Acta Palaeobotanica 39(2): 183–271, 1999

PALAEOECOLOGICAL RECONSTRUCTION OF THE ENVIRONMENTAL CONDITIONS AND ECONOMY IN EARLY MEDIEVAL WOLIN*

AGAINST A BACKGROUND OF THE HOLOCENE HISTORY OF THE LANDSCAPE

MAŁGORZATA LATAŁOWA

Laboratory of Palaeoecology and Archaeobotany, Department of Plant Ecology, University of Gdańsk, Al. Legionów 9, 80–441 Gdańsk, Poland

ABSTRACT. The Holocene history of the landscape of the south-eastern part of Wolin Island (southern Baltic coast) is presented as the basis for an evaluation of the environmental changes during the lifetime of the early medieval town of Wolin. Pollen and macrofossils from culture layers from the wharf dated to the 9th and 10th centuries and from a peat profile from a neighbouring fen are the main sources of data for the palaeoecological reconstruction. Diatom analyses supplement information on the hydrological changes. Some aspects of the economy of the early medieval town are discussed on the basis of palaeobotanical material representing wild plants which could potentially have been collected by the inhabitants, cultivated plants and field weeds. Palaeohydrological events reflected in the culture layers and in the upper part of the peat deposit from the fen, related to the youngest phase of the Baltic Sea transgression, are characterised. A comparison of pollen and macrofossil information from culture layers in the context of processes forming the Wolin port deposits is made. The full archaeobotanical data from early medieval Wolin obtained by different authors are compiled.

KEY WORDS: pollen, macrofossils, archaeobotany, palaeohydrology, Holocene, early Middle Ages, north-west Poland

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* Reviewed by K. Wasylikowa and D.E. Robinson

INTRODUCTION

Since early prehistory man has profited from natural plant resources but at the same time he has also transformed them. As a consequence of human impact several specific plant communities came into existence and in many areas new species alien to the local floras spread. The history of anthropogenic vegetation is best illustrated by studies of plant remains from archaeological sites (Wasylikowa 1981, Trzcińska-Tacik & Wasylikowa 1982, Willerding 1988, Behre & Jacomet 1991). Archaeobotanical investigations are also of crucial importance for complex studies of the history of material culture of ancient societies (Greig 1989) and for this reason they accompany many archaeological excavations across the world.

The early medieval town of Wolin has been the subject of the almost continuous archaeological investigations for more than 50 years. During that time some archaeobotanical material has also been analysed, first by Klichowska (1961, 1964, 1967a, b) and in later years by Alsleben (1995). The site is especially interesting from a palaeobotanical point of view because of its great significance as one of the largest and most active trading centres in the area of the Baltic Sea basin in the period from the 9th to 11th century (Filipowiak 1988). It is known from earlier palynological data that development of this town resulted in considerable changes in the environment (Latałowa 1992a, b). This implies that the processes of synanthropisation of the vegetation were intensive here and should be detectable using palaeobotanical methods.

In 1985 the extensive archaeological investigations in Wolin were concentrated on the former wharf. In addition to other botanical material, a more then 4 m long palaeobotanical profile was taken from the trench wall[1].

The archaeobotanical investigations are based mainly on macrofossils such as fruits and seeds, wood, charcoal and fragments of other plant tissues. Pollen analyses of culture layers of urban deposits are still relatively rare (Dimbleby 1985). In Poland these studies have been performed on early medieval samples from Kraków by Koperowa (Wasylikowa 1978, 1991), while those from other European early medieval and medieval towns, Behre (1969, 1983), Greig (1982), Krzywinski et al. (1983), Averdieck (1984), Vuorela and Hiekkanen (1991), Vuorela and Lempiainen (1993), Jankovská (1991, 1995) should also be mentioned here. The site of Wolin offers very special opportunities with respect to palynological investigations because of the great thickness of the culture layers, their peaty character and high water level which prevented pollen decomposition. The combination of parallel pollen and macrofossil analyses gives a special opportunity to test the values of both methods in a reconstruction of the past environment in the particular case of an archaeological site.

The main aim of the present paper is to reconstruct the environmental conditions in the area where the early medieval town of Wolin developed, as well as some elements of its economy dependant on the exploitation of the vegetation, the use of plant foods and the development of agriculture. The arguments are based on the author's material supplemented by the archaeobotanical data obtained so far by other authors working at this site. The natural and anthropogenic changes in vegetation, soil and hydrology, which took place during the early medieval period, were, however, only one episode in the environmental history of Wolin Island. They were notably dependent on processes which, took place here earlier, even in remote prehistory. The settlement of Wolin developed in an area, which had already been strongly transformed by man, and the vicissitudes of this port were consistent with hydrological processes which started here about 7000 years earlier. The above facts persuaded the author to present the most important elements of the environmental history of the area occupied by the town of Wolin as background for an understanding of the natural and eco-

[1] M. Góra examined some of macrofossil samples from this profile as the subject of her M.Sc. thesis (1989) supervised by the present author. This material, entirely revised and supplemented by identifications of new taxa, is included in the present publication.

nomic processes which occurred during the early medieval settlement's period of activity.

THE PRESENT-DAY NATURAL ENVIRONMENT

GEOMORPHOLOGY, SOILS AND CLIMATE

Wolin is the one of two islands straddling the mouth of the river Odra on the southern Baltic shore (Fig. 1). The modern island, 254 km^2 in area, is of complex structure and varied morphology. Its main part is built of Pleistocene formations, terminal and ground moraine clays and sandy clays, as well as sands covering kame terraces and filling patches of outwash plains. The terminal moraine hills reach an altitude of 115 m a.s.l. During the Holocene, due to changes in the Baltic Sea level in connection with the Littorina transgression, low-lying terrain was inundated by water and as a result the Pomeranian Bay to the north and Szczecin Lagoon the south were formed (Wypych 1980, Kotliński 1991). At the same time, sand bars started to grow to the north-east and north-west of the island (Rosa 1984, Borówka et al. 1986). In different periods of the Holocene the extensive depressions, both in the moraine area and in the accumulation plain, began to be filled with peat.

The varied origin of substrates influenced differentiation of the 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 sand. Similar poor soil types developed on kames and outwash plains. Podzols formed on dune sands. A chalk

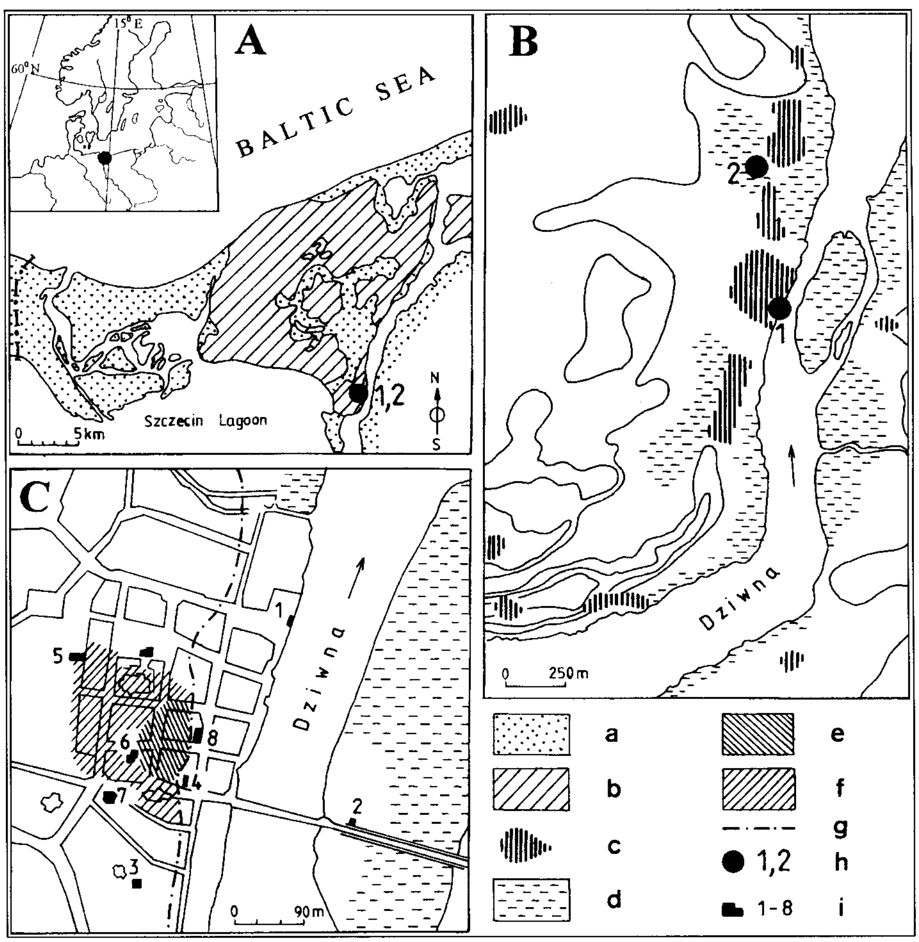


Fig. 1. Location of Wolin Island and of the investigated sites (maps B-C after Filipowiak 1988); **a** – Pleistocene deposits, **b** – Holocene deposits, **c** – area of the early medieval settlement, **d** – mires, **e** – settlement of the 6th–7th century, **f** – settlement of the 8th–9th century, **g** – extent of the former river bank, **h** – Wolin I (1) and Wolin II (2) profiles, **i** – archaeological trenches: **4**, **5** (botanical data elaborated by Klichowska 1961, 1967a, b); **6** (botanical data elborated by Alsleben 1995); **8** – port (botanical data elaborated by Alsleben 1995 and Latałowa this paper – Wolin I profile), **1–3**, **7** not investigated

outcrop in the southwest of the island is the only place where more fertile brown soils occur. Relatively extensive areas are covered with boggy soils which developed on peaty substrates (Borowiec 1969).

Wolin Island belongs to the Baltic climatic region, i.e. its climate is influenced by the sea. In the general atmospheric circulation of this area the oceanic air masses play an especially large part due to frequent strong winds from the west. The average annual temperature is 7.5°C to 8.0°C. Winters are relatively mild with an average January temperature of between 0°C and -6°C, while summers are rather cool with an average July temperature of between 17.0°C and 17.5°C. The annual precipitation is rather moderate, 550–650 mm on average (Młodzikowski 1986).

VEGETATION

The specific characters of climate, the considerable variation in habitat and human activity are responsible for the present-day vegetation of Wolin Island. Its most characteristic phytogeographical feature is the presence of a number of the so-called "Atlantic" species and communities with a western-type range (Fig. 2), which do not occur further to the east (Piotrowska 1966b, Matuszkiewicz 1980).

Woodland dominates on the elevated, central part of the island, now protected as a national park. 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. Mesophilous forest communities are spatially unimportant and include very rare, small fragments of fertile beech forest (*Melico-Fagetum*), oak-birch forest (*Betulo-Quercetum*) and oak forest (*Lonicero periclymeni-Quercetum*).

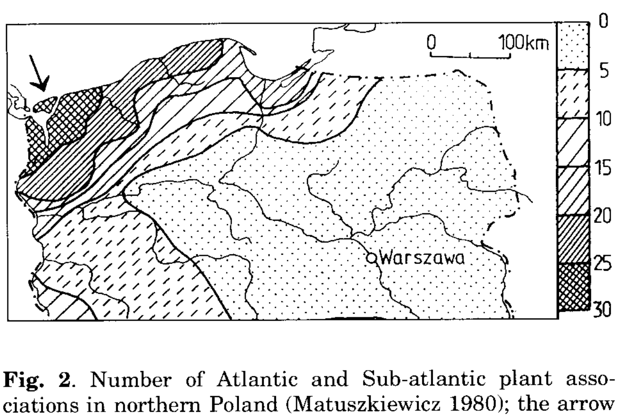


Fig. 2. Number of Atlantic and Sub-atlantic plant associations in northern Poland (Matuszkiewicz 1980); the arrow indicates Wolin Island

The dune-covered sandbars are partially overgrown by coastal pine forest (*Empetro nigri-Pinetum*). In the waterlogged depressions between the dunes alder swamps are found, while on more oligotrophic organic substrata marshy pine forest (*Vaccinio uliginosi-Pinetum*) and marshy birch woods (*Betuletum pubescentis*) are present (Piotrowska & Olaczek 1976, Piotrowska 1966b).

Large areas of Wolin Island, especially its eastern part, have been almost totally deforested. Anthropogenic open-land vegetation, meadows, pastures and arable fields, dominates on former woodland habitats. As a result of the prevalence of poor acid soils, acidophilous communities almost exclusively represent the field weed vegetation. 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 1966b).

Semi-natural grasslands have developed in many deforested areas. The *Corynephoretum canescentis* association is widespread on dry sandy formations of the gently undulating ground moraine, while on more fresh habitats patches of *Festuco-Armerietum* are found. Phytocoenoses of the very rare continental association of *Festuco-Koelerietum glaucae* cover a very small area on the sunny, south-facing cliff slopes overlooking the Szczecin Lagoon, where the substrate is exceptionally rich in calcium carbonate (Piotrowska & Celiński 1965).

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 have developed. The natural vegetation is present in inland stands, especially around numerous lakes, but it is particularly well developed and diverse along both rivers which flow across 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 gracilis*, *Caricetum rostrato-vesicariae* and *Caricetum elatae* are the most frequent. Vegetation of the Phragmition alliance has spread over extensive areas. The most common association of *Scirpo-Phragmitetum* forms belts along rivers, ditches, lakes and the lagoon; in shallow waters of the lagoon patches dominated by *Schoenoplectus lacustris* create large, elevated holms. Periodic inflows of saline water from the Baltic Sea to the Szczecin Lagoon have resulted in the spread of the semi-halophilous and halophilous species. In the coastal zone of the lagoon *Soncho-Archangelicetum litoralis* and *Scirpetum maritimi* have developed. The halophilous meadow vegetation is represented mainly by *Juncetum gerardi,* but in places patches of *Plantagino coronopodis-Bupleuretum tenuissimi* and *Junco maritimi-Samoletum* are also of importance (Piotrowska 1966b).

The southeastern part of the island, where the town of Wolin is located (Fig. 1), has been completely deforested. Acid meadows and pastures are dominant on the reclaimed wetlands; arable land prevails on the mineral soils. The small hills near the town are covered with thickets of *Rhamnus catharticus, Ligustrum vulgare, Ulmus laevis,* different species of *Crategus* and introduced shrubs alien to the flora. On their slopes, in the more open places, patches of dry swards are present with plants such 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.

LOCATION AND DEVELOPMENT OF THE EARLY MEDIEVAL TOWN OF WOLIN

The town of Wolin developed along the left bank of the Dziwna river (Fig. 1). It is located on sandy hills reaching ca. 20 m a.s.l. and small elevations (2–4 m a.s.l.) dissected by wetlands. In places it also spreads out on to low-lying boggy terrain.

According to the archaeological and radiocarbon data (Filipowiak & Gundlach 1992, Filipowiak 1994, Pazdur et al. 1994) the earliest medieval settlement at this place developed in the second half of the 6th century and continued in the 7th century. Its advantageous location at the crossing to the mainland enabled the development of trade and further extension of the settled area. At the turn of the 8th and 9th centuries it started to play an important role in long-distance trade in the southern Baltic region. After a fire, which took place around 825 AD, settlement activity rapidly increased and in the second half of the 9th century the early medieval town, ca. 9 ha in area, came into existence. During the 9th and 10th centuries several settlements developed in the immediate vicinity of the town as well as over a larger area, especially along both banks of the Dziwna river. Some of the nearest settlements played the role of suburbs and together with the town formed a large agglomeration, which at the end of the 10th century occupied an area of about 20 hectares and was inhabited by about 8 thousand people (Filipowiak 1986, Filipowiak & Gundlach 1992).

One of the most important parts of the town was its harbour (Filipowiak 1993). According to the dendrochronological (Ważny & Eckstein 1987, Ważny 1990) and radiocarbon (Pazdur et al. 1994) data the main construction works were carried out during the 9th and 10th centuries. However, Pazdur et al. (1994) suggest that some parts of the wharf are older, and can be dated back to the 7th century. The wharf was built of huge halves of oak trunks and extended over a distance of about 250–300 metres. Due to the peaty ground, the river bottom was lined with a layer of fascines and pieces of oak wood. This protection, however, was not sufficient against the progressive subsidence of the wharf. Sinking of the ground and the general rise in water level, which took place in the 10th century, forced a shifting of the port to the landward side and the building up of new wharves and footbridges.

The most prominent development of the Wolin town and its port fell in the 9th–11th centuries. The later decrease in importance was due to subsequent Danish attacks (Wolin was completely burnt down in 1173) and by natural shallowing of the water navigation routes in the area, what resulted in the stagnation of trade. The river Dziwna is characterised by a narrow valley with clearly delimited edges. Strong currents in alternating directions resulted in silting up of the river bottom and gradual overgrowing of its banks by reed swamp vegetation. The extent of the former riverbanks in the vicinity of the town is shown by the distribution of finds of early medieval boats (Filipowiak & Gundlach 1992).

PALAEOECOLOGICAL SITES AND SAMPLING PRCEDURES

WOLIN II

The fen, ca. 5 ha in area (Fig. 3), lies within the territory of the present-day town of Wolin, ca. 400 m west of the bank of the river Dziwna. It has a small pocket-like form, relatively well delimited, which earlier was probably part of large riverside mire complex. In places regularly shaped pits filled with water cover the surface of the fen; these are remnants of peat cutting. The dominant types in the local vegetation are various reed swamp communities of the Phragmitetea class, with *Phragmites australis, Typha latifolia, Glyceria maxima, Equisetum limosum,* which are especially abundant along ditches and around the pits, as well as patches of tall sedges of Magnocaricion with *Carex elata, C. rostrata, C. pseudocyperus, C. paniculata* and others. The peat profile was taken with an Instorf sampler 10 cm in diameter, in a place devoid of evidence of peat cutting, about half-way between the eastern edge of the mire and the pits.

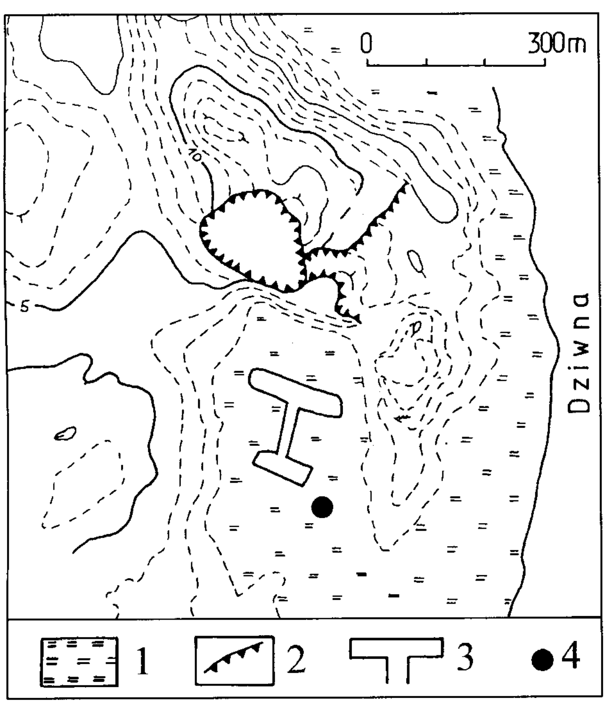


Fig. 3. Location of the Wolin II site; **1** – peat bog, **2** – artificial embankment, **3** – water-filled pits left after peat cutting, **4** – the Wolin II profile (from Latałowa 1992a)

The site is mostly surrounded by mineral formations of Pleistocene origin. These comprise deposits of sand and gravel from eskers and outwash plains and in some places clayey sand over boulder clay. From the north and northeast it is bordered by the artificial embankment of the early medieval settlement of Srebrne Wzgórze (the Silver Hill) dated to the 10th century (Cnotliwy et al. 1986).

WOLIN I

This site lies within the archaeological excavation (trench no. 8, Fig. 1C) of the early medieval port, situated about 60 m from the present bank of Dziwna river. The wharf was built of large oak trunks (Fig. 4). According to the dendrochronological data the main construction works at this fragment of the wharf took place in the 9th and 10th centuries (Ważny & Eckstein 1987, Ważny 1990).

The material for palaeobotanical investigation was taken directly from the over 4 m high wall of the excavation at a place which was almost free of vertical constructions (Fig. 4). Two vertical columns of sharp-edged metal boxes (20×12×5 cm) were inserted into the deposit in order to collect the profile. A supplementary 0.5 m section was taken from the bottom of the excavation with a 10 cm diameter Instorf corer. At the time when the palaeobotanical samples were collected it was difficult to establish the absolute depth parameters (in relation to the sea level). As a result, this profile has separate, unique labelling of the depth, relating to the surface of the ground, which is specified on Fig. 4, at the left. Correlation was made on the basis of the drawing and photographs taken in the field which indicate a number of reference points.

During the excavation other botanical samples, mostly of charred remains, were taken from culture layers in this trench. Alsleben (1995) has studied these samples.

LABORATORY METHODS AND PRESENTATION OF RESULTS

The deposits were briefly described in the field, and in more detail in the laboratory,

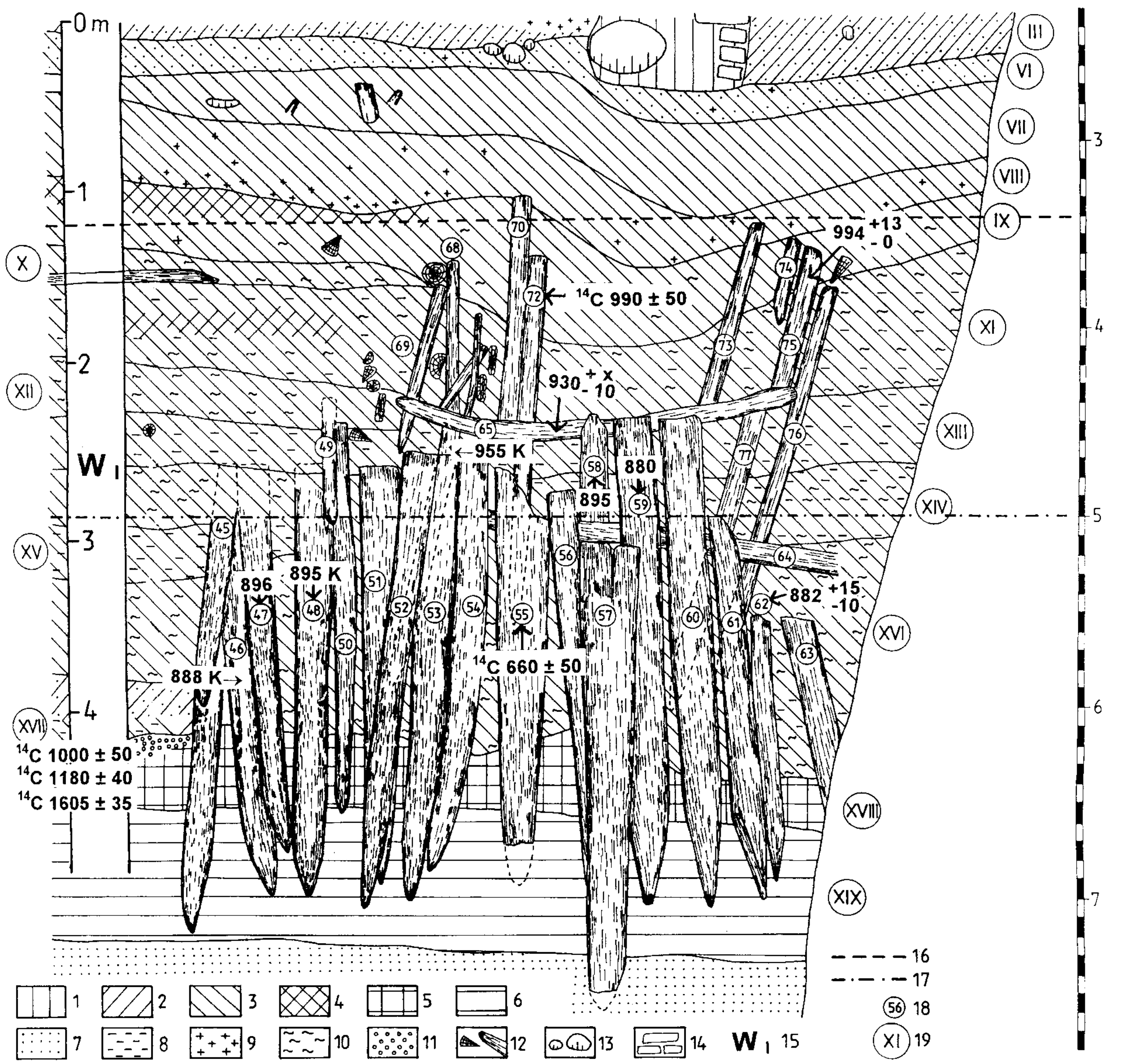


Fig. 4. Section of the trench wall in the Wolin port site; **1–10** deposits with various proportions of organic and mineral matter, **11** – layer of fascines, **12** – large wood fragments, **13** – stones, **14** – bricks, **15** – location of the Wolin I palaeobotanical profile, **16** – water level in the Dziwna in August 1995, **17** – suggested water level in the Dziwna 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. – supplemented, drawn by M. Jusza)

using Troels-Smith's (1955) system with some simplifications introduced by Aaby and Berglund (1986).

Pollen samples 1 cm^3 in volume were treated with potassium hydroxide, and then acetolysed; minerogenic matter was removed with HF (Faegri & Iversen 1989). Generally, ca. 1000 AP (Wolin II) and ca. 1000 AP+NAP (Wolin I) grains were identified and counted.

Samples for macrofossil examination of ca. 150 cm^3 (Wolin II profile) and ca. 250 cm^3 (Wolin I profile) in volume were soaked in a weak solution of KOH for 24–48 hours and then washed through three sieves with meshes of 2.0, 0.5 and 0.2 mm in diameter. The macrofossils were sorted at 16× magnification and stored in a mixture of water, glycerine and alcohol (1:1:1) with an admixture of tymol. The total content of the samples was analysed.

