *Thelypteris palustris* spread. As shown by the pollen diagram, at the same time also alder swamps gained in importance. The inundation probably resulted from the gradual transgression in the southern Baltic. This is suggested by the coincidence of the ^{14}C date of the bottom part of the peat deposit and dating of particular events registered in the Szczecin Lagoon sediments.

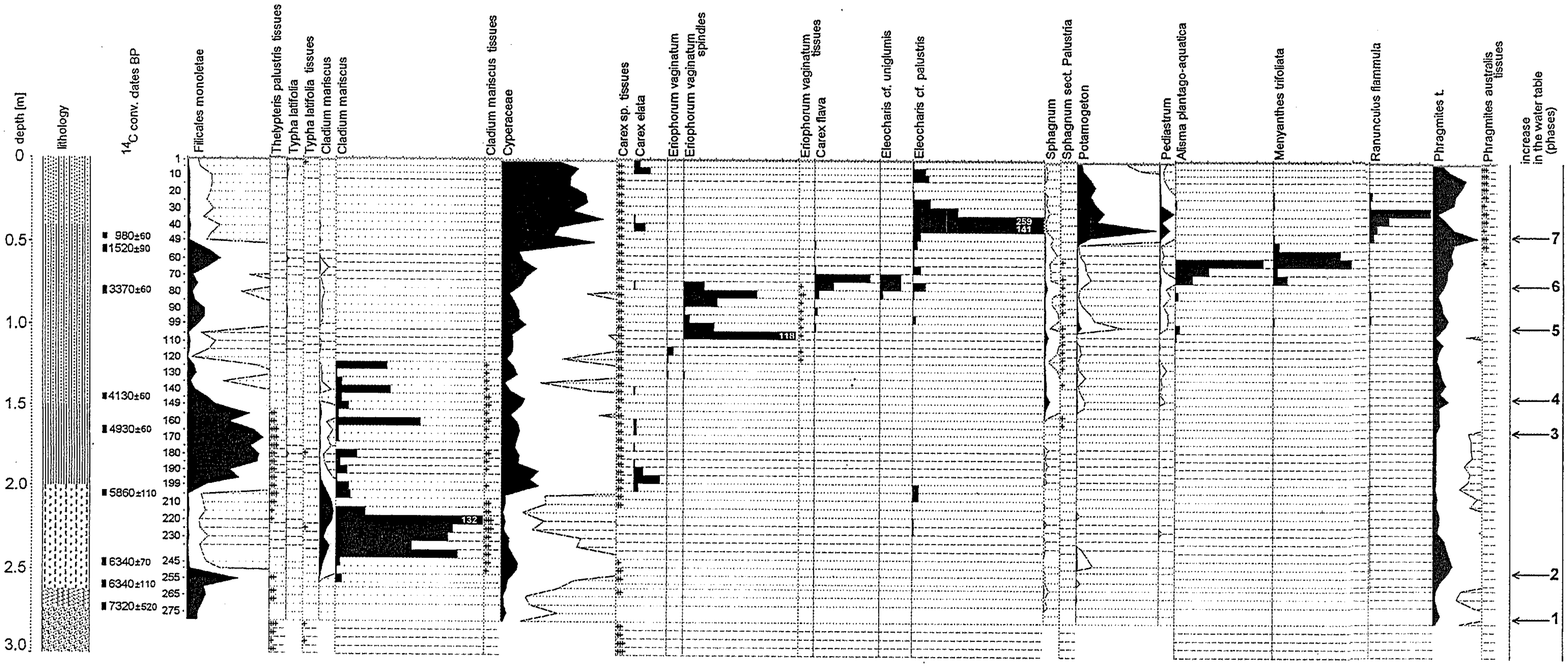

Fig. 40. Fig. 15. Selected pollen (curves) and macrofossil (bars) data illustrating succesion of local vegetation and hydrological changes in the Wolin II site (from Latałowa 1999)

Phase - 2. As a result of the further increase in the water level, since 6340±70 ^{14}C conv. years BP [ca. 5230 ^{14}C cal. years BC] *Cladium mariscus* invaded the area; presence of *Atriplex prostrata* subsp. *prostrata* is probably linked with saline waters which could penetrate to the site. In this case it is not easy to indicate the one, general cause of this event. The large-scale forest fire in the immediate vicinity of the site, documented on the basis of charcoal content in the sediments and illustrated by pollen analysis, could result in the short water level rise (peak of *Potamogeton* pollen ?). However, it also coincides with the further increase in the sea level as indicated by the radiocarbon dates from Szczecin Lagoon. The date ca. 6330 ^{14}C conv. years BP has been also specified by A. Tomczak (1995) as the beginning of the maximum of the Littorina transgression for the Gulf of Gdańsk region). It seems, that even if this new water rise on the mire was initiated by the deforestation, the further keeping up of the high water level on its surface in the condition of the fast growing peat deposit, should be explained by general increasing of the water table in the area due to the Littorina transgression.

The phase of dominance of *Cladium* came to the end at 5860±110 ^{14}C conv. years BP [ca. 4680 ^{14}C cal. years BC], when *Thelypteris palustris* spread again, probably in the condition of the lower water level on the mire surface, in respect to the previous phase. However, it not necessarily means the general water level lowering in the area, but most likely the effect of relatively fast thickening of the organic deposit at the site.

Phase -3. At 4930±60 ^{14}C conv. years BP [ca. 3670 ^{14}C cal. years BC] the slight input of water probably took place, and caused the new spread of *Cladium mariscus* and the gradual decline in the role played by *Thelypteris palustris*. This phase probably correlates with the Kluki-3 (5000-4500 ^{14}C conv. years BP) Littorina transgression phase characterised by K. Tobolski (1987 and following publ.)

Phase - 4. Since 4130±60 ^{14}C conv. years BP [ca. 2660 ^{14}C cal. years BC] the water level started to rise again (pollen of *Potamogeton* and coenobia of *Pediastrum*), what generated an appearance of shallow open water, probably limited in area. At the end of this phase large number of sclerotia of *Coenococcum geophilum* appears (soil erosion), coinciding with an increase in the pollen curves for cereals (comp. Fig. 37). The above hydrological changes could be, at least partly, produced by human activity in the direct vicinity of the mire. The rather abrupt transition from forest with *Pteridum aquilinum* undergrowth to *Calluna vulgaris* heath and erosion of gradually podsolized soils resulted in an increase in the water level and afterwards, the gradual acidification of habitats.

Phase - 5. The further succession of the local vegetation indicates clear change in the pH conditions on the mire, which enabled *Eriophorum vaginatum* to spread in the period of ca. 3600 to 3370±60 ^{14}C conv. years BP [ca.1590 ^{14}C cal. years BC]. The possible explanation of the acidification of the mire is based on the evidence of erosion of poor sandy soils covered by heath in the area adjacent to the site. The eroded material was transported to the mire as indicated by presence of *Coenococcum geophilum*, *Calluna* flowers and seeds as well as *Calluna* pollen (comp. Fig. 37), corroded typically for redeposited material. It suggests the input of acid drainage water from the catchment, what could influence pH on the mire surface.

Phase - 6. The rise in the water level ca. 2750* ^{14}C conv. years BP was followed by an increase in trophy and in pH on the mire. The open water body with *Alisma plantago-aquatica, Chara* cf. *contraria*, *Batrachium* sp. and *Sparganium erectum* developed and then was overgrown by *Menyanthes trifoliata.*At its margins patches of eutrophic vegetation with *Potentilla anserina* and *Ranunculus sceleratus* were present. This event cannot be dated accurately because of the very low peat accumulation rate in the discussed part of the profile; it is also difficult to show the one cause of this event. In this period the general increase in the water table in lakes and mires linked with the climatic change is observed (Ralska-Jasiewiczowa & Starkel 1988, van Geel & Renssen 1998). However, in the case of the uncertain chronostratigraphy of this part of the Wolin II profile, we cannot exclude, that this event is contemporaneous with the Kluki-4 post-Littorina transgression phase dated by K. Tobolski (1987) to 2100-1700 ^{14}C conv. years BP and, that once again it reflects influence of the hydrological changes at the southern Baltic coast.

Phase - 7. The substantial increase in the water table on the mire, which took place around 980±60 ^{14}C conv. years BP most probably resulted from the youngest transgression phase of the southern Baltic. The great number of *Potamogeton* pollen grains and significant participation of *Pediastrum* indicate reappearance of the open water surface.

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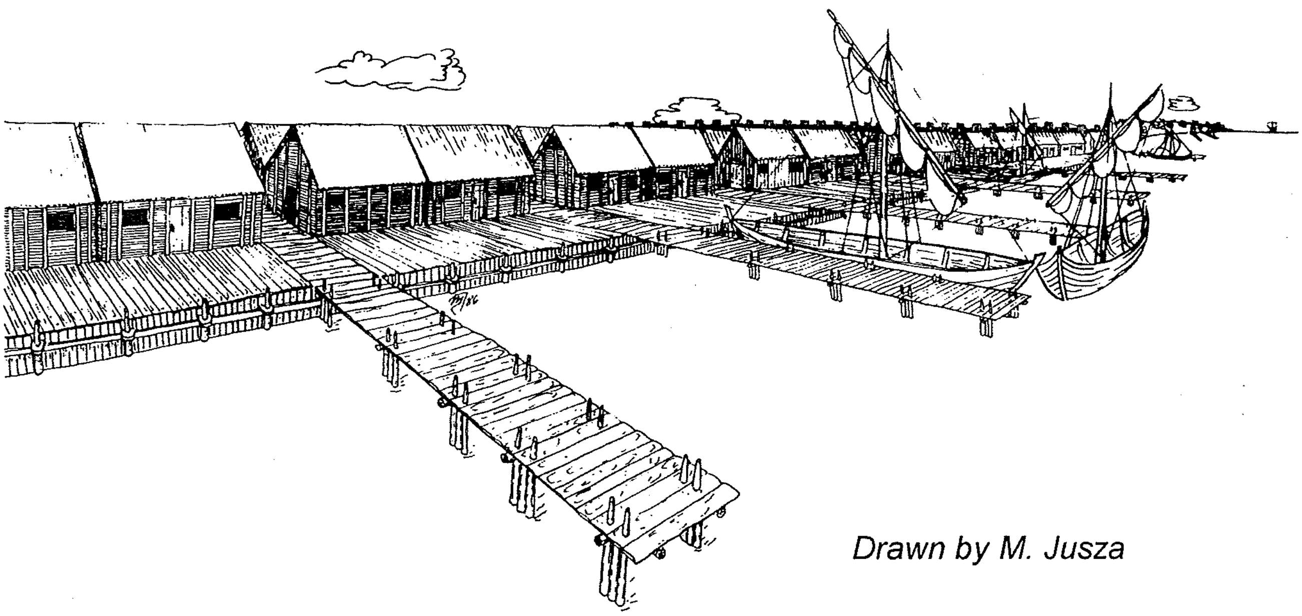
2. 3. STOP 3 - The town of Wolin
Development and fall of the early medieval town and port of Wolin in the light of archaeological and archaeobotanical data

2. 3. 1. HISTORY OF THE TOWN

Władysław Filipowiak

Lab. of Archaeology, Institute of Archaeology and Ethnology, Polish Academy of Science, ul. Zamkowa 16, 72-510 Wolin, Poland



Drawn by M. Jusza

Reconstruction of a fragment of the early medieval ($9^{th}/10^{th}$ century) port of Wolin (from Filipowiak, Gundlach H. 19992)

Wollin – ein frühmittelalterliches Zentrum an der Ostsee

WŁADYSŁAW FILIPOWIAK

(from: A. Wieczorek, H.-M. Hinz (eds.). 2000. Europas Mitte um 1000. Beiträge zur Geschichte, Kunst und Archäologie. Band 1. Theiss, Stuttgart, p.: 152-155)

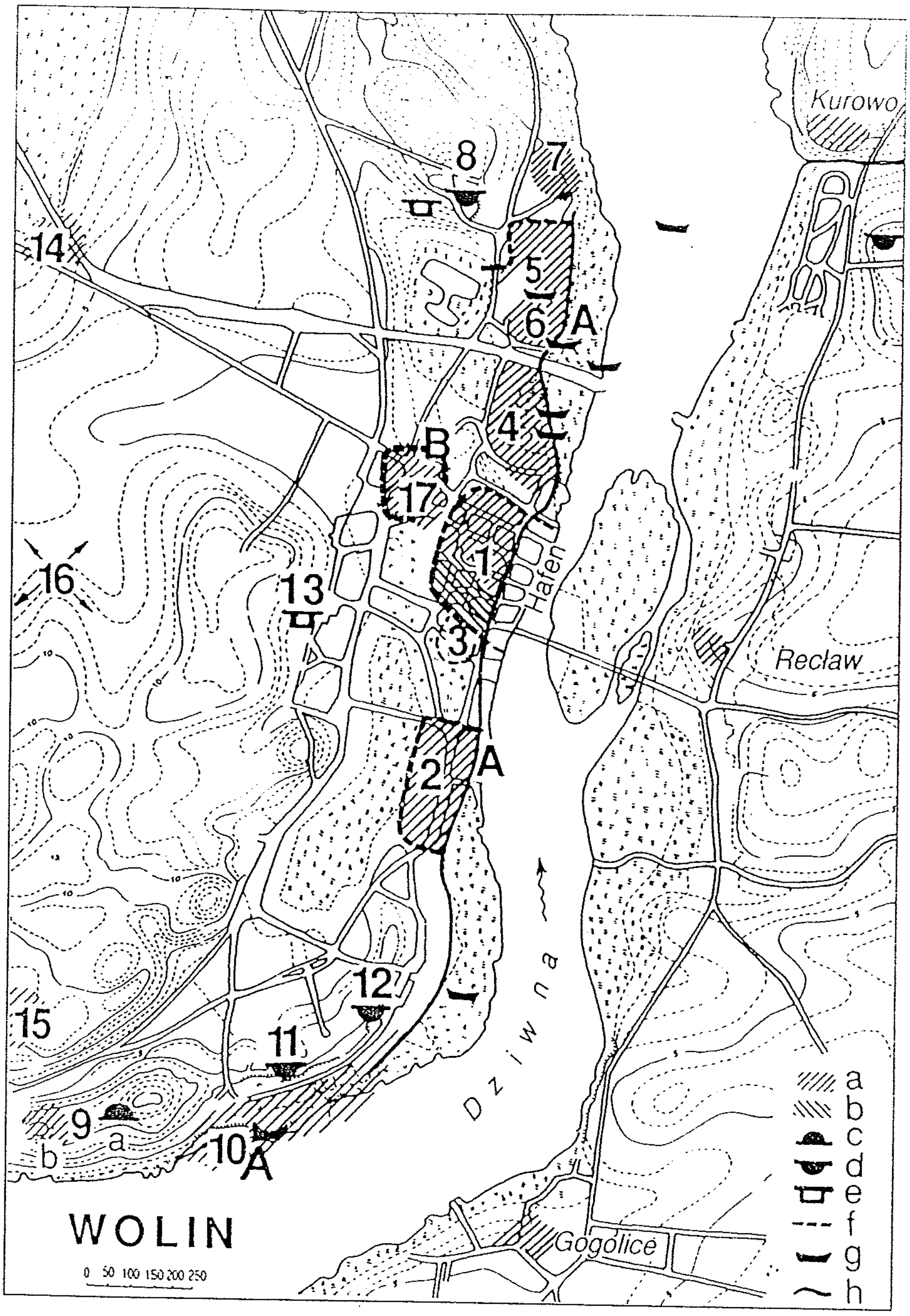
Wollin (Wolin) verdankt seine Entwicklung der günstigen Lage an der Kreuzung von großen Land- und Wasserwegen. Die Landstraßen verbanden es mit der großen Ost-West-Achse, ein Binnenweg führte ins Hinterland des Oder-Warthestromgebietes und der Fluss Dievenow mit der Ostsee und damit der gesamten damaligen Welt.

Die Verkehrswege kreuzten sich an der günstigsten Schnittstelle, die die Insel Wollin mit dem Festland verband, an einer Furt der Dievenow (Dziwna). Hier entstand, auf einem von Sümpfen umgebenen dünenartigen Hügel, im 8. Jahrhundert eine Fischer- und Bauernsiedlung, deren Bewohner auch Fährdienste verrichteten (Abb. 108, 1b). Die Lage der Siedlung bewirkte eine voranschreitende wirtschaftliche Entwicklung in der ersten Hälfte des 9. Jahrhunderts. Es kam zur Gründung einer Ansiedlung auf dem so genannten „Silberberg", deren Anfänge in die erste Hälfte des 9. Jahrhunderts datiert werden können (dendrochronologische Daten: 838, $889^{+15}/_{-10}$, $902^{+15}/_{-10}$) (Abb. 108, 6). In dieselbe Zeit datiert eine zweite Siedlung südlich des Flussüberganges, im Bereich der so genannten „Fischervorstadt" (Abb. 108, 2). Diese Siedlungsansammlung schuf die Anfänge einer Stadt, in der sich der unmittelbar am Flussübergang gelegenen Siedlung die besten Entwicklungschancen boten.

Neben der günstigen Verkehrslage gewährleisteten auch die in der unmittelbaren Umgebung liegende landwirtschaftliche Produktion und die dort vorhandenen Rohstoffe eine schnelle Entwicklung der Stadt. Die Siedlungsansammlung umfasste die Insel Wollin und das anliegende Festland (insgesamt etwa 1300 km^2), das Stammesgebiet der Wolliner. Untersuchungen ergaben, dass hier in der Zeit vom 7./8. bis zum 12. Jahrhundert eine dichte Besiedlung vorhanden war. Es wurden etwa 1050 Siedlungsbefunde, Burgwälle und Begräbnisstätten entdeckt. Im 9. Jahrhundert müssen die Wolliner eine bedeutende Rolle gespielt haben, da sie in der Beschreibung des Bayerischen Geographen um die Mitte des 9. Jahrhunderts erwähnt werden. Sollte sich bei den hier erwähnten *Velunzani* um die Bewohner Wollins handeln, so hätten sie 70 *civitates*, vermutlich in Form von Burgen und größeren Siedlungen besessen.

Ein allgemeiner Aufschwung der Seefahrt und des Handels im 8. und 9. Jahrhundert im Ostseeraum beeinflusste die Entwicklung Wollins, vor allem der am Flussübergang gelegenen Ansiedlung, wo sich schon seit der ersten Hälfte des 9. Jahrhunderts Handwerk und Handel entwickelt hatten. Es gab dort, neben der Keramikherstellung, Eisen- und Buntmetallverarbeitung sowie Bernstein- und Geweihverarbeitung. Es erscheinen Importerzeugnisse, wie Glasperlen, Kämme friesischen Typs, rheinische Keramik und so genannte Tatinger Kannen. Ein erstes aus Brettern erbautes Haus zeugt von der Anwesenheit fremder Handwerker, oder wohl eher Kaufleuten in Wollin – möglicherweise friesische Kaufleute.

Im 9. Jahrhundert fand eine schnelle wirtschaftliche und räumliche Entwicklung der gesamten Siedlungsansammlung statt. Neben den bereits vorhandenen Grubenhäusern aus früheren Zeiten, entstehen Häuser in Flechtwerkbauweise, mit Zwischenpfeilern sowie Bretter- und Blockbauten. Der ganze Hügel wird dicht bebaut und ein Netz aus sich kreuzenden Straßen angelegt. Am Dievenow-Ufer ensteht ein Hafen, der mit dem Straßennetz verbunden ist. An der höchsten Stelle des Hügels errichtete man eine Kultstätte, an deren Stelle im 9. Jahrhundert ein Tempel erbaut wurde. In der Nähe entdeckte man eine Holzfigur mit vier Gesichtern, die vermutlich den Gott Swantewit darstellt. Wahrscheinlich entstand um die Mitte des 9. Jahrhunderts in der Nähe des Flussübeganges eine kleine Burg (das 1294 aufgelöste *castrum*). Auch das Zentrum der entstehenden Stadt wurde mit einem Holz-Erde-Wall umgeben (Abb. 108, 3; 108, 1f). Die nördlich und südlichen gelegenen Siedlungen wurden in der zweiten Hälfte des 9. Jahrhunderts der Stadt angeschlossen und bildeten die Vorstädte. Es gab zwei Hauptbestattungsplätze für die verstorbenen Bewohner: Der ältere befand sich auf dem so genannten Galgenberg (Hügelgräber: 8. bis 11. Jahrhundert) und der etwas jüngere, große, auf dem so genannten Mühlenberg (Brand- und Körpergräber: 8. bis 12. Jahrhundert) (Abb. 108, 8–9; 11–12). Um die Stadt entstanden an beiden Ufern der Dievenow Siedlungen, die wirtschaftlich mit der gesamten Anlage verbunden waren (Abb. 108, 14–15). An der Wende vom 9. zum 10. Jahrhundert



108 Räumliche Entwicklung Wollins von der Mitte des 9. bis zum 12. Jahrhundert. a dichte Besiedlung; b vorstädtische Siedlung; c Hügelgräberfeld; d Brandgräber; e Körpergräber; f Stadt- und Vorstadtbefestigungen; g Wracks; h altes Dievenow-Ufer. 1 Stadt mit dem Hafen; 2 südliche Vorstadt mit Anlegestelle „A"; 3 Burg und Tempel des 12. Jahrhunderts; 4 Stadtteil „Ogrody" (Garten); 5 Markt des 12. Jahrhunderts; 6 Handels- und Handwerkerviertel „Silberberg" mit Anlegestelle „A"; 7 Siedlung; 8 Gräberfeld „Mühlenberg"; 9 „Galgenberg" mit Hügelgräberfeld (a) und Leuchtturm (b); 10 Siedlung; 11–12 Brandgräber; 13 Körpergräberfeld aus dem 12. Jahrhunderts (christlich) und Lage der St. Michaelis Kirche im 12. Jahrhundet; 14–15 Siedlung; 16 Ackerland; 17 Wendeschewik aus dem 10. bis 13. Jahrhundert mit Bronzegiesserei „B".

beginnt für die Stadt die Zeit ihrer größten Entwicklung. Hiervon zeugen das große Ausmaß der unternommenen Bauarbeiten sowie das rasche Anwachsen des Handwerks und des Warenaustausches. Aufgrund der dendrochronologischen Daten kann man feststellen, dass in der Zeit zwischen 896 und 900 im Stadtzentrum ein neuer Hafen erbaut wurde. Um das Jahr 903$^{+x}/_{-3}$ umgab man das Zentrum mit einem neuen, gewaltigen Palisadenwall und auch die südliche Vorstadt erhielt in den Jahren 904 bis 924 eine identische Befestigung (Abb. 108, 2f). Zu Beginn des 10. Jahrhunderts errichtete man einen gewaltigen Wall, der die Handwerkervorstadt auf dem Silberberg, einschließlich der „Ogrody"(Garten)-Vorstadt schützte (Abb. 108, 4–6). Zu dieser Zeit entstand auch eine neue Vorstadt auf der Westseite der Stadt, die um das Jahr 915 mit einem Palisadenwall befestigt wurde (Abb. 108, 17B). Es gab dort eine große Bronzegießerwerkstatt. Im Süden, am Galgenberg, entwickelte sich im 10. Jahrhundert eine Hafensiedlung. Hier wurde bei einem der vier ehemaligen Hafenkais ein in die Zeit um 870 datiertes Schiffswrack entdeckt (Abb. 108, 10A). Im 10. Jahrhundert erstreckte sich die gesamte städtische Anlage etwa 3 km entlang der Dievenow und erlebte zugleich ihre Blütezeit.

