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PALAEOECOLOGICAL EVIDENCES OF THE HYDROLOGICAL CHANGES IN THE EARLY MEDIEVAL PORT OF WOLIN (NW POLAND)*

Paleoekologiczne dowody zmian hydrologicznych we wczesnośredniowiecznym porcie w Wolinie (Polska północno-zachodnia)

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ABSTRACT. Pollen, diatom, macrofossil and chemical analyses of the profile taken from the archaeological excavation in the early medieval port of Wolin and another one from the neighbouring mire, afford valuable information on the palaeohydrological changes which complement earlier archaeological informations. These data indicate a considerable rise in a water level around one thousand years BP. Presence of mesohalobous diatoms and high content of sodium suggest inflows of marine waters in this area, which can be linked with the youngest phase of the post-Littorina transgression of the southern Baltic Sea. During the 11th century the port has been submerged and the wharf constructions have been covered by a thick layer of peaty and mudy deposit. This is in accordance with the historical data which tell us about a fall of the Wolin town where deteriorating navigation conditions are indicated among the most important causes.

KEY WORDS: Wolin, early medieval port, hydrology, pollen, diatoms, macrofossils, chemical analysis

INTRODUCTION

The postglacial hydrological changes in the Baltic coastal zone of Poland are one of the thoroughly discussed problems (e.g. Rosa 1987, Tobolski 1987, Florek 1991, Tomczak 1993, Latałowa in print b). However, the relatively numerous data elaborated mainly during the past 20 years are still fragmentary and do not make a sufficient base for a comprehensive synthesis. The shortage of modern interdisciplinary projects linking geomorphological investigations with a wide range of palaeoecological methods and radiocarbon datings is evident.

The hydrological changes during the last thousand years being the consequence of the southern Baltic Sea level fluctuation belong to the more interesting but relatively poorly documented topics. The aim of this paper is to supplement the hitherto existing informations with the results of the palaeoecological study on the hydrological changes in the early medieval port of Wolin and its close environs.

DESCRIPTION OF THE SITES

The early medieval town and port of Wolin developed in the southeastern part of Wolin Island, at the bank of the Dziwna river, close to the Szczecin Lagoon (Fig. 1). Archaeological and radiocarbon data (Filipowiak 1994, Pazdur et al. 1994) indicate that already in the 6th–7th century A.D. a small settlement existed here. The further development in the 8th and especially in the 9th century was con-

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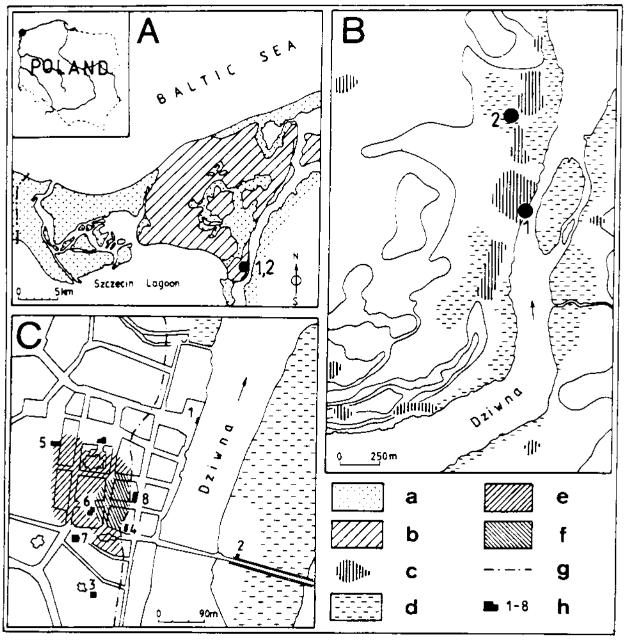

Fig. 1. Location of the investigated sites (maps B-C according to Filipowiak 1988). a – Pleistocene deposits, b – Holocene deposits, c – area of the early medieval settlement, d – mires, e – settlement of the 8th–9th century, f – settlement of the 6th–7th century, g – former river bank, h – archaeological trenches (8 – port, Wolin I); 1 – Wolin I profile, 2 – Wolin II profile

nected with the foundation of a large port. The most prominent period in the activity of the town and port of Wolin fell in the period of the 9th–11th century.

The archaeological excavation (Wolin I site) in the area of the former port (Fig. 1C – trench no. 8, acc. to Filipowiak 1988, 1994) exposed well preserved constructions of the early medieval wharf. It was built of hudge halves of oak trunks. Due to the peaty ground, before construction of the wharf wall the bottom of the river has been upholstered with a layer of fascine and pieces of oak wood. The thick peat deposit is of complex origin. It has been formed by natural processes as well as human activity (Latałowa in print b).