Only selected data on diatoms (studied by Bogaczewicz-Adamczak) and the chemical composition of the Wolin I profile are discussed. The full information on this topic is included in an earlier paper (Latałowa et al. 1995).

The radiocarbon dates were performed at the Radiocarbon Laboratory of the Silesian Technical University in Gliwice. The radicarbon age is expressed as ^{14}C conventional years BP and ^{14}C calendar years BP or BC/AD. In the tables and in the text the raw uncalibrated radiocarbon dates (^{14}C conv. years BP) are always given, while the calibrated dates [<median>^{14}C cal. years BC/AD] are given as additional information for the most important events, especially those related to the human activity. The calibration of radiocarbon dates was carried out using the computer program prepared by Walanus, which is based on Stuiver and Becker's (1993) curves. Some of palaeoecological events are dated by interpolation of the raw radiocarbon dates – the interpolated dates are marked by an asterisk (*) and expressed as ^{14}C conv. years BP.

POLPAL for Windows was used to produce the pollen and macrofossil diagrams (Walanus, Nalepka 1996, 1998).

The botanical nomenclature follows *Vascular plants of Poland – a checklist* (Mirek et al. 1995), with the exception of subspecies separated within *Spergula arvensis* L. according to the criteria discussed in Latałowa (1998b) and within *Polygonum calacatum* Lindm. according to the criteria given by Marek (1954).

RESULTS

LITHOLOGY, CULTURE LAYERS AND DATING

WOLIN II

The Wolin II profile is composed mainly of strongly decomposed peats which accumulated under varying fen (reed-swamp) vegetation (Tab. 1). Only the bottom part of the profile is composed of sand and silt.

Eight radiocarbon dates (Tab. 2) form the basis for chronological interpretation of this profile.

WOLIN I

The Wolin port deposits are composed mainly of coarse plant detritus with various admixtures of sand, silt and wood fragments (Tab. 3).

The port of Wolin has been thoroughly investigated with regard to the chronology of its foundation and later development. Numerous dendrochronological (Ważny & Eckstein 1987, Ważny 1990) and radiocarbon (Pazdur et al. 1994) dates for oak trunks which are remnants of the wharf were performed for this purpose. However, these data are useless for determining the chronology of the deposits which accumulated between the wooden elements of the wharf. The most appropriate ^{14}C dates for this purpose come from the bottom part of the excavation. A sample of charcoal lying below the layer of fascines (Gd-3153, 420–490 ^{14}C calib. AD) comes from the period preceding the foundation of the port, a sample of brushwood forming a fascine (Gd-3234, 810–880 ^{14}C calib. AD) is connected with the beginning of the construction works at this place and a sample of bone found in a culture layer situated directly above the fascine (Gd-3266, 1000–1090 ^{14}C calib. AD) shows the early period of activity at the port (Tab. 4).

The definitive dating of the culture layers

Table 1. Lithology of the Wolin II profile

Layer No	Depth (cm)	Description of lithology
1	0–8	brown, highly decomposed herbaceous peat with an admixture of sand, Th$^{3-4}$3, Ga&Gs1, As&Ag+++, nig3, elas1, strf0, sicc1, humo3–4 (H8–H10)
2	8–40	dark brown highly decomposed and compressed *Carex-Phragmites* peat with an admixture of sand, Th$^{3-4}$3, Ga&Gs1, As&Ag+++, nig3, elas1, strf1, sicc2, humo3–4 (H8–H10), lim.sup.0; an interbedding of silt and sand at a depth of 17–18 cm
3	40–150	dark brown, highly decomposed amorphic peat, distinctly drier towards the top of this section, Th^{4}4, Ga&Gs+++, nig3, elas2, strf0, sicc2, humo4 (H10–H11), lim.sup.0
4	150–200	dark brown, highly decomposed peat, Th^{4}4, Ga&Gs+, nig3, elas1, strf0, sicc2, humo4 (H10), lim.sup.0
5	200–262	dark brown highly decomposed *Cladium-Phragmites* peat, Th^{4}4, Ga&Gs+, nig3, elas1, strf0, sicc2, humo3 (H8), lim.sup.0
6	262–273	brown grey sand with highly decomposed peat, Ga&Gs3, Th$^{3-4}$1, As&Ag+++, Sh+++, nig2, elas0, strf0, sicc2, humo3–4 (H8–H10), lim.sup.1
7	273–300	brown grey sand with silt, Ga&Gs3, As&Ag1, Th^{3}+++, Sh+++, nig2, elas0, strf0, sicc2, lim.sup.0

Table 2. Radiocarbon dates for the Wolin II profile

Depth (cm)	Lab. No	^{14}C conv. years BP	^{14}C calib. years BP	
			interquartiles	median
49–45	Gd-2742	980±60	820–920	870
57–52	Gd-2743	1520±90	1360–1480	1420
77–82	Gd-5263	3370±60	3540–3640	3590
147–143	Gd-5264	4130±60	4580–4750	4660
168–163	Gd-5392	4930±60	5630–5710	5670
203–207	Gd-2789	5860±110	6580–6770	6680
243–248	Gd-4225	6340±70	7190–7280	7230
275–270	Gd-4228	7320±520	7800–8530	8150

Table 3. Lithology of the Wolin I profile

Layer No.	Depth (cm)	Description of lithology
1	0–6	sand with clay, gravel and fragments of bricks
2	6–27	dry brown coarse detritus with high proportion of sand and gravel
3	27–100	brown, strongly decomposed coarse plant detritus with admixture of mineral matter; large fragments of wood at 50–59 cm and 76–80 cm; numerous sandy, clayey and silty interbeddings
4	100–135	brown, strongly decomposed coarse plant detritus with admixture of sand and in places with gravel and small fragments of bricks; at a depth of 107–110 cm and 116–128 cm large wood fragments; at a depth of 100–107 cm dark-grey silty layer
5	135–193	dark brown decomposed coarse plant detritus and fragments of wooden constructions from the wharf; large pieces of oak wood at depths of: 135–155 cm, 161–165 cm, 170–182 cm, 185–189 cm, 192–194 cm; at a depth of 169–174 cm an interbedding of sand and silt
6	193–200	grey sand with silt
7	200–204	dark brown strongly decomposed coarse detritus
8	204–214	oak wood
9	214–385	dark brown strongly decomposed coarse detritus and admixture of mineral matter; at 229–234 cm and 264–280 cm large wood fragments; interbeddings of sand and silt at a depth of 252–253 cm, 261–264 cm, 270–274 cm, 296–306 cm, 341–346 cm; at a depth of 318–320 cm numerous fish scales
10	385–395	dark brown strongly decomposed coarse detritus with sand, numerous fragments of mollusc shells
11	395–406	dark brown strongly decomposed peat with admixture of plant detritus and sand; wood fragments
12	406–420	dark brown strongly decomposed peat with coarse detritus and small admixture of mineral matter
13	420–435	dark brown strongly decomposed peat with small admixture of mineral matter; numerous fragments of wood being the remnants of fascines
14*	450–491	dark brown, compact, strongly decomposed peat, with small admixture of sand; at a depth ca. 480 cm fragments of wood
15*	491–500	dark brown strongly decomposed peat with significant admixture of silt and sand

* the part of the profile taken with the Instorf corer from the bottom of the archaeological trench

at this site (Tab. 5) was made through the application of different methods, including the use of archaeological data.

Because of possible contamination of the upper part of the profile (fragments of bricks present in the deposit) the palaeobotanical investigations were performed on the section from 500–136 cm, excluding culture layers IX–III, i.e. those younger than the 10th century.

Table 4. Radiocarbon dates for the Wolin I profile (according to Pazdur et al. 1994)

Lab. No.	^{14}C conv. years BP	^{14}C calib. AD	
		interquartiles	median
Gd-3153	1605±35	420–490	450
Gd-1953	1360±40	650–680	660
Gd-3234	1180±40	810–880	840
Gd-2477	1060±40	940–1000	980
Gd-3266	1000±50	1000–1090	1020

Table 5. Dating of the culture layers in trench no. 8 (according to Alsleben 1995)

Culture layer	Datings
XVIII	middle of the 9th century
XVII	9th/10th century
XVI	9th/10th century
XV	beginning of the 10th century
XIV	first half of the 10th century
XIII	first half of the 10th century
XII	middle of the 10th century
XI	second half of the 10th century
X	end of the 10th century
IX	beginning-middle of the 11th century
VIII	end of the 11th century
VII	11th/12th century
VI	middle of the 12th century
V	second half of the 12th century
IV	end of the 12th century
III	13th–16 century

POLLEN ANALYSIS

WOLIN II

Pollen analyses from this site, including charcoal content, pollen concentration and pollen influx, have been presented in detail in an earlier publication (Latałowa 1992a). In the present paper only the most important data are discussed.

In the pollen diagram (Fig. 5) five local pollen assemblage zones (l paz) and five subzones (pa subz) are described.

W$_{II}$-1, *Alnus-Pinus-Betula* l paz (280–257 cm), 7320±520–6340±110 ^{14}C conv. years BP. High frequencies of *Pinus, Alnus, Betula* and a sharp increase in *Pteridium aquilinum* are the most characteristic features of this zone. At its upper limit the *Pinus* curve declines, while that of *Quercus* rises.

W$_{II}$-2, *Pinus-Quercus-Ulmus-Pteridium* l paz (257–152 cm), 6340±110 – ca. 4300* ^{14}C conv. years BP. Gradual decrease in *Pinus,* slight increase in *Corylus* and high frequencies of *Pteridium aquilinum* are typical of this zone. The *Quercus* curve rises and then falls in the upper part of this section of the diagram. Pollen grains of anthropogenic indicators including Cerealia and *Plantago lanceolata* appear. At the upper limit *Calluna* increases sharply.

This pollen assemblage zone is divided into three subzones:

W$_{II}$-2a, *Pinus* l pa subz (257–202 cm), 6340±110–5860±110 ^{14}C conv. years BP. In this subzone *Pinus* gradually decreases, *Quercus* increases, *Betula,* after an initial rise, remains at a stable, relatively high level, pollen curves of *Ulmus, Fraxinus, Tilia* and *Corylus* fluctuate at a relatively low level. *Pteridium aquilinum* culminates (max. 7%) and significant values of nitrophilous plants (*Urtica,* Chenopodiaceae) appear.

W$_{II}$-2b, *Corylus-Quercus* l pa subz (202–167 cm), 5860±110–4930±60 ^{14}C conv. years BP. A distinct decrease in *Pinus* and an increase in *Quercus* and *Corylus* are characteristic of this subzone. *Pteridium aquilinum* remains at a high level (mean 3%), single pollen grains of *Melampyrum* and *Jasione montana* are present. There are two distinct *Ulmus* declines. The first at a depth of 215–205 cm is radiocarbon dated to 5860±110 ^{14}C conv. years BP [4680 ^{14}C cal. years BC] and it appears together with a drop in *Fraxinus* and an increase in *Rumex,* followed by the first *Plantago lanceolata* pollen grain. The second, at a depth 185–175 cm and dated to ca. 5400*–5300* ^{14}C conv. years BP, is concurrent with declines in the *Fraxinus* and *Tilia* curves, a distinct peak of *Plantago lanceolata* (1.5%) and the appearance of the first pollen grains of Cerealia undiff. and *Hordeum*-type.

W$_{II}$-2c, *Alnus-Betula* l pa subz (167–152 cm), 4930±60 BP – ca. 4300* ^{14}C conv. years BP. Pollen curves of *Quercus, Ulmus* and *Tilia* decline, *Pteridium aquilinum* gradually decreases, while curves of *Rumex, Artemisia* and *Urtica* rise; pollen of *Plantago lanceolata* is continuously present.

W$_{II}$-3, *Corylus-Quercus-Tilia-Calluna* l paz (152–67 cm), ca. 4300* – ca. 2300* ^{14}C conv. years BP. The most characteristic feature of this zone is the high freqency of *Calluna* pollen (mean 10%, max. 17%). Pollen curves of *Pinus* and *Betula* decline, that of *Corylus* rises; *Tilia* attains relatively high values. The upper limit is definied by a decrease in *Quercus* and *Corylus* and the fall of *Tilia* and *Ulmus* percentages below 1%.

This pollen assemblage zone is divided into two subzones:

W$_{II}$-3a, *Corylus-Tilia* l pa subz (152–102 cm), ca. 4300* – ca. 3600* ^{14}C conv. years BP. The *Corylus* curve rises and subsequently dominates at a level of 18%; *Pinus* and *Quer-*

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

cus decrease. In the section dated to ca. 4300* (4130±60)–3800* ^{14}C conv. years BP anthropogenic indicators including *Plantago lanceolata* and Cerealia (*Hordeum*-type, *Triticum*-type and *Secale*) are more frequent than in the top of this subzone.

W_{II}-3b, *Pinus-Quercus* l pa subz (102–67 cm), ca. 3600* – ca. 2300* ^{14}C conv. years BP. Percentages of *Ulmus, Tilia, Fraxinus, Quercus* and *Corylus* decrease, while the curves for *Pinus, Carpinus* and *Fagus* rise distinctly. The role played by *Plantago lanceolata* and Cerealia increases. Most of this section of the profile is characterised by a very low peat accumulation rate which restricts the precision of palaeoecological reconstruction.

W_{II}-4, *Pinus-Fagus-Calluna* l paz (67–52 cm), ca. 2300*–1590±90 ?(980±60) ^{14}C conv. years BP. The very low accumulation rate in this part of the profile is a serious limiting factor in the interpretation of palynological results. Pollen of mesophilous trees appears in low percentages, that of *Pinus, Betula* and *Fagus* increases; *Calluna* decreases, pollen of cereals and other anthropogenic indicators increases in importance. At the upper limit of this zone AP and *Calluna* decrease sharply, while pollen curves for cultivated plants and weeds rise distinctly.

W_{II}-5, *Pinus-Gramineae-Cerealia-Juniperus* l paz (52–0.0 cm), 1590±90 ?(980±60) ^{14}C conv. years BP – 0. The most important feature of this pollen zone is a definite decrease in percentage values of all the trees except *Pinus,* and high participation of NAP, including pollen of cultivated plants and other anthropogenic indicators. *Calluna* and *Plantago lanceolata* are, however, present at relatively low values. *Juniperus* and *Salix* form rather high curves. Among microfossils of local plants, pollen of *Potamogeton* and coenobia of *Pediastrum* appear in huge numbers.

WOLIN I

The pollen diagram from this site (Fig. 6) shows several gaps which, with the exception of the lowest one, are the result of badly preserved pollen; in some of these sections, pollen was practically absent. The lowest gap separates the bottom part of the profile taken with the Instorf corer from the rest of profile sampled directly from the wall of the excavation (see sampling methods).

In the pollen diagram five local pollen assemblage zones (l paz) are distinguished.

W_I-1, *Pinus-Quercus* l paz (500–478 cm). In this zone AP dominates over NAP at a level of ca. 80%. *Pinus, Betula* and *Quercus* are the most important taxa. Pollen percentages of *Ulmus* and *Tilia* exceed 1%, while anthropogenic indicators appear in insignificant numbers; single pollen grains of cereals, including *Secale,* are present.

W_I-2, *Alnus-Carpinus-Fagus-Plantago lanceolata* l paz (478–455 cm). AP dominates over the NAP at a level of 70–80%. Pollen values of *Tilia* and *Ulmus* decrease, *Alnus* and *Corylus* increase; *Fagus* and *Carpinus* appear and their curves then attain a level of 2–3%. Anthropogenic indicators appear more regularly than in the previous zone and some of them (*Plantago lanceolata, Rumex acetosella*-type, *Artemisia*) form continuous curves. Only single pollen grains of cereals are still present. This paz is characterised by the appearance of very high values of *Pediastrum.* The chronological position of the W_I-1 and W_I-2 local pollen zones is difficult to establish. Comparing it with the Wolin II diagram and diagrams from the northern part of the island, *Fagus* and *Carpinus* pollen curves make the best reference points. They indicate that the age of this section (including both pollen zones) probably lies between 2–3 000 years BP.

W_I-3, *Pinus-Alnus-Fagus* l paz (425–370 cm), culture layers XVIII, XVII, 9th century. AP gradually decreases, but *Pinus* and *Alnus* are still important constituents of the pollen spectra. *Fagus* forms a continuous curve exceeding 2–3%. The participation of pollen of cereals, including *Secale,* increases distinctly.

W_I-4, *Pinus-Alnus-Cerealia*-t. l paz (370–301 cm), culture layers XVI, XV, 9th/10th and 10th centuries. This pollen zone is characterised by a further decline in the AP curves. *Pinus* and *Alnus* still play an important role. Pollen curves for cereals rise rapidly, weeds appear in greater diversity and at a higher frequency.

W_I-5, *Triticum*-t. l paz (263–135 cm), culture layers XIII, XII, XI, X, 10th century. NAP dominates over AP at a level of ca. 80%. Curves for Poaceae and *Triticum*-type attain their highest values. Values for *Secale* are relatively low. Plants of both dry habitats, such as *Calluna,* and of moist meadows, such as *Filipendula* (*ulmaria*) are well represented.

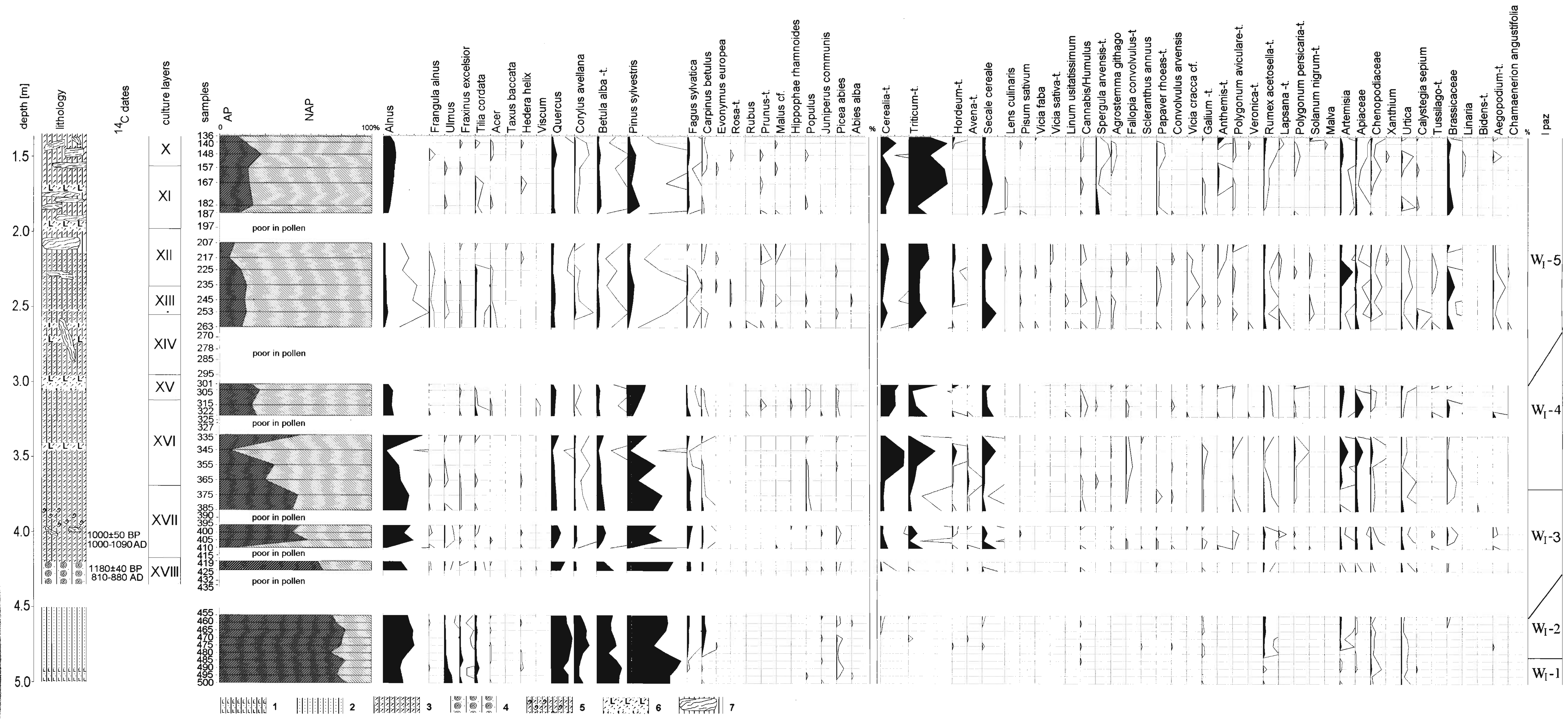


Fig. 6. Wolin I – pollen diagram; **1** – peat with sand and silt, **2** – herbaceous peat, **3** – layer of fascine, **4** – coarse plant detritus, **5** – plant detritus with admixture of mollusc shells, **6** – silt and sand, **7** – large wood fragments

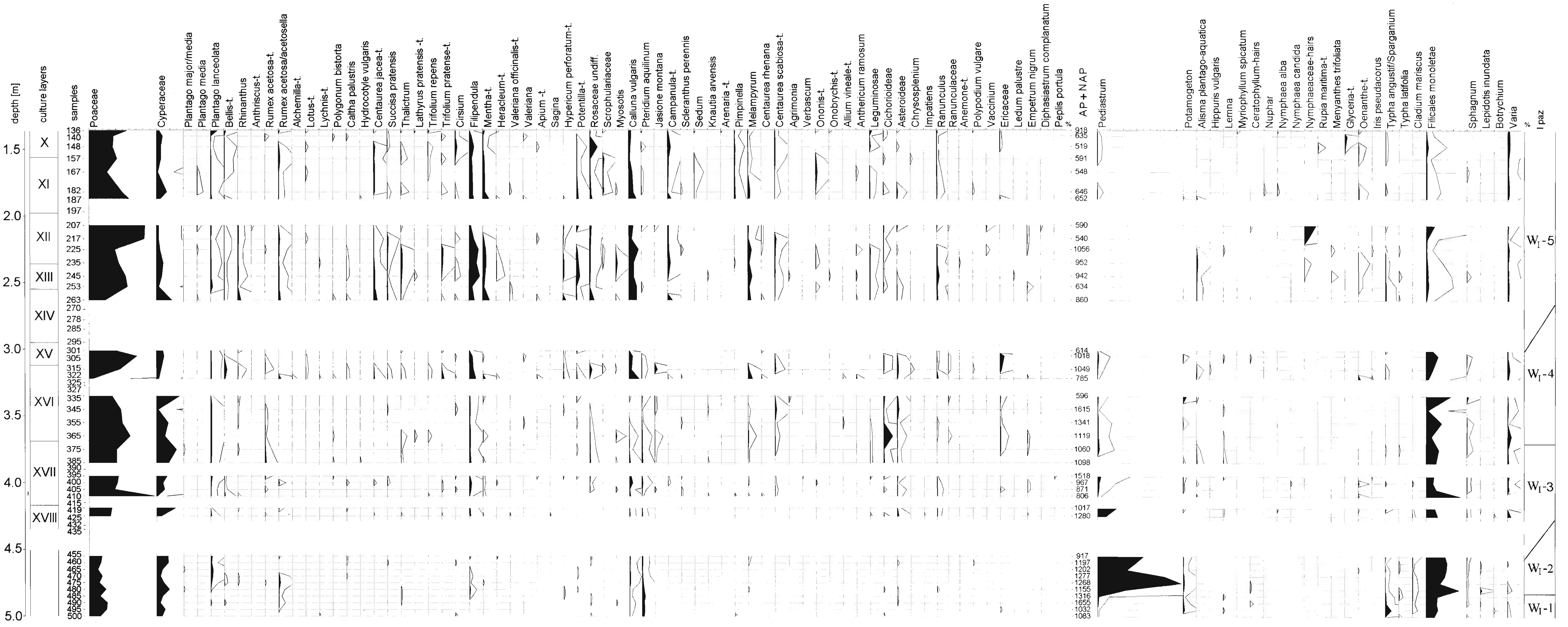


Fig. 6. Continued. Wolin I – pollen diagram

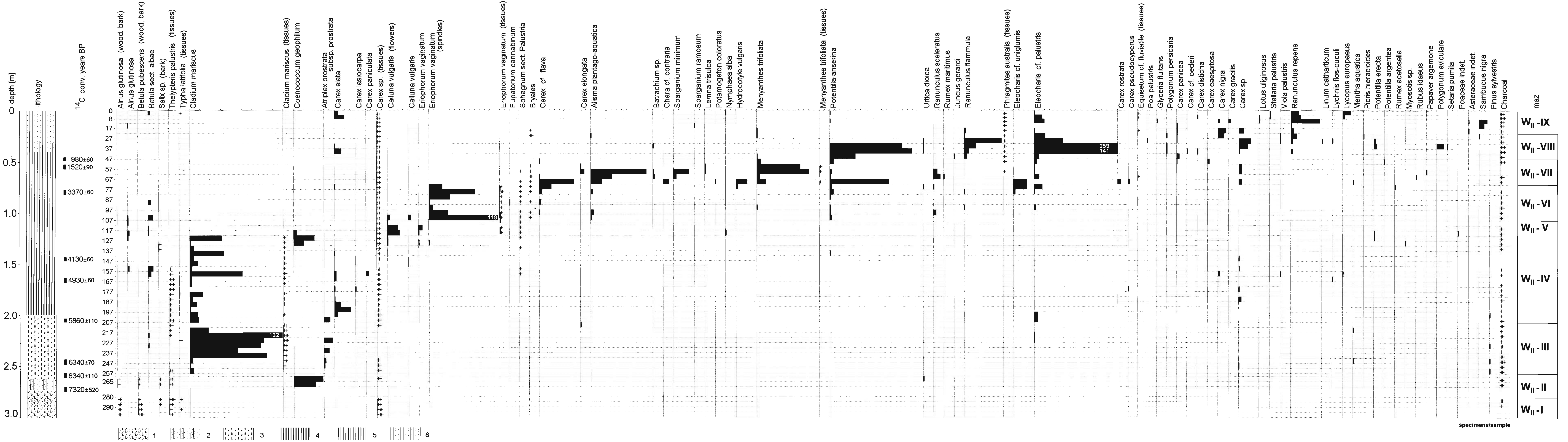


Fig. 7. Wolin II – macrofossil diagram; **1** – sand with silt, **2** – sand with decomposed herbaceous peat, **3** – *Cladium-Phragmites* peat, **4** – herbaceous peat, **5** – amorphous peat, **6** – *Carex-Phragmites* peat with sand

MACROFOSSIL ANALYSIS

WOLIN II

The diagram (Fig. 7) is divided into nine macrofossil assemblage zones (maz).