Es entstanden vor allem Gewerbebetriebe für Eisen- und Buntmetallverarbeitung, Schmuck-, Glas- und Keramikherstellung sowie in besonderem Maße Geweih- und Bernsteinverarbeitung. Bei letzteren kam es zur Massenproduktion in den im Stadtzentrum und in den Vorstädten ansässigen Werkstätten. Die Bedeutung und Intensität der Bernsteinverarbeitung bezeugen 270 000 Erzeugnisse, Halbfabrikate, Rohstoffteile und insbesondere Produktionsabfälle (Abb. 109). Aus Geweih fertigte man Kämme und Messergriffe, aus Bernstein massenweise Perlen, Anhänger, Amulette und kleine Kunstwerke in Form von Tierfigürchen. Diese Erzeugnisse wurden nicht nur in den Ostseeraum exportiert, sie erreichten über die Wolga auch die arabischen Länder. Als Gegenleistung erhielt man über Russland Luxuswaren wie Seide, Glas- und Bergkristallperlen. Vor allem Silber wurde in der Zeit vom 9. bis zum 10. Jahrhundert in Form von Münzen und Schmuck importiert. In der Stadt und ihrer nächsten Umgebung gibt es eine Ansammlung von 13 Hortfunden, darunter einen mit einem Gewicht von 11,5 kg Silber (Dramino-Piaski).

Die westliche Ausrichtung der Handelskontakte beweisen die bereits erwähnten Keramikimporte, die auch durch einen kürzlich aufgefundenen goldenen Denar aus dem 10. Jahrhundert(?) bestätigt werden. Aufgefundene Reste von Wollstoffen weisen auf Kontakte mit England und Skandinavien hin. Die besonders engen Kontakte mit dem dänisch-norwegischen Gebiet und Skåne verdeutlichen Funde wie Specksteinerzeugnisse, Schleifsteine aus Phyllit, Keramik, ein fein geschnitzter Drachenkopf und ein Holztäfelchen mit Runeninschrift.

Die weiten Kontakte über die See sicherte die Stadt mit einer eigenen Flotte. Dies bezeugen die freige-

109 **Berstein aus Wollin. Szczecin, Muzeum Narodowe.**

legte Werft aus dem Ende des 9. Jahrhunderts sowie die zahlreichen Schiffswracks und ihre Überreste in den Siedlungsschichten, die beim Bau der Häuser und Straßen vom 9. bis zum 12. Jahrhundert wiederverwendet wurden. Um das Jahr 1070 erwähnt Adam von Bremen den „Vulkantopf, den die Einwohner griechisches Feuer nennen". Es handelt sich hierbei um den ältesten Leuchtturm an der Ostsee, den man nach mehrjährigen Untersuchungen auf der Spitze des so genannten Galgenbergs lokalisiert hat (Abb. 108, 9b). Er war an das Verteidigungs- und Signalsystem an den Flüssen Dievenow und Swine (Świna) angeschlossen, das der Warnung vor Seeüberfällen diente. Nicht nur die See, sondern auch das weite Hinterland des Oder- und Warthestromgebietes sicherten der Stadt den Wirtschaftsaustausch. Aus Mähren kam Graphitkeramik, aus Schlesien stammten steinerne Handmühlen sowie Erzeugnisse aus Stein und auch Getreide, das man nach Skandinavien exportierte.

Wollin ist im 10. Jahrhundert eine gewaltige, unabhängige Stadt, die wir als selbständige „kaufmännische Republik" bezeichnen können. Ausdruck ihrer Unabhängigkeit ist die Kultstätte, die man an Stelle des ersten Tempels aus dem Ende des 9. Jahrhunderts im Jahre 965/66 errichtet hatte. Es handelte sich um einen prächtigen, von einem Hof umgebenen Tempel, mit einem Stall für ein Pferd, das man für Weissagungen nutzte. Die aufgefundenen eingesichtigen kleinen Götzenbilder zeugen davon, dass man hier einen Gott unbekannten Namens anbetete. Die Gründungsopfer (Tierschädel, Flechtkränze), Amulette und Kaptorgen (Amulettbehälter) aus Bronze und Holz, die Bronzefigur eines gesattelten Pferdes und eine Hirschfigur sind Ausdruck weit entwickelter magischer Glaubens- und Ritualformen. Trotz der geltenden lokalen Religion bestand völlige Toleranz gegenüber Andersgläubigen, was Adam von Bremen im 11. Jahrhundert bestätigt, indem er bemerkt, dass fremde Religionen zwar praktiziert, aber nicht öffentlich verkündet werden durften. Dies verlangte der internationale Charakter der Stadt, in der „Sachsen, Griechen und Barbaren" wohnten, wie es bei Adam von Bremen heißt. Archäologische Quellen bestätigen die Anwesenheit anderer Nationalitäten, wie die Skandinavier und die Balten.

Die wirtschaftliche Blütezeit der Stadt und ihrer Vorherrschaft an der Odermündung dauerte vom Ende des 9. bis zur zweiten Hälfte des 11. Jahrhunderts. Bereits 963 expandierte Polen unter der Herrschaft Mieszkos I. in Richtung Odermündung. Die von Ibrāhīm ibn Jakūb überlieferte Stadt „Weltaba" aus dieser Zeit (um das Jahr 965) kann mit Wollin identifiziert werden. Der arabische Kaufmann beschreibt eine „gewaltige Stadt am Ozean", die zwölf Tore und einen Kai besaß, bei dessen Bau man „halbierte Holzstämme" benutzt hatte. Sowohl die Größe der Stadt als auch das Vorhandensein eines derart konstruierten Hafens wurde durch die Archäologie für diese Zeit bestätigt. Im Jahre 967 erheben sich die Wolliner gegen Mieszko I., werden besiegt, und die Stadt muss die polnische Oberherrschaft anerkennen. Hiervon zeugt unter Umständen der gewaltige Wall mit Hakenkonstruktion aus dem Ende des 10. Jahrhunderts. Seit dieser Zeit sind enge wirtschaftlich-politische (auch dynastische) polnisch-skandinavische Kontakte nachweisbar, vor allem mit Dänemark. Hierher flüchtete im Jahre 986 der dänische König Harald Blauzahn und stirbt an den Wunden, die er im Kampf gegen seinen Sohn Sven davontrug. Im Jahre 1007 schickte die Stadt ihre eigenen Gesandten an den Hof Kaiser Heinrichs II., was ein Hinweis auf eine eigene unabhängige Politik der Stadt sein könnte. Im 11. Jahrhundert wurde Wollin zu einem sicheren Unterschlupf für dänische Flüchtlinge, was in damaliger Zeit zu inneren Unruhen und Konflikten sowie seeräuberischen Aktivitäten führte. So machte sich im Jahre 1043 Magnus der Gute nach Wollin auf und zerstörte die Vorstädte ohne die eigentliche Stadt jedoch einnehmen zu können. Zu dieser Zeit erscheint der Name Wollin zum ersten Mal in den skandinavischen Sagen (Magnusdrapa) als „Ióm". Nach den archäologischen Untersuchungen sank die Produktion im zweiten Viertel des 11. Jahrhunderts. Die Zahl der Werkstätten zur Bernstein- und Geweihverarbeitung nahm ab und es kam zu sinkenden Importen. Der letzte spärlich ausgestattete Münzhortfund datiert um 1060. Diese Veränderungen resultierten nicht nur aus den neuen Fernhandelsausrichtungen, sondern waren auch die Folge einer Krise, die die wirtschaftlichen Grundlagen betrafen. Beide Faktoren waren das Ergebnis des zeitweiligen Zusammenbruchs der Piastenmonarchie im zweiten Viertel des 11. Jahrhunderts und der daraus entstandenen Desorganisation des Marktes zwischen Oder und Warthe.

Über die Blütezeit der Stadt berichtet der zwischen 1070 und 1074 entstandene Bericht Adams von Bremen. Er zählt Wollin zu den größten Städten Europas und beschreibt dessen Lage und die Seeverbindungen von Hedeby/Haithabu über Starigard/Oldenburg bis Nowgorod.

Die Bedeutung der Stadt im wirtschaftlich-politischen Leben blieb auch in der zweiten Hälfte des 11. Jahrhunderts und Anfang des 12. Jahrhunderts bestehen, obwohl zu dieser Zeit der Aufstieg des benachbarten Stettin (Szczecin) begann. Wollin betrieb nach wie vor eine unabhängige Politik und gab weiterhin dänischen Flüchtlingen Unterschlupf, was zu einem Kriegszug des dänischen Königs Erik I. Ejgod nach „Julin" im Jahre 1098 führte. Größere Auseinandersetzungen oder Zerstörungen konnten jedoch vermieden werden, da die Einwohner die Flüchtlinge auslieferten, die dann sogleich enthauptet wurden.

Im 12. Jahrhundert gefährdeten zwei Faktoren die Unabhängigkeit der „freien kaufmännischen Republik Wollin". Zu Beginn des 12. Jahrhunderts wurde das benachbarte Cammin (Kamień) Sitz des pommerschen Fürsten während vom Süden der polnische Herrscher Bolesław Krzywousty (Schiefmund) anrückte und Pommern in seinen Landesgrenzen einschloss. Die Einführung des christlichen Glaubens, durch die Mission Ottos von Bamberg im Jahre 1124 führte dazu, dass 1140 in Wollin das erste pommersche Bistum entstand.

Die Berichte der Hagiographen Ottos von Bamberg liefern zahlreiche Informationen über die Rolle der Ältesten in der Verwaltung der Stadt, über die Abhängigkeit vom Fürsten, die gesellschaftliche Struktur der Bevölkerung und den herrschenden einheimischen Glauben. Aus den Überlieferungen geht hervor, dass in der Stadt zwar noch ein gewisses wirtschaftliches Potential vorhanden war, Wollin selbst jedoch keine führende Rolle mehr spielte, da diese zu jener Zeit bereits an Stettin übergegangen war. Diesen Zustand spiegeln auch die archäologischen Quellen wider.

Ein tragisches Schicksal traf die Stadt zur Zeit der dänischen Angriffe auf die Odermündung in den Jahren 1170 bis 1184. Im Jahre 1170 kam es zur Plünderung der Umgebung des bei Saxo Grammaticus ewähnten „Julin". In den Jahren 1173 und 1184 wurde die Stadt von den Dänen niedergebrannt. Nach den archäologischen Untersuchungen erreichte Wollin nie wieder seine frühere Bedeutung. Nur das Hauptzentrum der Stadt wurde erneut mit einem Erdwall und einer Palisade befestigt. Die früheren Handwerkervorstädte, nun wesentlich kleiner, beschäftigten sich hauptsächlich mit Fischfang und Landwirtschaft. Eine wesentliche Rolle im wirtschaftlichen und politischen Leben spielte nun Stettin.

Interessant ist, dass zur Zeit des Untergangs Wollins zwei Legenden entstanden, die über seine vergangene Pracht berichteten. Der Chronist Helmold erzählt in seiner um das Jahr 1170 entstandenen „Slawenchronik" im Kapitel *De civitate Vineta* die märchenchafte Geschichte einer versunkenen Stadt. So ist die Geschichte von Vineta entstanden und so wurde sie auch verbreitet. Der skandinavische Chronist Sven Aggeson, der an den dänischen Feldzügen teilgenommen hatte, gab Wollin 1184 den Namen „Hyumsburgh", der sich sicherlich auf das frühere Ióm, Iumne des 11. Jahrhunderts bezog. Zu Beginn des 13. Jahrhunderts entstand auf Island die wahrscheinlich auf die Geschehnisse aus Zeiten Harald Blauzahns bezogene, berühmte Jómsvikingasaga. Wenn wir die Größe und Bedeutung Wollins vom 9. bis zum 11. Jahrhundert und seine zahlreichen und lebhaften Kontakte mit dem gesamten Ostseeraum in Betracht ziehen, glauben wir, beide Legenden mit dieser größten Handelsmetropole an der Ostsee in Beziehung bringen zu können.

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2. 3. 2. THE ECONOMY OF THE EARLY MEDIEVAL WOLIN AS REFLECTED BY THE ARCHAEOBOTANICAL DATA

Małgorzata Latałowa

The archaeobotanical investigations in the early medieval Wolin have a long tradition. Several important data were published by M. Klichowska (1961, 1964, 1967 a, b, 1966) and then by A. Alsleben (1995). Pollen and macrofossil content of the profile Wolin I taken from the wall excavated in the port (Fig. 41) was subject of the study by the present author.

Exploitation of natural resources and gathering of plants

The development of the early medieval town and numerous rural settlements, which appeared on the Island and in its immediate neighbourhood, resulted in the large-scale environmental changes. The extension of agricultural areas is illustrated by the fall down of the pollen curves of trees and the concurrent substantial increase in pollen of cultivated plants, field weeds and those of plants typical of meadows and pastures (Wolin I, Wolin II, Kołczewo and Lake Racze sites). The intensity of land use caused soil impoverishment and erosion which are reflected in the palaeoecological data by the increasing input of mineral matter into lake sediments and gradually decreasing content of $CaCO_3$ in this inwashed material (Lake Racze). In the pollen diagrams evidences of spread of poor dry grasslands and heath instead of more fertile meadows and pastures are present.

The multi-functional town with diverse handicraft, boatbuilding, large port and high standard of the everyday life caused needs for timber. In Wolin, the main building material for constructions of the wharf and ships as well as some houses was oak. Smaller objects were made of different wood, also of species not recorded on Wolin Island by palaeobotanical methods, as for example some of cult statuettes found in the temple were produced from yew (Filipowiak, Gundlach 1992). In the archaeobotanical samples also bark and charred wood of pine (*Pinus sylvestris*), bast of willow (*Salix cinerea*) and bark of birch (*Betula* sp.) were found by M. Klichowska (1961).

Large number of species, especially those producing nuts and edible fleshy fruits, were gathered in woodland, in clearings and glades:

Corylus avellana	***Rubus idaeus***
Sorbus aucuparia	***R. fruticosus*-type**
S. cf. *torminalis*	***R. saxatilis***
Viburnum opulus	***R. caesius***
Vaccinium myrtillus	***Sambucus nigra***

V. vitis-idaea ***Prunus spinosa***
Fragaria vesca

Some remains present in archaeobotanical samples point to products gathered mainly for animal food:

Fagus sylvatica and ***Quercus* sp.** fruits
Pinus sylvestris cones and seeds
***Quercus petraea, Acer* sp.** and ***Salix* sp**. twigs and leaves

Different types of other natural or seminatural vegetation types were exploited by means of getting useful plants. In the list of fossil taxa from the early medieval Wolin there are numerous species known as food and medicinal plants, spices, famine food or technical plants. However, only small number of them is present in cultural layers in the context suggesting intentional gathering. Gathering of *Trapa natans* and *Iris pseudoacorus* is proved by the archaeobotanical material.

Agriculture

In the archaeobotanical samples several species of cultivated plants were identified:

1. ***Avena sativa*** **-oat**
2. ***Hordeum vulgare*** **subsp.** ***vulgare*-** **hulled barley**
3. ***Panicum miliaceum*** **-millet**
4. ***Secale cereale*** **-rye**
5. ****Setaria italica*** **– italian millet**
6. ***Triticum aestivum*** **s. l. - bread wheat**
7. ***T.compactum*** **Host - (M. Klichowska)** ***T. aestivum grex aestivo-compactum*** **- (A. Alsleben) clubwheat**
8. ***T. dicoccon*-** **emmer**
9. ***T. spelta*** **- spelt**
10. ***Fagopyrum esculentum*-** **buckwheat**
11. ***Lens culinaris*** **- lentil**
12. ***Pisum sativum*-** **pea**
13. ***Vicia faba*-** **celtic bean (horsebean)**
14. ***V. sativa*-** **common vetch**
15. ***Cannabis sativa*-** **hemp**
16. ***Linum usitatissimum*-** **flax**
17. ***Papaver somniferum*-** **opium poppy**
18. ***Humulus lupulus*-** **hop**
19. ****Apium graveolens*-** **celery**
20. ***Anethum graveolens*-** **dill**
21. ****Brassica rapa*-** **field cabbage**
22. ****Camelina sativa*-** **gold of pleasure**
23. ***Coriandrum sativum*-** **coriander**
24. ****Daucus carota*-** **carrot**
25. ****Pastinaca sativa*-** **spinach**
26. ***Petroselinum crispum*-** **petersile**
27. ****Spergula sativa*-** **spurrey**
28. ***Juglans regia*-** **walnut**
29. ***Malus*** **sp - apple**
30. ***Prunus avium*** **– sweet cherry**
31. ***P. cerasus*** **– sour cherry**
32. ***P. domestica*** **- damson**
33. ***P. insititia*-** **bullace**
34. ***Pyrus communis*-** **pear**

(*) cultivated or wild

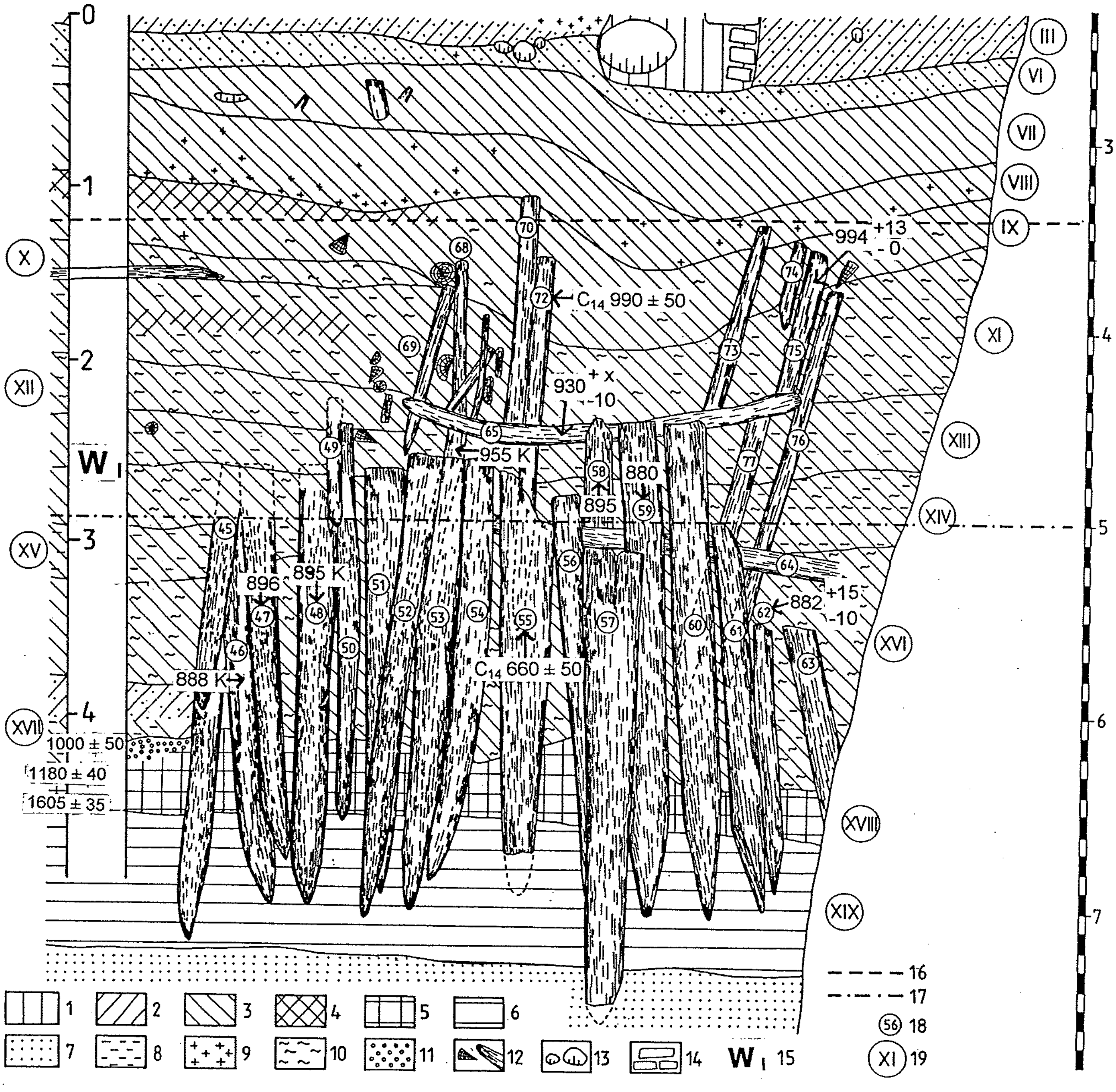

Fig. 41. Section of the trench wall in the Wolin port site; 1-10 deposits with various proportions of organic and mineral matter, 11- layer of fascines, 12- large wood fragments, 13- stones, 14- bricks, 15- location of the Wolin I palaeobotanical profile, 16- water level in Dziwna in August 1995, 17- suggested water level in the Dziwna river in the 10th century, 18- oak trunks , 19- culture layers; ^{14}C dates from Pazdur et al. 1994, dendrochronological dates from Ważny and Eckstein 1987; (according to Filipowiak unpubl. - changed, drawn by M. Jusza) (from Latałowa 1999)

The archaeobotanical data indicate that in the older phase of the early medieval period millet, rye and hulled barley were important cereals in Wolin and it is impossible to say which one was the main. Most probably, the archaeobotanical material illustrates differences between food used in ordinary houses in the town (mostly in form of porridge or pies of millet and barley) and that used in the temple (bread). It seems, that according to palynological data *Secale,* although an important crop, was not a dominant one, because its pollen values are always below that of other cereals. The same situation is registered in the pollen diagrams from the Wolin II site and from Lake Racze (Latałowa 1992a). Considering the much greater pollen production by rye in respect to other cereals and the much better pollen dispersal of this species, such proportions suggest its minor role in cultivated fields.