The Wolin II site is a mire ca. 5 ha in area lying in the immediate vicinity of the town (Fig. 1B). Previously it probably made a part of a large mire complex which extended along the Dziwna river banks. Much of its present surface is covered by pits, which are the remnants of peat cutting. The coring was made in a spot devoid of clear evidence of such activity. The local vegetation consists mainly of species characteristic of the Phragmitetea class.

MATERIAL AND METHODS

Description of the profiles

The paper is based on the material coming from the bottom part of the profile Wolin I and the upper part of the profile Wolin II.

The Wolin I profile has been collected in metal boxes directly from the about 4 meters high wall of the archaeological excavation. The lithology of the section of the profile which is a subject of the present paper has been described as follows:

layer no	depth (cm)	
1.	260–385	dark-brown strongly decomposed peat with admixture of mineral matter; the interbeddings of sand and silt at the depth of 261–264 cm, 270–274 cm, 296–306, 341–346 cm; at the depth of 318–320 cm numerous fish scales;
2.	385–395	dark-brown strongly decomposed sandy peat; numerous fragments of mollusc shells are present;
3.	395–406	dark-brown strongly decomposed peat with admixture of sand; wood fragments are present;
4.	406–420	dark-brown strongly decomposed peat with small admixture of mineral matter;
5.	420–435	dark-brown strongly decomposed peat with small admixture of mineral matter; numerous fragments of wood forming fascine are present.

The Wolin II profile has been taken with the Instorf corer 10 cm in diameter. The complete results of pollen analysis of this profile have been already published (Latałowa 1992 a). The part of the profile under discussion consists of the following lithological units:

layer no	depth (cm)	
1.	0–8	brown, highly decomposed, dried-up *Carex* peat with admixture of sand;
2.	8–40	dark brown, highly decomposed and compressed *Carex-Phragmites* peat with an admixture of sand; an interbedding of silt and sand at the depth of 17–18 cm;
3.	40–100	dark brown, highly decomposed amorphic peat, distinctly drier towards the top of this section.

Chronology

The numerous data determine chronology of the Wolin I site. Dendrochronological (Ważny & Eckstein 1987, Ważny 1990) and radiocarbon (Pazdur et al. 1994) datings of oak trunks being remnants of the wharf are concentrated mainly on the establishment of the chronology of the construction works in the port. They indicate that the main phase of its development at this place fell in the 9th and 10th centuries A.D. However, determination of the age of the particular cultural layers is more complex. The most appropriate dates for the purpose of this article come from the bottom part of the excavation (Tab. 1): sample 459/84 (fascine) and sample 1/85AB (a bone found in the cultural layer situated directly above the layer of fascine). The chronology of the upper part of the section discussed in this paper is determined due to the presence of characteristic pottery fragments at the depth of 372–375 cm, 337–340 cm and 240–241 cm. According to J. Wojtasik (oral inf.) all these fragments can be described as belonging to the period of the 10th–11th century A.D.

Table 1. The radiocarbon dates for the Wolin I (Pazdur et al. 1994) and Wolin II (Latałowa 1992 a) profiles

Sample	Laboratory No	^{14}C date BP (conventional)
Wolin I – early medieval port		
459/84	Gd – 3234	1180 ± 40
1/85AB	Gd – 3266	1000 ± 50
Wolin II – mire		
49–45	Gd – 2742	980 ± 60
57–52	Gd – 2743	1520 ± 90
77–82	Gd – 5263	3370 ± 60

Three ^{14}C dates which determine chronological position of the Wolin II profile (Tab. 1) indicate the very low peat accumulation rate for the section between 0.8–0.5 m, which has been confirmed by the particularly high pollen concentration (Latałowa 1992 a). The possibility of hiatus cannot be excluded here, which restricts interpretation of this section of the profile.

Pollen analysis

In this article the results of pollen analysis of the upper part of the profile Wolin II are discussed.

Pollen samples 1 cm^3 in volume were boiled in 10% KOH in a water bath and then treated with acetolysis (Faegri & Iversen 1989); minerogenic matter was removed with HF. Only selected curves representing total AP (*Alnus* separated) and NAP (Cerealia separated) and local aquatic and mire vegetation are presented in the diagram. Percentage calculations for local taxa were provided using the formula AP+NAP+taxon=100%.

Macrofossil analysis

The macrofossil data presented in this paper come from the Wolin I profile.

Samples 330–210 cm^3 in volume were soaked in a weak solution of KOH (solution concentration was regulated according to sample quality) during 24–48 hours, washed on two sieves with 0.5 and 0.2 mm mesh and segregated under 16x magnification. Selected specimens of fruits and seeds as well as fragments of tissues were stored in a mixture of water, alcohol, glycerine (1:1:1) with thymol. The macrofossil diagram presents only selected taxa representing local vegetation of the river bank.

Diatom analysis

The diatom analysis was carried out on the samples taken from the Wolin I profile.