W$_{II}$-I, *Alnus glutinosa-Betula pubescens-Thelypteris palustris* maz (300–280 cm), ?–7320±520 ^{14}C conv. years BP. The mineral sediment in this part of the profile is very poor in plant material and contains only small fragments of wood and bark of *Alnus glutinosa* and *Betula pubescens,* tissue of *Thelypteris palustris, Typha latifolia* and *Carex sp.* Small fragments of charcoal are also present.

W$_{II}$-II, *Thelypteris palustris-Coenococcum geophilum* maz (280–255 cm), 7320 ±520–6340±110 ^{14}C conv. years BP. This section contains mostly undeterminable detritus and charcoal. Tissue of *Thelypteris palustris* is constantly present. The most characteristic feature is the large number of sclerotia of *Coenococcum geophilum.*

W$_{II}$-III, *Cladium mariscus* maz (255–205 cm), 6340±110–5860±110 ^{14}C conv. years BP. *Cladium mariscus* fruits and tissue dominate in this zone. Seeds of *Atriplex prostrata* subsp. *prostrata* are frequent, but not abundant. Single seeds of *Pinus sylvestris* are present.

W$_{II}$-IV, *Cladium mariscus-Thelypteris palustris* maz (205–123 cm), 5860±110 – ca. 3900* ^{14}C conv. years BP. *Cladium mariscus* is still the most important constituent; in most of the zone tissue of *Thelypteris palustris* occurs. Fruits of *Carex elata*, *C. paniculata* and *Eleocharis* cf. *palustris* are present in some samples. In the uppermost part of the zone a significant number of sclerotia of *Coenococcum geophilum* appears.

W$_{II}$-V, *Calluna vulgaris* maz (123–107 cm), ca. 3900*–3750* ^{14}C conv. years BP. This short zone is characterised by the presence of *Calluna vulgaris* flowers and single seeds, and of single specimens of *Eriophorum vaginatum* fruits. The scattered leaves of *Sphagnum* sect. *Palustria* were identified.

W$_{II}$-VI, *Eriophorum vaginatum* maz (107–72 cm), ca. 3750*–2750* ^{14}C conv. years BP. Vegetative remains of *Eriophorum vaginatum* (mainly its characteristic spindles) dominate among the identifiable plant material. Especially in the upper part of the zone, fruits of *Carex flava* and *Eleocharis* cf. *palustris* appear, in addition to those of *E.* cf. *uniglumis.*

W$_{II}$-VII, *Menyanthes trifoliata-Alisma plantago-aquatica* maz (72–47 cm), ca. 2750*–980±60 ^{14}C conv. years BP. Remains of plants typical of shallow water dominate in this zone; *Alisma plantago-aquatica*, *Sparganium* •*minimum*, *Potamogeton coloratus, Batrachium* sp., *Lemna trisulca, Chara* cf. *contraria* should be mentioned here. The second group of species is that characteristic of boggy grounds with periodically stagnant water (*Menyanthes trifoliata* and *Hydrocotyle vulgaris*), while *Ranunculus sceleratus* and *Potentilla anserina* represent peaty meadows periodically flooded.

W$_{II}$-VIII, *Eleocharis palustris-Ranunculus flammula-Potentilla anserina* maz (47–22 cm), 980±60 ^{14}C conv. years BP – subrecent. This zone is characterised by the presence of a large number of fruits of *Eleocharis* cf. *palustris.* In the lower part *Potentilla anserina* and *Ranunculus flammula* are well represented, while in the uppermost part of this section fruits of *Carex nigra* and *Ranunculus repens* are frequent.

W$_{II}$-IX, *Ranunculus repens-Lycopus europaeus* maz (22–0 cm), subrecent. The most typical feature of this zone is the presence of different species that usually grow in wet or damp habitats. *Eleocharis palustris, Carex elata, Typha* sp. and *Equisetum* cf. *fluviatile* are characteristic of rushes. Others, such as *Ranunculus repens, Lythrum salicaria, Lotus uliginosus* or *Stellaria palustris* are usually common on peaty meadows which can be periodically flooded.

WOLIN I

List of taxa

The list of macrofossils includes 225 species and subspecies, 14 taxa identified to the genus level and 5 to the family level only (Tab. 6, Pls 1–13). The unidentified specimens are of insignificant number. Most of the taxa occur in high frequencies, but the group of rare species is also of importance. *Panicum miliaceum, Humulus lupulus, Rumex acetosella, Chenopodium album, Ch. murale, Polygonum lapathifolium* subsp. *pallidum, P. lapathifolium* subsp. *lapathifolium, Urtica dioica, Solanum nigrum, Eleocharis palustris / uniglumis, Ranunculus sceleratus, Lycopus europaeus* and *Corylus avellana* belong to the most frequent.

The group which includes species which are

Table 6. List of macrofossil taxa identified in the Wolin I profile arranged according to habitat groups (**a–h**); **H** – the most likely alternative habitat of the origin of fossil remains of a given taxon; for each taxon number of specimens in all samples from the indicated culture layer is given

Chronological interval	A	B			C			D			Total of		H
Culture layer		XVIII	XVII	XVI	XV	XIV	XIII	XII	XI	X	sam-ples	speci-mens	
Century AD		9	9/10	9/10	10	10	10	10	10	10			
Cultivated plants (a)													
Panicum miliaceum L.		48	125	331	21	22	12	72	35	9	46	675	
Secale cereale L.			2						1	1	4	4	
Hordeum vulgare L.				1				1			2	2	
Triticum aestivum L. s.l.									4		2	4	
Pisum sativum L.								1			1	1	
Linum usitatissimum L.							1	2			3	3	
Cannabis sativa L.						1			3		2	4	
Papaver somniferum L.	1	1			1		1				4	4	
Brassica rapa L.		1	8	9	1	30	7	29	40	56	32	181	c
Anethum graveolens L.									2		1	2	
Humulus lupulus L.		6	47	43		40	43	42	120	5	45	346	h
Malus sp.			2		2		1	7	47		12	59	h
Pyrus communis L.									6		1	6	h
Sum	1		624			183			483			1291	
Weeds of cereals and flax (b)													
Aethusa cynapium L.										1	1	1	c
Stachys annua (L.) L.				1							1	1	
Valerianella dentata (L.) Pollich				1							1	1	c
Lithospermum arvense L.			1					2			3	3	
Neslia paniculata (L.) Desv.			2	1				3	3		8	9	c
Melandrium noctiflorum (L.) Fr.			1		3						3	4	c
Anthemis arvensis L.				1	1				5	4	8	11	
Galium spurium L.			1	1		1		19	35	2	11	59	c
Silene gallica L.			1	7	1	1		1			7	11	
Spergula arvensis L. subsp. *maxima* (Weihe) O. Schwarz				9				3	2		7	14	
Papaver argemone L.		1	2	1	2	1	4	5	5	1	16	22	
Veronica cf. *hederifolia* L.									1		1	1	
Vicia hirsuta (L.) S.F. Gray									2		2	2	
Agrostemma githago L.		2	1	8	6	11	5	8	24	3	31	68	
Galeopsis ladanum L.			5	1				3	11		14	20	c
Rumex acetosella L.	2	14	50	47	13	30	37	33	23	2	54	251	c, g
Scleranthus annuus L.			3			1	1				5	5	
Viola arvensis Murray/ *tricolor* L.	1		10	12	1	3	1	4	5	1	23	38	c
Anagallis arvensis L.									1		1	1	c
Fallopia convolvulus (L.) Á. Löve		6	4	9	3	3	4	23	27	11	34	90	c
Galeopsis tetrahit L. – type		3	4	16	5	20	2	10	11	7	29	78	c
Cirsium arvense (L.) Scop.	2	1	2	4			1				9	10	c
Sum	5		234			161			301			701	
Weeds of millet, root crops, gardens and ruderal habitats (c)													
Setaria italica (L.) P. Beauv.					1				1		2	2	a
Setaria pumila (Poir.) Roem. & Schult.			4	3		2	3	28	129	14	21	183	
Setaria viridis/verticillata (L.) P. Beauv.		6	1	8	1			2	64	11	19	93	
Echinochloa crus-galli (L.) P. Beauv.			3				1		68	4	10	76	
Euphorbia helioscopia L.								1	1		2	2	
Thlaspi arvense L.			2	5	1	5	3	5	34	71	27	126	

Table 6. Continued

Chronological interval	A	B			C			D			Total of		H
Culture layer		XVIII	XVII	XVI	XV	XIV	XIII	XII	XI	X	sam-ples	speci-mens	
Century AD		9	9/10	9/10	10	10	10	10	10	10			
Myosotis arvensis (L.) Hill				1			1	1			3	3	
Stellaria media (L.) Vill.		1	1	1				1	6		8	10	
Spergula arvensis subsp. *sativa* Boenn.				6			1		3		5	10	**a, b**
Spergula arvensis subsp. *vulgaris* Boenn.			2	39		2		7	8	2	19	60	**b**
Erysimum cheiranthoides L.									1		1	1	
Atriplex patula L.		8	1	1				1		1	6	12	
Melandrium album (Mill.) Garcke		4	20	39	12	6	6	13	9	3	39	112	**b**
Lapsana communis L.		1					1		1	5	5	8	
Chenopodium album L. s.l.		20	44	60	9	19	8	63	24	9	30	256	
Chenopodium album L.	20	144	322	755	138	191	230	627	734	214	63	3375	
Chenopodium polyspermum L. – type	2	1	7	3			2	2	1		17	18	
Chenopodium hybridum L.		1		1				1	1		4	4	
Chenopodium murale L.	2	25	39	102	15	26	13	43	37	1	42	303	
Chenopodium ficifolium Sm.					1		1	1			3	3	
Chenopodium glaucum L./*rubrum* L.	1		1								2	2	
Chenopodium sp.	1	16	58	19	7	19	32	26	34	18	47	230	
Polygonum persicaria L.	27	2	2	8	1	1	3	15	1	13	24	73	**e**
Mentha arvensis L.		2	13	13	7	2	1	1	2	2	21	43	
Stachys arvensis (L.) L.							2		2		3	4	
Lamium album L.								1			1	1	
Lamium amplexicaule L.		1					1				2	2	
Anthemis tinctoria L.		1			1	1			1		4	4	
Polygonum aviculare L.	2	9	7	1	3	4	14	18	21	11	15	90	
Plantago major L.			2								2	2	
Rumex crispus L.		5	4	2	5			1	3	1	13	21	
Berteroa incana (L.) DC.			1		1						2	2	
Capsella bursa-pastoris (L.) Medik.		1									1	1	
Malva sylvestris L.									1	1	2	2	
Poa annua L. /*compressa* L.			1								1	1	
Ballota nigra L.	1								2	1	4	4	
Urtica urens L.			1	2	1		4	2	1		6	11	
Solanum nigrum L. em. Mill.	7	5	22	21	6	11	5	22	23	23	45	145	
Carex hirta L.			1	1				1			3	3	
Melandrium rubrum (Weigel) Garcke			3	3		1			5		7	12	
Atriplex nitens Schkuhr	1	1					1				3	3	
Linaria vulgaris Mill.		1									1	1	
Bunias orientalis L.				1			2				3	3	
Carduus crispus L.							1				1	1	
Polygonum lapatifolium subsp. *pallidum* (With.) Fr.		12	25	97	42	62	33	104	65	4	45	444	
Polygonum lapathifolium subsp. *lapathifolium* (With.) Fr.	2	7	5	49	4	12	5	48	171	31	41	334	**e**
Polygonum lapathifolium L. s.l.	1		12	10	1	2		8	68	77	27	179	**e**
Ranunculus repens L.	7	1	3	4		1	8	1	3	1	22	29	**e**
Polygonum hydropiper L.		1		3	1		1				6	6	**e**
Urtica dioica L.	30	102	73	19	30	4	5	5	2	2	45	272	**e, h**
Sum	104	2335			1047			3095				6582	
Aquatic plants (d)													
Chara sp.	17										6	17	
Najas marina L.	173										9	173	

Table 6. Continued

Chronological interval	A	B			C			D			Total of		H
Culture layer		XVIII	XVII	XVI	XV	XIV	XIII	XII	XI	X	samples	specimens	
Century AD		9	9/10	9/10	10	10	10	10	10	10			
Potamogeton natans L.	6										4	6	
Potamogeton rutilus Wolfg.					2						1	2	
Potamogeton coloratus Hornem.	2										2	2	
Zannichellia palustris L. subsp. *palustris* (Wahlenb.& Rosen) Hegi	1			1	1						3	3	
Zannichellia palustris L. subsp. *pedicellata* (Wahlenb. & Rosen) Hegi		1		1							2	2	
Sparganium erectum L. em. Rchb.				1		1					2	2	
Lemna trisulca L.		1									1	1	
Batrachium sp.		1	5	3	5		2	1	1		13	18	
Sum	199	14			11			2				226	
Wetlands, wet meadows, riverside (e)													
Schoenoplectus lacustris (L.) Palla	71	2	2	1	10	1				1	16	88	
Schoenoplectus tabernaemontani (C.C. Gmel.) Palla	234	6	9		35	2				1	21	287	
Bulboschoenus maritimus (L.) Palla	1					1					2	2	
Typha sp.	1	17	44	39			2		5		19	108	
Phragmites australis (Cav.) Trin. ex Steud.		2	1	1							3	4	
Cladium mariscus (L.) Pohl	95		1	1	1	1					12	99	
Eleocharis palustris (L.) Roem. & Schult/*uniglumis* (Link) Schult.	69	4	8	4	66	4	31	14	16	4	41	220	
Eleocharis sp.		1				1			1		3	3	
Glyceria fluitans (L.) R. Br.			1					1			2	2	
Triglochin maritimum L.	1										1	1	
Eupatorium cannabinum L.	1										1	1	
Oenanthe aquatica (L.) Poir.			1					1			2	2	
Peucedanum palustre (L.) Moench			3						3		5	6	
Iris pseudacorus L.						3					2	3	
Rumex hydrolapathum Huds.	29								1		6	30	
Carex distans L.		1		3	2		5		1		8	12	
Glyceria maxima (Hartm.) Holmb.			1								1	1	
Atriplex prostrata Boucher ex DC. subsp. *prostrata*	29	6	30	4	2			10	14	2	26	97	c
Thelypteris palustris Schott	45										5	45	
Mentha aquatica L.	30	5	9	3	6	4		3	2		26	62	
Lythrum salicaria L.		1	1						1		3	3	
Galium palustre L.	5	1	4	2			1	1	5		12	19	
Galium uliginosum L.		1									1	1	
Carex acutiformis Ehrh.	33		2		1						9	36	
Carex disticha Huds.	5	1	4	1			1			1	10	13	
Carex elata All.		2	1		1		2		1		6	7	
Carex elongata L.	5	2	3	1	2	5	2	2			14	22	
Carex pseudocyperus L.	54		4	1	3	4	2	1	2		18	71	
Carex paniculata L.	36	6	10	12	1	1	2	2	1		25	71	
Carex riparia Curtis	1			1							2	2	
Carex rostrata Stokes	33	1	1	6	5	5		2	1		17	54	
Carex echinata Murray	3										1	3	
Carex vesicaria L.	1			1	1		1				1	4	
Cicuta virosa L.	3										1	3	
Poa palustris L.			4	1		1		2	1		7	9	

Table 6. Continued

Chronological interval	A	B			C			D			Total of		H
Culture layer		XVIII	XVII	XVI	XV	XIV	XIII	XII	XI	X	sam-ples	speci-mens	
Century AD		9	9/10	9/10	10	10	10	10	10	10			
Stellaria palustris Retz.								3			1	3	
Ranunculus flammula L.	1		3	1		1	1	2			7	9	
Rumex conglomeratus Murray			3	3			1	1			5	8	
Rumex cf. *obtusifolius* L.			1								1	1	
Rumex sanguineus L.			1								1	1	
Juncus articulatus L. em. K. Richt.		1	3						5		4	9	
Juncus bufonius L.		3	5	2							3	10	c
Juncus subnodulosus Schrank	1										1	1	
Carex vulpina L.						2	1	2			5	5	
Carex panicea L.	1	1				1			1	1	5	5	
Carex pairae F.W. Schultz			1	2	1	1		1	1		7	7	
Carex leporina L.			6	3		2	3	1	4		12	19	
Myosoton aquaticum (L.) Moench			1								1	1	
Carex nigra Reichard		1	3	4	4	24	13	13	28	3	29	93	
Carex flava L./*oederi* Retz.	5	3	1	13	19	32	3	4	5		28	85	
Hydrocotyle vulgaris L.	5										3	5	
Pedicularis palustris L.							1		1		2	2	
Comarum palustre L.	1										1	1	
Menyanthes trifoliata L.	1		1		1						3	3	
Scirpus sylvaticus L.		6	9	9		2	1	2			15	29	
Juncus effusus L./*conglomeratus* L. em. Leers	2	1	11	2					1		9	17	
Filipendula ulmaria (L.) Maxim.		2	4		3	2				1	9	12	
Lycopus europaeus L.	12	1	42	5	2	9	5	4	4		36	84	
Cardamine amara L.				1							1	1	
Caltha palustris L.			1								1	1	
Glaux maritima L.							1	1			2	2	
Juncus gerardi Loisel.			3	1					1		4	5	
Ranunculus sceleratus L.	9	36	211	241	48	31	73	26	4	1	46	680	c
Potentilla anserina L.	28		3		10			1	1		12	43	c
Lychnis flos-cuculi L.		5	4	2		2	1				11	14	
Thalictrum flavum L.					1		1				2	2	
Deschampsia caespitosa (L.) P. Beauv.			2								1	2	
Molinia caerulea (L.) Moench			1			1		11	5		8	18	
Cirsium oleraceum (L.) Scop.			1	1							2	2	
Carex canescens L.	2				1						3	3	
Carex cespitosa L.							1				1	1	
Sum	853	456			524			242				2574	
Fresh meadows (f)													
Leontodon autumnalis L.								1			1	1	
Odontites serotina (Lam.) Rchb.			1								1	1	
Rumex cf. *acetosa* L.		1	1								2	2	e
Cerastium holosteoides Fr. em. Hyl.							1	1	1		3	3	
Sagina procumbens L.			1								1	1	
Plantago lanceolata L.						1			1		2	2	
Stellaria graminea L.								1			1	1	
Ranunculus acris L.		2	19	1						1	6	23	
Prunella vulgaris L.	1		4	4			3	5	2	1	15	20	
Plantago media L.			2								2	2	
Potentilla erecta (L.) Raeusch.	2	1		1	1		4	27	22		18	58	g

Table 6. Continued

Chronological interval	A	B			C			D			Total of		H
Culture layer		XVIII	XVII	XVI	XV	XIV	XIII	XII	XI	X	sam-ples	speci-mens	
Century AD		9	9/10	9/10	10	10	10	10	10	10			
Potentilla reptans L.	4								1		5	5	
Ranunculus sardous Crantz		19	3	1	1		2				9	26	
Poa trivialis L./*pratensis* L.									1		1	1	
Sum	7	61			13			65				146	
Dry grasslands, heath (g)													
Arenaria serpyllifolia L.		1	1								2	2	
Polycnemum arvense L.	1										1	1	
Polygonum calactum Lindm.		1	2	3			2	11	10		8	29	
Dianthus deltoides L.				2							2	2	
Petrorhagia prolifera (L.) P.W. Ball & Heywood		1					1	1		1	4	4	
Pimpinella saxifraga L.		1		1							2	2	
Ranunculus bulbosus L.						1					1	1	
Luzula campestris (L.) DC.			4								1	4	
Origanum vulgare L.			1								1	1	
Knautia arvensis (L.) J.M. Coult.			1								1	1	
Hypericum perforatum L.			1	1			1				3	3	
Prunella grandiflora (L.) Scholler		1								1	2	2	
Potentilla argentea L.	1	2		3		1	2	2	2		9	13	
Potentilla cf. *norvegica* L.			1								1	1	
Stachys recta L.				2			1	1			4	4	
Cerastium arvense L.		3	2	8	3	5	7	4			21	32	
Thalictrum cf. *minus* L.									1		1	1	
Carex pallescens L.	1										1	1	
Silene nutans L.				1							1	1	
Silene vulgaris (Moench) Garcke		3	10	24	1	13	2	7	3	1	31	64	
cf. *Clinopodium vulgare* L.	1										1	1	
Bromus hordeaceus L.						1					1	1	
Sum	4	80			41			45				172	
Forests, glades and clearings (h)													
Alnus glutinosa (L.) Gaertn.	109		1						2		9	112	
Betula pubescens Ehrh.	37	1		1				1			7	40	
Frangula alnus Mill.									1		1	1	
Viburnum opulus L.									1		1	1	
Rubus caesius L.			3	1			6	24	10	1	12	45	
Polygonum mite Schrank	2										2	2	
Solanum dulcamara L.	4		1	2				1			6	8	
Carex remota L.			2								1	2	
Ajuga reptans L.				1							1	1	
Betula pendula Roth	47	2	3	3					1		11	56	
Betula sect. *albae*	24		2	1		1		1	2		11	31	
Corylus avellana L.		1	9	7	2	2	4	10	6	2	36	43	
Moehringia trinervia (L.) Clairv.	26	2	7	2	2	2			1	1	13	43	**c**
Fragaria vesca L.		7	66	7	2	2	9	5	11	2	31	111	
Stachys sylvatica L.									1		1	1	
Pinus sylvestris L.	1										1	1	
Empetrum nigrum L.		2		4				1			6	7	**g**
Melampyrum cf. *pratense* L.									1		1	1	
Hieracium lachenalii C.C. Gmel.					1						1	1	

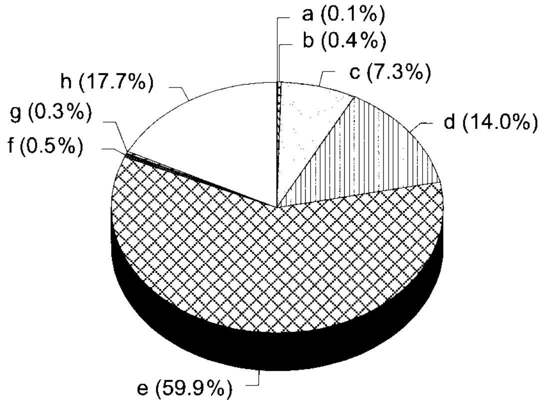
Table 6. Continued

Chronological interval	A	B			C			D			Total of		H
Culture layer		XVIII	XVII	XVI	XV	XIV	XIII	XII	XI	X	sam-ples	speci-mens	
Century AD		9	9/10	9/10	10	10	10	10	10	10			
Pteridium aquilinum (L.) Kuhn									1		1	1	g
Vaccinium myrtillus L.							1	4	62		8	67	
Vaccinium vitis-idaea L.					1				1		2	2	
Sorbus aucuparia L. em. Hedl.		4	11	1	2		1	9	70		16	98	
Sorbus cf. *torminalis* (L.) Crantz							1	1	3		3	5	
Rubus idaeus L.		9	23	5	3	2		4	5		24	51	
Rubus fruticosus L. – type			6	1	1	1	6	26	8	1	19	50	
Rubus saxatilis L.	1							1			2	2	
Rubus sp.			2						1		2	3	
Sambucus nigra L.		6	2	2	1	6			2		13	19	c
Salix sp.	1		1	1				1	1		5	5	
Sum	252	212			59			281				810	
Ecologically undefined													
Apiaceae indet.								1	1				
Atriplex sp.	10	2				1							
Brassicaceae indet.									2				
Carex sp.	53	2	14	18	17	1	1	8	1	4			
Caryophyllaceae indet.				3				1	1				
Juncus sp.	1			1									
Lamiaceae indet.	2	1		1									
Mentha arvensis L./*aquatica* L.			1		3		3						
Mentha sp.	7		4	1	1		4	1	1				
Myosotis sp.		1	1	2				1	1				
Poaceae indet.		2	1			2	1	1	11	3			
Polygonum sp.								1	1				
Potentilla sp.	2	2	1		1		1						
Rosa sp.			1										
Stellaria graminaea L./*palustris* Retz.										1			
Valeriana sp.				2			4	5					
Viola sp.	1			2					1				
Varia	28	6	4	4	3	2	8	8	4	4			
Others													
Coenococcum geophilum Fr.	7	4											
Daphnia sp. (ephippia)		138	260	8		1	3	16	1				

very rare in the recent flora of Wolin Island or which do not occur at all in the area (Piotrowska 1966a) is especially interesting (see Appendix). These are mainly field weeds typical of better soils, such as *Aethusa cynapium, Stachys annua, Lithospermum arvense, Valerianella dentata, Neslia paniculata, Melandrium noctiflorum, Galium spurium, Silene gallica* and *Bunias orientalis. Spergula arvensis* subsp. *maxima* is a weed of flax field and has practically disappeared in recent times not only from Wolin Island, but also from most European areas. *Setaria italica* and *Stachys arvensis*, both present in fossil material but absent in the present-day flora of Wolin are another examples of weeds, which are very rare on a regional scale.