In the period under discussion, flax *Linum usitatissimum* belonged to the most important cultivated plants in Wolin. Various kind of flax remains (seeds, capsules and especially shaves) are abundant in many samples taken in different places (port, temple, residential part of the town) and indicate, that it was used mainly for fibre. The other oil/fibre plant - *Cannabis sativa*, was found as single specimens of fruitlets in the samples dated to the 10th century.

The very high frequency of numerous records of hop is certainly linked with the production of beer. In Wolin, *Humulus lupulus* probably was cultivated in local gardens as early as the 9th century. A. Alsleben suggests the existence of a little garden in the area occupied by temple, where she found the large accumulation of the unripe hop fruitlets.

Pulses recorded both as macrofossils and/or as pollen - *Vicia faba, Lens culinaris, Vicia sativa, Pisum sativum* were found in small numbers. Single diaspores or only few specimens represent other species cultivated for food as *Coriandrum sativum, Fagopyrum esculentum, Petroselinum crispum, Apium graveolens, Anethum graveolens, Pastinaca sativa, Papaver somniferum.* It cannot be excluded that the remains of the first three species of this group are contamination of the foreign grain (discussed in Latałowa 1999). Some others belong to the native flora of Wolin (*Apium graveolens* and *Pastinaca sativa*) and especially in the case of the scarcity of fossil remains can represent wild form. More probable is cultivation of such native species as *Brassica rapa* and *Daucus carota*, found in great number of diaspores. Small number of diaspores of *Camelina sativa*, *Spergula sativa* and *Setaria italica* come probably from plants being weeds in other cultivated plants.

Remains of fruit trees are not numerous; *Prunus cerasus, P. domestica, P. insititia, P. avium, Malus* sp. and *Pyrus communis* should be mentioned here, although fruits of the three last species could have been collected also from the wild. It is remarkable, that frequency as well as number of fruit remains clearly increases towards the end of the 10th century. The find of *Juglans regia* probably comes from long-distance trade, however local cultivation of walnut cannot be excluded.

Regarding the archaeobotanical data on cultivated plants based on the samples dated to the younger phase of the early medieval period (11th - 12th century) against the information concerning the older phase (characterised above), no distinct differences can be shown. It should be stressed, however, that the database for both periods is not equivalent - it is much better for the 9th-10th century. The most important difference, which can be observed, is the lower participation of barley and increasing role of rye in the younger period. Probably also the role of millet is slightly decreasing in comparison with the previous phase.

Species composition and abundance of diaspores of characteristic **weeds** indicate that already in the 9th century specific segetal communities were well developed, including those typical of winter cereals. The weed community similar to that developing in the recent root-crops and millet cultures (Panico-Setarion alliance) was widespread. Presence of „linicolous weeds" *Spergula arvensis* subsp. *maxima* and *Lolium remotum* as well as *Silene gallica, Galium spurium* and *Camelina sativa* points to development of specific flax weed community classified today to the Lolio-Linion.

Presence of the following weed species typical of fertile calcareous soils is especially interesting:

***Adonis* sp., *Aethusa cynapium* L., *Bunias orientalis* L., *Bupleurum rotundifolium* L., *Galium spurium* L., *Lithospermum arvense* L., cf. *Legousia speculum-veneris* (L.) CHAIX, *Melandrium noctiflorum* (L.) FR., *Neslia paniculata* (L.) DESV., *Stachys annua* L., *Valerianella dentata* (L.) POLL.**

There are two possible explanations of the presence of the above species in the archaeobotanical material from the early medieval Wolin:

1- during the early medieval period soil conditions on Wolin Island were different from those of today and enabled growth of the above species;

2- these species are evidence of import of cereals from more distant warmer areas of fertile soils.

On Wolin Island and its neighbourhood mineral soils developed mostly from sandy clays and clayey sands, which were always rather poor in calcium carbonate; it is proved by the characteristic features of the vegetation developing here during the whole Holocene (Latałowa 1992). In this area only very small patches of better soils are present in its southwest part where Cretaceous outcrops are deposited within the Pleistocene morainic formations. Generally, it is difficult to imagine, that in any time, even the periods preceding intensive soil leaching caused by both - climate and agriculture, weed communities referring to the Caucalidion alliance could develop in this area. It is possible, however, that some of the relatively less demanding species from the group presented above, as for example *Galium spurium*, *Lithospermum arvense* or at least *Neslia paniculata* could spread in the fields situated on the patches of better soils in consequence of the sowing of grain transported to Wolin from other regions. Judging from the archaeobotanical data from the other early medieval sites along the Polish Baltic coastal zone, i. e. Wrzeœnica, Ko³obrzeg and Gdańsk, *Silene gallica* and *Galium spurium* (probably the adequate, specific subspecies) were relatively frequent in flax cultures in the region, what suggests that their appearance in the palaeobotanical samples from Wolin could be of the local origin. However, the presence of such as *Bupleurum rotundifolium*, (?) *Legousia speculum-veneris* and *Bunias orientalis* point to the presence of imported grain (discussed in detail in Latałowa 1992b, 1999).

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2. 3. 3. HYDROLOGICAL CHANGES DURING THE ACTIVITY OF THE EARLY MEDIEVAL PORT

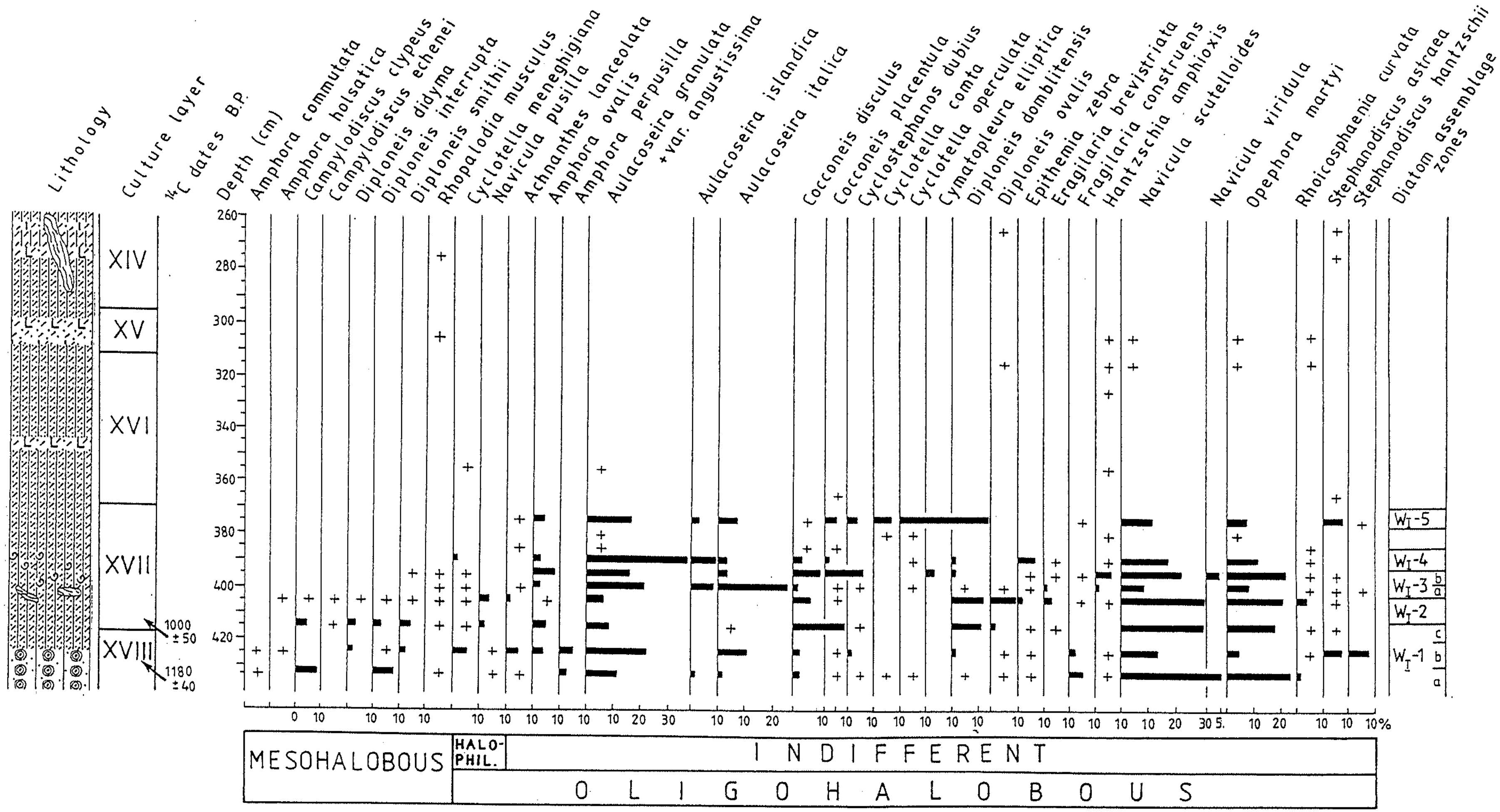
Małgorzata Latałowa

The palaeoecological data from the Wolin I and Wolin II profiles reflect some hydrological events, which happened in the Dziwna valley, close to the Szczecin Lagoon, during the lifetime of the early medieval town and port (Latałowa 1992, 1999, Latałowa et al. 1995). However, the data are still fragmentary and do not allow palaeohydrological reconstruction in full detail.

The most general information can be read from the upper part of the Wolin II profile, where at the level dated to 980±60 years BP there is a clear evidence of the appearance of a shallow water body with *Potamogeton, Pediastrum* and *Eleocharis palustris.* It indicates the water table rise, in the Dziwna valley. The more detailed data come from the Wolin I profile, where in the section 433-373 cm, dated for the second half and the turn of the 9th century, several hydrological episodes were registered mainly by the diatom analysis. The diatom flora present in the lowest part of the diagram (Fig. 42), shows especially distinct predominance of the littoral oligohalobous species and large participation of the mesohalobous taxa (W_I-1a and W_I-1c da subz) and thus indicates conditions typical for the littoral zone of the freshwater reservoir with an inflow of saline waters. The presence of saline waters is underlined by high concentrations of sodium, which in this part of the profile approximate mean Na values for the Baltic Sea surface sediments (Latałowa et al. 1995). The increase in planctonic forms (W_I-1b, W_I-3a da subz and W_I-4, W_I-5 daz) shows the short-living water level rises at the site. The water level lowering accompanied by increases in the alkalinity are recorded in the W_I-2 daz and W_I-3b da subz.

According to the archaeological estimations (Filipowiak & Gundlach 1992), due to the inundation, during the 10th century, the wharf of the Wolin port was shifted three times towards a more inland position. At that time the water level in Dziwna was about 1.6 m below that of the present day.

The palaeoecological data from the Wolin I and Wolin II profiles generally support earlier statements on the marine transgression on the southern Baltic coast during the medieval time. On the basis of the diatom analysis it is evident that this process was not of a continuous character, but at this site at least three inflows of saline waters occurred. Basing on the archaeological dating of culture layers in the port these events took place at the end of the 9th and at the beginning of the 10th century.



B. Bogaczewicz-Adamczak

Fig. 42. Wolin I - diatom diagram; (from Latałowa et al. 1995, supplemented)

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2. 4. STOP 4 - Przytor – the oak-birch forest

2. 4. 1. *BETULO-QUERCETUM* WITH *PTERIDIUM AQUILINUM* - A MODERN ANALOGUE FOR AN OAK-BIRCH FOREST RECONSTRUCTED FROM POLLEN DATA IN THE WOLIN II PROFILE

Małgorzata Latałowa[1], Agnieszka Popiela[2]

[1]*Lab. Of Palaeoecology and Archaeobotany, Dept. of Plant Ecology, University of Gdańsk*
[2]*Dept. of Botany, Szczecin University*

The birch-oak forest (*Betulo-Quercetum*) belongs to the forest communities of the West-European range. In Poland it was described from few localities situated exclusively along the sea shore. In Wolin Island different forms of this community were identified (Piotrowska 1966, Piotrowska et al. 2000). In Przytor phytocoenoses of the sub-association *Betulo-Quercetum typicum* with *Molinia caerulea* and *Pteridium aqulinum* cover a relatively large area. The sandy soils, in places very thin, underlain by peats or mud and the high ground water level are characteristic for the area. The main forest constituents are *Betula pendula*, *Quercus robur* and in places, *Fagus sylvatica*. *Sorbus aucuparia*, *Lonicera periclymenum* and *Frangula alnus* are frequent. The herb layer is dominated by *Molinia caerulea* and *Pteridium aquilinum*, which forms bushes attaining height exceeding 2 m. The great number of bracken specimens sporulate.

The similar forest type, but in the more dry form, developed in the vicinity of the Wolin II site, in the south-eastern part of Wolin Island, in the period of 6300-4900 BP, in consequence of the anthropogenic forest disturbances in habitat of the Quercus-Tilia forest.

In Przytor, fitocoenoses of the birch-oak forest border with different types of swamps. In the transition zone the magnificent stands of *Osmunda regalis* will be demonstrated. This very rare species is under the strict protection.

References:

Piotrowska H. 1966. Stosunki geobotaniczne wysp Wolina i południowo-wschodniego Uznamu. Monogr. Bot., 22: 3-157.

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2. 5. STOP 5 - Wolin National Park

2. 5. 1. THE GENERAL INFORMATION

The Wolin (Woliński) National Park was established on March 3, 1960. In the year 1996 its area was doubled. At present, the area of 10 937 ha comprises forests on 4 491 ha (41%), the Balic Sea shore on 2719 ha (25%) and Szczecin Bay covering approximately 2000 ha (18%). Apart from scientific, nature conservation and cultural functions, the Wolin National Park serves an educational purpose.

Among different ecosystems protected within the Park boundaries, various types of old beech forests deserve special attention. The best preserved fitocoenoses are under strict protection in six reserves. Two other reserves, protecting fragments of swamps, are located beyond the boundaries of the Park.

The Wolin National Park is a habitat of many rare animal species, especially of birds. The white-tailed sea eagle (*Haliaeetus albicilla*) finds its hunting ground here. Kite, sparrow hawk, goshawk and buzzard should be mention among other interesting species. Large area of Szczecin Lagoon, and its surroundings, provides good conditions for numerous species of waterbirds.

The Park is also known for its bison (*Bison bonasus bonasus*) reserve established in 1976. Roe-deer and wild boar are among mammals, that can be meet in woodland.

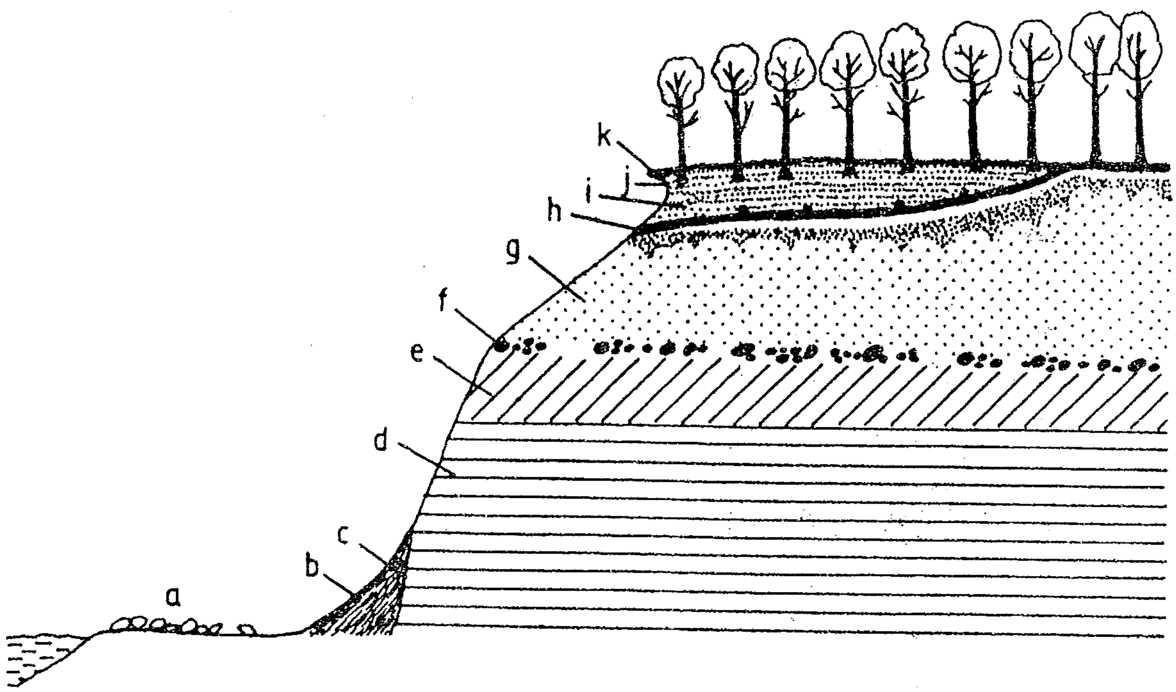
2. 6. STOP 6 - The Professor Czubiński Nature Reserve

2. 6. 1. THE BEECH FOREST WITH ORCHIDS (*CARICI FAGETUM BALTICUM*)

Małgorzata Latałowa[1], Agnieszka Popiela[2]

[1]Lab. Of Palaeoecology and Archaeobotany, Dept. of Plant Ecology, University of Gdańsk
[2]Dept. of Botany, Szczecin University

The 50-100 m wide belt of bechwood with orchids (*Carici Fagetum balticum*) stretches along the top of a high cliff overlooking the sea. On the landward side it borders on *Luzulo pilosae-Fagetum*. The cliff rises here to a height of 70 m above sea level. It is steep and strongly abraded. The very particular topsoil, named cliff naspa (Prusinkiewicz 1971) is formed from calcium carboanate rich particles blown off the cliff-wall by the wind and intercalations of humus. This soil is underlain by a fossil podzol formed under a pine forest (Fig. 43).



Morphology of the cliff in the neighbourhood of the beech forest with orchids (adapted from Prusinkiewicz 1971)
a – narrow stony beach, b – colluvium, c – abrasion step, d – grey boulder clay, e – brown boulder clay, f – residual pavament, g – fluvioglacial sands, h – fossil podzolic soil, i – aeolian sands with soil – a cliff naspa, j – deflation niche, k – overhanging soil bank

Fig. 43- from Piotrowska 1993

The origin, history and spatial dynamics of this community was investigated by Piotrowska (1993). This type of beech forest develops in the conditions of the undergoing geodynamic processes. In this area, the cliff edge receeds by about 1 m per year. In the past it approached the phytocoenoses of pine forest covering patches of sandy soils and material blown-off from the cliff wall and deposited on the surface of its top started formation of the cliff naspa. This substrate was colonised by beech and neutrophilous herbs. According to the above author estimations, the cliff-top soils, c. 60-70 cm thick, started to be formed about 150 years ago; the oldest beech trees in the *Carici-Fagetum balticum* phytocoenoses are of the same age.

The cliff-top beech forest is characterised by specific ecological conditions. Though close-conopied it offers good light conditons due to the light which penetrates laterally from the cliff edge. The herb layer is very rich what is in contrast with the neighbouring phytocoenoses of *Luzulo pilosae-Fagetum.* It is dominated by grasses - *Brachypodium sylvaticum, Poa nemoralis, Dactylis glomerata* and to the less extent *Deschampsia flexuosa*. The most characteristic are several calciphilous species of orchids:

Cephalantera rubra
C. damansonium
Corallorhiza trifida
Malaxis monophyllos (extinct in the last years)
Neottia nidus-avis
Platanthera bifolia
Listera ovata
Epipactis atrorubens
E. latifolia

The belt of beechwood with orchids is constantly disappearing on the seaward side as a result of the abrasion, but at the same time it is expanding on the landward side at the expanse of the neighbouring acid beech forest. However, the area occupied by this type of forest is narrowing, because more area is lost than gained.