Diatom samples 0.5 cm^3 in volume were dissolved in 10% HCl to eliminate calcium carbonate and treated with 15% and 30% H_2O_2 in a water bath in the temperature of 60–90^{0}C to remove the organic matter. For the samples containing an admixture of sand flotation with cadmium liquid of specific weight 2.5 was adopted. Naphrax (1.72) was used for the preparation of the diatom slides.

The diatom flora has been divided according to Kolbe's (1927) halobian system:

1 – Euhalobous – typical maritime species having their optimum in the water salinity of 20–40;

2 – Mesohalobous – species typical of brackish waters

3 – Oligohalobous – species of freshwaters:

a/ halophilous – species living in fresh water but the low salinity (up to 5) stimulates their development

b/ indifferent – freshwater species, the euryhalinous forms of which can live in saline waters but they do not develop in such conditions

c/ halophobous – species which do not support even the lowest salinity

The diatom flora has been also divided into pH groups according to Hustedt (1939):

1 – Alkalibiontic – species occurring at pH values over 7

2 – Alkaliphilous – species occurring at pH values about 7 but preffering slightly higher pH values

3 – Indifferent – species occurring equally on both sides of pH = 7

4 – Acidophilous – species occurring at pH = 7 but preffering slightly lower pH values

5 – Acidobiontic – species occurring at pH values under 7 but having optimum at pH about 5.5 or even lower.

The main diatom diagram presents only these of taxa, which exceed 2% of the total number of specimens in the samples.

Physical and chemical analyses

Selected types of physical and chemical analyses of the Wolin I profile are presented in this paper.

The loss on ignition was measured by samples drying at 105^{0}C (dw) and then ignition at 550^{0}C. To calculate the silica (SiO_2) content the row ash was digested with HCL (Maciak & Liwski 1970).

To determine magnesium (Mg) and sodium (Na) content samples were dried in the temperature of 105^{0}C, treated with 40% hydrofluoric acid (HF) and then mineralized with a mixture of concentrated HNO_3 and $HClO_4$ in the temperature of 180–200^{0}C. The residuum was digested in 0.1 M HCl. Magnesium was determined by the method of atomic absorption spectroscopy, while sodium by the method of emission in the air-acetylene flame.

RESULTS

POLLEN ANALYSIS

Changes in the pollen curves of local mire and water plants enabled specific zonation related exclusively to these taxa (Fig. 2). These pollen assemblage zones are marked by “bis” for distinction from the original zonation of the diagram (Latałowa 1992 a).

Phragmites-t. strongly fluctuate. It is difficult to establish the exact chronological position of this zone, because of the very low accumulation rate in this part of the profile. The radiocarbon date 1520±90 BP falls on the central part of the zone.

WII – 3 bis, *Potamogeton-Pediastrum* PAZ (47–27 cm). Pollen of *Potamogeton* sect. *Eupot.* and coenobia of *Pediastrum* are in abundance. Pollen curve of *Phragmites*-t. declines. The lower limit of this zone is chronologically defined by the ^{14}C date 980±60 BP and it coincides with a strong increase in Cerealia pollen.