Habitat groups

The taxa identified in the Wolin I profile represent different habitats and various plant communities. Affiliation of a particular species to the habitat groups (Tab. 6, Figs. 8, 9) is based on their occurrence in the present-day vegetation in the territory of Poland (Matusz-



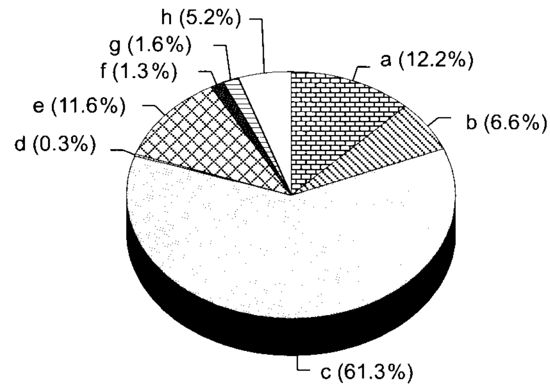


Fig. 8. Representation of particular habitat groups (according to number of diaspores); **A** – in the deposit dated to the period preceding foundation of the port, **B** – in culture layers (9th–10th century); **a** – cultivated plants, **b** – weeds of cereals and flax, **c** – weeds of millet, root crops, gardens and ruderal habitats, **d** – aquatic plants, **e** – wetlands, wet meadows and riversides, **f** – fresh meadows, **g** – dry grasslands and heath, **h** – forests, glades and clearings

kiewicz 1982, Zarzycki 1984) and especially on Wolin Island (Piotrowska 1966a, b, Nowiński 1964, Piotrowska & Celiński 1965) as well as in the specific context of the particular archaeobotanical samples. It should be stressed, however, that this "broad" grouping cannot be treated as a definitive division. Many of the specified taxa are frequent in different plant communities. One of the best examples is *Rumex acetosella.* This species occurs in dry swards, pastures and heaths, it spreads into ruderal habitats and is found in different

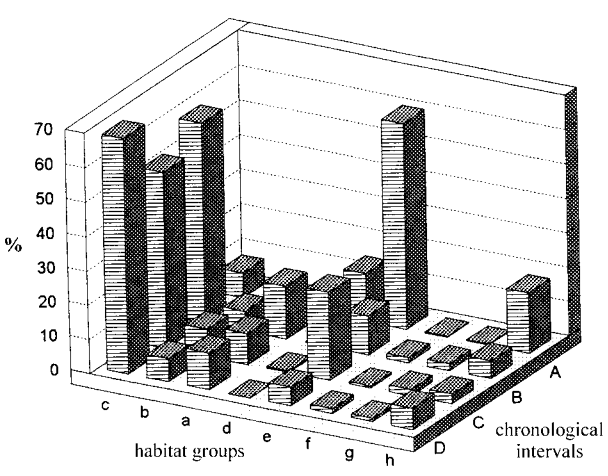


Fig. 9. Representation of particular habitat groups (participation of diaspores) according to chronological intervals; **A** – period preceding foundation of the port, **B** – second half of the 9th century and to the 9th/10thcentury, **C** – first half of the 10th century, **D** – second half of the 10th century; **a** – cultivated plants, **b** – weeds of cereals and flax, **c** – weeds of millet, root crops, gardens and ruderal habitats, **d** – aquatic plants, **e** – wetlands, wet meadows and riversides, **f** – fresh meadows, **g** – dry grasslands and heath, **h** – forests, glades and clearings

crops, especially cereals. In the archaeobotanical material discussed here, its remains are abundant in the samples rich in *Panicum miliaceum* glumes. It can be assumed that it was one of the most important weeds in fields of millet; this phenomenon is also observed in modern times (Wójcik 1973).

The material is discussed in the light of the chronological grouping of the particular culture layers into following intervals: A – peat deposits representing the period preceding the founding of the early medieval port, B – culture layers dated to the second half of the 9th century and to the 9/10th century, C – culture layers dated to the first half of the 10th century and D – culture layers dated to the second half of the 10th century.

Cultivated plants. In the material under discussion remains of cultivated plants are rather poorly represented. This is mainly due to the specific, waterlogged conditions at the site, which are especially unfavourable for the preservation of uncharred cereal grain and pulses. Diaspores of millet *Panicum miliaceum* and hop *Humulus lupulus* are present in most of samples and in high numbers. The other important species is *Brassica rapa.* Pips of apple *Malus* sp. are rather frequent but they appear abundantly only in some samples. Others (rye *Secale cereale,* barley *Hordeum vulgare* subsp. *vulgare,* bread wheat *Triticum aestivum* s.l., peas *Pisum sativum,* flax *Linum usitatissimum,* hemp *Cannabis sativa,* opium poppy *Papaver somniferum,* dill *Anethum graveolens* and pear *Pyrus communis*) were recorded in single samples and in small numbers. Finds of apple *Malus* sp. and pear *Pyrus communis* could originate from wild or cultivated fruit trees.

Remains of cultivated plants are practically absent from samples coming from the bottom of the excavation (dated to the period between ca. 2–3000 ^{14}C conv. years BP). In the profile taken from the trench wall they generally constitute ca. 12% of the total number of diaspores and the species composition does not show any substantial differences with reference to the subsequent time-slices. However, distinct changes are observed in relation to the proportions of remains of particular taxa. Uncharred glumes of *Panicum miliaceum* are the most numerous in the layers dated to the second half of the 9th century and to the turn of the 9/10th century while the numbers and proportions of *Humulus lupulus* fruitlets, seeds of *Brassica rapa* and pips of *Malus* sp. increase in the material dated to the 10th century (Tab. 6, Figs 8, 9).

Weeds of cereals and flax. Among remains of weeds typical of cereal and flax cultivation, *Rumex acetosella, Fallopia convolvulus, Agrostemma githago, Galium spurium, Viola arvensis/tricolor*, *Galeopsis ladanum* and *G. tetrahit*-type are the most frequent and numerous. Seeds of *Agrostemma githago* and *Papaver argemone*, weeds characteristic mostly for winter cereals, are more abundant in the samples dated to the 2nd half of the 10th century than in the older material. Some of species classified to this group, especially *Rumex acetosella* and *Fallopia convolvulus*, were probably also associated with millet and other summer crops, as suggested by the composition of the archaeobotanical samples (Alsleben 1995) and the presence of these species in the present-day segetal communities (Wójcik 1978). The obligatory flax weed (*Spergula arvensis* subsp. *maxima*) and others, such as *Galium spurium* and *Silene gallica*, indicate the earlier presence of flax material at the site.

Diaspores of species characteristic of rather poor soils dominate. In this context the presence of species characteristic of warmer, calcareous soils, which do not occur in the recent flora of Wolin (*Stachys annua, Valerianella dentata, Galium spurium, Melandrium noctiflorum, Silene gallica*) or are very rare here (*Aethusa cynapium, Lithospermum arvense, Neslia paniculata*), is especially interesting. Some of the above species (*Silene gallica, Stachys annua* and *Valerianella dentata*) are known from historical records (Lucas 1860, Müller 1904 – after Piotrowska 1966a) from single localities, where they probably appeared as ephemerophytes. With regard to *Aethusa cynapium*, only its ruderal form (*A. cynapium* subsp. *cynapium*) has been recorded in this area.

Weeds of millet, root crops, gardens and ruderal habitats. A large number of species falls to this category (Tab. 6) and fossil fruits and seeds of some of them appear in abundance. Most of species are characterised by wide tolerance with respect to the type of cultivation and ruderal habitat into which they can spread. Apophytes of nitrophilous habitats (e.g. *Chenopodium album, Polygonum lapathifolium* subsp. *pallidum* and *P. l.* subsp. *lapathifolium, P. persicaria, Urtica dioica*) are the most important in this group. Several species represent weeds which spread mainly in millet. *Setaria pumila, S. viridis/verticillata*[2] and *Echinochloa crus-galli,* which characterise extant field weed associations of the Panico-Setarion alliance, are of importance here. The presence of two specimens of *Setaria italica* (one charred hulled caryopsis and one uncharred spikelet) is interesting, and as suggested earlier by Alsleben (1995), its rare records from Wolin probably indicate that it was not a crop in this area, but more likely a weed of millet cultivation. Diaspores of several species requiring damp soils (*Ranunculus repens*, *Polygonum hydropiper*, *P. persicaria*, *P. lapathifolium* subsp. *lapathifolium*) may originate from ruderal or field habitats as well as from damp meadows and the riverside.

Aquatic plants. The aquatic plants form a separate assemblage in the lowermost samples taken with the Instorf corer from the base of the excavation, in which seeds of *Najas marina* and oospores of *Chara* sp. occur. The frequency and abundance of diaspores from this group are negligable in the overlying culture layers. Supplementary information can be gained from the presence of numerous ephippia of *Daphnia* sp. in the samples taken from

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2 Probably *S. viridis*, because according to Piotrowska (1966a) only this species is present in the recent flora of Wolin Island, while *S. verticillata* is known only from historical data as an ephemeral species.

culture layers dated to the 9th and 9th/10th century.

Wetlands, wet meadows, riverside. Species of this group represent different natural, semi-natural and anthropogenic herbaceous plant communities developing under conditions of high ground water level. With respect to the number of diaspores, some species forming reed-swamp vegetation are the most important (*Schoenoplectus tabernaemontani, Eleocharis palustris / uniglumis, Typha* sp., *Cladium mariscus* and several sedges – *Carex pseudocyperus, C. rostrata, C. flava / oederi, C. nigra*). *Ranunculus sceleratus,* a plant typical of muddy riverbanks, is very well represented. A large number of taxa classified to this group are common both in natural marsh and mire vegetation and in anthropogenic damp and wet meadows (*Scirpus sylvaticus, Filipendula ulmaria, Lychnis flos-cuculi, Lycopus europaeus, Molinia caerulea*). Halophilous or semi-halophilous species appear at some levels: *Schoenoplectus tabernaemontani, Bulboschoenus maritimus, Triglochin maritimum, Carex distans, Atriplex prostrata* subsp. *prostrata, Juncus gerardi* and *Glaux maritima.*

Fresh meadows. The term "fresh" has been accepted according to Ellenberg et al. (1992) for soils, which are neither moist nor dry. Only few species belong to this group and, with the exception of *Potentilla erecta, Prunella vulgaris, Ranunculus acris* and *R. sardous*, their diaspores appear in small numbers.

Dry grasslands. This type of habitat is represented by 21 species which with the exception of *Silene vulgaris, Cerastium arvense* and *Potentilla argentea*, occur sporadically. *Polycnemum arvense, Dianthus deltoides* and *Petrorhagia prolifera* belong to the most interesting plants recorded in this material, as all of them are very rare in the present-day flora of Wolin Island.

Forests. Species occurring in various forests, forest glades, clearings and brushwood are affiliated to this group. They fall into two main categories. The first, represented by *Alnus glutinosa, Betula pubescens, Frangula alnus* or *Solanum dulcamara*, indicates the local flora of the riverside and probably reached the site by natural means of short-distance diaspore transport. The second comprises mainly seeds or fruit stones of plants producing edible fleshy fruits, very important in human diet, such as *Fragaria vesca, Empetrum nigrum, Vaccinium myrtillus, V. vitis-idaea, Rubus idaeus, R. fruticosus*-type, *R. caesius, R. saxatilis, Sambucus nigra* and *Sorbus aucuparia* or nuts such as *Corylus avellana.*

Macrofossil diagram

The macrofossil diagram (Fig. 10) indicates that, apart from the lowest part, which illustrates the natural vegetation of a body of shallow water and its surrounding wetlands, most of the profile contains remains representing a subfossil flora of complex origin. The participation of particular groups of species, e.g. local aquatic and wetland plants, cultivated plants and field weeds, various groups of useful plants taken from nature, is shaped in its own way. Even with all the above reservations, the diagram presents a rather consistent picture indicating both changes in the local environment at the wharf and some aspects of human activity.

Macrofossil assemblage zones were not constructed in this case. The material is considered relative to the chronological intervals specified above.

In the samples from the lowermost part of the profile (A) diaspores of wetland species dominate and those of aquatic plants are of importance too. The presence of large numbers of seeds of *Najas marina* and the appearance of *Chara* sp., *Potamogeton natans, P. coloratus* and *Zannichellia palustris* indicate that a shallow body of water existed at the site in the period preceding the early medieval settlement. *Schoenoplectus tabernaemontani, S. lacustris, Cladium mariscus, Eleocharis palustris* and/or *E. uniglumis, Thelypteris palustris, Rumex hydrolapathum, Atriplex prostrata* subsp. *prostrata, Mentha aquatica, Potentilla anserina* and different species of sedges (mainly *Carex pseudocyperus, C. rostrata* and *C. acutiformis*) formed the vegetation of the littoral zone. Various species affiliated to other habitat groups, such as *Alnus glutinosa* (forests), *Urtica dioica, Polygonum persicaria* and *Chenopodium album* (ruderal weeds), in this case certainly also represent the damp habitats of the river bank. Remains of cultivated plants (except for one seed of *Papaver somniferum*) and those of typical field weeds are practically absent from this material.

In the culture layers dated to the second

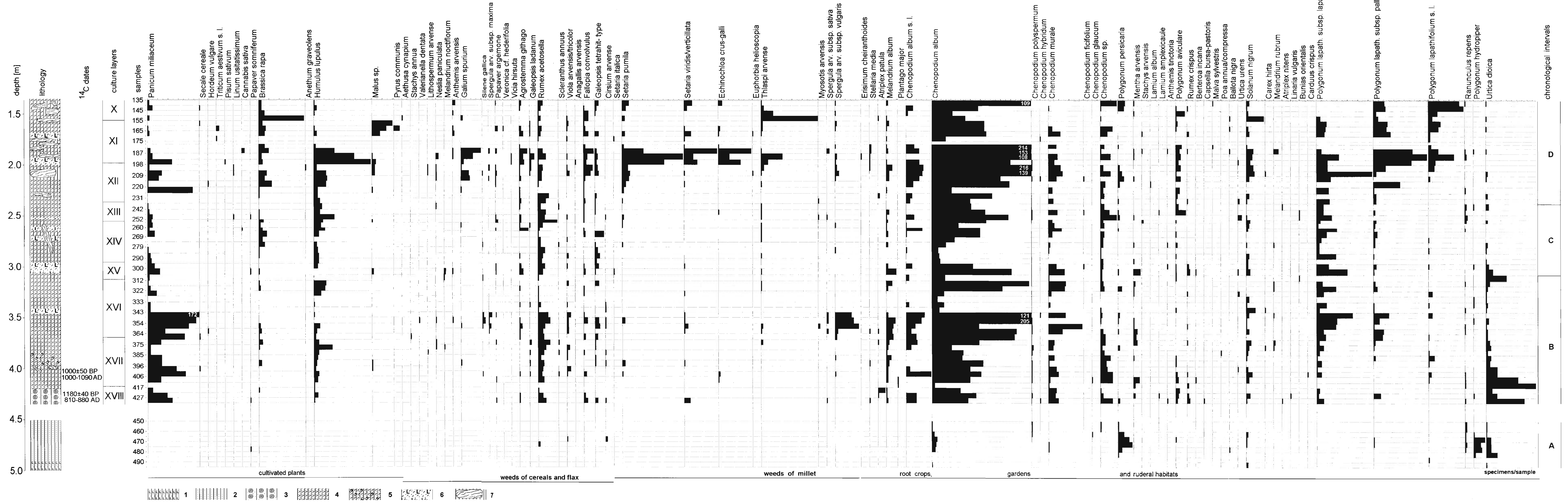

Fig. 10. Wolin I – macrofossil diagram (cultivated plants, weeds of cultivated fields, gardens and ruderal habitats); chronological intervals: **A** – period preceding foundation of the port, **B** – second half of the 9th century and 9th/10 century, **C** – first half of the 10th century, **D** – second half of the 10th century; 1 – peat with sand and silt, **2** – herbaceous peat, **3** – layer of fascine, **4** – coarse plant detritus, **5** – plant detritus with admixture of mollusc shells, **6** – silt and sand, **7** – large wood fragments

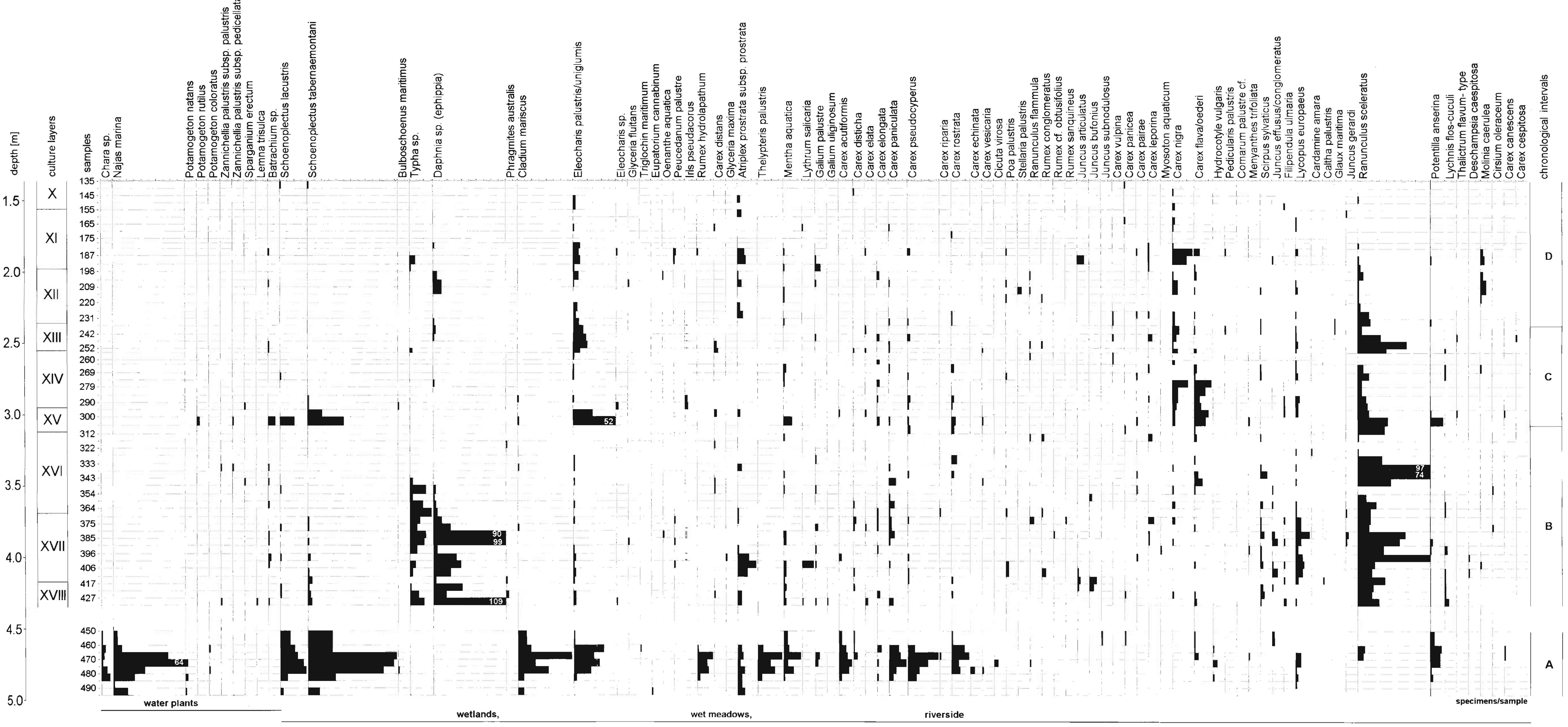

Fig. 10. Continued. Wolin I – macrofossil diagram (aquatic plants, plants of wetlands, wet meadows and riversides)

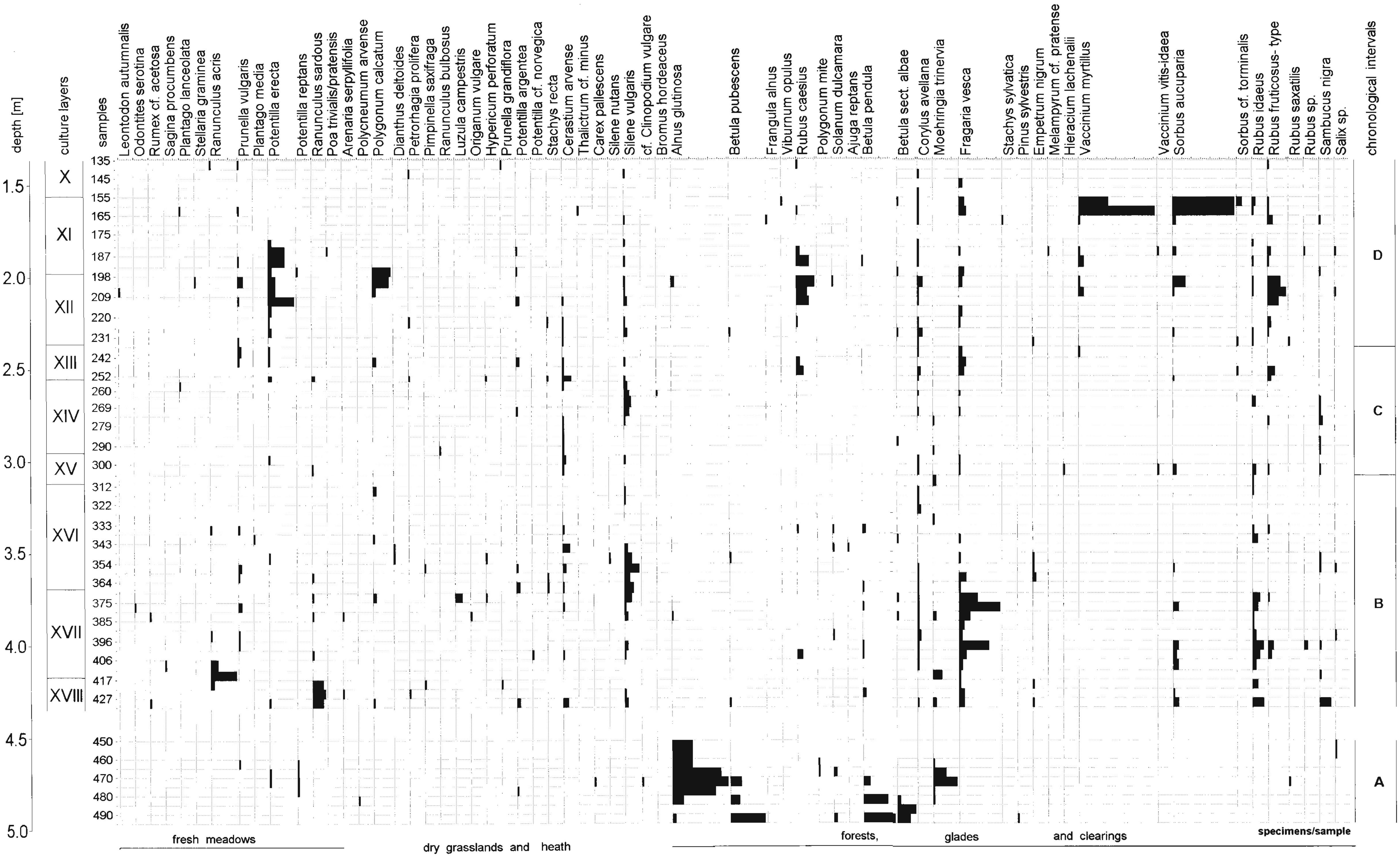

Fig. 10. Continued. Wolin I – macrofossil diagram (fresh meadows, dry grassland and heath, forests, glades and clearings)

half of the 9th century and to the 9/10th century (B) subfossil remains of field and ruderal weeds are the most important element. Among them are species typical of winter cereals such as *Agrostemma githago, Scleranthus annuus, Papaver argemone, Vicia hirsuta, Lithospermum arvense, Stachys annua, Neslia paniculata* and *Melandrium noctiflorum*. In some samples seeds of *Spergula arvensis* subsp. *vulgaris* appear in large numbers, while achenes of *Rumex acetosella* and seeds of *Melandrium album* are regularly present in relatively high numbers; only a few specimens of glumes of *Setaria pumila, S. viridis/verticillata* and *Echinochloa crus-galli* were recorded. Remains of *Spergula arvensis* subsp. *maxima, Galium spurium* and *Silene gallica* probably originate from flax cultivation. *Panicum miliaceum* and *Humulus lupulus* are the best represented cultivated plants. *Brassica rapa* is also relatively frequent. *Secale cereale, Hordeum vulgare* and *Papaver somniferum* diaspores were found only as single specimens. In these samples the presence of *Typha sp.* and ephippia of *Daphnia* sp. illustrates aquatic and reed-swamp environments. The nitrophilous habitats of the river bank are probably reflected in the presence of numerous remains of *Urtica dioica, Chenopodium album, Ranunculus sceleratus, Atriplex prostrata* subsp. *prostrata*. Anthropogenic activity at the site is shown by frequent and abundant presence of *Fragaria vesca, Corylus avellana, Sorbus aucuparia* and other food plants remains.

The macrofossil content of culture layers dated to the first half of the 10th century (C) is similar to that described above. The most important difference is the higher participation of weeds typical of winter cereals. Aquatic and wetland species (*Potamogeton rutilus, Zannichellia palustris, Batrachium* sp., *Schoenoplectus lacustris, S. tabernaemontani, Eleocharis palustris/uniglumis*) are better represented only in the two samples described as culture layer XV. *Carex nigra, Carex flava/oederi, Ranunculus sceleratus* and *Potentilla anserina* indicate damp habitats, probably supplied with sodium. Diaspores of *Humulus lupulus, Brassica rapa* and *Panicum miliaceum* are the most frequent and numerous remains of cultivated plants. *Cannabis sativa, Papaver somniferum* and *Linum usitatissimum* occur sporadically. In the group of winter weeds *Agrostemma githago* and *Papaver argemone* appear regularly. Dispores of *Anthemis arvensis, Melandrium noctiflorum, Galium spurium, Silene gallica* and *Scleranthus annuus* are present in small numbers or as single specimens. *Rumex acetosella*, which can infest a variety of crops, is one of the best represented taxa. Among the large number of ruderal species and weeds of root crops, *Chenopodium album, Polygonum lapathifolium* subsp. *pallidum* and *Solanum nigrum* belong to the most important. The presence of *Bunias orientalis* and *Setaria italica* is worthy of note.