The phytocenoses of *Carici-Fagetum balticum* on Wolin Island are under the strict protection.

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2. 7. Stop 7 – Lake Racze (M. Latalowa)

Lake Racze (Fig. 44) is a small kettle-hole lake, 4.95 ha in surface area and 12 m deep, filling up a cryptodepression of 9 m below sea level. It lies in the area of slightly undulating landscape covered by the Pleistocene light sandy clays. Although the immediate vicinity of the lake has been completely deforested, the weed flora indicates the *Fago-Quercetum* habitat. Some decades ago, the lake was still classified as oligotrophic because of the considerable purity of its waters and the presence of species typical of the so called „ *Lobelia* lakes" (*Isoetes lacustris, Lobelia dortmanna, Ranunculus reptans*). Those species were not recorded in more recent investigations and today, as a result of increasing eutrophication; beds of reeds and rushes have become established in many places along the shore. Two cores 2.5 m deep were collected ca. 80 m from the southern shore of the lake, between 8 and 10 m isobaths. They cover the Lateglacial and the whole Holocene sequence.

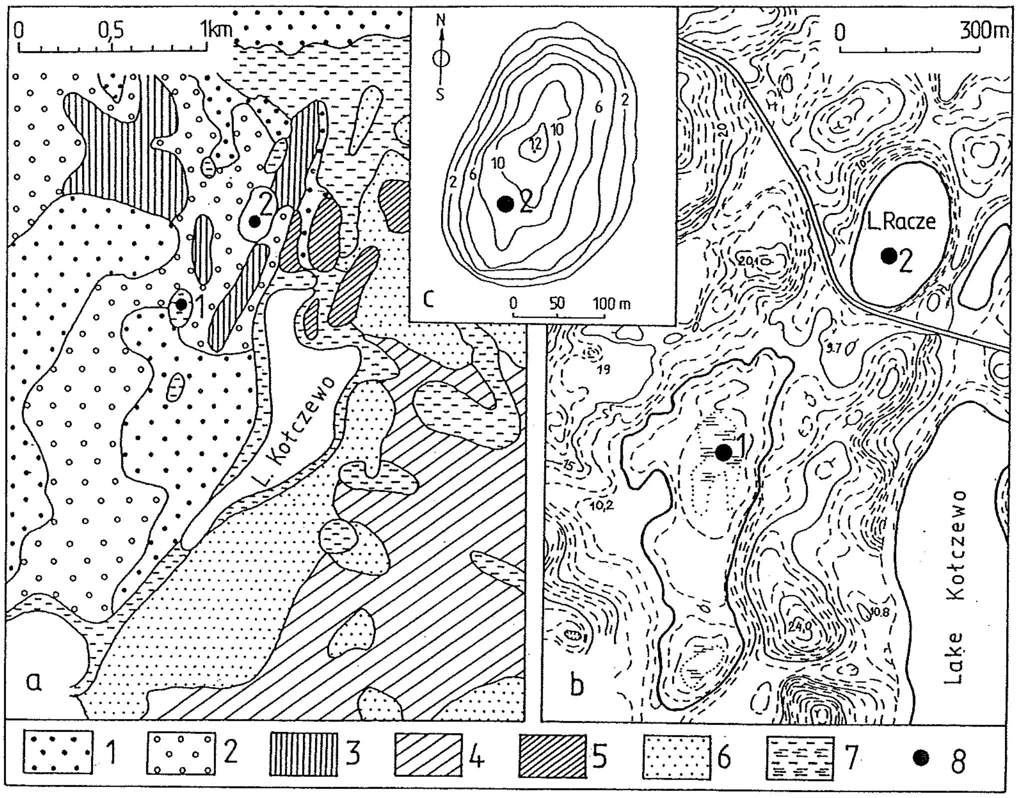

Fig. 44. Location of the Lake Racze and Kołczewo sites: a- Quaternary deposits (after Mapa Geologiczna Polski 1:150 000), b- topography; 1-sand and gravel of kame plateau, 2- clayey sands of kame plateau, 3- clays of kame plateau, 4- clayey sand on boulder clays, 5- boulder clays, 6- outwash sand and gravel, peats and mud of lake and river origin, 8- location of sites:
1- Kołczewo, 2- Lake Racze (from Latałowa 1992)

2. 7. 1. THE LATE VISTULIAN ENVIRONMENTAL CHANGES IN WOLIN ISLAND

Results of pollen analysis (Fig. 45) and complementary macrofossil data from three Lateglacial sites on Wolin Island: Lake Racze, Kołczewo and Warnowo enable the preliminary description of the environmental changes in the Lateglacial Interstadial and in the Younger Dryas Stadial. Pollen and macrofossil data obtained so far seem to be promising because of presence of several bioindicator taxa. Traces of *Laacher See Tephra* (LST) found in the site of Warnowo (Juvigné et al. 1995 a, b) are of special interest.

The Lateglacial Interstadial

Due to scarcity of data the chronology and correlation of the oldest part of the Interstadial remain an open problem, while its youngest part can be correlated with the upper Alleröd. This phase was characterised by development of open pine-birch forest. Also *Populus* (*P. tremula*) spread. Presence of patches of tundra with *Betula nana, B. humilis* and heliophytes typical of drier habitats *Dryas octopetala*, *Gypsophila fastigiata* and *Saxifraga* cf. *stellaris,* are documented. The development and stabilisation of topsoil is confirmed by very low input of minerogenic matter to the sediments. The same picture can be drawn from the palaeoecological data from the biogenic horizon in Świętouście (see description of the stop 9).

The Younger Dryas Stadial

The Younger Dryas cooling resulted in retreat of forest vegetation, but in places pine and tree birches probably formed patches of park-tundra vegetation; their presence is confirmed by macrofossils. In the Wolin landscape thickets with *Juniperus* were certainly very characteristic at that time. On mineral ground heath vegetation with *Empetrum, Arctostaphylos alpina, A. uva-ursi, Rumex acetosella* and steppe with *Artemisia,* Chenopodiaceae, some species of *Helianthemum* and probably *Ephedra distachya* covered large areas. in different tundra habitats vegetation with *Betula nana, B. humilis,* dwarf-willows, *Selaginella selaginoides, Dryas octopetala, Saxifraga* spp. was present. In all sites under discussion rich water vegetation developed in this period. Very high proportions of *Pediastrum* indicate rather good trophic conditions. Among the macrophytes *Potamogeton filiformis, P. pusillus, P. praelongus* i *P. natans* were common.

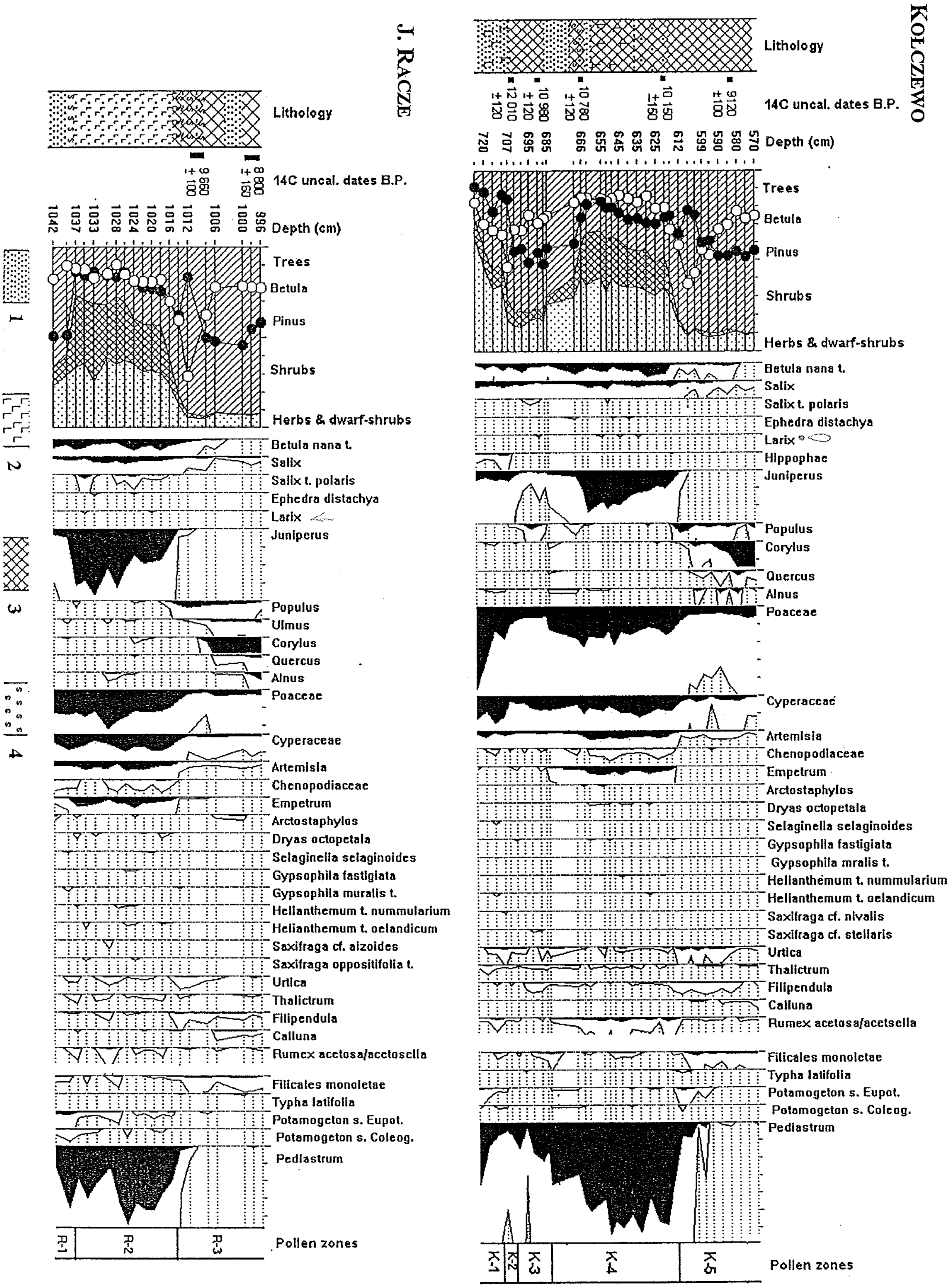

Fig. 45. The Lateglacial pollen sequences from the Kołczewo and Lake Racze sites (from Latałowa 1999)

Presence of *Nymphaea alba* (at the close of the Stadial) and subatlantic *Groenlandia densa,* two relatively termophilous species is of special importance.

Selected data on plant remains determined to the species level in Kołczewo and Warnowo. The attribution of the macrofossil finds to particular geoclimatic units is based on pollen diagrams and lithological correlation (from Latałowa 1999).

Taxon name (in alphabetic order)	Geoclimatic units		
	Lateglacial Interstadial		Younger Dryas
	a+b	c	
Arctostaphylos alpina (L.) Spreng	-	-	+
Arctostaphylos uva-ursi (L.) Spreng	-	-	+
Betula humilis Schrank	+	+	+
Betula nana L.	-	+	+
Betula pendula Roth	-	+	+
Betula pubescens Ehrh.	-	+	+
Betula tortuosa Ledeb.	-	+	+
Carex cf. *aquatilis* Wahlenb.	-	+	-
Carex cf. *elata* All.	-	+	-
Carex lasiocarpa Ehrh.	-	+	+
Carex pseudocyperus L.	-	-	+
Carex rostrata Stokes	-	+	+
Comarum palustre L.	-	-	+
Dryas octopetala L.	-	+	+
Empetrum nigrum s. l.	-	+	+
Groenlandia densa (L.) Fourr.	-	-	+
Gypsophila fastigiata L.	-	-	+
cf. *Gypsophila muralis* L.	-	-	+
Menyanthes trifoliata L.	-	+	+
cf. *Minuartia stricta* (Sw.) Hiern	+	-	-
Myriophyllum spicatum f. *squamosum* Laest.	-	-	+
Nymphaea alba L.	-	-	+
Pinus sylvestris L.	-	+	+
Potamogeton filiformis Pers.	+	-	+
Potamogeton natans L.	-	+	+
Potamogeton praelongus Wulf.	-	-	+
Potamogeton pusillus L.	-	-	+
Potentilla cf. *norvegica* L.	-	-	+
Ranunculus flammula L.	-	+	+
Rorippa palustris L.	-	-	+
Rumex acetosella L.	-	-	+

The Laacher Sea Tephra (LST)

The Warnowo site forms small depression of the kettle-hole character at the border of the large channel, close to the southern shore of the Lake Domysławskie. It is surrounded by sandy formations building the surface of the subglacial channel and its slopes (Juvigné et al. 1995 b). Recently it is overgrown by rush vegetation, which spread in form of a large belt around the lake. Three cores were taken from this site. In the layer of strongly decomposed, dark brown-moss peat at the depth of 329.5 cm the 1 mm thin layer of LST was identified by E. Juvigné. The second site with traces of LST was found in cliff of Niechorze, some tens km east from Wolin Island (Juvigné et al. 1995 a,b). The seldom pollen diagram was elaborated by A. Stach (Juvigné et al. 1995 b). Unfortunately, this diagram is only of restricted palynological value because of the large participation of the rebedded Tertiary material as well as badly developed sequence, probably of the Alleröd age. For this reason, in collaboration with the first authors (co-ordinated by the Late Professor Stefan Kozarski), the re-investigation of this site has been undertaken by the present author. However, only the preliminary macrofossil analysis of two profiles were performed so far (Latałowa unpubl., Stencel 1996).

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2. 7. 2. CLIMATE AND HUMAN IMPACT ON THE LAKE RACZE ECOSYSTEM DURING THE LAST 1000 YEARS - AS REGISTERED BY PALAEOECOLOGICAL DATA

In the Lake Racze profile, the evidence of the anthropogenic eutrophication in a form of sharp increase in the *Pediastrum* curve, appears as early as the first anthropogenic phase distinguished in the pollen diagram. Throughout prehistoric times, the *Pediastrum* content of this originally eutrophic lake, fluctuated with changes in farming intensity within the lake catchment. However, the most interesting data come from the upper part of this profile. The palaeoecological investigation of this lake was originally planed as a joint study, however limnologists limited their study to the upper part of the profile and the results were published without reference to the palynological data (Rybak 1987, Rybak et al. 1987). In consequence, in some points, they presented completely wrong interpretation of ecological processes driving limnological changes in the lake.

Selected pollen, diatom and chemical data (Fig. 46) enable to distinguish four zones illustrating changes in the lake ecosystem.

I - it reflects the state of the lake before deforestation of the lake catchment: low influx of terrigenic material into the lake is illustrated by the high organic matter content and low Si, Mg, Al and Fe content; the oxygen conditions in the lake were good (low Fe:Mn ratio)

II- this zone illustrates lake conditions in the situation of the rapid deforestation; increased leaching (decrease in calcium carbonate) and erosion of soil (rise in Si, Al, Fe and Mg content) enabled development of diatom community dominated by *Stauroneis anceps* and *Navicula vulpina*. Eutrophication is also reflected by the distinct increase in the curve of *Pediastrum*.

III- this zone is associated with palynological evidence of hemp retting. All indicators of soil erosion and eutrophication of the lake attain high values. The increase in the Fe:Mn ratio and the lowering of the CD:TC (chlorophyll derivatives:total carotenoids) ratio point to high anoxic conditions in the lake. *Gleotrichia echinulata* is abundantly present in pollen slides indicating high trophy of the water. Among diatoms *Tabellaria focculosa* var. *flocculosa,* an epiphyte, is found in great number. It could overgrow aquatic macrophytes, which at that time spread along the lake margin, as well as hemp steams sinking in the lake. Due to the intensive water mixing in course of hemp retting, chains of

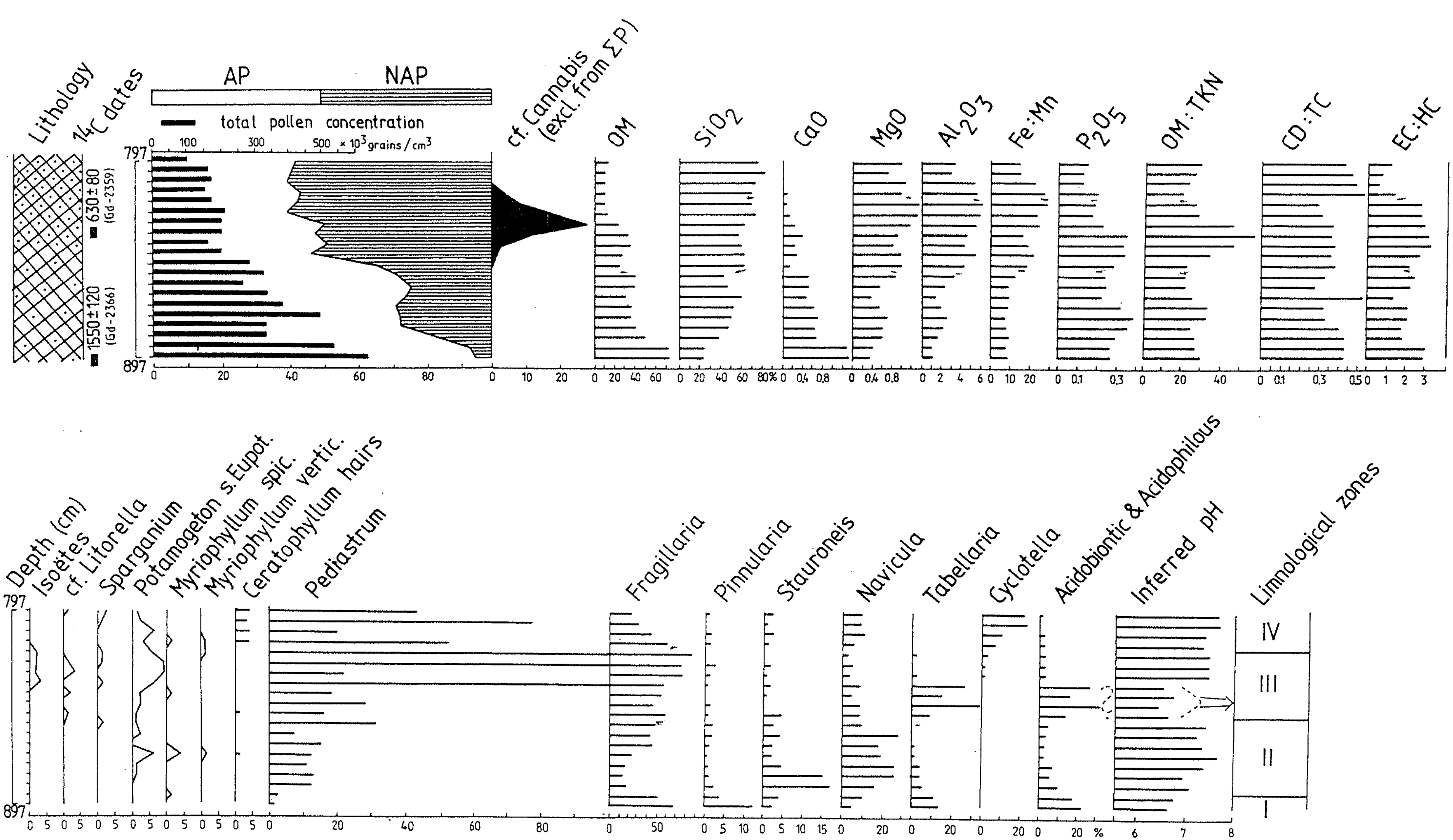

Fig. 46. Selected palynological and limnological data from the uppermost part of the Lake Racze profile: QM- organic matter, TKN- total Kjeldhal nitrogen, CD- chlorophyll derivatives, TC- total carotenoids, EC- epiphasic carotenoids, HC- hypophasic carotenoids (from Latałowa 1992)

cells of *Tabellaria*, that are easy to burst, remained as pseudoplancton and then were displaced towards the central part of the lake.

IV- the increase in planctonic forms represented mainly by *Cyclotella comta,* shows the development of pelagic zone, while the CD:TC and Fe:Mn ratios indicate an improvement in the hypolimnetic oxygen conditions. In the last 400-500 years the lake trophic status decreased attaining only a slightly higher level than in the zone preceding hemp retting period, even the strong increase in farming activity around the lake. This is probably due to the favorable ratio between the small catchment area and the relatively large water volume of the lake and a very low calcium carbonate in the surrounding soils.

The fairly reliable evidence of the climatic deterioration has been registered in the above part of the Lake Racze profile (zone IV). Formation of the pelagic zone i. e. the 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 years earlier. The lower limit of this zone is situated above the horizon radiocarbon dated to 630±80 BP and, thus, it corresponds to the climatic deterioration during **the Little Ice Age**.

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2. 8. STOP 8 - Kołczewo (Małgorzata Latałowa)

Kołczewo site lies about 600 m south-west from Lake Racze (Fig. 44) and fills part (ca. 4 ha) of a once-larger kettle-hole. Recently, the earlier ombrotrophic raised bog, almost disappeared overgrown by *Molinia caerulea,* young pines and birches. The bog is surrounded by small elevations covered by the Pleistocene formations composed mostly of poor sands or clayey sands, now covered mainly by about 50-year-old pine plantation established on former arable land. In places, patches of beech-oak forest and remnants of *Betulo-Quercetum* phytocoenoses can be identified.