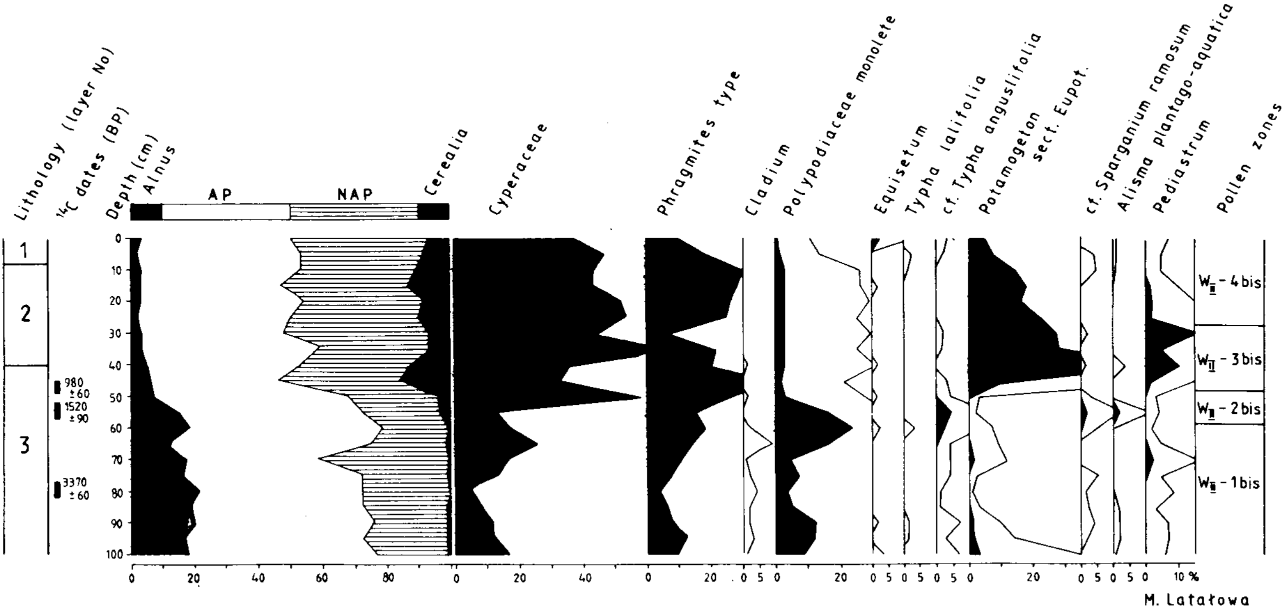

Fig. 2. Selected pollen curves of the local mire and water plants (Wolin II profile)

WII – 1 bis, Polypodiaceae-Cyperaceae-*Phragmites*-t. PAZ (>100–57 cm). In this zone Polypodiaceae monolete, Cyperaceae and *Phragmites*-t. dominate among pollen of local plants. *Cladium mariscus* and cf. *Typha angustifolia* form continuous curves. Pollen curves of water plants (*Potamogeton* sect. *Eupot.*, cf. *Sparganium ramosum, Alisma plantago-aquatica)* fluctuate. The upper limit of this zone lies slightly below the ^{14}C date 1520±90 BP.

WII – 2 bis, *Typha angustifolia-Sparganium ramosum-Alisma plantago-aquatica* PAZ (57–47 cm). Peaks of cf. *Typha angustifolia,* cf. *Sparganium ramosum, Alismaplantago-aquatica* are the most characteristic feature of this zone. The curve of Polypodiaceae monolete distnctly declines. Cyperaceae and

WII – 4 bis, *Phragmites*-t.-Cyperaceae-*Potamogeton* PAZ (27–0 cm). In this zone participation of water plants relatively diminishes. Pollen curve of *Phragmites*-t. clearly rises; Cyperaceae pollen are the most frequent.

The Wolin II pollen diagram reflects hydrological changes in the area of mire complex extending along the Dziwna River banks. Mainly different types of rush vegetation dominated here since the very beginning i.e. ca. 7 000 years BP (Latałowa 1992 a) up to about 1 000 years BP. In the discussed section of the profile (Fig. 2) the slight increase of the water level on the mire (WII-2 bis PAZ) could be caused by natural processes (climate?) or by deforestations especially on the habitats of alder forest (*Alnus* curve distinctly declines). Around 1000 years BP (980±60 BP) the water level sharply increased which was followed by a spread of plant communities of the Potamogetonetea class (WII-3 bis PAZ).

MACROFOSSIL ANALYSIS

The macrofossil flora described from the discussed section of the profile Wolin I is very rich in respect to species composition as well as to number of diaspors. It consists of species of different plant communities, which illustrates the complex origin of the investigated deposit (Latałowa in print b). The most important group is formed by representatives typical of ruderal, nitrophilous, moist habitats. The great number of diaspors are of allochtonous origin and come from cultivated fields, forests, swards, meadows and pastures neighbouring with the town of Wolin or even from more distant areas (Latałowa 1992 b).

The macrofossil flora coming from the specific riverside plant communities is not clearly diversified along the profile (Fig. 3), which precludes definition of macrofossil assemblage zones.

Remnants of water plants are rather sparse. Among them single specimens of *Lemna trisulca* and *Zannichellia pedicellata* are worth noting. The rush communities are better represented. In the section of 427–347 cm fruits of *Typha* sp. dominate indicating habitats typical of eutrophic, stagnant or slowly running waters. Presence of *Scirpus tabernaemontani* and *S. maritimus* sugests probability of brackish conditions. The accumulation of diaspores of *Eleocharis palustris/uniglumis, Scirpus tabernaemontani* and *S. lacustris* at the depth of 300–305 cm is probably artificial. The large number of *Ranunculus sceleratus* seeds and *Polygonum nodosum* fruits as well as single specimens of *P. hydropiper* fruits come from plant communities which developed on the emerged river banks.