In the culture layers dated to the second half of the 10th century (D) a further increase in the group of weeds is evident. The most important is the group of the Panico-Setarion alliance: *Setaria pumila, Setaria viridis/verticillata* and *Echinochloa crus-galli. Fallopia convolvulus, Thlaspi arvense, Polygonum aviculare* should be mentioned as being abundantly present. Weeds of winter cereals (*Agrostemma githago, Papaver argemone, Anthemis arvensis*) also increase in importance. Remains of weeds typical of flax cultures (*Spergula arvensis* subsp. *maxima, Silene gallica, Galium spurium*) are present. Some of weed species are indicative of better soils (*Neslia paniculata, Galium spurium, Lithospermum arvense, Silene gallica, Aethusa cynapium*), but those of poor soils dominate. In this part of the profile *Humulus lupulus, Panicum miliaceum* and *Brassica rapa* remains are the most important from cultivated plants. *Secale cereale, Hordeum vulgare, Triticum aestivum, Pisum sativum, Linum usitatissimum, Cannabis sativa* and *Anethum graveolens* appear as single specimens of fruits or seeds. Local vegetation is represented mainly by a nitrophilous flora composed of species of *Chenopodium* and *Polygonum*. Small numbers of diaspores of aquatic and reed-swamp species have been noticed only in some samples. In this section remains of various edible fleshy fruits (*Malus* sp., *Pyrus communis, Vaccinium myrtillus, Sorbus aucuparia* and *Rubus* ssp.) are especially frequent.

SELECTED DIATOM AND CHEMICAL DATA FROM THE WOLIN I PROFILE

The presence of the diatom flora was recorded only in the bottom part of the profile from the excavation, in the section from 433–373 cm (Fig. 11), dated as a whole to the 9th

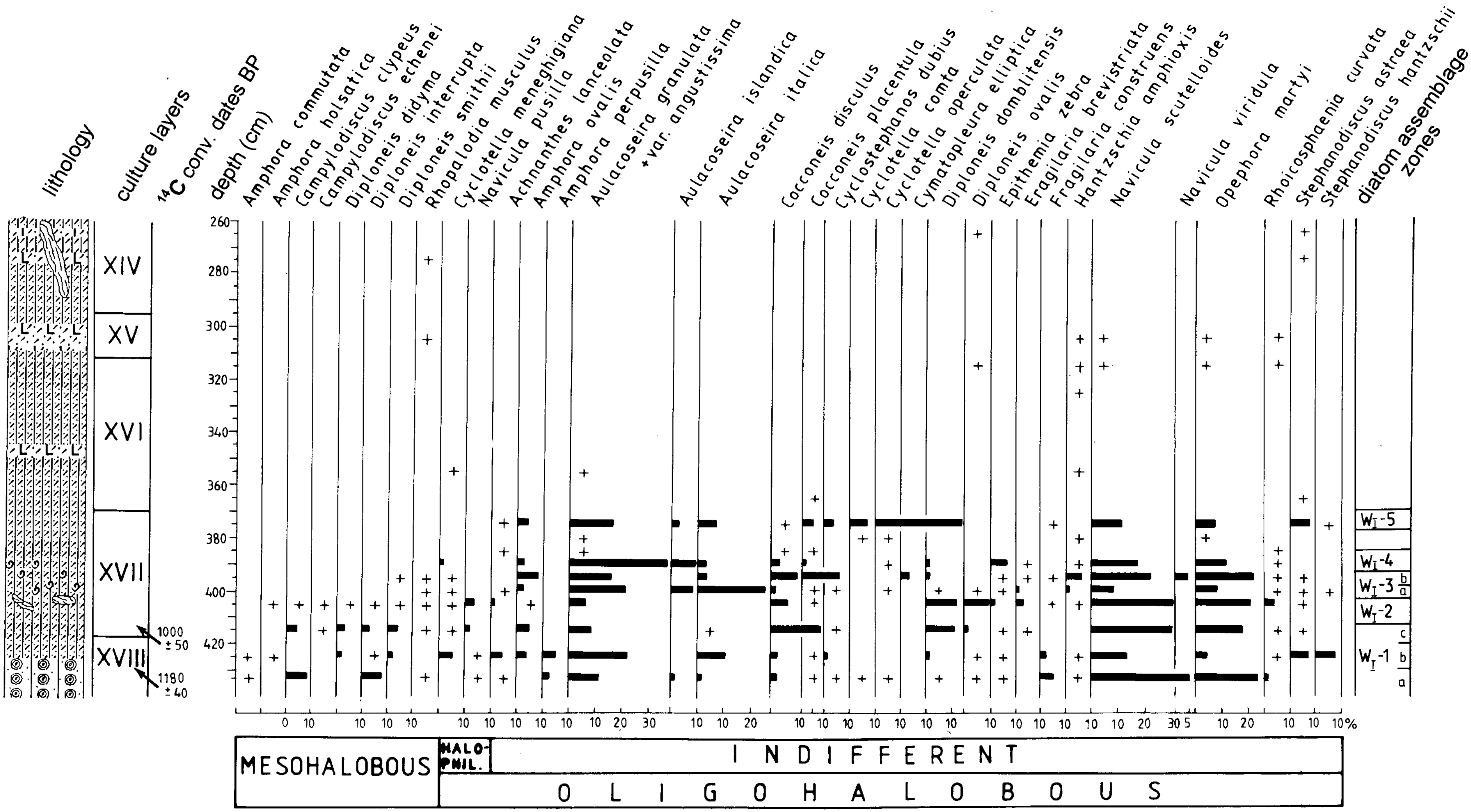

Fig. 11. Wolin I – diatom diagram; lithology: see explanation in Fig. 10 (from Latałowa et al. 1995, supplemented)

century AD. In other sections of the profile, only single specimens of diatoms were present, what precludes definition of diatom assemblage zones and further environmental reconstruction. Among 95 taxa identified by Bogaczewicz-Adamczak (Latałowa et al. 1995), the cosmopolitan, freshwater epiphytic forms characteristic of a littoral zone of fertile reservoirs with alkaline waters, are the most important. Mesohalobous (8 taxa) and oligohalobous halophilous (11 taxa) diatoms recently living in brackish waters of lagoons and coastal lakes are of special interest. In the section under discussion, five diatom assemblage zones (daz) and five subzones (da subz) are distinguished on the basis of species composition and relations between particular ecological groups.

W_I-1, *Navicula scutelloides-Campylodiscus clypeus* daz (433–410 cm). The alkaliphilous and alkalibiontic freshwater diatoms such as *Navicula scutelloides* W. Sm. and *Opephora martyi* Hrib. dominate in this zone. The mesohalobous species attain values of up to 15% – *Campylodiscus clypeus* Ehr. and several species of *Diploneis* should be mentioned here. This zone is divided into three subzones according to differentiation into ecological groups.

W_I-1a, *Campylodiscus clypeus-Diploneis interrupta* da subz (433–429 cm). In this subzone freshwater littoral forms (*Navicula scutelloides* and *Opephora martyi*) dominate, but also mesohalobous *Campylodiscus clypeus* and *Diploneis interrupta* are of importance. The frequency of diatoms is low.

W_I-1b, *Aulacoseira granulata-Stephanodiscus hantzschii* da subz (429–420 cm). Planktonic forms of *Aulacoseira* (*A. granulata* (Ehr.) Ralfs. + *A. granulata* var. *angustissima* O. Mll., and *A. italica* (Ehr.) Ktz.) are the most important. The frequency of diatoms is high.

W_I-1c, *Campylodiscus clypeus-Cocconeis disculus* da subz (420–410 cm). Littoral forms with *Navicula scutelloides, Opephora martyi* and *Cocconeis disculus* (Schm.) Cl. dominate, mesohalobous diatoms including *Campylodiscus clypeus* and species of *Diploneis* increase in importance. The frequency of diatoms is generally low. The presence of teratological forms of *Navicula* and numerous fragments of valves of mesohalobous species is characteristic of this subzone.

W_I-2, *Navicula scutelloides-Diploneis ovalis* daz (410–403 cm). The freshwater littoral forms constitute up to 97% of the total number of specimens. Epiphytic *Navicula scutelloides* and *Opephora martyi* dominate. Benthic species (e.g. *Diploneis domblittensis* (Grun.) Cl. and *D. ovalis* (Hilse) Cl.) reach 20%. The participation of mesohalobous species diminishes. The frequency of diatoms is even lower than in the previous W_I-1c zone.

W_I-3, *Aulacoseira granulata-Opephora martyi* daz (403–393 cm). A high frequency and numerous species of freshwater diatoms is typical of this zone. *Aulacoseira granulata, A. granulata* var. *angustissima, A. italica, A. islandica, Navicula scutelloides, Opephora martyi, Cocconeis disculus, C. placentula* Ehr. and *Achnanthes lanceolata* should be mentioned here. This zone is divided into two subzones with respect to the participation of planktonic and littoral forms.

W_I-3a, *Aulacoseira italica* da subz (403–397 cm). In this subzone planktonic forms of *Aulacoseira* are the most characteristic.

W_I-3b, *Cocconeis placentula* da subz (397–393 cm). The littoral species of *Navicula scutelloides, Opephora martyi, Cocconeis placentula* and *C. disculus* dominate in this subzone.

W_I-4, *Aulacoseira granulata* var. *angustissima* daz (393–383 cm). The characteristic feature of this zone is the high participation of planktonic forms represented mainly by such diatoms as *Aulacoseira granulata* var. *angustissima*. However, some of littoral species, such as *Navicula scutelloides* and *Opephora martyi*, are also of importance.

W_I-5, *Cyclotella operculata-Aulacoseira granulata* daz (378–373 cm). The rich freshwater flora is dominated by planktonic species. *Cyclotella operculata* (Ang.) Ktz., *C. comta* (Ehr.), Grun., *Aulacoseira granulata* var. *angustissima* and *A. italica* belong to those best represented.

In the same section of the Wolin I profile which was analysed with respect to diatom content, determination of magnesium (Mg) and sodium (Na) was carried out by Bolałek (Latałowa et al. 1995) (Fig. 12). The concentration of sodium ranges between 0.2 to 25.0 $mg.g^{-1}$ dw. The highest values are recorded in the section between 433–400 cm, what coincides with the diatom assemblage zones W_I-1

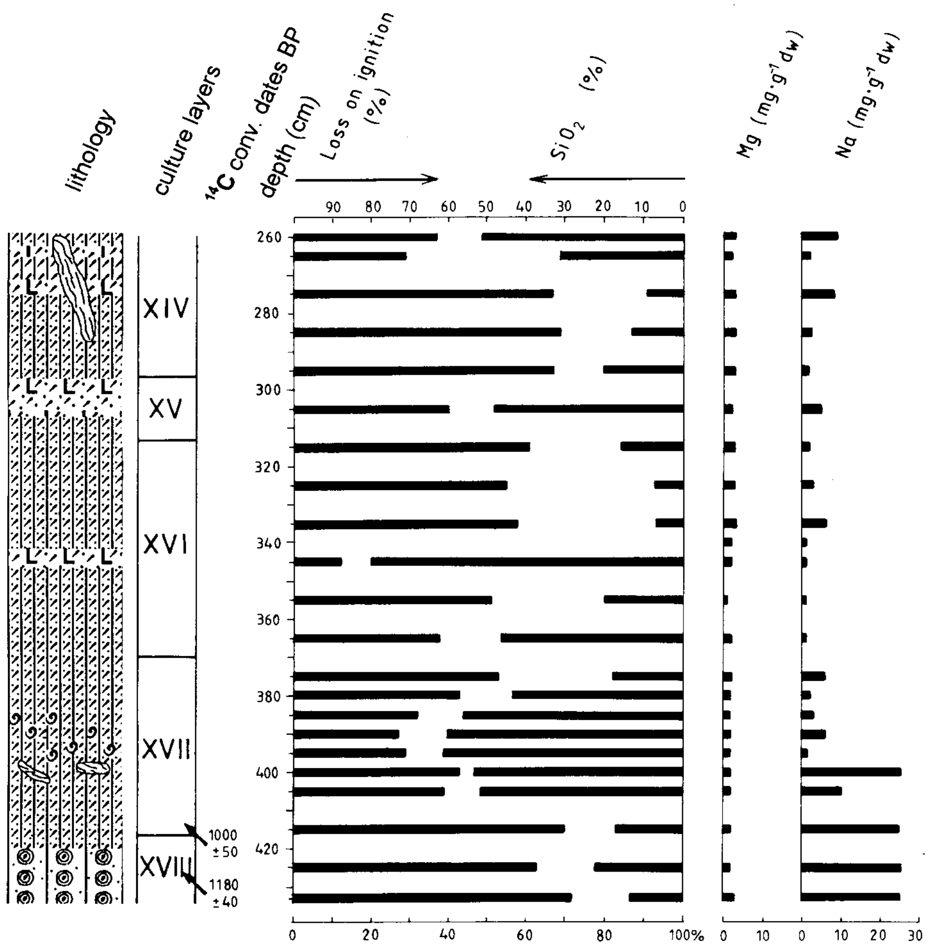

Fig. 12. Selected physical and chemical properties of the bottom part of the Wolin port deposit; lithology: see explanation in Fig. 10 (from Latałowa et al. 1995, supplemented)

and W_I-2 daz. The concentration values for magnesium are low and almost constant (ranging between 1.0–3.5 mg.g^{-1} dw).

AN OUTLINE OF THE HOLOCENE HISTORY OF THE LANDSCAPE PRIOR TO THE EARLY MEDIEVAL PERIOD AS SHOWN BY POLLEN AND MACROFOSSIL ANALYSES

The Holocene history of the areas adjacent to the town of Wolin is reflected in the pollen diagram from the Wolin II site. However, the peat profile from this site does not contain sediments older than 7320±520 ^{14}C conv. years BP. The earlier periods are know from the palaeobotanical sites located in the northern, morainic part of the Island (Latałowa 1992a) and from bottom sediments of Szczecin Lagoon (Zachowicz, in Wypych 1980).

WOODLANDS AND HEATH

In the climatic optimum of the Holocene, 7320±520 ^{14}C conv. years BP [ca. 6150 ^{14}C cal. years BC], on more elevated areas of mineral soils, and especially on light soils, mixed forest communities with a large participation of *Tilia* and others with a predominance of *Pinus* were common; *Quercus* and *Corylus* were present as an admixture. In forest glades, patches of heliophilous vegetation with *Calluna vulgaris, Pteridium aquilinum* and *Melampyrum* were present. As shown by the high content of charcoal dust in the sediments (Latałowa 1992a), this area has been constantly visited by man.

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, contribute to an understanding of the further succession of vegetation surrounding the bog (Fig. 13), which was certainly initiated by a fire. Pine,

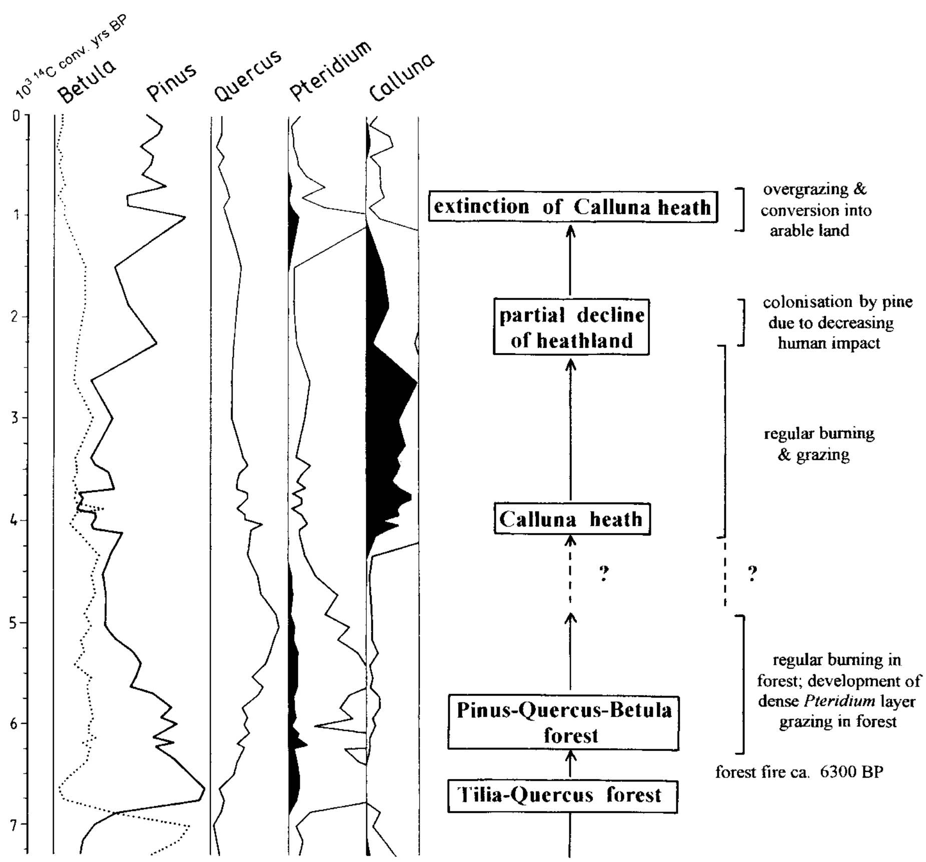

Fig. 13. History of *Calluna* heath on Wolin Island

as the first, spread into disturbed habitats previously occupied by the *Tilia-Quercus* woodland, later *Quercus* and *Betula* gradually replaced it. The erosional processes after the fire are documented by the appearance of large numbers of sclerotia of *Coenococcum geophilum* (cf. Fig. 7), a fungus typical of mineral soils (Jensen 1974).

The *Pinus-Quercus-Betula* forest was of a rather open structure and its herb layer was dominated by *Pteridium aquilinum*. During the approximately next two thousands years its undergrowth was probably regularly burnt and grazed, first by wild and later by domestic animals. The former is supported by the constant presence of charcoal since at least 5860±110 ^{14}C conv. years BP [ca. 4680 ^{14}C cal. years BC] and the latter by anthropogenic indicators related to animal husbandry (Figs 5 and 7). This type of forest management on the light, sandy soils caused the gradual degradation of habitats. Spontaneous renewal of pine was also restricted both by regularly repeated fires and the spread of *Pteridium aquilinum*, which if present at large concentrations, strongly shades the lower vegetation layers and inhibits growth of heliophilous pine seedlings (Markowski 1971, Rackham 1980).

As a result of the 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], *Calluna* heath started to expand onto the mineral soils in the immediate vicinity of the Wolin II site, as shown by the presence of corroded pollen clumps of *Calluna* on the pollen slides. In the overlying peat deposits flowers and seeds of heather and a large number of *Coenococcum geophilum*, washed out of the mineral soil, indicate intensive erosion. Due to regular burning and grazing during approximately the next two thousand years, the heath developed. This is illustrated by: (1) the high, constant presence of macroscopic charcoal in the sediments (Fig. 7), (2) high values of charcoal dust (Latałowa 1992a) and (3) pollen of anthropogenic indicators suggesting permanent stock farming in the area (Fig. 5).

During the period between ca. 2300*–?1520±90 ^{14}C conv. years BP [ca. 580 ^{14}C cal. AD] the heathland certainly declined in importance, but due to the lack of detailed pollen evidence (because of the very low accumulation rate in the appropriate part of the profile) it is not possible to present a comprehensive history of this time. The negative correlation between the *Pinus* and *Calluna* curves suggests that exploitation of heathland probably ceased temporarily, which allowed pine to encroach. Unfortunately, it is impossible to point out more exactly the time, at which this process took place.

The pollen profile from the Wolin II site offers the best documentation of the Holocene history of woodland and the subsequent succession stages on the poor, sandy soils. However, the data on the development of vegetation in other types of habitats are also of importance.

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 forest, probably caused by human activity, started before 5860±110 ^{14}C conv. years BP [ca. 4680 ^{14}C cal. years BC], (the first *Ulmus* decline) and then ca. 5400*–5300* ^{14}C conv. years BP (the second *Ulmus* decline). Both of the elm declines (Fig. 14) are linked with a drop in the *Fraxinus* and *Tilia* curves and the appearance of pollen of anthropogenic indictors, including *Plantago lanceolata* (both cases) and the first pollen grains of cereal type (the second case). As it has been previously supposed (Latałowa 1992a), the above, as well as the later fluctuations in these tree pollen curves, probably reflect intensive pollarding and other coppicing techniques developing together with increasing animal husbandry. In some places, small patches of pasture with Plantago *lanceolata* developed already prior to 5 000 years BP.

The time of the final destruction of the forests with *Ulmus, Fraxinus* and *Tilia* is indicated by a date of 3370±60 ^{14}C conv. years BP [ca. 1590 ^{14}C cal. years BC]. Their fertile habitats were used for pastures and then for cultivated fields during the subsequent periods. Secondary woodland with pine expanded onto the abandoned deforested areas during the migration period. *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, may have been at least an insignificant admixture in woodland in the area under discussion.

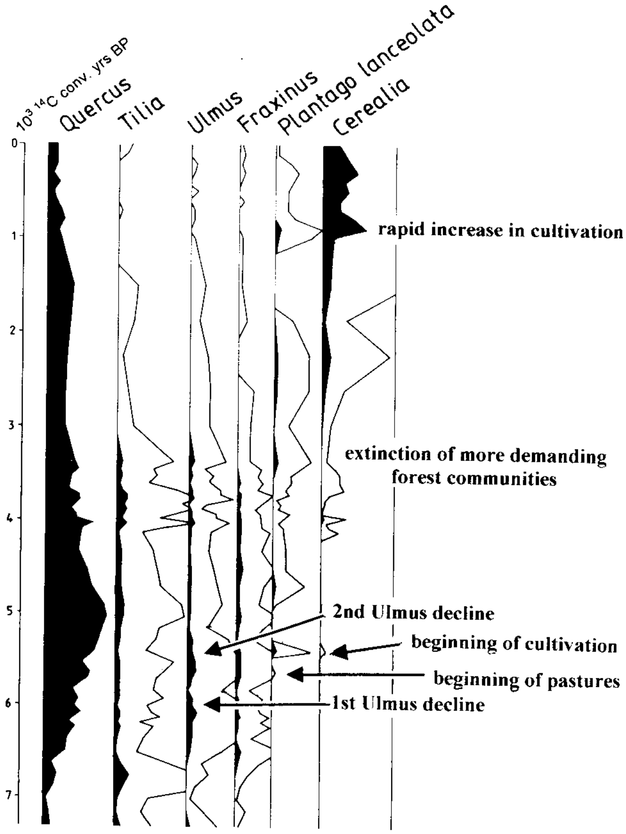

Fig. 14. Selected events resulting from human impact recorded in the Wolin II profile

WETLANDS

The Wolin II macrofossil diagram supplemented by some of palynological data (Fig. 15) illustrates the history of wetlands, which spread along the Dziwna river close to the town. At this site organogenic deposits started to fill the low-lying areas around 7320±520 ^{14}C conv. years BP [ca. 6150 ^{14}C cal. years BC].

On the inundated ground, vegetation dominated by *Thelypteris palustris* spread initially (phase 1). Alder swamps in the vicinity of the site also gained in importance (Fig. 5, W_{II}-1). As a result of a further increase in the water level (phase 2) after 6340±70 ^{14}C conv. years BP [ca. 5230 ^{14}C cal. years BC] *Cladium mariscus* invaded the area; the presence of *Atriplex prostrata* subsp. *prostrata* is probably linked with saline waters being able to reach the site.

The phase with *Cladium* dominance came to an end at 5860±110 ^{14}C conv. years BP [ca. 4680 ^{14}C cal. years BC], when *Thelypteris palustris* spread again, probably as a result of the lower water level on the mire surface, with

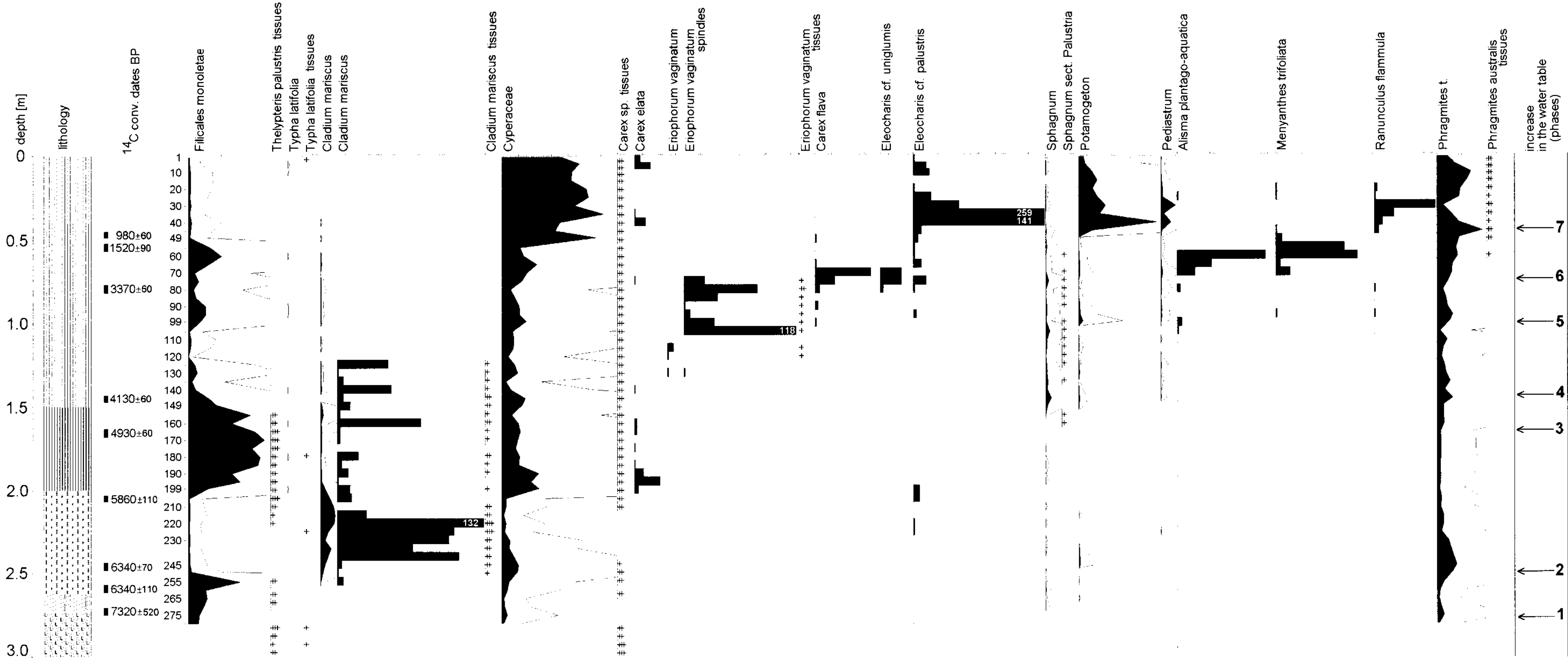

Fig. 15. Selected pollen (curves) and macrofossil (bars) data illustrating succession of the local vegetational and hydrological changes at the Wolin II site; lithology: see explanation in Fig. 7

respect to the previous phase. However, this does not necessarily mean a general lowering of the water level in the area, but most probably the effect of relatively high peat accumulation rate at the site. Both species coexisted up to about 3900 ^{14}C conv. years BP, and during this period only slight changes in the water level occurred. It seems that in the period between 5860±110–4930±60 ^{14}C conv. years BP the water level on the mire surface was rather stable. At 4930±60 ^{14}C conv. years BP [ca. 3670 ^{14}C cal. years BC] a slight input of water probably took place, and caused the renewed spread of *Cladium mariscus* and a gradual decline in the role played by *Thelypteris palustris* (phase 3). After 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*), which caused the appearance of shallow open water, probably limited in area (phase 4). At the end of this phase large numbers of sclerotia of *Coenococcum geophilum* appear (soil erosion), coinciding with an increase in the pollen curves for cereals (Fig. 5).