In the period from 12 010±120 to 4730±100 conv. years BP limnic sediments (fine detritus gyttja) were accumulated (with mineral intercalations in the bottom part corresponding with the late Vistulian period), in the period 4730±100 - 3440±120 conv. years BP peats composed of brown mosses dominated, while from the layer dated to 3440±120 conv. years BP to the present time, ombrogenic peat was developing; The bog is underlain by fluvioglacial sands.

2. 8. 1. THE HOLOCENE HISTORY OF VEGETATION IN THE MORAINIC PART OF WOLIN ISLAND

In the early Holocene (Fig. 47) *Betula-Pinus* forests with *Populus* and then pine forests covered the area. *Ulmus* at about 9 900, *Corylus* at about 9800 and *Quercus* at about 9200 started to spread in woodland. The phase of increasing role of *Corylus* is dated to the period of c. 9200-8300 conv. years BP.

In the period c. 8000 - 5800 years BP forests with *Quercus, Tilia, Ulmus* and *Fraxinus* was gradually replacing pine woods. High proportions of charcoal and constant presence of pollen of heliophilous and nitrophilous plants indicate presence of Mesolithic tribes.

Period of c. 5800-3400 years BP was characterised by distinct man-made changes in woodland. High contribution of pollen of broad-leaved trees, especially of *Quercus*, increasing role of *Corylus* and appearances of *Plantago lanceolata*, pollen of cereals and other anthropogenic indicators suggest maintenance of coppice woods.

In the period c. 3400-2700 years BP the large scale deforestation in all forest types were made. Forests with *Ulmus, Tilia* and *Fraxinus* were succesively destroyed

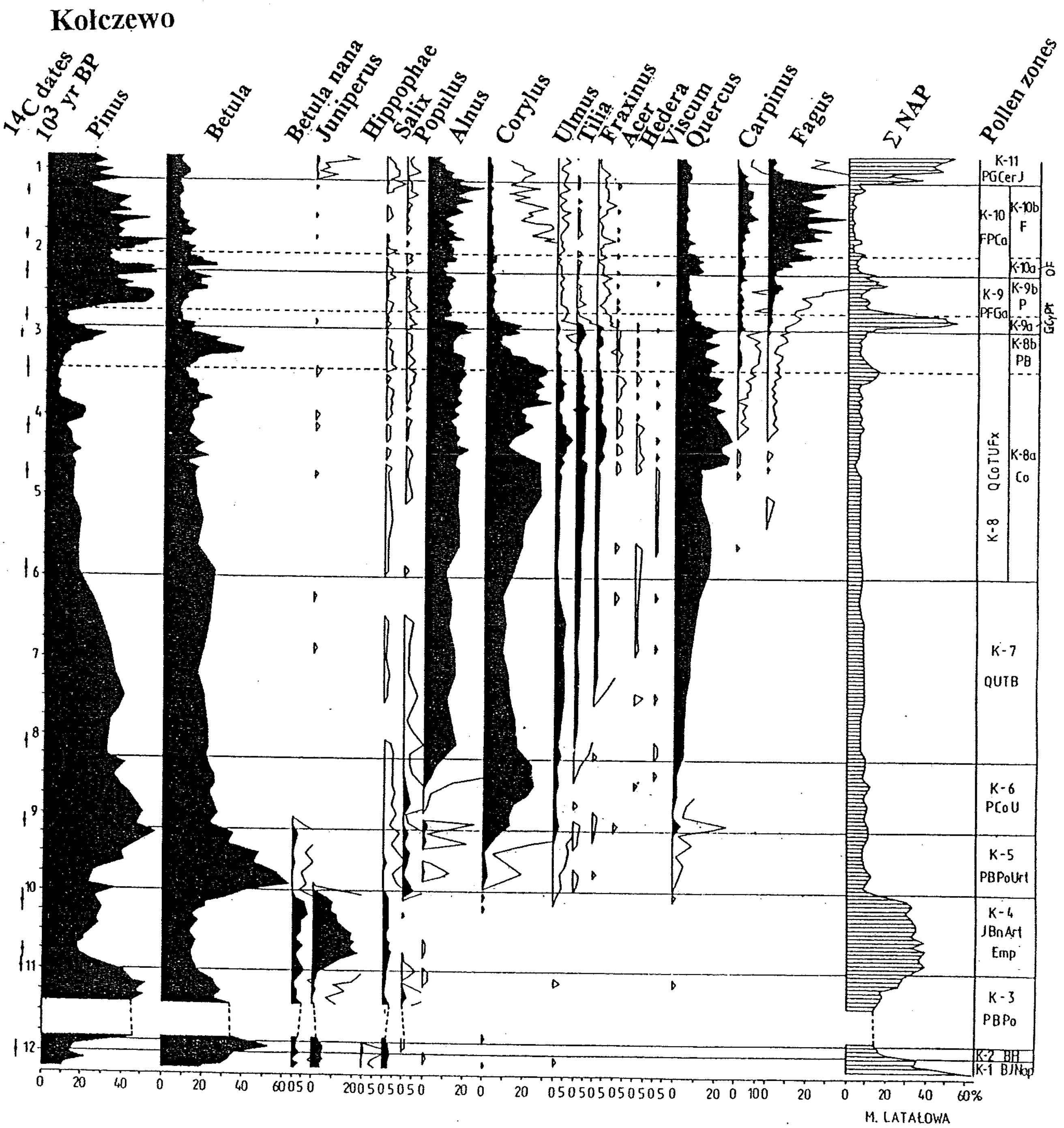

Fig. 47. Simplified pollen diagram from the Kołczewo site

during this period, while *Corylus* was significantly restricted. *Betula* and *Pinus* were the most important pioneer trees in forest regeneration on fallow land. *Carpinus* and *Fagus* started to spread.

Period of c. 2700-1300 years BP was characterised by a gradual reforestation of the area due to decrease in human activity. Woodland with predominance of beech covered areas with clayey soils. On the areas of light sandy soils, *Pinus* was dominant constituent of forest communities.

From c. 1300 years BP the general deforestation and gradual formation of the present-day cultural landscape began.

The pollen diagrams from Lake Racze and Kołczewo enabled the detailed reconstruction of the history of beech forests in this area (Fig. 48).

2. 8. 2. PREHISTORIC ECONOMY REFLECTED IN THE POLLEN DIAGRAMS FROM LAKE RACZE AND KOŁCZEWO

In both profiles sections of the early and partly middle Holocene are relatively badly developed what restricts their detailed interpretation. However, large quantities of charcoal particles and presence of some indicators of fires and forest glades point to the presence of **Mesolithic tribes**. Their activity caused disturbances in forest structure, development of rich herb layer in which *Pteridium aquilinum* played an important role, and then, spread of patches of light demanding herb communities.

Long sections in the pollen diagrams reflecting the period c. 5800-3400 years BP are interpreted as giving evidence of coppicing. In this part o Wolin Island the first Neolithic activity recorded in the pollen diagrams is slight and corresponds probably to the **Corded Ware culture**. The high charcoal content, the evidence of coppicing and the only scattered pollen of cereals (Cerealia-type, *Triticum* -type) suggest the slush-and-burn cultivation. At that time, animal husbandry was certainly more important activity than plant cultivation. This type of economy was dominant at least up until the Lusatian culture phase (c. 3400 years BP).

During **the Lusatian culture** phase (c. 3400-2700 years BP) a considerable opening up of the landscape took place, what resulted in the soil erosion at a dramatic scale. The extent of deforestation in the late Lusatian culture was, in places, comparable to that of the early medieval times. The pollen diagrams afford data on the development of

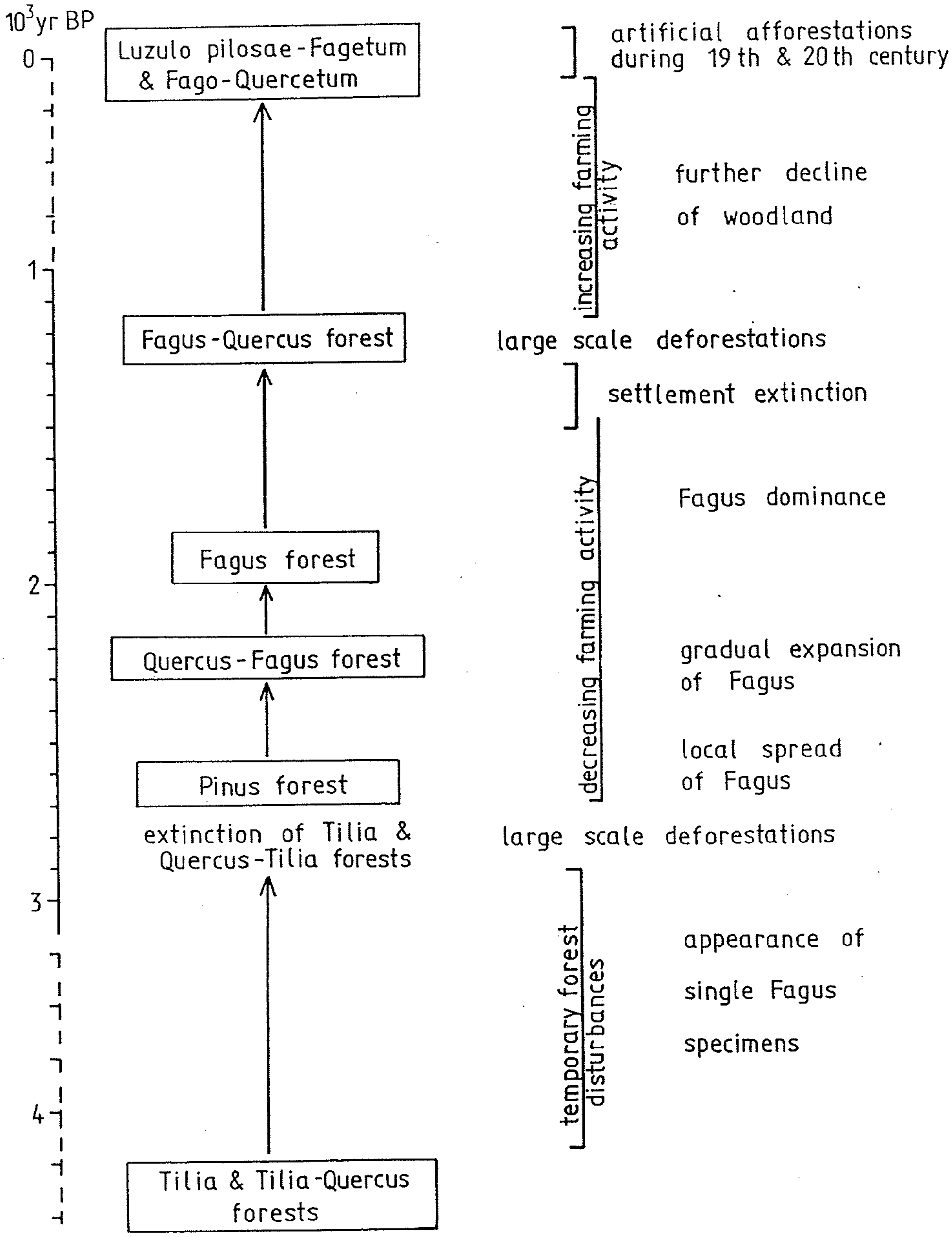

Fig. 48. History of beech forests in the morainic part of Wolin Island (from Latałowa 1992)

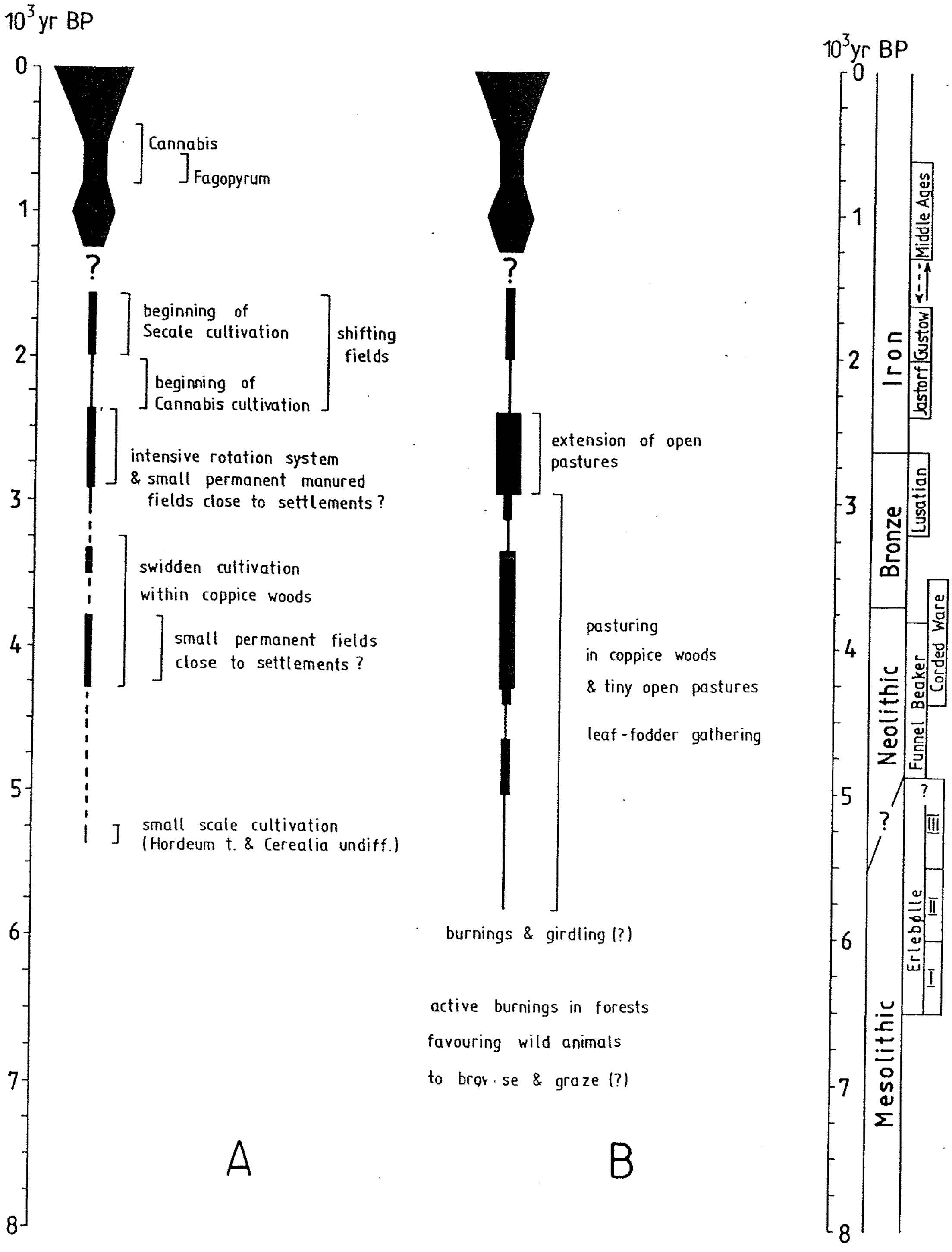

Fig. 49. The main stages of the development of farming in Wolin Island (from Latałowa 1992)

extensive open pastureland. Also cultivation increased in importance. On the basis of weed flora identified in pollen diagrams, presence of more permanent fields, especially in close vicinity of settlements, cannot be excluded. There are also indications of the spread of nitrophilous weeds, what may indicate that at least some fields were manured.

During **the Iron Age**, human impact declined but in a reduced number of settlements cultivation rose in importance. The sharp fluctuations in the *Fagus* and *Pinus* curves may illustrate series of small-scale deforestation and forest regeneration phases on fallow land, which may be indicative of shifting fields. During the **pre-Roman Iron Age** (Jastorf culture) the indications of animal husbandry are much stronger than those of cultivation. In the next phase (**the Roman Iron Age** - Gustow group) role of cereal cultivation distinctly increased; for the first time, the *Secale* pollen frequency exceeds that of other cereals.

The increase in acreage of arable land took place in **the early Middle Ages**, in connection with the development of numerous settlements and the early medieval town of Wolin. The increased population density on the island and its surroundings resulted in extension of arable fields, probably even onto the poorest soils.

The data on the development of economy reflected in the pollen diagrams from Lake Racze, Kołczewo and Wolin II profiles are a background for the synthetic compilation presented on the Fig. 49.

2. 8. 3. HYDROLOGICAL CHANGES CAUSED BY HUMAN IMPACT AND CLIMATE REGISTERED IN THE KOŁCZEWO PROFILE

The following phases in the bog development were characterised by the different hydrological regime. At the first stages, the shallow water body and the water level in the mire with brown mosses (mainly *Calliergon trifarium* and *Drepanocladus revolvens*) were dependent on fluctuations of ground water level in the area surrounding the kettle-hole. Due to sandy formations at the bottom, reactions of the kettle-hole hydrology on the changes in the ground water level in the area were very distinct. In the ombrogenic phase, the hydrological changes in the bog ecosystem were dependent on climate.

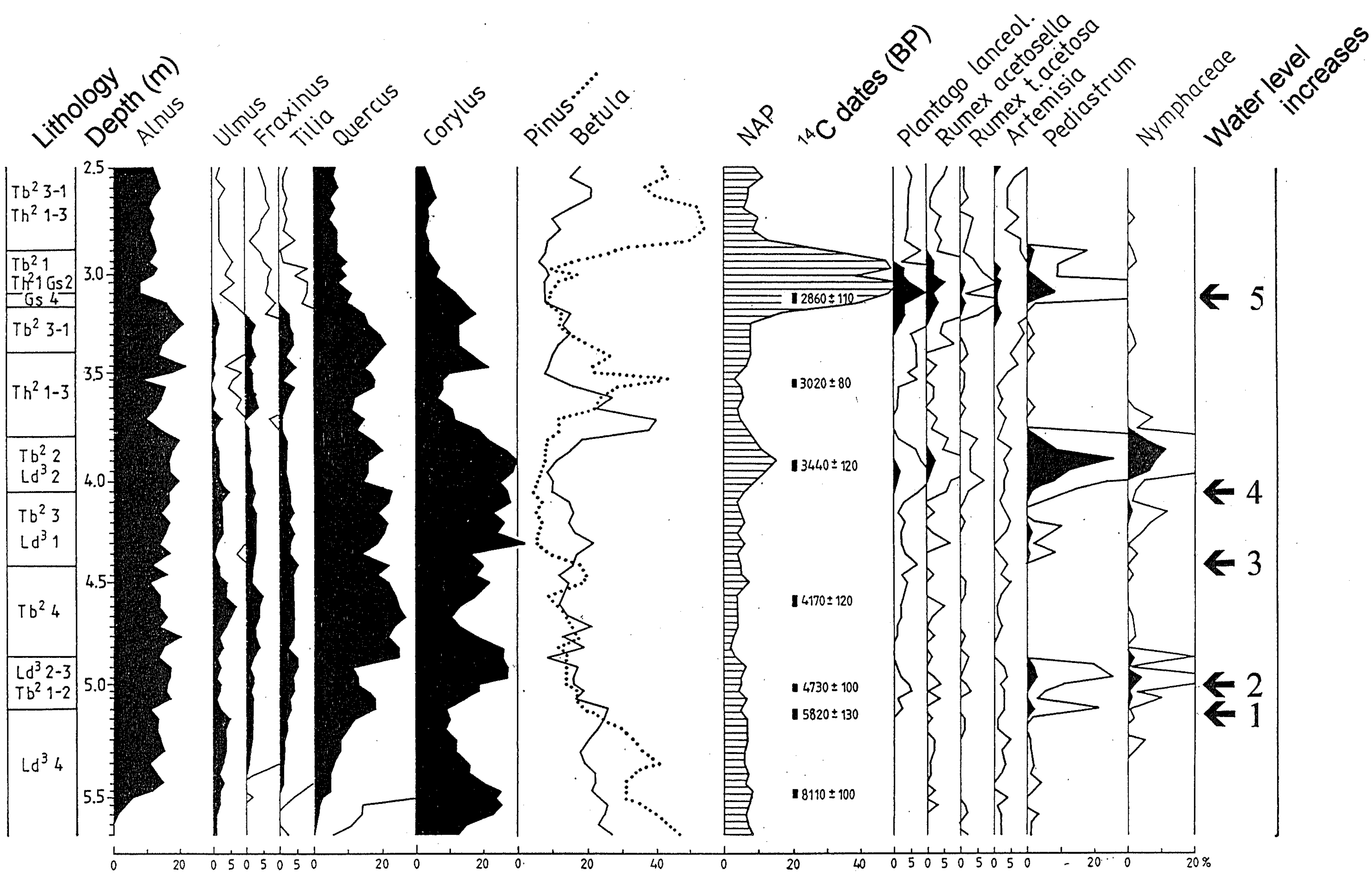

Fig. 50. Selected pollen data from the Kołczewo profile (from Latałowa 1999)

The pollen diagram (Fig. 50) indicates five phases of the water level increase, that can be linked with human disturbances in woodland:

phase 1- 5820±130 conv. years BP, **phase 2**- 4730±100 conv. years BP

phase 3- c. 3900 conv. years BP, **phase 4**- 3440±120 conv. years BP

phase 5- 2860±110 conv. years BP

Increases in the *Pediastrum*, pollen and trichosclereids of Nymphaceae and pollen of *Potamogeton* are always associated with the fall in the broad-leaved tree pollen curves and the rise in proportion of anthropogenic indicators. It is interesting, that the above hydrological changes were associated not only with deforestation, but also with anthropogenic disturbances described rather as changes in forest structure (coppicing). The strongest increases in the water table took place during the Lusatian culture activity (phases 4 and 5). In the phase 5, the raised bog succession, that started about 100-150 years earlier, was interrupted by a rise in the ground water table. Ground water penetrated the c. 60 cm thick ombrogenic peat layer and a small water body with eutrophic aquatic vegetation appeared once more. The few cm thick fine sand layer with seeds of some weeds (e.g. *Chenopodium album*) and sclerotia of *Coenococcum geophilum* points to the strong erosion of cultivated land in the immediate vicinity of the site. Those drastic changes were certainly accelerated by the climate deterioration of that time.