DIATOM ANALYSIS

The diatom analysis of the Wolin I profile enabled identification of 95 taxa. Most of them belong to the cosmopolitan freshwater epifitic diatoms characteristic for littoral zone of fer-

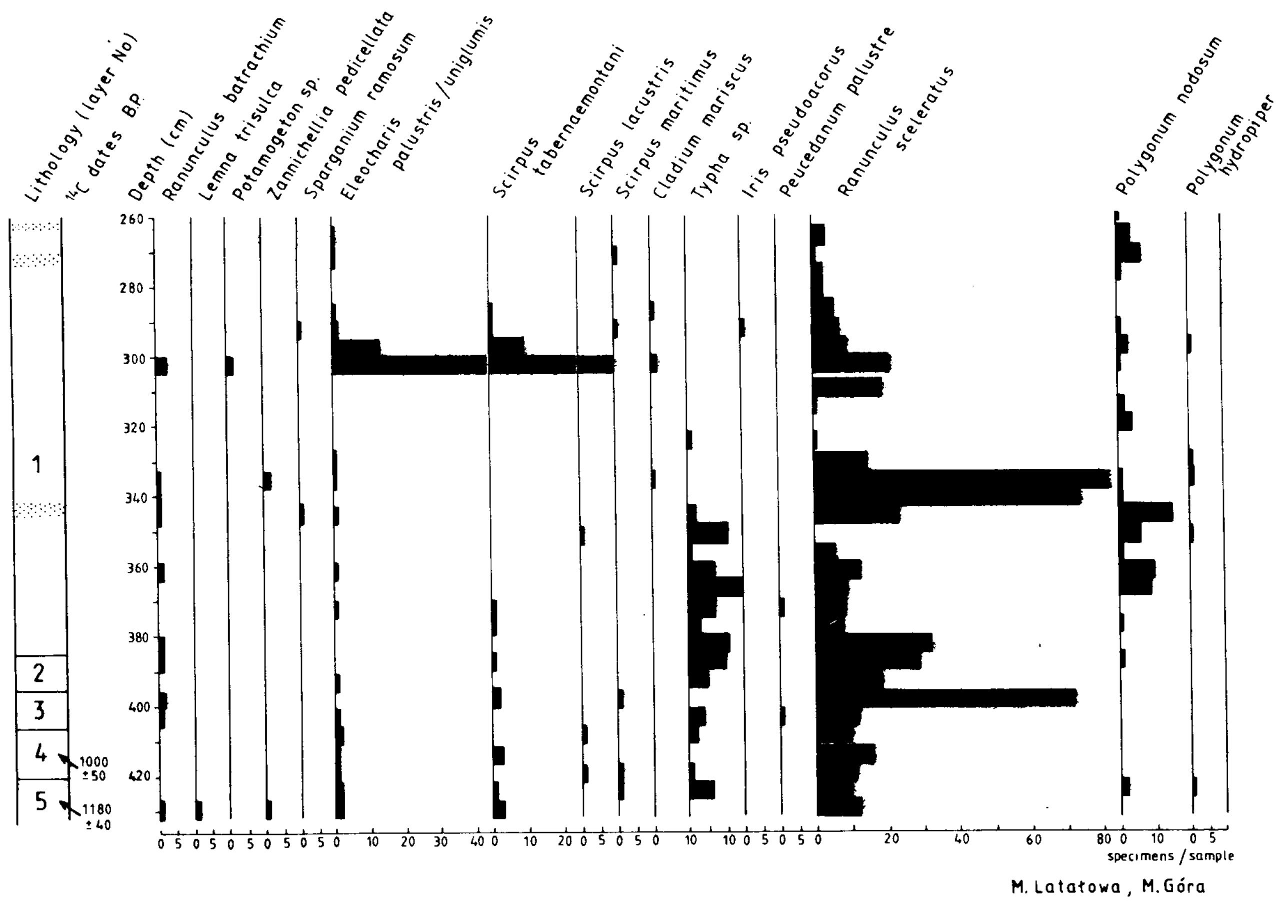

Fig. 3. Macrofossil diagram of selected taxa typical of a river bank (Wolin I profile)

tile reservoirs with alkaline waters. The group of mesohalobous (8 taxa) and oligohalobous halophilous (11 taxa) species recently living mostly in brackish waters of lagoons and coastal lakes is of special importance.

On the basis of species composition and relation between ecological groups the five diatom assemblage zones (DAZ) and five subzones (da subz) are distinguished (Fig. 4).

WI-1, *Navicula scutelloides-Campylodiscus clypeus* DAZ (433–410 cm). In this zone alkaliphilous and alkalibiontic freshwater diatoms, mainly *Navicula scutelloides* W. Sm. and *Opephora martyi* Hrib., dominate. However, mesohalobous diatoms which attain up to 15% are also of importance in this part of the profile. They are represented mainly by *Campylodiscus clypeus* Ehr. and several species of *Diploneis* e.g. *D. interrupta* (Ktz.) Cl., *D. smithii* (Brb.) Cl., *D. didyma* Ehr. This diatom assemblage zone is divided into three subzones in respect to differentiation in ecological groups.

WI-1a, *Campylodiscus clypeus-Diploneis interrupta* DA SUBZ (433–429 cm). This subzone is characterised by the low frequency of diatoms. Typical freshwater litoral forms as *Navicula scutelloides* and *Opephora martyi* dominate, mesohalobous *Campylodiscus clypeus* and *Diploneis interrupta* are of importance too.