The further succession of the local vegetation is rather surprising. It indicates clear change in the pH conditions on the mire which enabled *Eriophorum vaginatum* to spread (phase 5) in the period from ca. 3600* to 3370±60 ^{14}C conv. years BP [ca. 1590 ^{14}C cal. years BC]. A possible explanation for the acidification of the mire is based on evidence of the 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* sclerotia, *Calluna* flowers and seeds (Fig. 7) as well as *Calluna* pollen (Fig. 5) showing corrosion typical of redeposited material. This suggests the input of acid drainage water from the catchment which could influence the pH on the mire surface.

The rise in the water level at ca. 2750* ^{14}C conv. years BP was followed by an increase in trophic level and in pH on the mire (phase 6). An open body of water 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 type of vegetation was probably dominant here up to 980±60 ^{14}C conv. years BP [ca. 1130 ^{14}C cal. years AD], when a new increase in the water table took place (phase 7). The great number of *Potamogeton* pollen grains and significant presence of *Pediastrum* indicate reappearance of the open water surface.

A preliminary reconstruction of hydrological changes at this site has already been carried out (Latałowa 1992a, Latałowa in print) exclusively on the basis of the pollen content. However, the new data obtained from the macrofossil analyses enable a better understanding of hydrological processes, as expressed by the succession of local vegetation. These new data help to define more accurately some of the earlier statements.

The inundation of this area at about 7320±520 ^{14}C conv. years BP probably resulted from the first phase of the Littorina transgression in the Southern Baltic. This is suggested by the coincidence of the ^{14}C date for the basal part of the peat deposit and dating of particular phases in the development of Szczecin Lagoon (Wypych 1980) as well as the general estimation of the age of marine transgressions in the area (Kotliński 1991, Tomczak 1995). A further rise in water level took place at 6340±110 ^{14}C conv. years BP. In this case it is not easy to indicate one general cause of this event. A large-scale forest fire in the immediate vicinity of the site, documented on the basis of the charcoal content in the sediments and illustrated by pollen analysis, could have resulted in a short-term rise in the water level (peak of *Potamogeton* pollen ?). However, it also coincides with a further increase in sea level (a date of ca. 6330 ^{14}C conv. years BP is for example specified by 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 in the mire was initiated by deforestation, the further maintenance of the high water level on its surface under conditions giving a rapidly growing peat deposit, should be explained by general increase in the water table in the area (the influence of the Littorina transgression ?). This process probably declined or stopped at about 5860±110 ^{14}C conv. years BP. This phase, as a whole, can be correlated with the Kluki-1 (7300–5850 ^{14}C conv. years BP) Littorina transgression phase described by Tobolski (1987).

The subsequent increase in the water table, which took place at around 4930±60 ^{14}C conv. years BP, caused a gradual decline in the participation of *Thelypteris palustris* suppressed by *Cladium mariscus.* This phase probably correlates with the Kluki-3 (5000–4500 ^{14}C conv. years BP) Littorina transgression phase characterised by Tobolski (as above).

The hydrological changes in the period from 4130±110 – ca. 2750* ^{14}C conv. years BP could be, at least partly, the product of 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.

The new appearance of a shallow, open body of water at this site cannot be dated accurately because of the very low peat accumulation rate in the relevant part of the profile, but it happened at approximately 2750* ^{14}C conv. years BP. It is also difficult to demonstrate one cause of this event. In this period a general increase in the water table in lakes and mires linked with climatic change is observed (Ralska-Jasiewiczowa & Starkel 1988, van Geel & Renssen 1998). However, in the light of the uncertain chronostratigraphy for 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 Tobolski (1987) to 2100–1700 ^{14}C conv. years BP and that it once again reflects the influence of hydrological changes at the southern Baltic coast.

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 in the Southern Baltic.

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 (Fig. 5) as well as the constant presence of charcoal particles in the peat deposit (Latałowa 1992a) and the presence of even larger charcoal fragments (Fig. 7) indicate that this area has been 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 the activity of Ertebølle tribes. This hypothesis has been presented in earlier papers (Latałowa 1992a, 1994) and will probably be confirmed by recent archaeological data; in 1998, in the course of earthworks in the Dziwna valley, tools of a "proto-neolithic character" (the Ertebølle culture?) were discovered[3]. At that time people regularly induced burning in the woodland, probably to facilitate hunting and, perhaps, to enrich the undergrowth which was a source of fodder for herds of wild animals. As was described earlier, this kind of management caused thinning of the forests 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. 3670 ^{14}C cal. years BC] people of the Ertebølle culture continued the earlier type of forest management on light, sandy soils, resulting in further destruction of woodland. Probably at that time new forms of economy started to develop. The gathering of leaf fodder could have provoked the two subsequent elm, ash and lime declines, which are evident in this phase. Peaks in *Plantago lanceolata*, which suggests the presence of tiny pastures, also show the beginning of animal husbandry. The first slight evidence of cereal cultivation appears at the end of this period. This evidence of agriculture, distinctly earlier than the development of the typical Neolithic culture (the Funnel Beaker culture) in this area, is especially interesting. It has been discussed in more detail in Latałowa (1992a, 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, the 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 evident in the Wolin II diagram could have been of special importance for the feeding of sheep and

[3] Oral information presented with permision of K. Kruk, the Director of the Archaeological Museum in Wolin.

goats. Cultivation was of minor importance. *Triticum* and *Hordeum* were used in the Funnel Beaker settlement, which developed directly in the area now occupied by the town of Wolin. This is confirmed both by pollen analysis (Fig. 5) and macrofossil data (Klichowska 1967a). Two pollen grains of *Secale* found in the Wolin II profile probably represent rye as a weed. On the basis of the 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 coppiced woods on a large scale (Latałowa 1992a).

The human pressure on the natural environment increased rapidly in connection with the middle and especially the late Bronze Age and the beginning of the Iron Age, i.e. with development of the Lusatian culture. Unfortunately this period is poorly 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 (Fig. 5) that it was a time of continued increase in farming activity. Both crop cultivation and animal husbandry were intensive. The best palynological information for this period comes from the pollen data from the north of Wolin Island (Latałowa 1992a). These data indicate that a considerable opening up of the landscape took place during this period, resulting in increased soil erosion. In places, the extent of deforestation in the late Lusatian culture was probably comparable to that of early medieval times. Slash-and-burn cultivation continued during this period, but other cultivation methods were probably also developed. A pollen diagram from Kołczewo suggests that the presence of more permanent fields cannot be excluded especially in the close vicinity of settlements. Presumably, at least some of these fields were manured (Latałowa 1992a, 1994). The archaeobotanical data (Klichowska 1967a, b) from two sites located within the present-day town of Wolin indicate that the Lusatian people grew cereals (*Panicum miliaceum, Triticum aestivum, Hordeum vulgare*) and pulses (*Vicia faba, Pisum sativum*). Two imprints of *Secale cereale* grains should probably be interpreted as showing the presence of weed rye.

The later part of the Iron Age is poorly illustrated in the Wolin II diagram for the same reason as was the case with the Lusatian culture. Some information can, however, be inferred from the pollen data from the north of the Island. During this period human impact declined in the area, however at a reduced number of settlements cultivation increased in importance. The course of the pollen curves suggests the presence of shifting fields. In the Pre-Roman Iron Age (Jastorf culture) animal husbandry was more important than crop cultivation. The role of arable farming increased in the Roman Iron Age (Gustow group). At that time the sowing of rye as a separate crop was introduced (Latałowa 1992a).

During the Migration Period a general decline in settlement occurred, but the economic recession was not expressed uniformly over the whole area. A total extinction of settlement took place on the morainic part of the island around the 5–7th century, but according to Filipowiak (1986, 1988) a small settlement probably survived in the vicinity of the Dziwna crossing. During that time woodland recovered over large areas of the island. In the northern, morainic part of this area mainly beech forests spread, while on lighter soils pine and mixed oak-pine forests developed. Alder invaded damp, organogenic soils (Latałowa 1992a, 1997b).

THE ECONOMY OF THE EARLY MEDIEVAL WOLIN AS REFLECTED BY PALAEOECOLOGICAL DATA

The data discussed in this chapter are a combination of botanical information elaborated by the present author with that included in several earlier publications by Klichowska (1961, 1964, 1966 1967a, b) and Alsleben (1995). Details concerning the occurrence of particular species in the fossil material dated to the earlier (9th–10th century) and the later (11th–12th century) phases of the early medieval period compared with their presence in the recent vegetation of Wolin Island are presented in the Appendix.

Changes in the natural environment due to economic activity are illustrated in both pollen diagrams presented in this paper (Fig. 5, 6) as well as in the pollen diagrams from the morainic part of the island (Latałowa 1992a). These more distant areas were densely inhabited at that time (Filipowiak 1973) and certainly constituted an important economic base and source of raw material for the town.

The development of the early medieval town and of numerous rural settlements, which appeared on the island and in its immediate neighbourhood, resulted in large-scale environmental changes. The extension of agricultural areas is illustrated by the decline in the pollen curves of trees and the concurrent substantial increase in pollen of cultivated plants, field weeds and plants typical of meadows and pastures (Fig. 5 and Latałowa 1992a). The intensity of the land use caused soil impoverishment and erosion. These are reflected in the palaeoecological data by the increasing input of mineral matter into lake sediments and gradually decreasing content of calcium carbonate in this inwashed material (Lake Racze). In the pollen diagrams evidence for the spread of poor dry grasslands and heath instead of more fertile meadows and pastures is present (Latałowa 1992a).

EXPLOITATION OF NATURAL RESOURCES AND GATHERING OF PLANTS

The multi-functional town with its diverse handicrafts, boat building, large port and high standard of living created a demand for timber. In Wolin the main building material for the construction of the wharf and for ships, as well as some houses, was oak. Smaller objects were made of different woods, including those species which, according to the pollen data, would probably have been very rare in the area. For example, some of cult statuettes found in the temple were produced from yew (Filipowiak, Gundlach 1992). Bark and charred wood of pine (*Pinus sylvestris*), bast of willow (*Salix cinerea*) and bark of birch (*Betula* sp.) were also found in archaeobotanical samples by Klichowska (1961).

Large numbers of species, especially those producing nuts and edible fleshy fruits, were gathered from woodland to supply food resources. Some of these are present in the subfossil material from the culture layers. *Corylus avellana* nutshells belong to the most frequent, especially in the samples from the 9th and 10th centuries. Fruits of *Sorbus aucuparia*, *S.* cf. *torminalis*, *Viburnum opulus*, *Vaccinium myrtillus* and *V. vitis-idaea* were also collected. Numerous remains come from species typical of forest margins, clearings and glades: *Fragaria vesca*, *Rubus idaeus*, *R. fruticosus*-type, *R. saxatilis*, *R. caesius* and *Sambucus nigra*, *Prunus spinosa*; their abundant presence points to the wide distribution of habitats such as these on Wolin Island. Fruits of beech and oak (present in archaeobotanical samples) were certainly used to feed domestic animals, especially pigs, which were very important in early medieval Wolin (Filipowiak & Gundlach 1992). Records of cones and seeds of *Pinus sylvestris* may indicate their gathering. Pine seeds are rich in oils and ethnographic sources show that they have been used for human food and as fodder for domestic animals (Maurizio 1926); no evidence of the use of pine bark to produce bread (cf. Hansson 1995) is known from Wolin or from other Polish sites studied so far. Twigs and leaves of some species were collected as animal fodder. Leaves of *Quercus petraea*, *Acer* sp. and *Salix* sp. were recorded in the archaeobotanical samples by Klichowska (1961). Probably herds of domestic animals were pastured in open woodlands.

The beginning of early medieval deforestation in the close vicinity of the town of Wolin cannot be dated accurately because of the extremely low peat accumulation rate (or a hiatus?) in the relevant section of the Wolin II profile. On the morainic part of the Island deforestation started at about 1300±60 ^{14}C conv. years BP [ca. 790 ^{14}C cal. AD] and then, around 1000 years ago, large areas had already been entirely cleared of forest. During this period all the woodlands were destroyed, even the alder swamps which hitherto had been little affected. These data are in accordance with those presented in the Wolin I profile, where tree pollen decreases from ca. 80% to below 30% in the pollen spectra from culture layers dated to the 9th and to 9/10th century[4]. At that time most of tree species were intensively exploited, resulting in their gradual decline. The deforested areas were converted into arable fields and open grazed land. Among numerous taxa identified in the fossil material, those typical of meadows and pastures on different habitats, are of great im-

[4] It should be stressed that pollen data from culture layers are of a different character from those from lakes and mires and should be interpreted with special caution.

portance. Species characteristic of wetlands and wet or moist meadows are the most numerous. Several species of sedges (e.g. *Carex nigra*, *C. flava/oederi*, *C. rostrata*), *Scirpus sylvaticus*, *Lycopus europaeus*, *Filipendula ulmaria*, *Molinia caerulea*, *Ranunculus sardous* and *Lychnis flos-cuculi* belong to the most frequent. Fossil remains of plants growing mostly in fresh meadows and pastures are not so common, showing that this kind of vegetation was of minor importance in the vicinity of the town. Only *Potentilla erecta*, *Prunella vulgaris* and *Ranunculus acris* are represented by more numerous finds. Also dry grasslands, although certainly restricted in area, were used for grazing domestic animals, as confirmed by the presence of *Cerastium arvense*, *Stachys recta*, *Potentilla argentea*, *Petrorhagia prolifera* and *Dianthus deltoides*.

Different types of natural or seminatural vegetation were exploited through the aquisition of useful plants. The list of subfossil taxa from early medieval Wolin contains numerous species used as food and medicine, spices, famine food or for technical purposes. However, only a small number of them are present in cultural layers in a context suggesting intentional gathering. Most of them have been mentioned above as having been collected in woodlands. According to the present author, gathering of the only two other species found in Wolin has been proved by the archaeobotanical evidence: *Trapa natans* and *Iris pseudacorus*.

Trapa natans is known as one of the most important prehistoric and historic food plants. Roasted or dried nuts were ground and used for bread or pies (Kluk 1808, Maurizio 1926). Klichowska (1966) and Alsleben (1995) found only four fragments of nuts, but the presence of large diaspores of this aquatic plant within the territory of the town cannot be accidental. This species belongs to the extinct elements in the flora of Wolin Island.

Iris pseudacorus is known as medicinal plant, moreover the yellow pigment from the flowers and the black from the rhizomes were used in dyeing (Kluk 1808). In addition to single finds, accumulations of seeds and fragments of capsules of this plant were found in 17 samples by Klichowska (1961); Filipowiak and Gundlach (1992) mention that some of the fragments of woollen textiles found in Wolin were probably originally yellow in colour.

CULTIVATED PLANTS

The archaeobotanical data presented in this paper, as well as in the earlier work of Klichowska (1961, 1964, 1967a, b) and Alsleben (1995), afford rich information especially on some aspects of agriculture and utilisation of vegetable foods and technical plants in early medieval Wolin.

In the earlier phase of the early medieval period (9th–10th century) millet (*Panicum miliaceum*), rye (*Secale cereale*), bread wheat (*Triticum aestivum* s.l.) and hulled barley (*Hordeum vulgare* subsp. *vulgare*) were important cereals, though Klichowska (1961) and Alsleben (1995) have differing opinions on the role played by particular cereal species. According to Klichowska millet and barley were the most important, while Alsleben underlines the dominant role of rye. No support for the arguments on this topic is given by the macrofossil content of the Wolin I profile, where only uncharred glumes of millet are present in abundance, while in the absence of charred material, remains of other cereals are virtually lacking[5].

It is usually very difficult to draw any reliable conclusions regarding relative proportions of particular plant species cultivated in a given area on the basis of archaeobotanical samples. This is especially so with regard to species which are all either abundantly present in the subfossil material, or on the contrary, are present as small numbers of diaspores. There are various factors influencing this aspect of archaeobotanical data. Firstly, if comparing uncharred and charred material, selective decomposition should be taken into account (Körber-Grohne 1991). This favours, for example, glumes of millet in uncharred samples and grains of other cereals in charred ones. Different methods of grain storage, often dependant on its subsequent destination (e.g. meal, groats, malt, animal fodder, seed corn), are also of great importance. Moreover, the composition of botanical remains depends on the type and former function of the archaeological object (e.g. house, storage place, cesspit, etc.). The hazardous nature of archaeobotanical data is certainly diminished with reason-

[5] The results of analyses for the presence of bran material (cf. Dickson 1987 or Robinson et al. 1992) were also negative.

able increases in the number of samples and objects analysed. According to the present author, the latter two statements are of crucial importance in resolving the controversy regarding “the most important cereal” in early medieval Wolin.

Klichowska analysed ca. 900 samples (of unknown volume and weight) covering the period from the 9th to the 14th century and coming from different objects, mainly in the central part of the town, while Alsleben investigated 72 samples of the same age (0.6–1200 g in weight) from the two very specific places: the temple and the port. With regard to the period under discussion (9th–10th century), *Panicum miliaceum* remains are certainly the most frequent and the most numerous. Klichowska found large accumulations of millet in 448 samples coming from only one archaeological trench, while remains of rye were present in 30 samples and those of barley in 33 samples. The raw number of barley grains exceeds that of rye by ca. 25%. In the 27 samples of the same age analysed by Alsleben, millet was present in 23 samples, in 6 samples it dominated absolutely and in 14 it was an important constituent. Rye was present in all 27 samples and in 17 it dominated absolutely. Barley was an unimportant admixture in 24 samples.

The above results are a fairly good example illustrating the dependence of the botanical composition of the archaeological material on the function a particular place had in the past. They also underline that general conclusions concerning the role of a particular cultivated species in the people’s diet or the agrarian system in an area, cannot be drawn on the basis of data coming from the “exceptional” objects or places. In the publication by Alsleben all charred archaeobotanical material dating from the 9th–10th century (with the exception of one sample) comes from the temple, which certainly constitutes an “exceptional” object. The one remaining sample, representing storage grain found in the port, is also of atypical composition: it comprises a mixture of different cereals (rye, wheat, oat and a small admixture of barley) excluding millet.

The archaeobotanical data indicate that in the earlier 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 one. It is difficult to accept the conclusion presented by Alsleben (1995, p. 197) that *Secale cereale* was the leading cereal crop in the 9th century in Wolin. Another remark made by the same author (p. 197) is more reliable. It says, that the archaeobotanical material illustrates differences between food used in ordinary houses in the town (mostly in form of porridge or pie of millet and barley) and that used in the temple (bread). A further argument against the dominant role of *Secale* is provided by the pollen diagrams. Usually palynological data give only limited information on the full richness of a cultivated species. Many of them are not identifiable by their pollen, others are characterised by very low pollen production and/or dispersal. In the Wolin I profile (Fig. 6), pollen curves of Cerealia-type, *Triticum*-type and *Secale* are present. The poor state of pollen preservation precludes the possibility of more precise pollen identification for cereals with the exception of Secale. According to palynological data it seems that *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 relevant sections of the pollen diagrams from the Wolin II site and from Lake Racze (Latałowa 1992a). Considering the much greater pollen production by rye with respect to other cereals and the much better pollen dispersal of this wind pollinated cereal species, such proportions suggest its minor role in cultivated fields.

In addition to the main cereals mentioned above, bread wheat *Triticum aestivum* s.l., emmer *T. dicoccon,* spelt *T. spelta* and oat *Avena sativa* were cultivated in the 9th–10th century at Wolin. With the exception of remains of *Triticum aestivum* s.l., which appear in greater numbers in the 10th century (especially at its conclusion), the other species probably played an insignificant role. On the basis of her own results, Alsleben suggests that winter sowing of spelt was practised at that time. Both authors indicate the presence of clubwheat (*Triticum compactum* Host – according to Klichowska and *T. aestivum* grex *aestivo-compactum* – according to Alsleben) within the *T. aestivum* s.l. complex.

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, hemp *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. Alsleben suggests the existence of a little garden in the area occupied by temple, where she found a large accumulation of unripe hop fruitlets.

The presence of a rather large quantity of seeds of *Brassica rapa* in the uncharred material from the Wolin I profile (Fig. 10) is worthy of note. Their number clearly increases from the 9th to the end of the 10th century. In the paper by Alsleben only *B. nigra/rapa* or *Brassica* sp. were distinguished and the first of these has been classified as a segetal weed of summer cultivation. *Brassica rapa* certainly belongs to those plants, which are known as weeds in fields or ruderal habitats. However, it is also mentioned among cultivated plants occurring at Polish archaeological sites since the Hallstatt period (Wasylikowa 1984, Wasylikowa et al. 1991). It could have been cultivated for oil or as a vegetable (Kluk 1805, Maurizio 1926).

Pulses recorded both as macrofossils and/or as pollen – *Vicia faba, Lens culinaris*, *Vicia sativa*-type and *Pisum sativum* were found in small numbers. Single diaspores or only a few specimens represent other species, which could have been cultivated for food, such as *Fagopyrum esculentum, Apium graveolens, Anethum graveolens, Pastinaca sativa* and *Papaver somniferum.* Some of them belong to the indigenous flora of Wolin (*Apium graveolens*[6], *Pastinaca sativa*[7]) and, especially in cases where fossil remains are scarce, can represent wild forms. Small numbers of diaspores of *Camelina sativa*, *Spergula sativa* and *Setaria italica* probably come from plants being weeds in other cultivated crops.

A separate group is that of fruit trees. Remains of this category, however, are not numerous; *Prunus domestica, P. insititia, Cerasus vulgaris, C. avium, Malus* sp. and *Pyrus communis* should be mentioned here, although fruits of the latter three species could also have been collected from the wild. It is remarkable that the frequency as well as the number of fruit remains clearly increases towards the end of the 10th century.

With regard to the archaeobotanical data for cultivated plants based on the samples dated to the later phase of the early medieval period (11th–12th century) relative to the information concerning the earlier phase (characterised above), only few differences can be demonstrated. 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 is the lower participation of barley and the increasing role of rye in the later period. The role of millet probably also slightly decreases in comparison with the previous phase. Two species, *Daucus carota* and *Petroselinum crispum*, appear for the first time in the samples dated to the 10th/11th century. Although *Daucus carota* is a native element, characteristic of fresh meadows, the rather large accumulation of its fruits in one of the samples (27 specimens – Alsleben 1995) suggests that we are probably dealing here with the cultivated plant.

AGRICULTURE IN THE LIGHT OF THE SPECIES COMPOSITION OF FOSSIL WEEDS AND THE PROBLEM OF THE ORIGIN OF SOME CROP REMAINS

The archaeobotanical material from early medieval Wolin illustrates a rich weed flora typical of arable land. Only samples investigated by Klichowska afford very scanty data on weeds, certainly a consequence of the methods used forty-fifty years ago. Pollen diagrams from the sites of Wolin I, Wolin II (this paper) and Lake Racze (Latałowa 1992a) supply complementary information.

The use of finds of subfossil weeds to reconstruct former agriculture (Wasylikowa 1981, Jones 1988, Behre & Jacomet 1991) belongs to the most thoroughly discussed problems in the archaeobotanical literature. Information on different tilling procedures (Jones 1988), rotation systems (Karg 1995) as well as harvesting (Hillman 1981, Engelmark 1989), processing (Hillman 1981, Engelmark 1989, Henriksen & Robinson 1996) and storage (Alsleben 1995)

6 Element of halophilous vegetation; its present natural eastern range crosses the island of Uznam, bordering to the east with Wolin Island (Piotrowska 1966a).

7 Element of fresh meadows.

of crops can be gained from archaeobotanical data. One of the most important problems concerns the use of data regarding the ecological properties and requirements of present-day weeds and, particularly, of weed communities, in the reconstruction of processes which took place in the past (Behre & Jacomet 1991, Küster 1991).

Several questions should be answered before undertaking an interpretation of the subfossil material in terms of the problems specified above. One of them, which is particularly important for the reconstruction of past weed communities, refers to different natural and anthropogenic processes which bring about selective reduction of diaspores at a site (Engelmark 1989). Another concerns the origin of an archaeobotanical sample: is it a palaeobiocenose, i.e. an assemblage of fossil remains of plants which in the past grew in the same field and composed the same community, or a thanatocenose, i.e. a mixture of elements from different vegetation types, mostly of accidental character ? (Willerding 1979).

Palaeobiocenoses, which have the greatest potential when reconstructing past vegetation, are relatively rare among archaeobotanical materials. Those referring to ancient crops have been described for example by Wasylikowa (Szydłowski & Wasylikowa 1973), Wieserowa (1967), Karg (1995), Henriksen and Robinson (1997), Kroll (1987) and others. In recent years this kind of data has also been reported from archaeological sites in the Polish coastal area (Badura 1998, Latałowa 1998b). It should be stressed, however, that if palaeobiocenoses give an opportunity to investigate details concerning a particular crop, the large number of samples representing thanatocenoses (weed remains dispersed in culture layers) offer general information on segetal communities and their habitats in the area studied (e.g. Wasylikowa 1978, 1991, Behre 1983, 1991).