The following, climatically driven shifts toward wetter conditions are illustrated in the ombrogenic peat (Fig. 51):

phase a- c. 3000-2900 conv. years BP **phase b**- c. 2600-2500 conv. years BP

phase c- 2300±100 conv. years BP **phase d**- c. 2000 conv. years BP

phase e- c. 1700 conv. years BP **phase f**- c. 1500 conv. years BP

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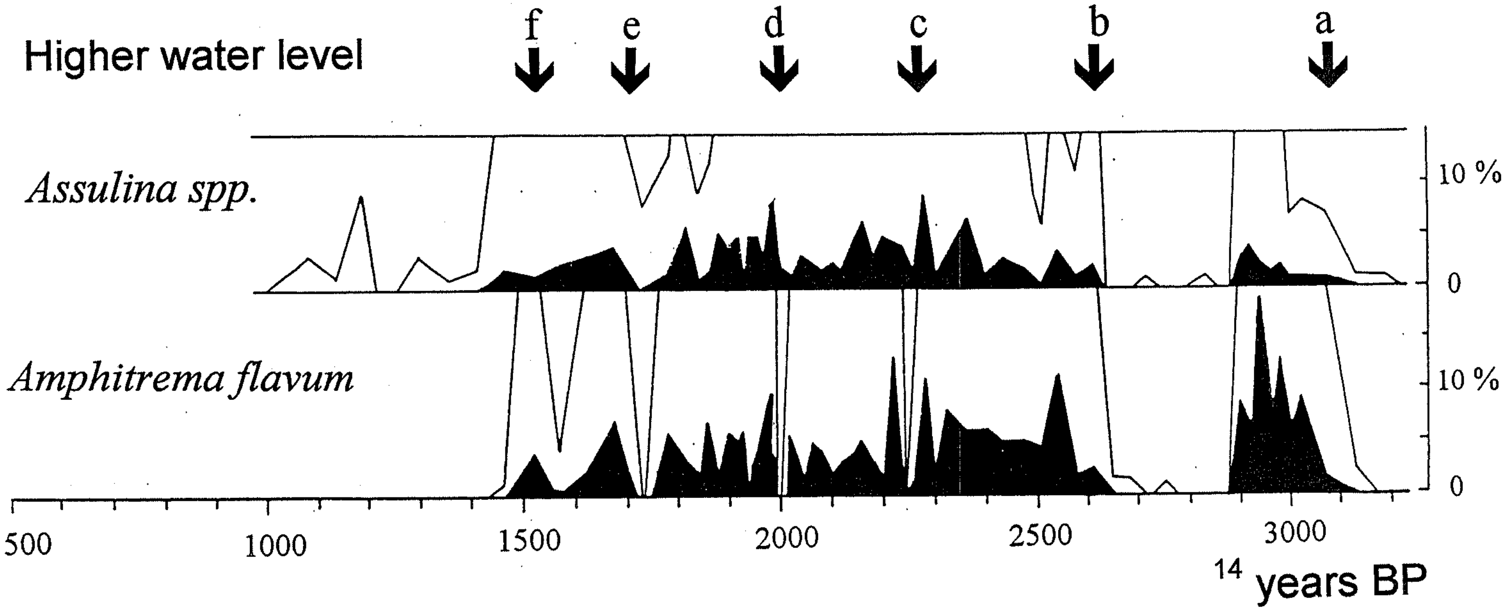

Fig. 51. Amphitrema and Assulina curves from the Kołczewo profile (from Latałowa 1999)

2. 9. Stop 9 - Świętouść

2. 9. 1. EOLIAN COVER-SANDS AND FOSSIL SOILS IN THE VICINITY OF ŚWIĘTOUŚĆ

Ryszard K. Borówka, Anna Belczyńska

Szczecin University, Department of Nature Sciences, Marine Research Institute

On the Wolin Hills there has been documented an existence of thick covers of eolian sand placed unconformably over disturbed glacial, fluvioglacial and lacustrine-alluvial deposits, under-cut from the side of Pommeranian Bay by active cliffs (Borówka et al. 1982, 1986). These covers appear both in the neighbourhood of Świętouść (Fig. 52, 53 A) as well as on the section of cliff stretching from Międzyzdroje to Grodno (Fig. 53B). The thickness of the covers series of eolian sands is very diversified, varying from few meters in culmination zones of Wolin Hills up to several metres (12-14 m) in the areas between culmination points.

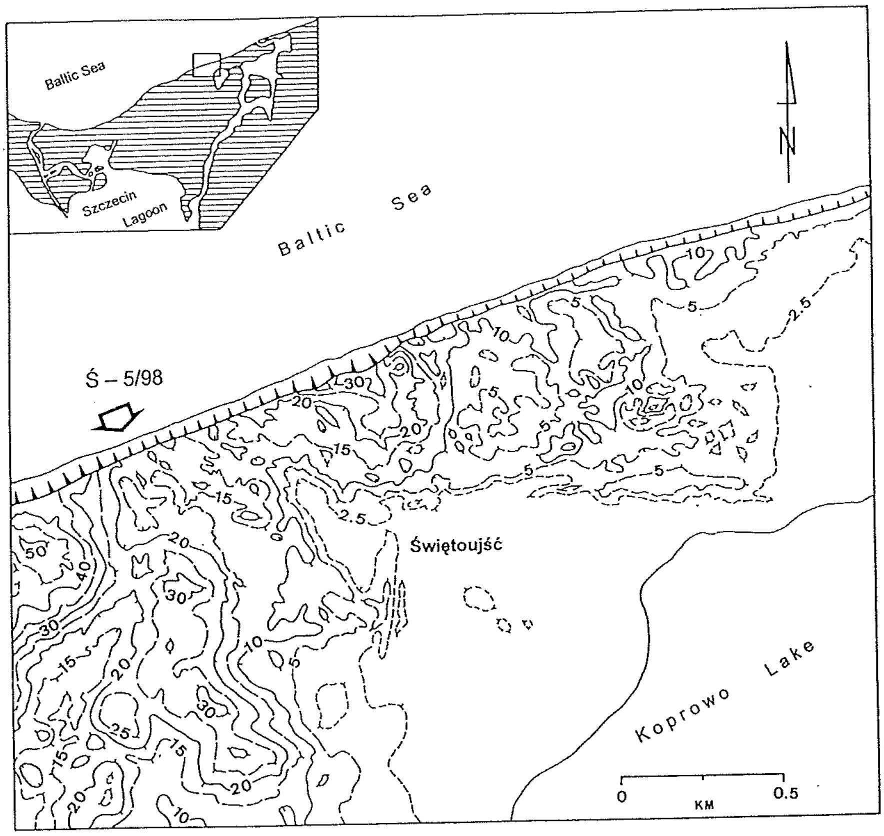

Fig. 52. Location of the study sites near Świętouść

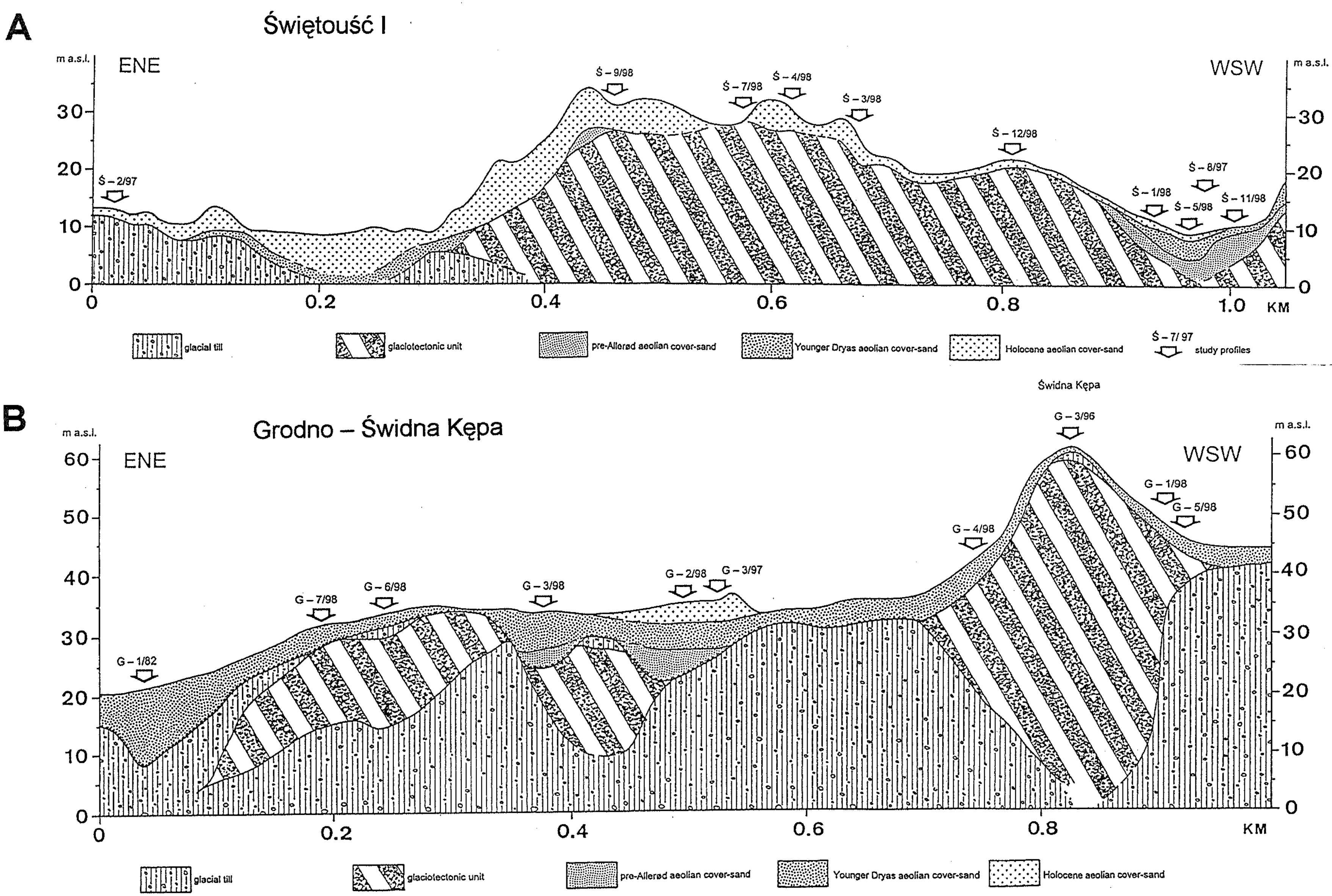

Fig. 53. Distribution of the eolian cover deposits in Świętouść I (A) and Grodno-Świdna Kępa (B) sites (after Borówka, Belczyńska, Duda, Babski 1999)

The closest basement of the eolian cover is a residual pavement, within which there are often found eologliptolites, and sometimes well formed ventifacts as well. This pavement is a discordant surface, separating the deeper-placed series of disturbed Quaternary formations from the eolian sands placed above. At some places occur thin intercalations of fluvial sediments, especially at sites situated in the lowest topographical positions at the border of pavement and the eolian series.

The eolian series placed above the pavement are not homogenous. Within it, horizons of fossil soils are often found, which have a significant spatial stretch at many places. At present, there has been documented the existence of two fossil soil horizons (Fig. 54).

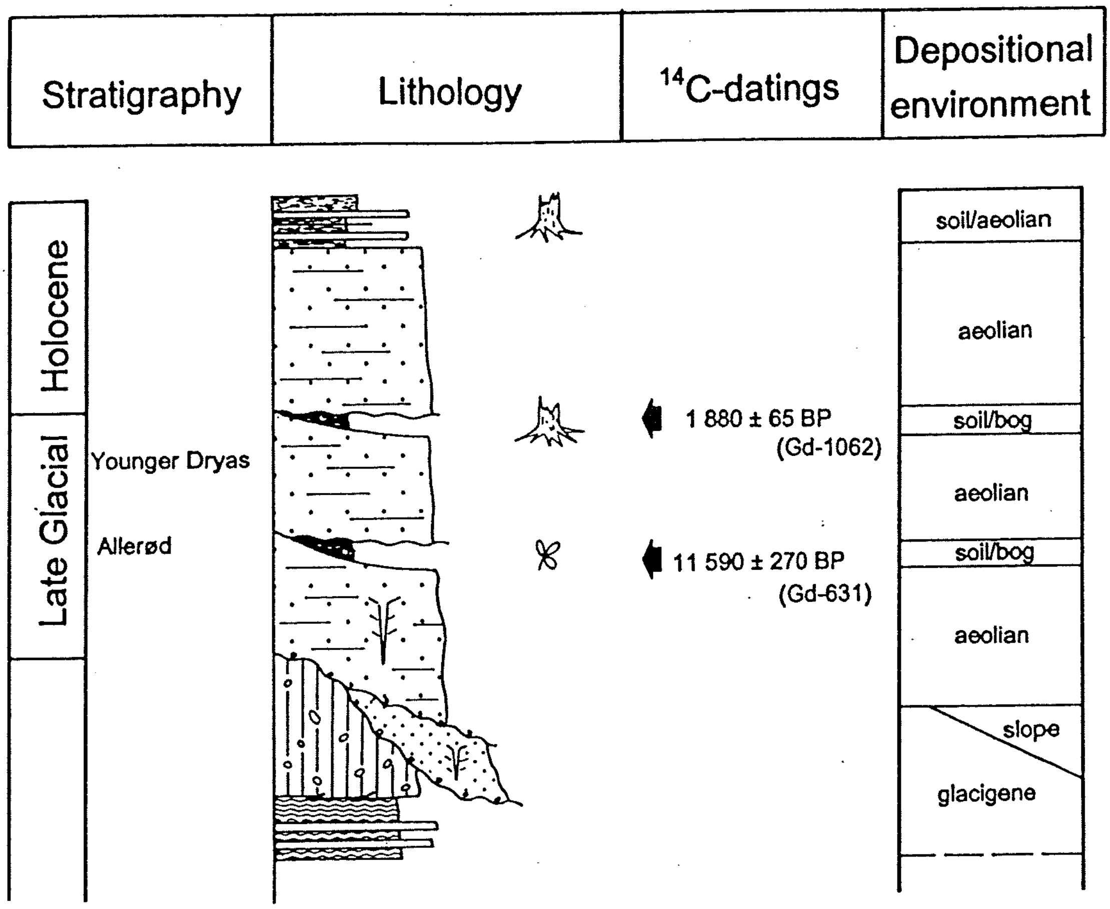

Fig. 54. Świętouść – synthetic profile of the eolian cover deposits

Older one is the fossil soil of Usselo type, whose radiocarbon age has been determined at one site to 11 590 ± 270 years BP (Gd-631). Whereas, the younger fossil soil horizon was probably developing almost through the whole Holocene. At some places it creates contemporary soil horizon, but usually is covered by some-metres sandy or sandy-organic cover. It forms then a fossil soil, dated at one of the sites to 1880 ± 65 years BP (Gd-1062). In case of fossil soils, results of C-14 data give the time of their burial.

The degree of the development of the older soil horizon, which was connected with the Alleröd Interstadial, is diversified. It widely depends on topographical situation (Belczyńska 1998). In the lowest topographical placements this soil is characterised by a very deep profile, reaching e.g. at Świętouść 5/58 site to about 130 cm. This horizon passes there into limnic-swampy deposits, which develop in the depression of the area. On slopes and at culmination of particular elevations thickness of the soil profile does not usually exceed 20-30 cm. At Grodno I site, where the Alleröd soil covers a quite broad flat deflational surface, it indicates properties of structural soil, developing in periglacial conditions at least in the final stage (Borówka, Belczyńska, Tomkowiak 1999).

The younger Holocene soil, formed as a podsolic soil or a podsolic-rusty soil characterises oneself much bigger thickness, reaching usually over 1.5 m. However, it is usually not preserved as a whole because both the humic accumulation horizon (A) and the albic horizon have been blown away. Simultaneously, the spodic horizon has been preserved, cemented usually by alluminium and iron compounds.

The mentioned fossil soils divide on three different-age eolian series. The oldest serie (ODS) dates from pre- Alleröd period, middle (YDS) from Younger Dryas and the youngest (SAS) from Subatlantic period.

The pre-Alleröd eolian sands (ODS) are distinctly stratified. Sets of flat stratification and rarely tabular-cross ones are predominant with a diagonal laminae slope within interval from 6 to 12°. There are individual ice-wedges casts within these series, and also horizontal ferric stripes (pseudo-fibres), formed probably in the conditions of presence and degradation of permafrost and overlaying epigenetic processes. There has been also concluded a presence of numerous faults and small reversed thrusts. Most of them are of relaxation character, but part of them corresponds to some thrusts present within disturbed glacial, fluvioglacial and lacustrine-alluvial sediments deposited below residual pavement. Amplitude of these former thrusts diminishes usually gradually within the oldest eolian series. The development of this series became therefore already at the final phase of Wolin ended moraine forming and lasted until Alleröd.

The middle eolian series (YDS) deposited between the Alleröd and Holocene soils consists mainly of horizontally stratified sands. There is sometimes not so thick zone (up to about 10 cm) between two distinct horizontal layers, where lamina course is visibly disturbed, resembling convolute stratification. Such sand layers with the disturbed lamination were probably accumulated on snow (niveo-eolian sands). Similar as in the older series, ferric stripes (pseudofibres) are also commonly present here.

The youngest eolian series (SAS) has usually complicated character. In bottom, horizontally stratified sands are predominant, whereas in top sandy layers are intercalated with humus layers. This top part of eolian cover sediments is according to Prusinkiewicz (1971) humus-sand mantles, developing contemporarily above upper cliff edge during storm seasons.

The particular eolian series differ slightly with sediment grain-size. Despite this fact it is observed quite distinct decrement tendency of silt fraction content and increment of mean grain diameter in the younger eolian series (Borówka et al. 1982).

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2. 9. 2. POLLEN AND MACROFOSSIL CONTENT OF THE BIOGENIC HORIZON IN ŚWIĘTOUŚĆ

Małgorzata Latałowa

Pollen analysis (Fig. 55) indicates that the sediments accumulated during the later part of the Allerod. In the pollen spectra *Pinus* pollen absolutely dominates, but towards the top of the profile, its curve is distinctly lowering. The *Betula alba*-type pollen curve shows the opposite tendency. Also curves of many taxa indicative of more open landscape as *Artemisia*, *Empetrum* and *Juniperus* rise in the upper part of the diagram. Pollen of the *Betula nana* -type and of other representatives of different heliophilous plant communities (*Dryas octopetala*, *Saxifraga stellaris*-type, cf.*S.hirculus, Gentianella campestris, Botrychium lunaria, Artemisia, Pulsatilla, Gypsophila fastigiata/repens* and many others) indicates existence of dry grasslands as well as tundra vegetation, which were expanding in the later part of the period represented in the diagram. It probably illustrates climate deterioration at the Allerod/Younger Dryas break. The conclusion drawn of the pollen data are supported by the lithological composition of the profile; in the upper part of the profile the intercalations of sand appear.

The biogenic material was accumulated in a shallow water body. In the older, bottom part, it was dominated by representatives of *Spirogyra* and by *Pediastrum boryanum* cfr. v. *carribeanum.* In the macroscopic material water plants are not represented. The large number of charcoal fragments is characteristic for this part of the profile. Numerous seeds of *Arctostaphylos uva-ursi* and *Empetrum nigrum* document formation of heath-type vegetation.

In the later phase *Botryococcus browni* and different species of *Pediastrum: P. boryanym v. brevicorne, P. borynum v. boryanum, P. alterans, P. angulosum v. angulosum* appeared in great number. *Groenlandia densa* was the most common among macrophytes.