WI – 1b, *Aulacoseira granulata-Stephanodiscus hantzschii* DA SUBZ (429–420 cm). The high frequency of diatoms and predominance of planctonic forms with *Aulacoseira granulata* (Ehr) Ralfs. (+ *A. granulata* var. *angustissima* O. Mll.) and *A. italica* (Ehr.) Ktz. are the characteristic features of this subzone.

WI – 1c, *Campylodiscus clypeus-Cocconeis disculus* DA SUBZ (420–410 cm). The low diatom frequency, presence of teratological forms of *Navicula* and numerous fragments of valves belonging to mesohalobous species is typical for this subzone. Littoral forms with *Navicula scutelloides*, *Opephora martyi* and *Cocconeis disculus* (Schm.) Cl. dominate. The mesohalobous diatoms including *Campylodiscus clypeus* and species of *Diploneis* increase in importance again.

WI – 2, *Navicula scutelloides-Diploneis ovalis* DAZ (410–403 cm). In this zone further decrease in diatom frequency and presence of fragments of valves is observed. The participation of mesohalobous species clearly diminished. The freshwater littoral diatoms make 97% of the total number of specimens. Epiphytic *Navicula scutelloides* and *Opephora*

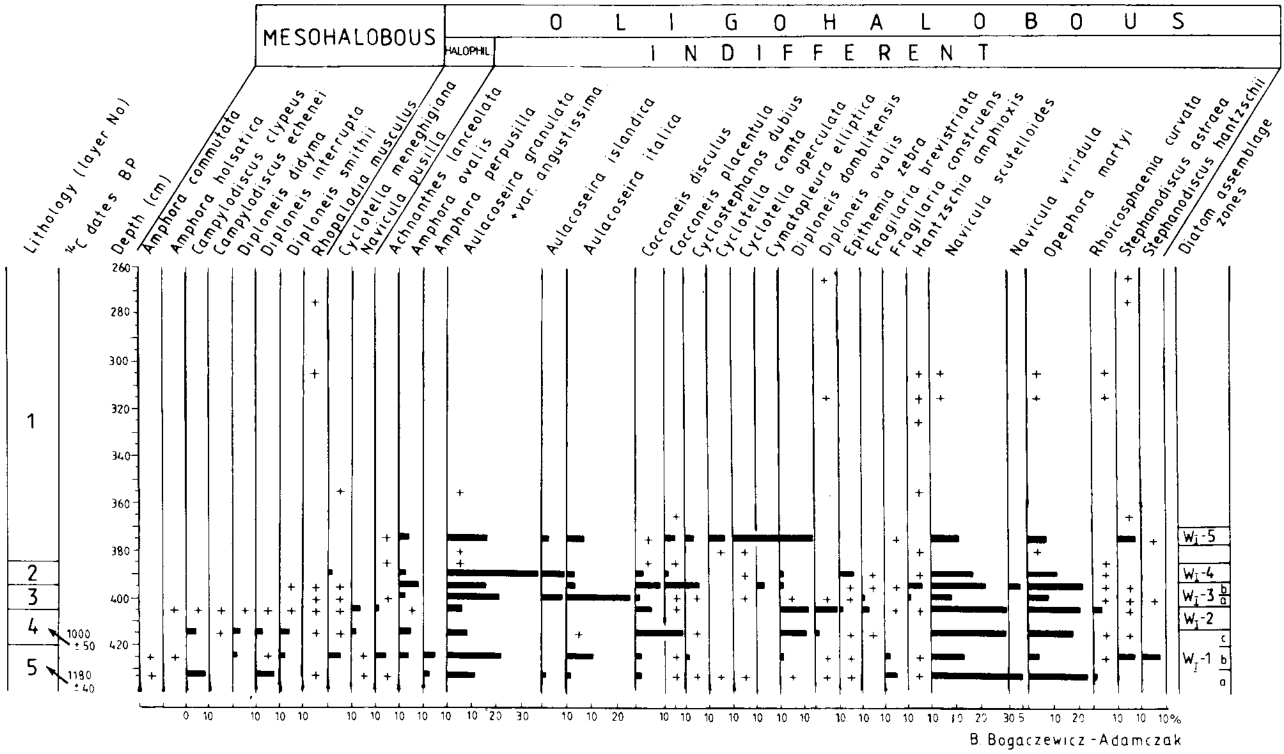

Fig. 4. Diatom diagram (Wolin I profile)

martyi dominate but also some of benthic species as *Diploneis domblittensis* (Grun.) Cl. and D. ovalis (Hilse) Cl. are of importance reaching 20%.

WI – 3, *Aulacoseira granulata-Opephora martyi* DAZ (403–393 cm). This zone is represented by the rich freshwater diatom flora with *Aulacoseira granulata*, *A. granulata* var. *angustissima*, *A. italica*, *A. islandica*, *Navicula scutelloides*, *Opephora martyi*, *Cocconeis disculus*, *C. placentula* Ehr., *Achnanthes lanceolata* (Brb.) Grun. and others. The varied relation between planctonic and littoral forms enabled separation of the two subzones.