With regard to the archaeobotanical material from early medieval Wolin, only some of samples investigated by Alsleben (1995) seem to fulfil the approximate requirements for a palaeobiocenose. Most of the material, including all the samples from the Wolin I profile, represents thanatocenoses.

Certainly, the most precise data on weed floras associated with particular crops are those produced by Alsleben. Nonetheless, selective reduction of diaspores probably occurred in this material, especially in the samples of charred grain (Alsleben 1995). In these samples, species such as for example *Rumex acetosella* and *Spergula arvensis* are either totally absent or present as very low numbers of diaspores.

Species composition and the abundance of diaspores of characteristic weeds indicate that specific segetal communities were well developed already in the 9th century. In the samples of rye, as well as in mixtures of rye with other cereals, *Agrostemma githago* and *Bromus secalinus* are best represented. *Vicia hirsuta*, *V. angustifolia*, *Anthemis arvensis*, *Fallopia convolvulus*, *Galium spurium* and *Lithospermum arvense* are also rather frequent and in some of samples occur in good numbers. In the samples of charred grain a small number of fruits and one inflorescence of *Centaurea cyanus* were found. The above data show the presence of fully developed segetal communities typical of winter cereals. In all of these samples *Chenopodium album*, *Polygonum lapathifolium*, *P. persicaria*-type, *Setaria pumila*, *S. viridis* and *Echinochloa crus-galli* are regularly present, but usually in relatively low numbers.

In the samples of millet, diaspores of *Chenopodium album*, *Setaria pumila*, *S. viridis*, *Echinochloa crus-galli*, *Polygonum lapathifolium*, *Fallopia convolvulus*, *Rumex acetosella* and *Spergula arvensis* belong to the most numerous. This indicates the presence of a weed community similar to that developing in recent root crops and millet cultures (Panico-Setarion alliance).

All samples in which flax remains appear in greater numbers are distinguished by the presence of the "linicolous weed" *Spergula arvensis* subsp. *maxima*. *Galium spurium* and *Camelina sativa* also occur in significant numbers. *Lolium remotum* and *Silene gallica* were recorded in single samples. The presence of the above species indicates the development of a specific flax weed community classified today to the Lolio-Linion.

The numerous remains of weeds dispersed in culture layers of the port (Wolin I profile) are of a different character. Traces of cultivated plants (with the exception of millet and hop) are scarce or absent, but the earlier presence of crop material at the site is demonstrated alone by the abundance of diaspores of segetal plants.

In the profile as a whole, species which are usually common in fields of millet and root crops are best represented (*Chenopodium album*, *Polygonum lapathifolium* subsp. *pallidum*). Unfortunately, these two weeds are of relatively low indicator value with respect to the type of cultivation in which they could spread; they also grow in a range of different natural and anthropogenic nitrophilous habitats. A portion of their diaspores present in the Wolin port deposit comes, with certainty, from ruderal vegetation. Some of species in this group are scarce in the samples dated to the 9th century but appear in great numbers in the layers of the 10th century (*Setaria pumila*, *S. viridis / verticillata*, *Echinochloa crus-galli* and *Thlaspi arvense*). As remains of *Panicum miliaceum* are substantial constituents of the subfossil material, the above weeds probably come mostly from fields of millet. This suggestion is proved by the data on the botanical composition of samples of millet grain described by Alsleben (1995).

A group of species represents weeds which are most common in cereals and flax, some of them almost exclusively in winter-sown cereals or flax. *Rumex acetosella*, *Melandrium album*, *Fallopia convolvulus*, *Viola arvensis / tricolor* and *Galeopsis tetrahit*-type belong to the most frequent and numerous of these weeds. All these species can infest different cereals, in addition to root crops and millet, and for this reason they are of low indicative value with respect to the reconstruction of the type of cultivation. *Agrostemma githago*, *Galeopsis ladanum*, *Scleranthus annuus* and *Papaver argemone* are species typical of winter-sown crops. Generally their role increases towards the top of the profile, i. e. in the culture layers dated to the 10th century. The total lack of both macroremains and pollen of *Centaurea cyanus* in the profile is worthy of note. At some levels species typical of flax fields appear in significant numbers (*Spergula arvensis* subsp. *maxima*, *Galium spurium* and *Silene gallica*) indicating presence of flax material at the site in the 9th and 10th centuries, though flax seeds are scarce or absent in the samples taken from the Wolin I profile.

Generally speaking, the subfossil weed flora described by Alsleben and that present in the Wolin I profile are very similar. The similarities are distinct not only at the level of the most common taxa, but also several rare elements were recorded in both sets of material, for example species classified today to the Caucalidion alliance.

According to the ecological spectrum of the weeds present, millet was cultivated on fresh, light sandy-clayey soils, moderately acid, well supplied with nitrogen, meaning that the soil was manured. A similar soil type was used for flax. Both crops were therefore cultivated in accordance with their edaphic requirements (Herse 1982).

Weeds characteristic of other cultivation types are much more diverse with respect to the soil on which they usually grow. Most species are typical of mesotrophic/eutrophic, moderately acid soils, i.e. soils which are widely distributed on Wolin Island. The striking feature of the species composition of the samples in the Wolin I profile are the relatively high values for *Rumex acetosella*[8], indicating that poor, acid soils were also cultivated. These soils types are also common on Wolin Island.

The presence of several weed species typical of fertile calcareous soils is especially interesting. Most of them have been recorded both in the material investigated by Alsleben and in the Wolin I profile (Tab. 6, Fig. 7), while because of the lack of the appropriate habitats, they do not occur in the present-day flora of Wolin Island, or at least some of them are known from single, mostly historical (no longer existing) localities. Because of the special importance of these species, they are characterised below.

***Adonis* sp.** Alsleben identified two fruits of this genus in one sample containing a mixture of different cereals, dated to the 10th century. Three species can be taken into consideration: *A. aestivalis* L., *A. flammea* Jacq. and *A. vernalis* L. All these species are thermophilous and calciphilous (Zarzycki 1984) and have been never found on Wolin Island (Piotrowska 1966a). In the Polish flora *A. aestivalis* and *A. flammea* are archaeophytes (Zając & Zając 1975). They are old weeds occurring in segetal communities classified to the Caucalidion alliance (Zarzycki 1984). *A. vernalis* is a rare now protected plant, which occurs in calciphilous dry grasslands, mainly in southern Poland (Zając & Zając 1997).

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[8] In the Wolin I profile most of *Rumex acetosella* fruits certainly originate from plants growing as weeds, because dry swards and heath are generally poorly represented in the material.

***Aethusa cynapium* L.** Alsleben found one fruit in a sample of mixed cereals dated to the 10th/11th century. Another fruit was found in the Wolin I profile in a sample dated to the 10th century. *A. cynapium* L. includes two subspecies, which should be taken into consideration: *A. cynapium* subsp. *agrestis* (Wallr.) Dostál, a segetal plant and *A. cynapium* subsp. *cynapium* (Wallr.) Dostál, a ruderal plant (Koczwara 1960); they are indistinguishable by their fruits. *A. cynapium* is a calciphilous plant (Zarzycki 1984). *A. cynapium* subsp. *agrestis* represents the Caucalidion alliance and has been never recorded on Wolin Island, while *A. c.* subsp. *cynapium* is present at single localities (Piotrowska 1966a).

***Bunias orientalis* L.** A half of a fruit and two seeds with remnants of the inner layer of the pericarp were found in the Wolin I profile in culture layers dated to the 9th/10th and 10th century. It is a calciphilous plant (Zarzycki 1984) occurring mainly on ruderal habitats but also on fields and meadows (Sychowa 1985). In the Polish flora it has been classified as a kenophyte, i.e. anthropophyte, which appeared in Polish territory in modern times, after the end of the 15th century (Kornaś 1968). Its expansion from the southeast can be observed in the Polish flora since the 19th century (Sudnik-Wójcikowska 1998), but it has been never found on Wolin Island (Piotrowska 1966a). It should be stressed that the archaeobotanical data may change previous opinions regarding the status of *Bunias orientalis* in the flora of Poland. The first record of this species has been described by Klichowska (1955, 1972) from a medieval locality in Central Poland, where in two archaeological features, a well and a storage place (?) she found 35 fruits. Two seeds were recently found in culture layers at medieval Elbląg (Jarosińska 1999). On the other hand, all of these fossil records could derive from foreign material transported from distant areas to these sites and not from plants growing in the area. This interpretation is accepted by the present author to explain the presence of *Bunias orientalis* in archaeobotanical samples from early medieval Wolin.

***Bupleurum rotundifolium* L.** Three fruits in two samples dated to the 10th and 10th/11th century were described by Alsleben. This is a thermophilous and calciphilous plant (Zarzycki 1984) which has never been recorded in the present-day flora of Wolin (Piotrowska 1966a). Its nearest localities are in southern Poland, where patches of the most fertile calcareous soils (rendzinas) occur (Kornaś 1972). It is a characteristic species of the Caucalidion alliance.

***Galium spurium* L.** Numerous (333) fruits in 14 samples of charred grain (mainly rye) and uncharred flax and millet, dated to the 9th–12th centuries, were recorded by Alsleben. Three fruits in three samples are reported by Klichowska (1961), moreover, 59 fruits are present in 11 samples in the Wolin I profile. It includes two subspecies: *G. spurium* subsp. *infestum* (Waldst. & Kit.) Janch. and *G. spurium* subsp. *spurium* which are not distinguishable in the subfossil material. *G. spurium* subsp. *infestum* thrives in different agrocoenoses, but it is most characteristic of winter cereals, while *G. spurium* subsp. *spurium* is a flax weed. Both forms prefer soils well supplied with calcium carbonate, but they also occur on lighter soils (Tymrakiewicz 1959). *Galium spurium* has been never recorded in the recent flora of Wolin (Piotrowska 1966a).

***Lithospermum arvense* L.** 68 fruits in 11 samples (Alsleben 1995), 19 fruits in two samples (Klichowska 1961), and three fruits in three samples (Wolin I) dated to the 9th–12th centuries have been recorded from this species. This is a relatively thermophilous and calciphilous plant, but it is more tolerant with respect to both factors in comparison to other species of this group (Tymrakiewicz 1959); it grows mainly in winter cereals. This species is known in the recent flora of Wolin, but only from a few localities, mostly extinct (Piotrowska 1966a).

***Melandrium noctiflorum* (L.) Fr.** Five seeds in two samples (Alsleben 1995) and four seeds in three samples (Wolin I profile) dated from the 9th to 10th century were recorded in the culture layers of early medieval Wolin. This calciphilous plant, characteristic of the Caucalidion alliance (Wójcik 1978), has been not described from the present-day flora of Wolin (Piotrowska 1966a).

***Neslia paniculata* (L.) Desv.** Six fruits in four samples (Alsleben 1995) and nine fruits in eight samples (Wolin I profile) were recorded in culture layers dated to the 9th and 10th centuries. It is characteristic of calcareous soils (Caucalidion alliance), but it can also grow on basic soils with a lower content of calcium carbonate (Tymrakiewicz 1959, Wójcik 1978). It is a very rare element of the contemporary Wolin flora, known from three extinct localities (Lucas 1860 – after Piotrowska 1966a) and one recent (Nowiński 1964).

***Silene gallica* L.** Six seeds in one sample of uncharred remains of flax dated to the 9th century were recorded by Alsleben and 11 seeds in seven samples dated to the 9th and 10th centuries were found in culture layers in the Wolin I profile. This is mostly a calciphilous plant (Oberdorfer 1983) today characteristic of the *Geranio-Silenetum gallicae*, the association of weeds developing in winter cereals in submontane, Carpathian regions (Kornaś 1972). However, according to *Flora Europaea* (Tutin et al. 1964), *S. gallica* L. includes former *S. linophila* Rothm. a weed characteristic of flax cultures. In the archaeobotanical material from Wolin we are probably dealing with the flax weed. *S. gallica* (described as var. *sylvestris*) has been recorded by Lucas (1860) from one locality on Wolin Island – it grew as a weed in a garden (Piotrowska 1966a).

***Stachys annua* (L.) L.** Only one fruit was found in the Wolin I profile in a culture layer dated to the 9th/10th century. Three now extant localities for this calciphilous plant characteristic of the Caucalidion alliance (Wójcik 1978) are known from Wolin Island, where according to Piotrowska (1966a) it appeared as an ephemerophyte.

***Valerianella dentata* (L.) Poll.** Seven fruits in four samples (10th/11th and 12th century) were recorded by Alsleben and one fruit was found in the Wolin I profile in a culture layer dated to the 9th/10th century. It is a calciphilous plant characteristic of the Caucalidion alliance (Wójcik 1978). Only two former localities reported in 1860 by Lucas are quoted by Piotrowska (1966a).

Among the weed species **cf. *Legousia speculum-veneris* (L.) Chaix** found by Alsleben also belongs to the most interesting. The ecological character of this plant is different in comparison to that of the species presented above. It is a distinctly thermophilous and basiphilous weed (Ellenberg et al. 1992). It occurs mostly in southern and southeastern Europe (Tacik 1971). In the Polish flora it has the status of an ephemerophyte (Mirek et al. 1995).

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

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

2 – these species are evidence of the importing of cereals from more distant, warmer areas with fertile soils.

Regarding the first possibility, it is necessary to stress that all the conclusions arising from the comparison of archaeobotanical results with data on the recent geographical distribution and phytocenotic role of particular species should be drawn with special caution. Among the various factors, which are of the greatest significance in this particular case, changes in soil composition during the last millennium and the well-known process of extinction of several groups of weed species in recent times, especially those of the Caucalidion (Kornaś 1971), should be given a special mention here. On the other hand, it is known that field manuring changes soil properties and can result in the replacement of, for example, acidophilous weeds by neutrophilous ones (e.g. Kulp & Cordes 1986).

On Wolin Island and its neighbouring areas mineral soils developed mostly from sandy clays and clayey sands which were always rather poor in calcium carbonate. This is shown by the characteristic features of the vegetation which developed here during the whole of the Holocene (Latałowa 1992a). In this area only very small patches of better soil are present in the southwestern part where Cretaceous outcrops occur within the Pleistocene morainic formations. Generally speaking, it is difficult to imagine that in any time, even in 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 mentioned above, for example *Galium spurium*, *Lithospermum arvense* or at least *Neslia paniculata*, could grow in fields situated on the patches of better soil as a 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. Wrześnica (Latałowa 1999), Kołobrzeg (Badura in print b), Gdańsk (Latałowa et al. unpubl.), *Silene gallica* and *Galium spurium* (probably the relevant, specific subspecies) were relatively frequent in flax fields in the region. This suggests that their appearance in the palaeobotanical samples from Wolin could be from local origin. The presence of other species and especially *Bupleurum rotundifolium*, (?) *Legousia speculum-veneris* and *Bunias orientalis* points to the presence of imported grain.

The problem of whether the archaeobotanical data from early medieval Wolin indicate the importing of grain or not is a subject of controversy between the present author (Latałowa 1992b) and Alsleben (1995, p. 100, 108) who argues for the local origin of the investigated material. However, the inconsistencies in the argument are revealed, at least in part, when the same author suggests the Pyrzyce region, lying ca. 100 km south from Wolin and inhabited by a separate Slavonic tribe, as a source of supplementary agricultural products (Alsleben 1995, p. 100).

In the archaeobotanical samples several species typical of fertile, calcareous soils do actually occur. Their presence is not accidental as shown by the frequency and number of their diaspores. According to the present-day distribution of the relevant soil and vegetation types in Poland, it is clear that the nearest area from which crops infested with calciphilous weeds could come is the Pyrzyce region. The next question is whether all the mentioned species could grow in that region. Certainly most of them could, but the presence of others is rather doubtful. The fertile, calcareous soils of the Pyrzyce region belong to the heavy, badly aerated silty soils which developed on the area of a Pleistocene dammed lake. In this area *Melandrium noctiflorum, Neslia paniculata, Galium spurium and Lithospermum arvense* occur in the present-day segetal vegetation (Borowiec et al. 1977). Other species of this group, the most characteristic of the Caucalidion such as *Bupleurum rotundifolium*, *Stachys annua* and *Adonis* sp., require soil of a different structure, which is loose and well aerated (rendzinas); this soil type occurs exclusively in southern Poland (Kornaś 1972). The presence of (?) *Legousia speculum-veneris* and *Bunias orientalis* is even more doubtful, not only in the Pyrzyce region, but in Poland as a whole. These species suggest more distant trade with the south or south-east. It is also possible that single finds of diaspores of food plants such as *Petroselinum crispum*, *Fagopyrum esculentum* and *Coriandrum sativum,* found in samples of grain (Alsleben), are contamination indicating, together with the above weeds, the foreign origin of that grain and not the use of them as plant food in early medieval Wolin.

It is interesting to analyse the possible purposes of the grain trade to Wolin. It could be assumed (as suggested by Alsleben) that the ca. 8000 inhabitants of Wolin, as well as people in the numerous settlements in the surrounding area, used mainly local products, i.e. those produced on the island itself and in the large agricultural territory occupied by the Wolinian tribe (Filipowiak 1973). This is probably reflected by the data from the craftsmen's quarter in the town, where in dozens of archaeobotanical samples Klichowska (1961) found no calciphilous weeds with the exception of a few *Galium spurium* fruits and 18 fruits of *Lithospermum arvense*, concentrated in the one sample. It is hard to imagine that she could overlook large diaspores such as those of, for example, *Neslia paniculata* or *Bupleurum rotundifolium*.

It should be stressed that in the above respect, the material from the temple (Alsleben) and from the port (Alsleben and Wolin I profile) is of a special character. It is not so strange that in the temple, the best (imported?) grain was used in addition to that of local origin. In the port local, as well as "foreign", grain was traded and probably trans-shipped. There are archaeological data indicating intensive trade contacts between Wolin and territories along the Odra River valley (including fertile regions of Pyrzyce and the more distant Silesia) and the Viking settlements (Filipowiak & Gundlach 1992); some of trade routes extended further away to Central and Eastern Europe. According to the above authors, at that time some types of boats were adapted for the transportation of mass products, mainly iron and grain. Trade in cereal grain from the fertile territories of Central Europe to Northern Europe has been demonstrated by van Zeist for the Netherlands (van Zeist et al. 1987, van Zeist 1990). His data from Leeuwarden suggest that in the 9th–11th century foreign grain imports were even more common than in the subsequent 13th–15th century. The presence of imported grain is also suggested by some Scandinavian data (Helbaek 1975, Hjelmqvist 1979).

EXOTIC PLANTS IN EARLY MEDIEVAL WOLIN

Among plant material found in early medieval culture layers in Wolin, three exotic species were recorded. One uncharred fruit of coriander (cf. *Coriandrum sativum* L.) was found in a culture layer dated to the 10th/11th century, in a yard which belonged to the temple (Alsleben 1995). This aromatic plant is probably a native of the Mediterranean areas of Asia Minor and is one of the most common food flavourings used in the past; it was traded by the Romans (Zohary & Hopf 1988). It is not a frequent find in early medieval deposits from Central and Northern Europe; single finds are known, for example, from the Danish Viking Age (Jensen 1985). It appears to be much more numerous in the high medieval and later periods (e.g. Greig 1996). In the Polish material studied so far (Wasylikowa et al. 1991), coriander is known from the only one site (Gdańsk, 11th century), where several fruits were recorded (Mądalski 1952, Lechnicki et al. 1961).

One walnut shell (*Juglans regia* L.) was discovered by Klichowska (1961) in a culture layer dated to the second half of the 11th century. The earliest archaeobotanical records of this plant from Poland are from the late Roman period (i.e. the 2nd and the 3rd/4th century AD); two walnut shells bound by bronze (Klichowska 1971) and silver ribbons (Latałowa 1994) were found in women's graves at Pruszcz Gdański (N. Poland). Both finds certainly had the role of amulets and were of imported origin. Although archaeobotanical finds of this species are still not numerous from the early medieval period in Poland (Wasylikowa et al. 1991) walnuts certainly have been cultivated locally since at least the 10th century. This fact is supported by both pollen data and written sources. Several pollen grains of *Juglans regia* have been found in culture layers dated from the 9–10th to 11–12th century in Kraków (Wasylikowa 1978, 1991). On the other hand, in the chronicle written by Herbord (after Kiersnowscy 1970), the ancient historiographer who described the life of the Bishop Otto from Bamberg[9], the large, old walnut tree growing at the beginning of the 12th century at Szczecin (60 km south of Wolin) is mentioned. According to that author it had been held sacred by pagans and a monk had been lived under the tree to protect it from being cut down by Christians; the monk was fed on walnuts. It should be stressed, however, that in this area growing *Juglans regia* probably was something exceptional at that time. Most of early medieval walnut finds from Northern Europe, including those from the southern Baltic coast, probably come from long-distance trade.

In a book on early medieval Wolin the authors (Filipowiak & Gundlach 1992) present a beautiful picture (p. 106) of an uncharred seed and describe it as *Mucuna* Adans (p. 99). According to these authors it was found in a culture layer dated to the 12th century, located in archaeological trench no. 8 (port). The seed has apertures at both sides which indicates that it has been used as a necklace or amulet. The present author does not know any other find of this genus in European archaeobotanical material from any period; seeds of *M. elliptica* (Ruitz et Pav.) Dc. have been discovered in a pre-Columbian grave in Chile (Gunckel 1967). *Mucuna* is a representative of a tropical-subtropical genus of the Leguminosae family. It is characterised by a large geographical distribution both in the Old and New World and includes a large number of species. Seeds of many of them have a similar shape and dimensions to those which can be learned from the photograph[10]. Therefore, the specimen could be of Asiatic (Indian) or African origin showing, as suggested by the above authors, long distance trade contacts.

THE USE OF PLANTS AND DEVELOPMENT OF AGRICULTURE IN EARLY MEDIEVAL WOLIN COMPARED WITH DATA FROM OTHER CONTEMPORARY SITES

The role of particular cereal species used at Wolin is comparable to that presented in syntheses illustrating the importance of different food plants at early medieval sites in Poland (Wasylikowa 1984, Wasylikowa et al. 1991), and in the western part of the distribution of the Slavonic tribes (Lange 1971). The only dif-

[9] Bishop Otto from Bamberg introduced Christianity to western Pomerania (1124–1125 and 1128 AD).

[10] The present author has not had access to the specimen. An opinion on this *Mucuna* find was consulted with Dr. O. Poncy, Muséum National d'Histoire Naturelle, Paris.

ference in respect to the general Polish data is the lower participation of bread wheat (*Triticum aestivum* s.l.) in relation to other cereals, especially in the earlier part (9th–10th centuries) of the period under discussion. In comparison with the contemporary Viking sites situated in the nearest regions (Behre 1981, 1983, Müller-Wille et al. 1988, Robinson et al. 1992, Robinson 1994) the archaeobotanical material from Wolin differs by way of the great role of millet and low participation of oats. As at most of Slavonic and Viking sites in the 9th–10th century, the roles of rye and barley were probably similar. In the later period the importance of rye increased distinctly, while that of barley decreased. This development is also observed at other sites in Poland (Wasylikowa et al. 1991).

Although we can assume that some vegetables and pulses were commonly used at Wolin, they are rather poorly represented in the archaeobotanical samples. This is probably a result of the type of archaeological site and the kinds of fossil material analysed so far. In the 9th–10th century, the presence of *Vicia faba*, *V. sativa*-type (pollen), *Pisum sativum* and *Lens culinaris* is documented. All except *Vicia sativa* are known from contemporary sites in Poland and at Viking sites. At that time *Brassica rapa*, *Pastinaca sativa* and *Daucus carota* could have been cultivated, but their status as culture plants has not been definitively proved. Even weaker conclusions can be drawn from presence of pollen of *Vicia sativa*-type. In the archaeobotanical synthesis for Poland, only *Brassica rapa* has been included among cultivated plants (Wasylikowa et al. 1991). It should be stressed that it has not been recorded in the recent flora of Wolin Island.

The use of spices in early medieval Wolin is shown by the presence of *Anethum graveolens* (10th century), probably *Apium graveolens* (10th/11th and 12th century) and (?) *Coriandrum sativum* (10th/11th century). All these records are the earliest in the archaebotanical material from Poland; scarce finds of fossil remains of these plants are known from some Viking sites (Robinson et al. 1992).

The presence of single finds of *Fagopyrum esculentum* (9th/10th century) and *Petroselinum crispum* (10th/11th century) identified by Alsleben are worthy of note. *F. esculentum* is relatively rare in archaeobotanical material earlier than the high medieval period (Badura in print a); in Northern and Central Europe fossil remains of *P. crispum* are known from the 13th century onwards, but the plant has been mentioned in the British historical sources as early as the end of 10th century (Greig 1996).

Opium poppy (*Papaver somniferum*), recorded as a few seeds scattered in culture layers of the Wolin I profile dated to the 9th–10th century, is not frequent at early medieval sites. It is unknown at the other Polish sites dated to the earlier phase of the early medieval period (Wasylikowa et al 1991); only rare finds are known from Viking sites as, for example, from Viborg (Robinson et al 1992).

Flax (*Linum usitatissimum*) has been one of the most important cultivated plants at Wolin. Large accumulations of shaves, the processed by-product, show that it was used mainly for fibre production. The great importance of flax already in the earlier phase of the early medieval period, is also illustrated at other Polish sites, especially along the Baltic coast, as for example in Kołobrzeg-Budzistowo (Klichowska 1972) or Wrześnica (Latałowa 1998, 1999). As shown by the data from the Viking area, it was the main fibre/oil plant here (Behre 1981, Robinson et al. 1992). The other fibre/oil plant, hemp *Cannabis sativa*, probably played an insignificant role at Wolin. A similar situation has been recorded at other sites in the area under discussion.

Hop (*Humulus lupulus*) should be mentioned among the most significant useful plants at Wolin. As suggested by Alsleben it probably grew in local gardens. Behre (1984, 1998) has discussed the data on hop cultivation from other parts of Europe. As shown by this author, the cultivation of hops, one of the most important flavouring and preservative agents used in brewing, started to spread in the 9th century due to the development of monasteries and the increasing urban activity. Hops have also been the subject of long-distance trade as indicated by the find of the Graveney boat with its hop cargo, which probably was transported from mainland Europe to Britain in the 10th century (Wilson 1975). It seems, with regard to Poland, that the use of hops was much more common in the area of the Baltic coast, where large accumulations of *Humulus lupulus* fruitlets are known not only from Wolin, but also from Kołobrzeg-Budzistowo (Klichowska 1972). At other sites, also from the later phase of the early medieval period, the presence of hops is not so significant.