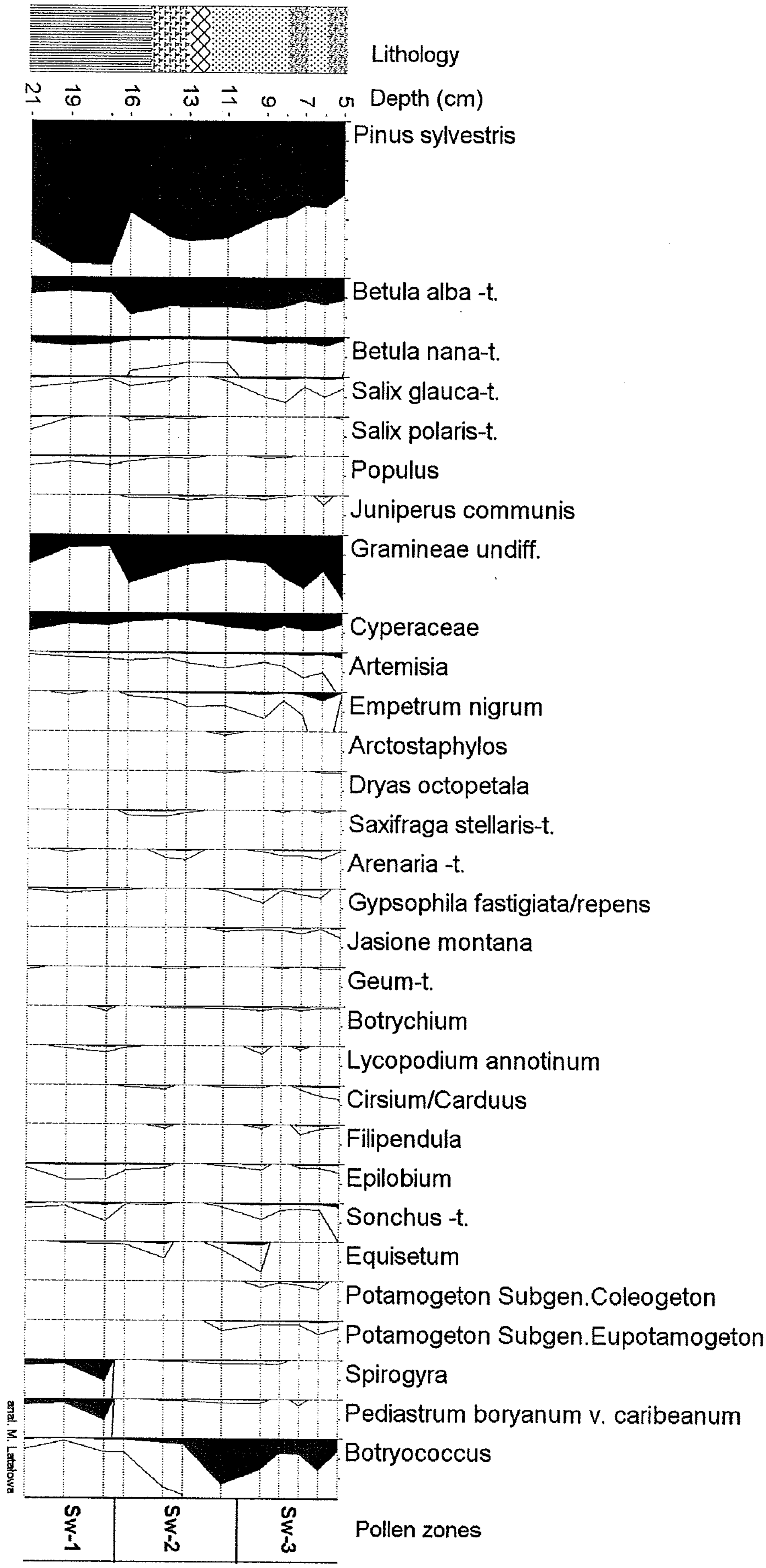

Fig. 55. Selected pollen curves from the biogenic horizon in Świętouść

2. 10. Stop 10 - The Wolin Lakeland

2. 10. 1. LANDSCAPE AND VEGETATION OF THE WOLIN LAKELAND

Małgorzata Latałowa, Agnieszka Popiela

Lakes belong to the most beautiful and attractive elements of the Wolin Island landscape. They are differentiated in respect to their origin (channel lakes - e. g. Czajcze, Domysławskie and Warnowo Lakes, kettle-hole lakes - e. g. Lake Racze, off-shore lake – Koprowo Lake and artificial lakes –Turkusowe and (?) Grodno Lakes), geology, vegetation and degree of anthropogenic transformation.

The large complex of channel lakes mentioned above, occupies the central part of Wolin Island. They are relatively shallow (maximum depth is from about 2.8 m in Warnowo Lake to c. 6 m in Lake Czajcze) and separated with barriers.

Several interesting species of water plants and species of wet habitats, now extinct or very rare in other parts of the Island, survived here e. g. *Nuphar pumila, Nymphaea candida, Ophioglossum vulgatum, Epipactis palustris* (Piotrowska 1996).

Lake Czajcze belongs to the most beautiful of channel lakes. Their western and southern shores border with the well preserved forests of *Betulo-Quercetum, Luzulo-pilosae-Fagetum and Fago- Quercetum* (Piotrowska-Olaczek 1991).

Remains of the early medieval settlement are situated at the top of the lake's penninsula (being earlier an island). Their partly preserved ramparts attain height of about 10 m.

References:

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II. Drawa National Park

3. The general information on the area

Jolanta Kujawa-Pawlaczyk

Drawa National Park

3. 1. THE MOST IMPORTANT GEOGRAPHICAL DATA

Localisation:

NW Poland, Pomeranian Lake District, Drawa Outwash Plain;

Longitude: 15º 45' - 16º 45' W

Latitude: 53º 00' - 53º 15' N

☐ Area:

11081 ha (forest = 79%, waters = 10%, meadow and abandoned fields = 5%, others = 6%); 100 % of area is state owned and managed by Drawa National Park.

Created:

1990, May 01st

3. 2. THE NATURE OF THE DRAWA NATIONAL PARK

The Drawa National Park is one of the 23 Polish national parks. It was created in 1990, in the heart of the Drawa Great Forest, in the young post-glacial landscape, on the great postglacial outwash plain.

The Drawa National Park represents the typical landscape of postglacial outwash plain, with complicated net of guillies, partly filled by lakes, also with numerous kettle holes. The plain is covered by a big forest complex. The post-glacial deposits (mainly sands) building the bedding of the area of the Park are rich in calcium carbonate, what is reflected in the geochemistry of substrates and also in the flora (calciphilous species, as twig rush *Cladium mariscus*, calciphilous plant associations in lakes and in swamps).

The Drawa National Park represents the "forest and lakes" type of landscape, typical for the Polish Lake District, what is reflected by the composition of fauna of mammals and birds; numerous species demanding the both kind of biotops for their live (for example trees for nesting and lakes for feeding) are characteristic for the area.

The greatest natural wealth of the Park are ecosystems connected with water (rivers, lakes, swamps). They cover about 15% of the area.

The most valuable nature elements are rivers - Drawa and Płociczna - of a character typical of the young post-glacial landscape (the rapid current, little variability of flux in annual cycle, winding river-bed). These rivers have interesting reophilous plant communities (communities of the algae - *Hilderbrandtia rivularis*, communities *of Batrachium sp.*) and reophilous fish fauna with *Salmo trutta, Thymallus thymallus, Phoxinus phoxinus* and *Cottus gobio.*

Lakes in the Park represent almost the whole scale of diversity: from mesotrophic lakes with stone worts (*Charales*) "meadow" on it's bottom, through eutrophic lakes with *Myriophyllum, Ceratophyllum, Batrachium* and *Potamogeton sp.* div., to distrophic peatbog lakes.

Also swamp communities represent the full diversity scale: from lake-adjoining marshes, through moss communities on the chalk-bed, to ombrogenic peatbogs. Swamps supplied by spring waters are quite common.

Forests of the Drawa National Park are in the greater part of the area strongly transformed by the 19th and 20th century forestry. But some fragments representing forest associations typical of this part of Europe have remained: rich beech woods, acid lowland beech woods, acidophilous oak-beech woods, oligotrophic pine woods renewing in a natural way and stream-adjoining alder woods.

Inn the area of the Drawa Nationa Park some spontaneous processes of vegetation dynamics may be observed - primary succession (transforming of lakes into swamps), secondary succession (afforestation of abandoned meadows and fields), regeneration of forest relieved from the forestry pressure, fluctuations in the quasi-natural forest phytocoenoses.

The Drawa National Park administration tries to preserve the existing natural values of the Park and makes efforts to renaturalise elements of its nature, which were disturbed by human activity in the past.

Flora

c. 900 species of vascular plants, including rare in Poland: *Chamaedaphne calyculata* (one of 10 Polish localities), *Vaccinium microcarpum, Drosera anglica, Drosera intermedia, Cladium mariscus, Liparis loeseli, Lilium martagon, Sorbus torminalis, Carex dioica, Carex diandra, Epipactis palustris;* 27 native trees species.

c. 200 species of mosses, including rare in Poland: *Dicranum bergeri, Sphagnum tenellum, Sphagnum fuscum, Sphagnum subsecumdum, Helodium blandowii, Pohlia sphagnicola*, *Cinclidium stygium, Neckera crispa.*

above 206 species of lichenes, including rare in Poland: *Lecania sylvestris, Micraea intrusa, Poegrapha subparalella, Arthonia aspersella, Aspicilla excavata.*

Fauna

c. 100 species of breeding birds, including rare in Poland: *Haliaetus albicilla, Pandion haliaetus, Aquila clanga, Bubo bubo*, numerous *Bucephala clangula, Mergus merganser, Motacilla cinerea, Alcedo atthis, Phalacrocorax carbo, Ciconia nigra, Milvus milvus, Milvus migrans, Pernis apivorus, Tringa ochropus.*

c. 40 species of mammals, including numerous population of rare in Poland: otter (*Lutra lutra*) and beaver (*Castor fiber*); lack of big carnivores !

c. species of fish, including rare in Poland: *Salmo salar, Salmo trutta, Thymallus thymallus, Vimba vimba, Coregonus lavaretus, Coregonus albula.*

Potential natural vegetation

10 % = water and open swamp vegetation

63 % = beech (*Fagus sylvatica*) and oak-beech (*Quercus petraea & Fagus sylvatica* forests

15 % = oligotrophic pine (*Pinus sylvestris*) forests

9 % = alder (*Alnus glutiniosa*) swamp and floodplain forests

3 % = mixed deciduous forests dominated by *Carpinus betulus.*

Real vegetation

47 % = artificial pine stands on the site of deciduous forests

16 % = water and open swamp vegetation (natural and seminatural)

13 % = seminatural oligotrophic pine forests

5 % = seminatural meadows and pastures and abandoned fields

8 % = netural beech and oak-beech forests

8 % = alder swamp and natural floodplain forests

3 % = natural deciduous forests with *Carpinus betulus*

Forest stand structure

Dominating species

Pine (*Pinus sylvestris*) = 80 %

Beech (*Fagus sylvatica*) = 9 %

Alder (*Alnus glutinosa*) = 3 %

Oak (*Quercus petraea* & *Quercus robur*) = 3 %

Birch (*Betula pendula* & *Betula pubescens*) = 2 %

Spruce (*Picea abies*) - not native on this area = 1%

Age structure of forests

younger than 20 years = 5 %

between 20 - 80 years = 40 %

above 80 years = 55 %

Plant communities in peatbog sites in Drawa National Park

Scheuchzerio-Caricetea nigrae (Nordh. 1937). R. Tx. 1937

Scheuchzerietalia palustris Nordh. 1937

Rhynchosporion albae Koch 1926

Caricetum limosae Paul 1910 ex Osvald 1923

Rhynchosporetum albae Koch 1926

Eriophoro angustifolii-Sphagnetum recurvi M. Jasn., J. Jasn., S. Mark. 1968

Sphagno-Caricetum rostratae Steffen 1931

Caricion lasiocarpae Vanden Bergh. ap. Lebrun et al. 1949

Caricetum lasiocarpae Osv. 1923 em. Koch 1926

Caricetum appropinquatae (Koch 1926) Soó 1938

Caricetalia nigrae (Koch 1926) Nordh. 1936 em. Br.-Bl. 1949

Caricion nigrae Koch 1926 em. Klika 1934

Calamagrostietum strictae (Steff. 1931) Tołpa 1956

Menyantho trifoliatae-Sphagnetum teretis Warén 1926 em. Dierssen 1982

Caricetum nigrae Br.-Bl. 1915

Oxycocco-Sphagnetea Br.-Bl. et R. Tx. 1943

Sphagnetalia magellanici (Pawł. 1928) Kästn. et Flössn 1933 em. Dierssen 1975

Sphagnion magellanici Kästn. et. Flössn. 1933

Sphagnetum magellanici (Malc. 1929) Kästn. et Flösn. 1933 comm. *Ledum palustre-Sphagnum fuscum*

young *Vaccinio uliginosi-Pinetum*

comm. *Eriophorum vaginatum*

comm. *Molinia caerulea-Sphagnum*

4. Description of sites

Tuesday September 4

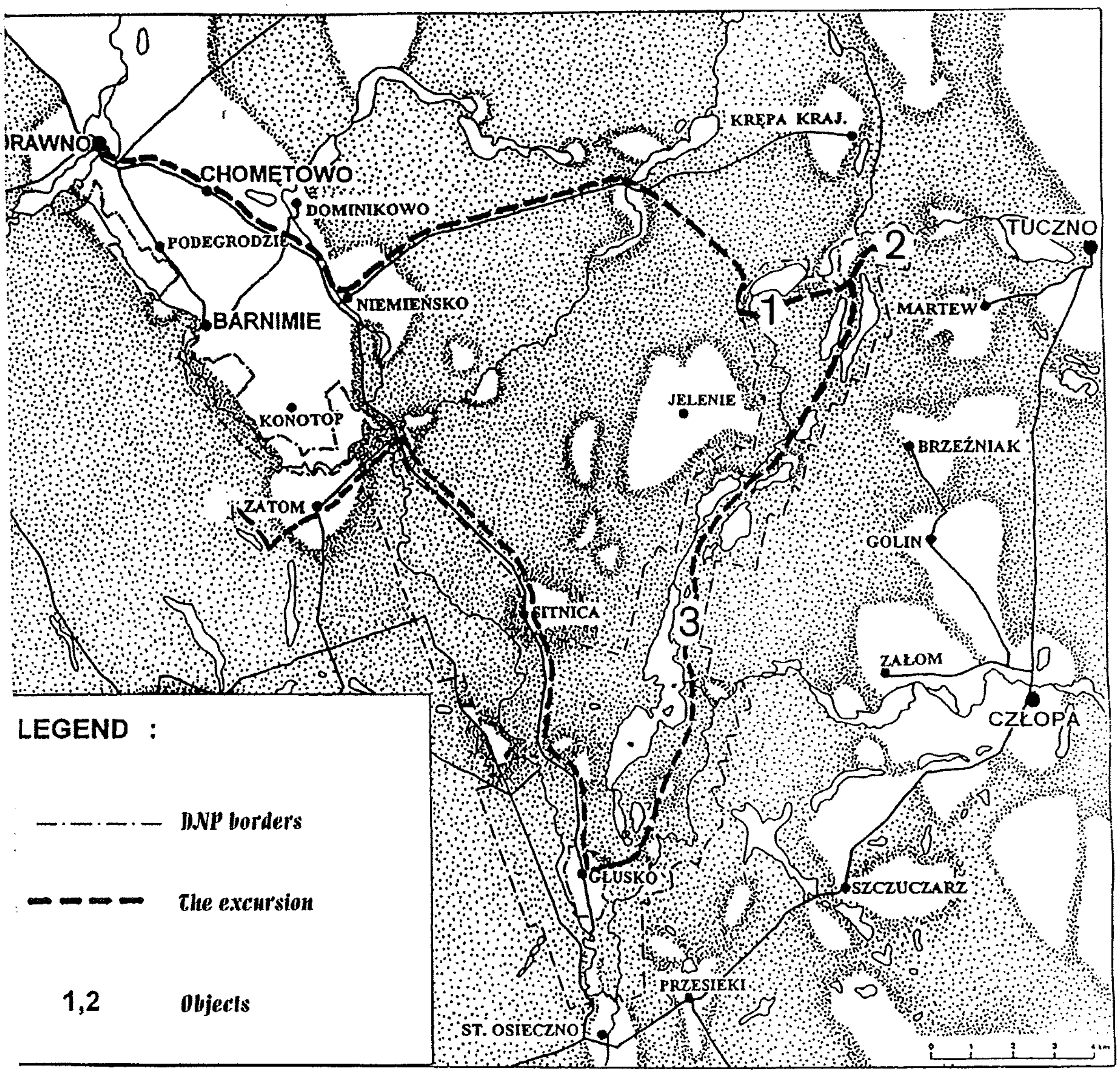


Fig. 56. The excursion route and location of sites

4. 1. Stop 11 - "SICIENKO" peatbog

4. 1. 1. VEGETATION

Jolanta Kujawa-Pawlaczyk

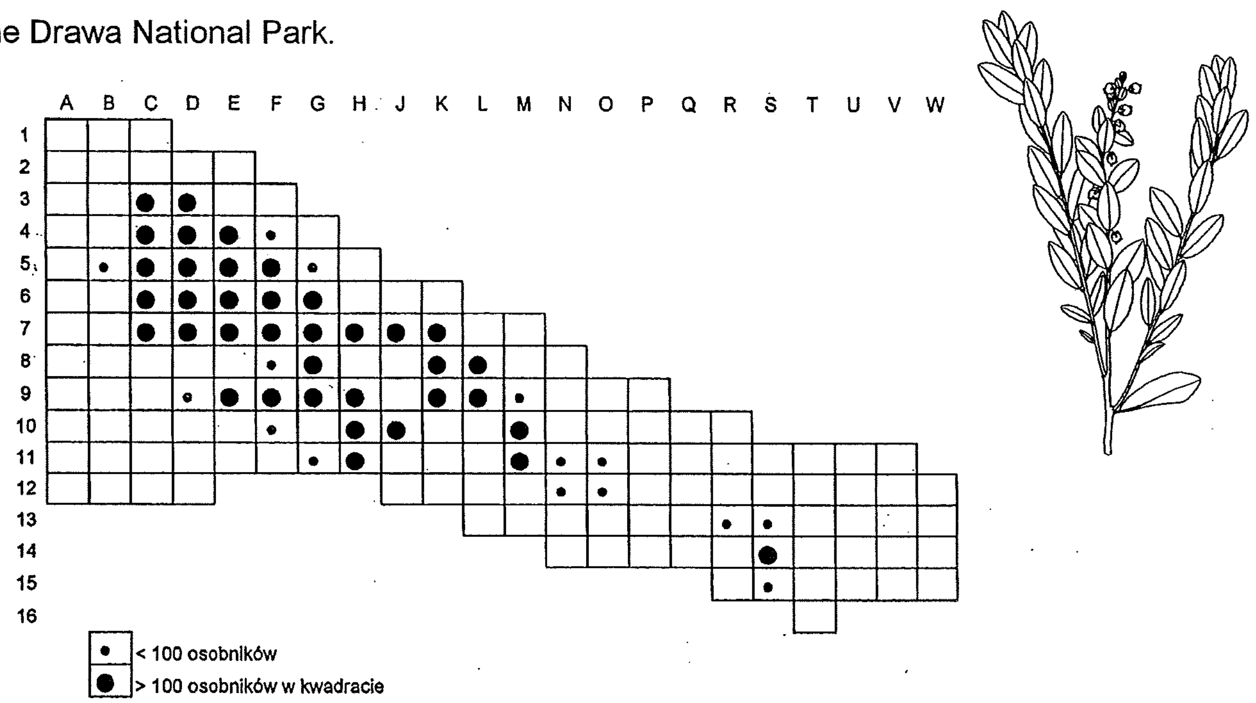
This is a small (2,11 ha) raised bog in the north-eastern part of the Drawa National Park . This is one of the 10 Polish localities of *Chamaedaphne calyculata* and the most south-western locality of this species in Europe. The peatbog is *Sphagnum*-type, oligotrophic one.

The community of *Sphagnetum magellanici* is dominating vegetation. In the central part of the bog *Caricetum limosae* spread.

Approximately 2000 shoots of *Chamaedaphne calyculata* spread on the bog surface (Fig. 57). It regenerates mainly vegetatively. There is a research plot for the *Chamaedaphne* population.

Also *Vaccinium microcarpum, Dryopteris cristata, Scheuchzeria palustris, Carex limosa, Eriophorum latifolium* grow here. Peat deposit and underlied gyttja sediments are 11.6 m deep.

In 1988-1990 there was a nature reserve here, in 1990 this area became a part of the Drawa National Park.



Ryc. Rozmieszczenie Chamaedaphne calyculata (L.)Moench w rezerwacie "Sicienko" na terenie Drawieńskiego Parku Narodowego

Fig. 57. Distribution of the *Chamaedaphne calyculata* (L.) Moench population in the site of Sicienko

4. 1. 2. SICIENKO - HISTORY OF VEGETATION

Małgorzata Latałowa

The data presented below base on the authors unpublished results of palaeoecological investigations being still in progress.

History of vegetation on mineral grounds surrounding the site

The pollen diagram (Fig. 58) illustrates history of vegetation from the Allerod period to the present time.