WI – 3a, *Aulacoseira italica* DA SUBZ (403 – 397 cm). The predominance of planctonic forms represented mainly by species of *Aulacoseira* (*A. italica, A. granulata* var. *angustissima*, *A. islandica*) is typical for this subzone.

WI – 3b, *Cocconeis placentula* DA SUBZ (397 – 393 cm). The littoral species, mainly *Navicula scutelloides*, *Opephora martyi*, *Cocconeis placentula* and *C. disculus* dominate in this subzone.

WI – 4, *Aulacoseira granulata var. angustissima* DAZ (393–383 cm). Planctonic species dominate again in the diatom flora of this zone. *Aulacoseira granulata* var. *angustissima* is the most numerous among them. Littoral species as *Navicula scutteloides* and *Opephora martyi* are of importance too.

WI – 5, *Cyclotella operculata-Aulacoseira granulata* DAZ (378–373 cm). The rich freshwater diatom flora dominated by planctonic species as *Cyclotella operculata* (Ag.) Ktz., *C. comta* (Ehr.) Grun., *Aulacoseira granulata* var. *angustissima* and *A. italica* has been identified in this zone.

At the depth of 383–378 cm as well as in the section of 373 – 365 cm only single specimens of diatoms are present which precludes definition of diatom assemblage zones.

The above diatom sucession reflects hydrological changes during accumulation of the peat deposit in the early medieval port of Wolin (Fig. 5). The diatom flora preserved in the bottom part of the profile (WI – 1 daz) and especially a distinct predominance of the littoral oligohalobous species and important participation of the mesohalobous species (WI – 1a and WI – 1c subzones) testifies to the conditions typical for littoral zone of the freshwater reservoir with an inflow of maritime waters. The increases in the planctonic forms (WI – 1b, WI – 3a subzones and WI – 4, WI – 5 zones) indicate the short-living water level rises in a freshwater reservoir. The predominance of the alkaliphilous and alkalibiontic littoral diatoms, decrease in total number of species as well as in number of specimens, presence of broken valves, and above all, the increasing participation of benthic forms (WI – 2 zone and WI – 3b subzone) inform of the lowering water level accompanied by an increase in the water alkalinity.

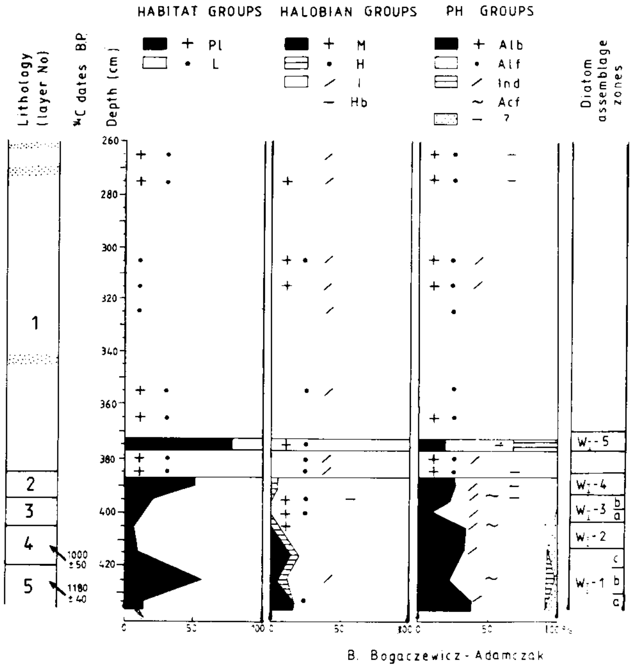

Fig. 5. Synthetic diatom diagram for the Wolin I profile. Pl – planctonic, L – littoral, M – mesohalobous, H – halophilous, I – indifferent, Hb – halophobous, Alb – alkalibiontic, Alf – alkaliphilous, Ind – indifferent, Acf – acidophilous

PHYSICAL AND CHEMICAL ANALYSES

Proportions in organic matter (loss on ignition) and SiO_2 (Fig. 6) show great differentiation within the Wolin I profile. Several increases in silica content are the consequence of deposition of thin layers of muddy sediments of the riverine origin (e.g. at the depth of 300–305 cm where diaspores of rush plants are accumulated) or of human activity in the port (e.g. at the depth of 341–346 cm where large number of diaspores of field weeds occurs (Latałowa 1993).