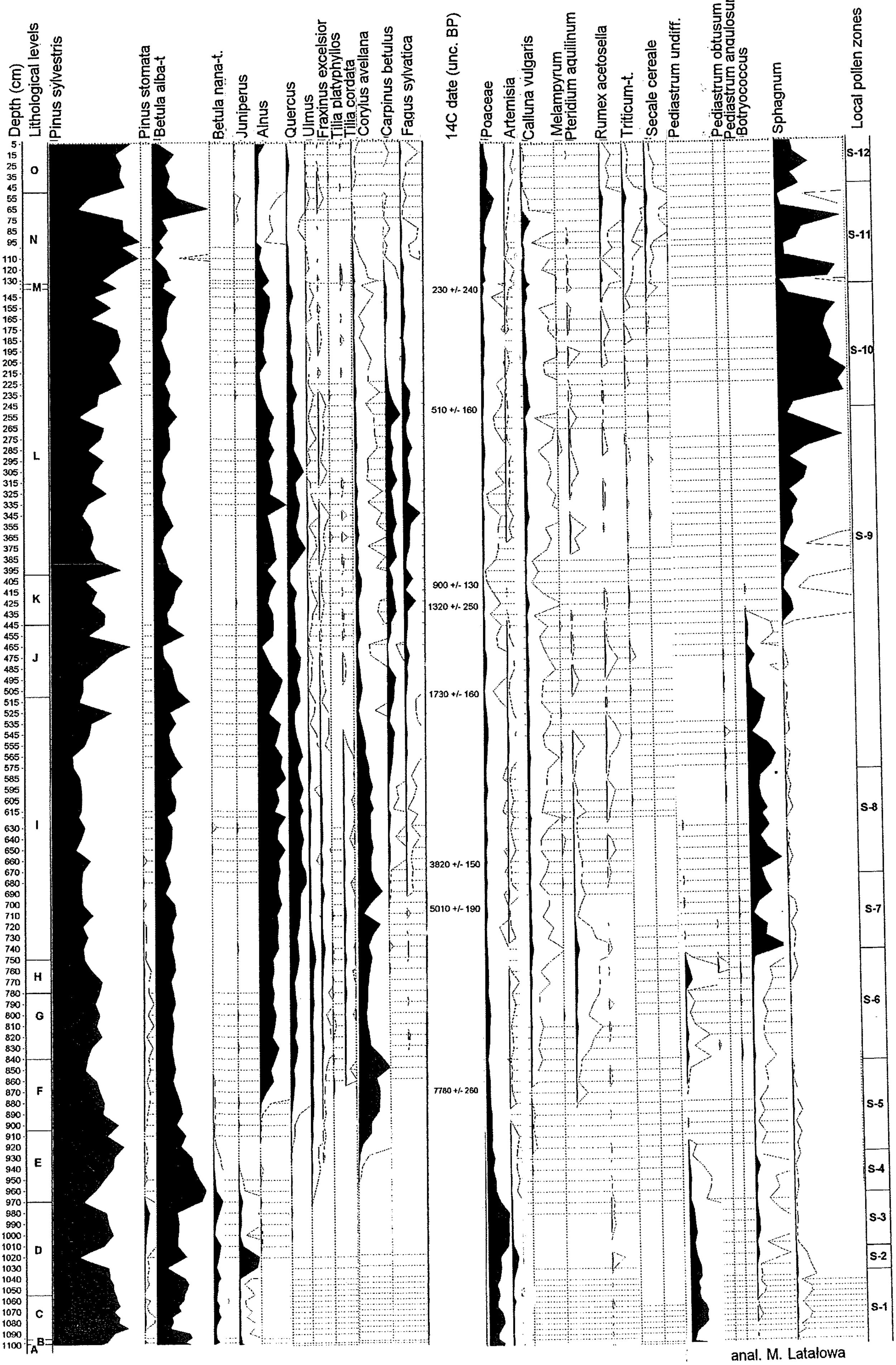
The **Allerod** vegetation was characterised by the development of pine-birch woodland. Patches of heliophilous vegetation are documented by the presence of *Juniperus, Empetrum nigrum, Betula nana, Rubus chamaemorus, Dryas octopetala* and species of *Saxifraga.*

During the **Younger Dryas** the heliophilous vegetation types gained in importance, however forests communities with pine and birch were still widespread in the area. The climate amelioration is clearly reflected in the younger part of this period.

During the whole **Holocene** forest communities with large participation of pine were the most common as a consequence of the prevalence of poor sandy soils in this area. Probably phytocoenoses of oak-pine forest were especially widespread. Patches of *Pteridium aquilinum* and *Calluna vulgaris* were common in disturbed forest habitats. The mesophilous broad-leaved forests spread mainly into the alluvial habitats. At about 4 ths years BP *Carpinus* and *Fagus* started to spread, but they have never played an especially important role in the surrounding of the site. After the medieval deforestation *Pinus* invaded fallow land.

In the topmost part of the profile the clear evidence of forest regeneration is observed. It can be linked with the period of the last 50 years, which is characterised by a low economic activity in this area in comparison to the previous period.

The pollen diagram suggests, that already in the early and middle Holocene, activity of Mesolithic tribes could affect ecological conditions in the area and start degradation in the poor sandy habitats. It is documented by early and vigorous spread of *Pteridium aquilinum* and *Calluna vulgaris* as well as other acidophilous species (*Rumex acetosella, Melampyrum*).



anal. M. Latałowa

Fig. 58. Selected pollen data from the Sicienko site

The evidence of the first agricultural activity (together with the elm decline) is dated to the around 5 ths years BP, what is in agreement with the archaeological opinion on the expansion of Neolithic tribes in this area. Clear occupation phases developed in connection with the Bronze and Iron Ages. It seems, however, that prehistoric settlements have never developed in the immediate vicinity of the site, throughout the whole Holocene (except of the very recent time).

Development of the local vegetation with special emphasis to the history of *Chamedaphne calyculata* (L.) Moench

In the Late Vistulian the site was filled with dead ice. Melting processes probably started in the Allerod, when the shallow water body appeared. At that time, the bottom of the water body was situated some meters higher than the mineral bottom of the kettle-hole and the surface water of Sicienko were probably in contact with those of the neighbouring lake. Fish remains suggest, that at that time the site could form a bay of Sitno lake. During the Allerod and then in the Younger Dryas sedimentation of gyttja rich in calcium carbonate (in the YD with significant admixture of silt and sand) took place.

With the climate amelioration, at the start of the Holocene, several species of macrophytes (representatives of Characeae, Nymphaceae, *Potamogeton*, *Najas*) invaded the site. Algae communities with several species of *Pediastrum* and *Botryococcus*, and periodically with blue-green Algae - *Gleotrichia* and *Anabena*, developed mainly, pointing to the mesotrophic-eutrophic conditions. Brown mosses, mostly representatives of *Calliergon* and *Drepanocladus* formed of patches of floating vegetation.

The intensification of processes of overgrowing the site with mire vegetation started around 5 ths years BP. In the profile thick layers of brown mosses appear, but remains of water plants are still present. Among algae remains those of *Botryococcus browni* are the most numerous.

The distinct changes in habitat conditions started at about 1730±160 conv. years BP, when participation of brown mosses diminished; at that time *Sphagnum fallax* and *Sheuchzeria palustris* started to spread. The fully ombrogenic phase in the bog development started about one thousand years ago. First *Sphagnum magellanicum* and then *Sph. fuscum* were the main constituents of the raised bog vegetation.

Regarding the history of the *Chamedaphne calyculata* population in this site, it is clear that since the Late Vistulian up to about one thousand years ago, both in the Sicienko site and in its surroundings, habitat conditions were not suitable for this species survival. Nor macrofossils or the pollen type (*Erica ciliaris* type) of this plant were found in the palaeoecological material, except of the few pollen grains at the very top of the profile. It seems that *Chamedaphne calyculata* is a relatively young member of the raised bog flora in the Sicienko site. Therefore, in contradiction to the previous opinions, it cannot be regarded as a relict of the Late glacial flora in this site.

4. 2. Stop 12 – The "Głodne Jeziorka" site

Jolanta Kujawa-Pawlaczyk

There are five peatbogs and dystrophic lakes (11,27 ha in total) situated in the north-eastern part of the Drawa National Park (Fig. 59). There are localities of rare plants: *Carex limosa, Vaccinium microcarpum, Sphagnum fuscum*

Water of the lakes is rich in humus, therefore brown and acid. At the peatbog margins, "belt" of *Carex limosa* and *Carex lasiocarpa* forms the most distinct type of vegetation. The rare *Odonata* species live here, for example *Nenhalennia speciosa.*

In 1988-1990 there was a nature reserve here, in 1990 this area became a part of the Drawa National Park.

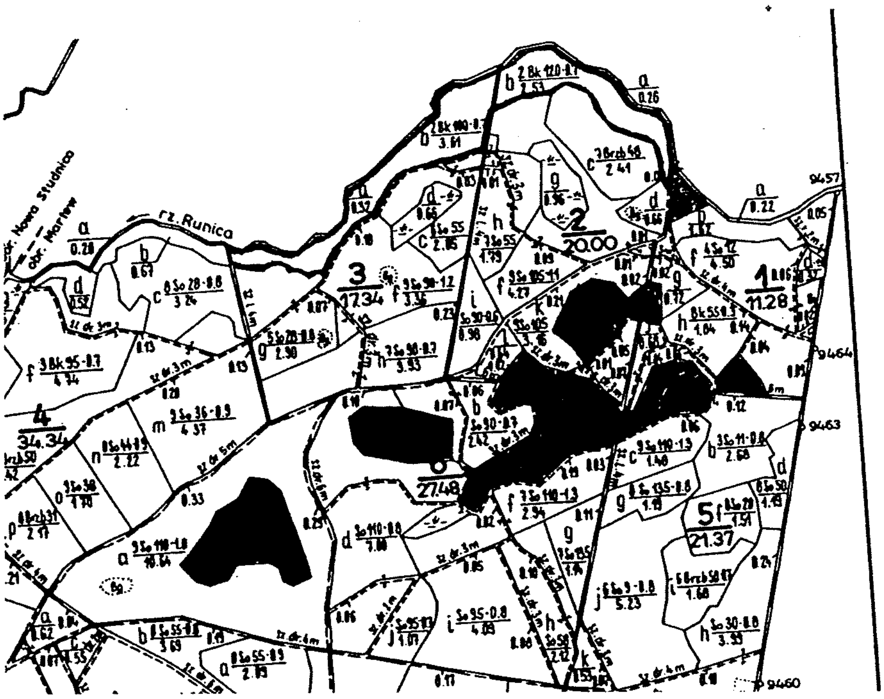


Fig. 59. Location of the „Głodne Jeziorka" sites.

4. 3. Stop 13 – The fen of "Kłocie Ostrowickie"

Jolanta Kujawa-Pawlaczyk

The former lake gulf, overgrown by rush of *Cladium mariscus* with brown moses is situated at the eastern boundary of the Park. In the northern part of the site, *Sphagnum* community, with *Drosera rotundifolia* and *Liparis loeselii* is present. In places, rooted by wild boars, there are populations of *Eleocharis quinqueflora*. The bog alder forest covers area around the site (Fig. 60).

In 1988-1990 this area was protected as nature reserve, in 1990 it ecame a part of the Drawa National Park.

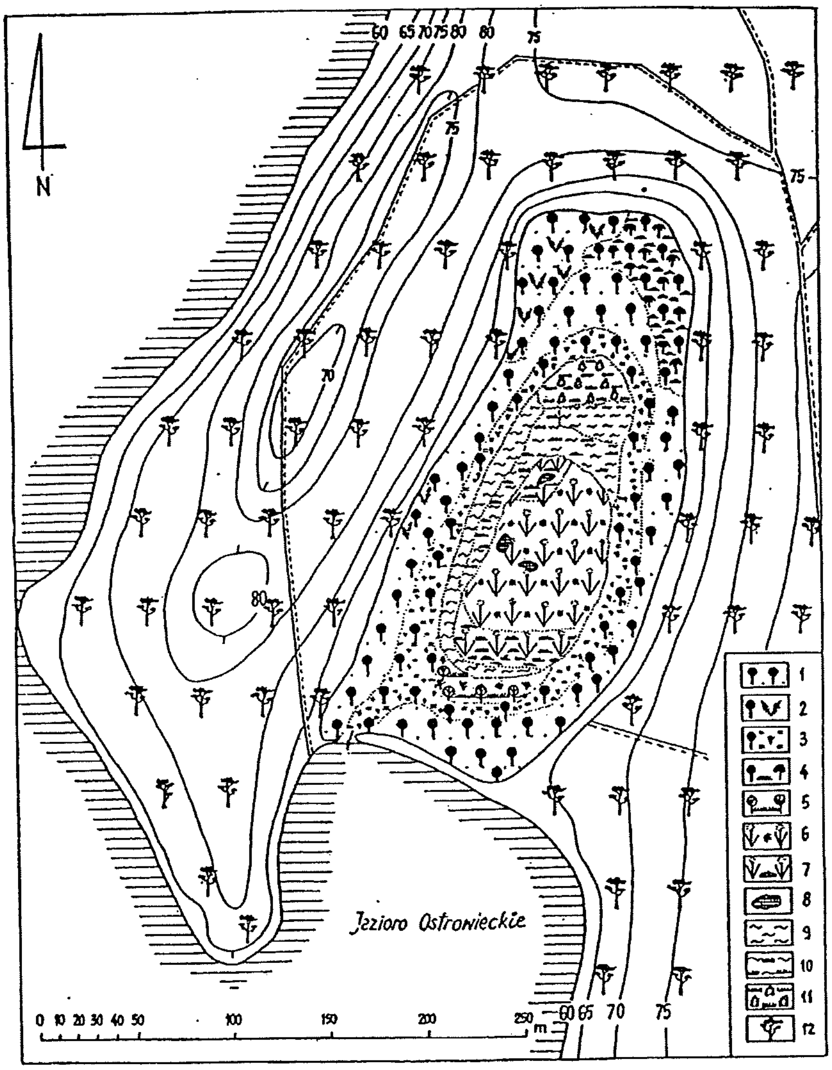


Fig. 60. Peat-forming vegetation of mossy fen and lakeside alder swamps in "Kłocie Ostrowickie" site; plant communities: 1-*Carici elongatae-Alnetum,* 2- *Athyrio-felix femina-Alnetum,* 3- *Carici acutiformis-Alnetum,* 4- *Sphagno squarrosi-Alnetum,* 5- *Acrocladium-Valeriana dioica-Alnus*, 6- *Drepanoclado-Cladietu,* 7- *Drepanoclado-Cladietum sphagnetosum,* 8-*Scorpidio-Eleocharietum quinqueflorae,* 9- *Drepanocladdus intermedius-Carex lasiocarpa,* 10- *Carici-Sphagnetum teretis,* 11- *Sphagnum-Pinus-Alnus,* 12-Dicrano-Pinion all. (from Jasnowscy 1991)

25TH BOG EXCURSION
NAMES AND ADDRESSES OF PARTICIPANTS

Elisabeth **ALMGREN** - Onskeringvägen 13, S - 16763 Bromma, Sweden
elisabeth.almgren@telia.com

Brigitta **AMMANN** - Inst. of Geobotany, University of Bern,
Altenbergrain 21, CH-3013 Bern, Switzerland
Brigitta.Ammann@ips.unibe.ch

Monika **BADURA** - Dept. of Plant Ecology, University of Gdańsk,
Al. Legionów 9, PL-80-441 Gdańsk, Poland
dokmb@uni.gda.pl

Andrew **BAUEROCHSE** - Niedersächsisches Landesamt für Denkmalpflege,
Scharnhorstr. 1, D – 30175 Hannover, Germany
bauerochse@gmx.de

Karl-Ernst **BEHRE** - Postfach 2062, D – 26360 Wilhelmshaven, Germany
karl-ernst.behre@nihk.terramare.de

Felix **BITTMANN** - Institut für Palynologie, Viktoriastr. 26/28,
D - 26382 Wilhelmshaven, Germany
Felix.Bittmann@nihk.terramare.de

Anne **BJUNE** - Botanical Institute, University of Bergen,
Allegaten 41, 5007 Bergen, Norway
Anne.Bjune@bot.uib.no

Tatiana **BLIAKHARTCHOUK** - Institute of Biology and Biophysics,
State University of Tomsk, Lenina street 36,
634015 Tomsk, Russia

Krzysztof **BORÓWKA** - Marine Research Institute, University of Szczecin,
ul. Felczaka 3A, PL-71-412 Szczecin, Poland

Anna **CEDRO (BELCZYŃSKA)** - Marine Research Institute, University of Szczecin,
ul. Felczaka 3A, PL-71-412 Szczecin, Poland
abcania@univ.szczecin.pl

Tomasz **DUDA** - Marine Research Institute, University of Szczecin,
ul. Felczaka 3A, PL-71-412 Szczecin, Poland
Tomasz_Duda@univ.szczecin.pl

Ueli **EICHER** - Schlossgutweg 42, CH – 3072 Gümlingen, Switzerland,
info@dialogpersonal.ch

Władysław **FILIPOWIAK** - Laboratory of Archaeology,
Institute of Archaeology and Ethnology,
Polish Academy of Science
ul. Zamkowa 16, PL-72-510 Wolin, Poland

Thomas **GIESECKE** - Dept. of Earth Sciences Quaternary Geology, Villavägen 16, SE – 75236 Uppsala, Sweden, Thomas.giesecke@geo.uu.se

Erika **GOBET** - Inst. of Geobotany, University of Bern, Auf der Mauer 3, CH – 3176 Neuenegg, Switzerland erika.gobet@ips.unibe.ch

Philippe **HADORN** - Rue des Coteaux 25, CH – 2016 Cortaillod, Switzerland, philippe.hadorn@ne.ch

Adam **HÖLZER** - Staatl. Museum für Naturkunde, Erbprinzenstr. 13, D - 76042 Karlsruhe, Germany aa.hoelzer@t-online.de

Joanna **JAROSIŃSKA** - Dept. of Plant Ecology, University of Gdańsk, Al. Legionów 9, PL-80-441 Gdańsk, Poland, biojj@uni.gda.pl

Petra **KALTENRIEDER** - Inst. of Geobotany, University of Bern , Ägertenstr. 79 , CH – 3005 Bern, Switzerland petra.kaltenrieder@ips.unibe.ch

Sabine **KARG** - National Museum of Denmark, Ny Vestergade 11, DK – 1471, Denmark Sabine.Karg@natmus.dk

Pim **VAN DER KNAAP** - Inst. of Geobotany, University of Bern, Altenbergrain 21, CH-3013 Bern, Switzerland knaap@ips.unibe.ch

Robert **KRISAI** - Linzerstr. 18, A – 5280 Branau/Inn, Austria Robert.Krisai@sbg.ac.at

Jolanta **KUJAWA-PAWLACZYK** - Drawa National Park, ul. Leśników 2, PL -73-220 Drawno, Poland

Norbert **KÜHL** - Institute of Paleontology, Nussallee 8, 51335 Bonn, Germany, kuehl@uni-bonn.de

Małgorzata **LATAŁOWA** - Dept. of Plant Ecology, University of Gdańsk, Al. Legionów 9, PL-80-441 Gdańsk, Poland bioml@uni.gda.pl

Jacqueline **VAN LEEUWEN** - Geobotanisches Institut, Altenbergrain 21, CH – 3013 Bern, Switzerland

Michał **LORENC** - Marine Research Institute, University of Szczecin, ul. Felczaka 3A, PL-71-412 Szczecin, Poland
Michal_Lorenc@univ.szczecin.pl

Marzena **OLAS** - Marine Research Institute, University of Szczecin, ul. Felczaka 3A, PL-71-412 Szczecin, Poland

Andrzej **OSADCZUK** - Marine Research Institute, University of Szczecin, ul. Felczaka 3A, PL-71-412 Szczecin, Poland
andros@univ.szczecin.pl

Krystyna **OSADCZUK** - Marine Research Institute, University of Szczecin, ul. Felczaka 3A, PL-71-412 Szczecin, Poland
osadczuk@univ.szczecin.pl

Agnieszka **POPIELA** Dept. of Botany, University of Szczecin, ul. Felczaka 3A, PL-71-412 Szczecin, Poland
Agnieszka.Popiela@univ.szczecin.pl

Anne-Marie **RACHOUD-SCHNEIDER** - Tattes d'oies 19, 1260 NYON, Switzerland
arachoud@iprolink.ch

Cesare **RAVAZZI** - CNR - IDPA, Piazza Cittadella 4, I – 24129 Bergamo, Italy
cnrbg1@mediacom.it

Astrid **RÖPKE** - Seminar für Vor- und Frühgeschichte (Archäobotanik) Poelzig.-Bau, Grüneburgplatz 2, 60323 Frankfurt, Germany
A.Roepke@em.uni-frankfurt.de

Klara **RÖTHLISBERGER** - Oberstrasse 8B, CH – 3550 Langnau, Switzerland

Siegfried **SCHLOSS** - Gartenstr. 18, D – 76751 Jockgrim, Germany
Dr.Schloss@vg-jockgrim.de

Per **SJÖGREN** - c/o Herner, Sunnanvägen 2N, S-22226 Lund, Sweden
persjoegren@hotmail.com

Helena **SVOBODOVÁ** - Czech Academy of Sciences, Paleoecologial W.G. CZ – 25243 Pruhonice/Prag, Czech Republic

Martina **STEBICH** - Forschungsstation fuer Quartaerpalaeontologie Steubenstr. 19a, D – 99423 Weimar, Germany
martina.stebich@fossi.uni-weimar.de

Vanja **STEFANOVA** - 202 Park St. Ap. 3, New Haven, CT – 06511 USA
vanja_stefanova@yahoo.com

Joanna **ŚWIĘTA** - Dept. of Plant Ecology, University of Gdańsk, Al. Legionów 9, PL-80-441 Gdańsk, Poland,
lasaint@wp.pl

Willy **TINNER** - Dept. of Plant Biology,
505 South Goodwin Avenue, USA – 61801 Urbana, Illinois,
willy.tinner@ips.unibe.ch

Verushka **VALSECCHI** - Institute of Plant Sciences, University of Bern,
Altengergrain 21, CH - 3013 Bern, Switzerland,
verushka.valsecchi@unimi.it

Andrzej **WITKOWSKI** - Marine Research Institute, University of Szczecin,
ul. Felczaka 3A, PL-71-412 Szczecin, Poland

Herb **WRIGHT** - Limnological Research Center,
Pillsbury Hall 221, MN – 55455 Minneapolis, USA,
hew@maroon.tc.umn.edu

Brygida **WAWRZYNIAK-WYDROWSKA** - Marine Research Institute, University of Szczecin,
ul. Felczaka 3A, PL-71-412 Szczecin, Poland

Willy **TINNER** - Dept. of Plant Biology,
505 South Goodwin Avenue, USA – 61801 Urbana, Illinois,
willy.tinner@ips.unibe.ch

Verushka **VALSECCHI** - Institute of Plant Sciences, University of Bern,
Altengergrain 21, CH - 3013 Bern, Switzerland,
verushka.valsecchi@unimi.it

Andrzej **WITKOWSKI** - Marine Research Institute, University of Szczecin,
ul. Felczaka 3A, PL-71-412 Szczecin, Poland

Herb **WRIGHT** - Limnological Research Center,
Pillsbury Hall 221, MN – 55455 Minneapolis, USA,
hew@maroon.tc.umn.edu

Brygida **WAWRZYNIAK-WYDROWSKA** - Marine Research Institute, University of Szczecin,
ul. Felczaka 3A, PL-71-412 Szczecin, Poland