In the investigated part of the profile concentration of sodium ranges from 0.2 to 25.0 $mg.g^{-1}$ dw. The highest values recorded in the

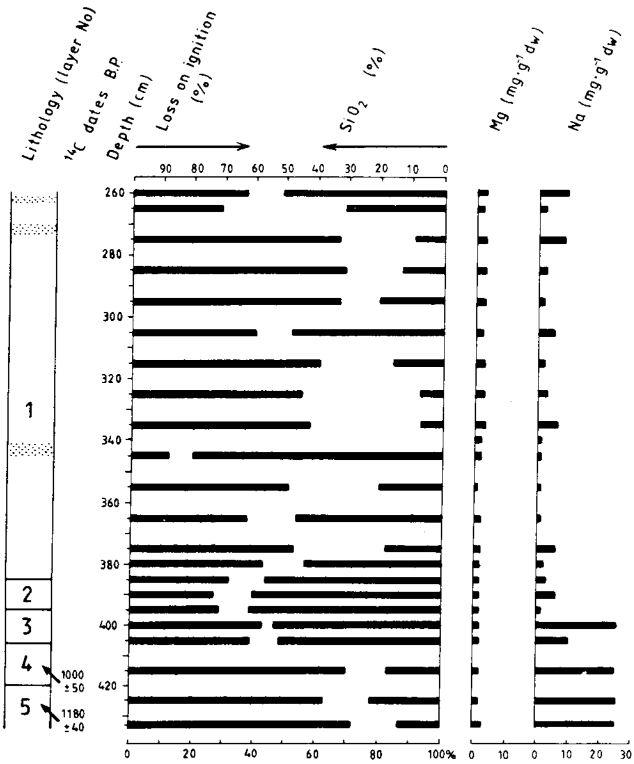

Fig. 6. Some physical and chemical properties of the port deposits (Wolin I profile)

section of 433–400 cm approximate the mean Na concentrations in the Baltic Sea surface sediments. For example, in the Bornholm Basin sediments it averages 31.0±2.8 mg.g^{-1} dw while in sediments of the Gdańsk Bay 27.2±2.5 mg.g^{-1} dw (Skwarzec et al. 1985). The concentration values of magnesium (1.0–3.5 mg.g^{-1} dw) are about 4–5 times lower then in the Baltic Sea surface sediments (Skwarzec et al. 1985).

The relatively high concentrations of sodium in the bottom part of the Wolin port deposits indicate the inflow of marine waters in this area. The registration of this event was possible due to good sorptive and retention properties of peats.

DISCUSSION AND CONCLUSIONS

The palaeoecological data from the early medieval port of Wolin and from the neighbouring mire illustrate the hydrological changes which took place in this area in the early Middle Ages. The precisely radiocarbon dated (980±60 BP) event of the rise in a water level on the Wolin II site is registered by the pollen curves of local mire and water plants. The diatom analysis shows changes in the water level and water salinity in the port (Wolin I site) during the 10th and probably at the beginning of the 11th century. Presence of the mesohalobous species and high content of sodium indicate inflows of marine waters at that time. In this case the macrofossil analysis has been not enough susceptible tool for registration of the hydrological changes. The main reasons could be defined as follows:

1 – the rush vegetation which grew in the port at that time was composed of species supporting considerable oscillations of the water level;

2 – the vegetation which developed at the port wharf has been probably a subject of a continuous destruction by man;

3 – processes of redistribution and redeposition of plant detritus which certainly occurred along the river banks could affect formation of fossil assemblages.

The increase in the water level described in this paper can be linked with the youngest phase of the post-Littorina transgression of the southern Baltic Sea. The beginning of this phase is dated by Kliewe and Janke (1978) to ca. 1500 years BP, by Tobolski (1987) to ca. 250 years BP; dates 1100 years BP and 900±100 BP are quoted by Tomczak (1994) and Witkowski (1990) respectively. The archaeological data are of crucial importance here. It is known, that the water level in the early medieval ports of Wolin (Filipowiak oral inf., see also Latałowa 1992 a) and Puck (Zbierski 1986) was about 1.5 m below the present-day's and that harbour constructions in both localities have been submerged in a relatively short time. Archaeological investigations show that during the 10th century, due to innundation, the wharf of the Wolin port was shifted three times towards a more inland position. The time of the Puck harbour submergence was determined by Zbierski (1986) to fall in the 11–12th centuries A.D.

During the 11th century the very fast accumulation of peaty deposit occurred in the port (373–260 cm – Wolin I profile). This was certainly connected with the processes of silting up of the Dziwna river, but significant input of allochtonous material originating from human activity in the port could be of importance too. It is known from the historical sources, that in the 12th century the town of Wolin lost its position as a centre of trade not only because of the following Dutch overrides (Filipowiak 1986) but also due to slimming of the waterways in this area.

The direct link between archaeological and palaeoecological information is particularly important in the present study. The palaeoecological data support earlier archaeological observations and define the nature of the event. Further investigations carried out on the profile taken from the bottom of the archaeological excavation should help to determine local conditions before foundation of the Wolin port.

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