At Wolin the use of fruits of cultivated fruit trees was rather limited, as shown by relatively low numbers of fruitstones of *Cerasus vulgaris, Prunus domestica* and *P. insititia. Cerasus avium, Malus* sp. and *Pyrus communis* could have been cultivated or collected from the wild. *Juglans regia* was probably imported. A similar situation is observed at most of the early medieval sites in Poland and in the Viking area. However, at some sites *Prunus persica* and *Vitis vinifera* were recorded (Wasylikowa et al 1991, Behre 1981), whereas both of these species are absent from Wolin. Among the early medieval sites in the area of the Slavonic tribes and Vikings, only that of Hedeby (Behre 1983) offered a large number of fruit remains.

The collecting of fleshy fruits, nuts and herbs played an important role at Wolin. The list of taxa, as well as the number of remains, is very large relative to other sites in Poland (Wasylikowa et al. 1991). This is probably a result, at least in part, of the different types of sites and of fossil material or maybe, in some cases, from the use of different laboratory methods. Viking sites, with the exception of Hedeby (Behre 1983) are also not very rich with respect to this group of species.

One of the most interesting problems as regards the economy of the early medieval settlements is trade in food. As demonstrated before, grain cargoes were arriving at the port of Wolin already in the 9th and 10th centuries. The question whether that grain was used by people living in Wolin (maybe only on a restricted scale as a luxury, as for example in the temple) remains open. Probably most of these cargoes were trans-shipped here and then traded on to Scandinavia. This suggestion is only weakly supported by information on the possible presence of "foreign" grain in that area. Only Helbaek (1975) presents data which hint at the presence of the imported rye grain at Fyrkat in Jutland, while Hjelmqvist (1979) gives some suggestions on the grain trade in explanation of the early presence of bread wheat at some Swedish sites. However, data from other areas (van Zeist et al. 1987, van Zeist 1990) show that the grain trade was certainly practised in the period under discussion. Contrary information comes from other Viking sites, such as for example Hedeby and Elisenhof. According to Behre (1983) people in these settlements used exclusively food plants that were grown in the respective surroundings, which resulted in great differences in human nutrition between the different sites.

HYDROLOGICAL CHANGES DURING ACTIVITY OF THE EARLY MEDIEVAL PORT

The palaeoecological data from the Wolin I and Wolin II profiles reflect some hydrological events which took place in the Dziwna valley, close to the Szczecin Lagoon, during the lifetime of the early medieval town and port. However, the data are still fragmentary and do not allow a detailed palaeohydrological reconstruction.

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 clear evidence for the appearance of a body of shallow water with *Potamogeton, Pediastrum* and *Eleocharis palustris.* It indicates a rise in the water table in the Dziwna valley. More detailed data come from the Wolin I profile where, in the section at 433–373 cm dated to the second half of the 9th century and beginning of the 10th century, several hydrological episodes were registered mainly by diatom analysis. The diatom flora present in the lowest part of the diagram (Fig. 11) shows especially distinct predominance of littoral oligohalobous species and great participation by mesohalobous taxa (W_I-1a and W_I-1c da subz) and thus indicates conditions typical of the littoral zone of a freshwater reservoir with an inflow of saline water. The presence of saline water is underlined by high concentrations of sodium (Fig.12), which in this part of the profile approximate mean Na values for the Baltic Sea surface sediments (Skwarzec et al. 1985). The increase in planktonic forms (W_I-1b, W_I-3a da subz and W_I-4, W_I-5 daz) shows a short-lived rise in water level at the site. Lowering of the water level, accompanied by increases in alkalinity, are recorded in the W_I-2 daz and W_I-3b da subz.

The gradual increase in the water level during early medieval times, recorded at several sites along the Southern Baltic, has been thoroughly discussed. It has been registered in mires (Tobolski 1987), in the today's shallow bays and lagoons (Tomczak 1994, Witkowski 1990) and at submerged archaeological sites (Zbierski 1986, Filipowiak 1993, Latałowa & Badura in print, Pomian et al. in print). All these records are interpreted as a result of the youngest phase of the Southern Baltic transgression (Tomczak 1995). The exact age of the beginning of this phase has not been determined so far. A date of ca. 1500 ^{14}C conv. years BP is indicated by Kliewe and Janke (1978), ca. 250 ^{14}C conv. years BP by Tobolski (1987), while dates of 1100 and 900±100 ^{14}C conv. years BP are quoted by Tomczak (1994) and Witkowski (1990) respectively. Zbierski (1986) estimated the time of the Puck harbour submergence to the 11th/12th century and more recent studies at this site (Latałowa & Badura 1998, Pomian et al. in print) do not as yet allow a more precise date to be given.

According to archaeological estimations (Filipowiak & Gundlach 1992), the wharf at Wolin was shifted inland three times during the 10th century due to inundation. At that time the water level in the 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 marine transgression of the southern Baltic coast during medieval times. 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 water occurred. Based on the archaeological dating of culture layers at the port (Tab. 5) these events took place at the end of the 9th and at the beginning of the 10th centuries. The general increase in the water table is illustrated in the upper part of the Wolin II profile.

POLLEN VERSUS MACROFOSSIL DATA IN DEPOSITS AT THE PORT OF WOLIN

The origin and preservation of different types of fossil material is of crucial importance when interpreting palaeoecological data. Natural processes shaping fossil assemblages in lake and peat deposits are of a complex nature, but those referring to culture layers are much more complicated.

In the last two decades, and especially in the recent years, a number of studies have been undertaken to clarify the relationship between fossil pollen assemblages and the past vegetation. These are based mainly on data from recent pollen spectra analysed in the light of the present-day local (Tobolski 1991) or regional (Janssen 1984, Cambon 1994, Hicks 1994) vegetation. Some of them deal with specific problems such as that concerning the reflection of old-fashioned types of the land use, and so-called "anthropogenic indicators" in the local pollen rain (Gaillard et al. 1994). Sugita (1993, 1994), for example, elaborated theoretical estimations of the role played by distance from the pollen source and basin size. Processes relating to the formation of macrofossil assemblages in lakes and mires seem not to be so complicated and are only rarely the subject of investigation (e.g. Birks 1973).

The pollen and macrofossil content of culture layers is much more unpredictable and is to a much greater extent dependant on human activity at the site. It is difficult to define the rules determining the formation of fossil assemblages. Plant macro- and microfossils from waterlogged deposits usually represent both the natural vegetation and plant material brought to the site by man (Greig 1982, 1989).

In the consecutive sections of the Wolin I profile particular groups of pollen (Fig. 6) and macrofossil taxa (Fig. 10) play different roles. At its base pollen spectra illustrate vegetation outside the port, including the composition of woodland in the area, while macrofossils reflect the local vegetation of a shallow body of water. This is typical for pollen and macrofossil data from natural sites such as lakes and mires. In the upper part of the profile the arboreal pollen and, in part, also the non-arboreal pollen, still reflect primarily conditions outside the port and the pollen spectra resemble those from the mire. Macrofossils, on the other hand, are typical of culture layers and include diaspores of cultivated plants, weeds and other plants from anthropogenic habitats. Diaspores from the local vegetation at the site are rather scarce.

The relationship between the pollen and macrofossil content in the Wolin I profile is best illustrated by two groups of taxa: 1/ cultivated plants and segetal weeds (Fig. 16) and 2/ local plants (Fig. 17).

In the first combined diagram (Fig. 16) pol-

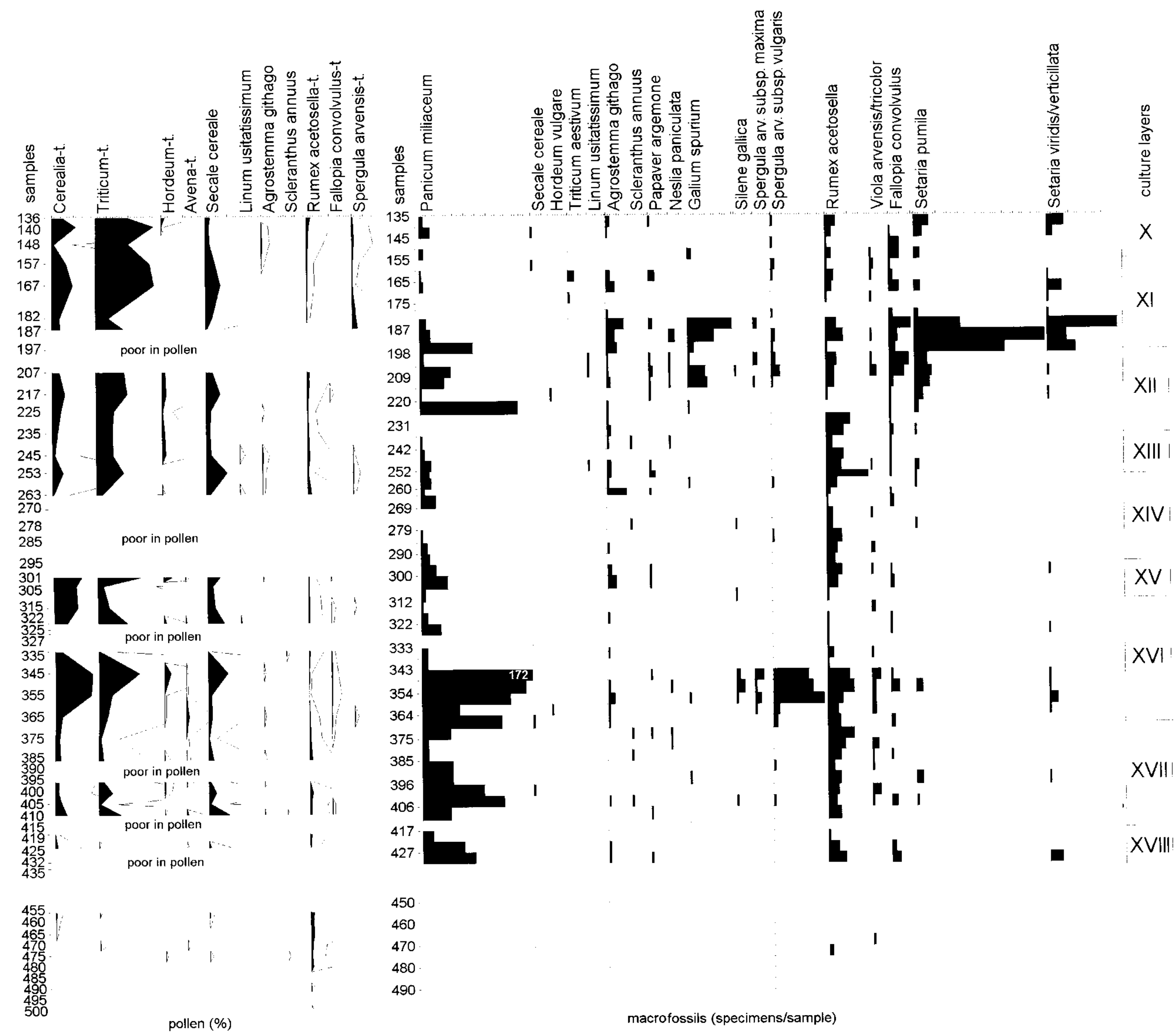

Fig. 16. Selected pollen and macrofossils of cultivated plants and field weeds in the Wolin I profile

len of cereals is well represented, while their macrofossils are practically absent. In the bottom part of the profile, formed before funding of the port, cereal pollen curves correspond to those shown in the diagram from the Wolin II site. In the remaining part of the profile, especially in the samples from mineral intercalations, pollen curves for cereals[11] rise rapidly. With regard to macrofossils, with the exception of *Panicum miliaceum,* which is present as a number of uncharred glumes, other cereals are represented only by single carbonized specimens of caryopses. The conditions at the waterlogged site, especially unfavourable for the preservation of uncharred cereals (Körber-Grohne 1991), caused selective decay of the grains. Their previous, original presence at the site is shown by the presence of numerous diaspores of characteristic cornfield weeds; peaks in cereal pollen curves usually coincide with increasing numbers of macrofossils of field weeds. One may suppose that some cereal pollen reached the site by natural pollen transport from the area outside the port, but in majority the pollen could have been transported here by man, for example adhering to straw or grain (Greig 1989, Joosten & van der Brink 1992). This may be linked with the trading of grain at the port. In the absence of macrofossil remains of cereals (except of millet)

[11] An attempt to separate *Panicum miliaceum* pollen according to the criteria given by Beug (1961) was unsuccessful because of the generally poor preservation of Poaceae and Cerealia pollen; pollen of *Panicum* is probably included partly in Cerealia-type and partly in the Poaceae curve.

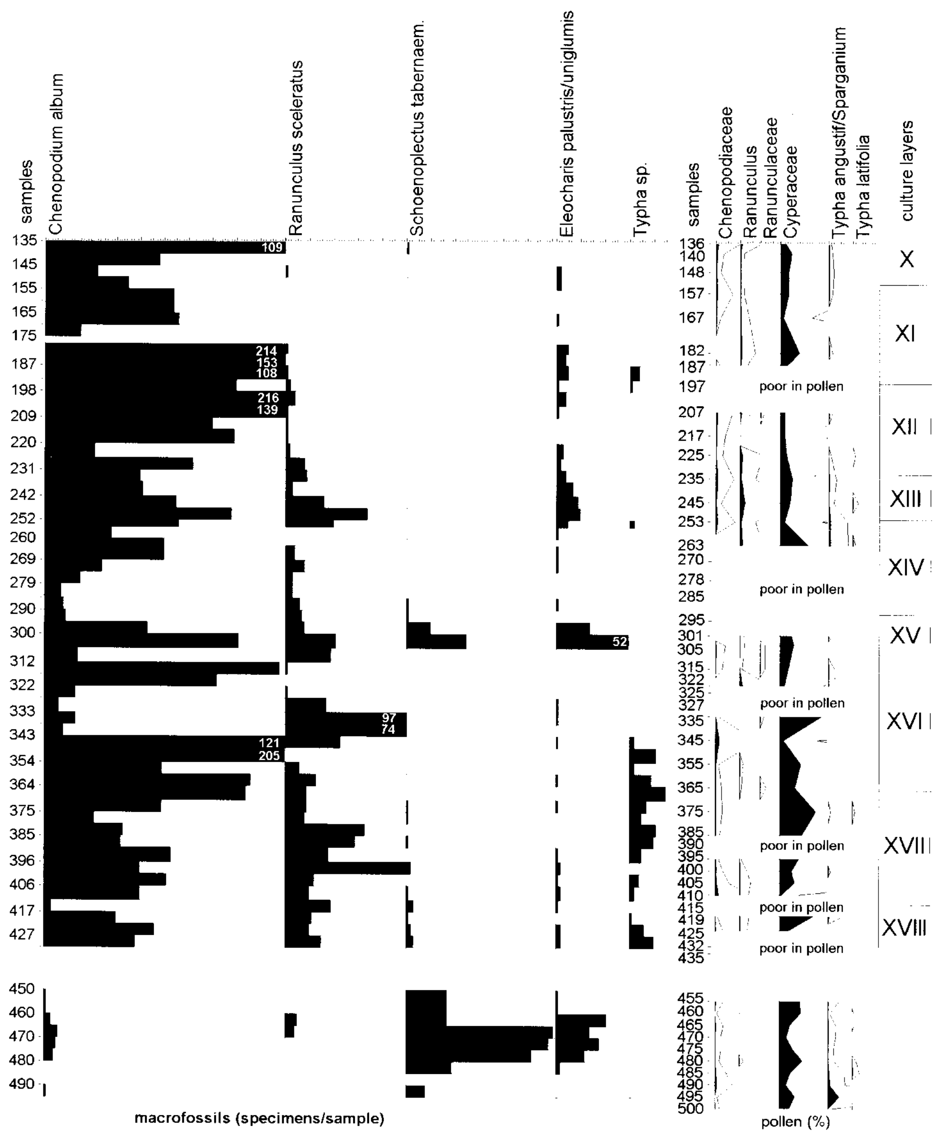

Fig. 17. Selected macrofossils and pollen of potentially local plants at the port in the Wolin I profile

pollen of different cereal types complements information on food plants present at the site. Even more interesting is the case of remains of *Linum usitatissimum*. Both pollen and macrofossils of this plant are almost absent from the profile, while earlier presence of flax material at the site is shown by the occurrence of specific linicolous weeds such as *Spergula arvensis* subsp. *maxima* and *Silene gallica*. Flax seeds usually undergo rapid decay at most waterlogged sites and if not charred they are preserved only in exceptionally favourable conditions. With regard to pollen, it is known that flax produces little pollen. This is hard to find even in soil samples from a field in which flax is actually growing, or adhering to the stem or the bolls of the flax plant (Gennard 1985).

The other group (Fig. 17) represents taxa which potentially could be elements of the local flora of the port, are abundantly present among the macrofossils and are more or less identifiable by their pollen. No positive relationships have been observed when comparing, for example, the occurence of *Ranunculus sceleratus* fruits with that of Ranunculaceae pollen or of *Chenopodium album* seeds with that of Chenopodiaceae pollen. A similar picture has been obtained for other local plants in the samples. Where *Eleocharis palustris/uniglumis, Schoenoplectus lacustris* and *S. tabernaemontani* are present in great numbers as macrofossils, the pollen curve of Cyperaceae is only about 5%. *Typha* is also well represented in macroflora but appears only as single pollen grains. *Potamogeton* and *Lemna* are the exact opposite; they are frequent as pollen and rare as macrofossils.

The interpretation of the above data cannot be uniform. The observed low pollen representation of each of the taxa probably results from different factors such as for example low pollen production (*Ranunculus sceleratus*) or easy decay of pollen grains (Cyperaceae), etc. The possibility cannot be excluded that the group of species under discussion, so abundantly present as macrofossils, did not grow in the immediate vicinity of the place where the profile was taken, and that the presence of their diaspores at the site is the result of different forms of natural and anthropogenic transport.

This analysis shows the different sources of pollen and macrofossils which accumulated in connection with the culture layers at the Wolin I site. With some exceptions, the pollen spectra illustrate mostly environmental conditions outside the town (as in natural deposits of lakes and mires), while macrofossil assemblages represent the local vegetation at the port and different aspects of human activity at the site. Comparison between pollen and macrofossil data from the Wolin I profile indicates different levels of coincidence, showing that groups of species and layers in this profile should be regarded separately against the background of the processes involved in forming the fossil assemblages.

The above pollen data confirm results obtained from other urban archaeological sites (Vuorela 1997). Pollen spectra are characterised by a high NAP/AP ratio, a large number of pollen taxa and a relatively poor state of pollen preservation. Strong pollen corrosion leads to over- and under-representation of particular pollen types; especially pollen of Cyperaceae, *Populus* and *Urtica,* as well as of some Poaceae, probably disappears from the culture layers. Abundance of Asteraceae and Brassicaceae and rather low frequencies of the pollen of field weeds (Vuorela & Hiekkanen 1991, Vuorela & Lempiainen 1993) is typical of these kinds of sites.

Joint studies on the pollen and macrofossil content of archaeological layers are still uncommon. The results of such investigations present many problems which differ from those typical of natural sites. Moreover, each archaeological site and each culture layer is clearly characterised by specific features which require the application of specific methods and interpretations.

THE ORIGIN OF THE WOLIN PORT DEPOSIT – FORMATION OF CULTURE LAYERS AT THIS SITE

The Wolin I profile shows differentiation with respect to its pollen and macrofossil content, reflecting environmental conditions prior to the founding of the port and during the period of its activity. In the first phase the deposits formed exclusively under natural conditions typical of the marginal zone of rivers and lakes.

In the next phases a combination of processes typical of natural sites and those characteristic of the formation of culture layers shaped the deposits (Fig. 18). Due to natural processes autochtonous material, deriving from the local vegetation growing on the riverbank at the port, and allochtonous material, transported mainly by water and by air from vegetation growing outside the port, accumulated. In addition, allochtonous material transported by man in the form of food remains, remnants of products being traded or shipped and materials used for construction works at the port was an important component of the deposits at this site.

A characteristic feature of the deposits is also their thickness. This is certainly connected with the processes involved in the silting up of the Dziwna river, but a significant input of allochtonous material originating from human activity in the port could be of importance too. It is known from historical sources that in the 12th century the town of Wolin lost its position as a centre of trade, not only because of the subseqent Danish attacks and the burning down of the town, but also due to shallowing of the waterways in this area (Filipowiak & Gundlach 1992).

SUMMARY

Pollen and plant macrofossil analyses supplemented by diatom and chemical data form the basis for the reconstruction of the environmental changes during the lifetime of the

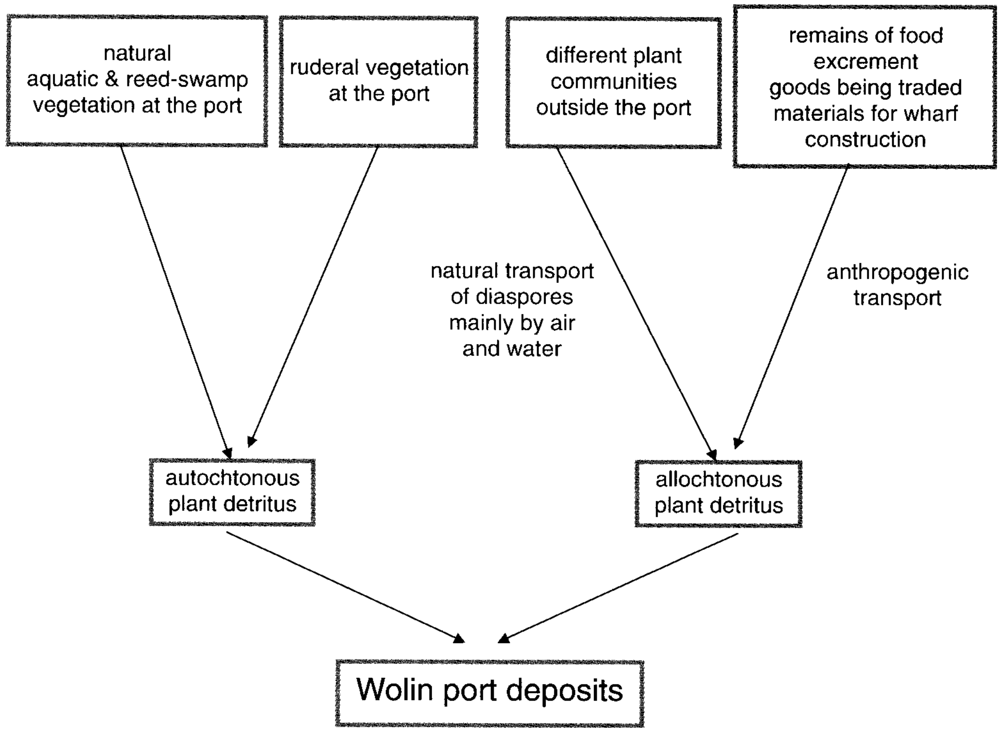

Fig. 18. The main paths of formation of the Wolin port deposits (from Latałowa 1988, revised)

early medieval town of Wolin, as well as of some aspects of its economy. The role of cultivated and other useful plants is discussed using archaeobotanical data elaborated by other authors working previously at this site. An outline of the Holocene history of the vegetation and palaeohydrological events in the southeastern part of Wolin Island, where the town has developed, provides a background for the ecological characteristics of the area.

The early medieval town of Wolin developed in an area which has been intensively transformed by man since the earliest prehistory. Exploitation of woodland on light soils caused the spread of patches of heathland already in the Neolithic. Soil erosion and impoverishment of habitats determined ecological conditions in the environs of the town. The activity of the early medieval settlement resulted in large-scale deforestation not only in the immediate vicinity of the town, but also of more distant areas.

In the palaeobotanical profile taken from culture layers (9th–10th century AD) in the port of Wolin, diaspores of 225 species and subspecies were identified as well as about 19 other taxa of a higher taxonomic level. They represent dispersed botanical material of diverse origin. In the absence of charred samples, remains of cultivated plants (with the exception of millet and hops) are not abundant. In contrast, the group of segetal and ruderal weeds is rich in species and is the most numerous with respect to the number of diaspores. Weeds of millet, root crops and those of gardens and ruderal habitats are the most important, while species typical of cereal cultivation are present in smaller numbers. Those most frequently found in winter-sown crops increase distinctly in subsequent culture layers dated to the 9th and 10th centuries. Species of wetlands, wet meadows and the riverside are also of importance in this material. The presence of their diaspores is partly due to the location of the site on the riverbank but it also indicates that fens and mires in the vicinity of the town were transformed to meadows and intensively exploited. Fresh meadows and dry grasslands were probably more restricted in area and, accordingly, of minor importance as a source of animal fodder. A separate important group comprises those species which, due to their edible fruits, were collected from the wild such as *Corylus avellana*, *Fragaria vesca*, *Vaccinium myrtillus*, *V. vitis-idaea*, various species of *Rubus*, *Sambucus nigra*, *Sorbus aucuparia* and others.

The author's own data from the port of Wolin, complemented by the important results obtained by other authors working in this early medieval town (Klichowska 1961 and other papers, Alsleben 1995), has enabled an estimation of the role of some crop plants. Millet (*Panicum miliaceum*), hulled barley (*Hordeum vulgare*) and rye (*Secale cereale*) belonged to the most important cereals already in the 9th–10th centuries. The role of barley probably diminished gradually while that of rye was increasing. Other cereals, including bread wheat (*Triticum aestivum* s.l. as well as *T. aestivo-compactum*) and oats (*Avena sativa*), were of distinctly minor importance. Grains of emmer (*Triticum dicoccon*) and spelt (*T. spelta*) have been found, but only in small numbers. Several large finds of various remains of flax (*Linum usitatissimum*) point to the importance of this oil/fibre plant in early medieval Wolin. Hops (*Humulus lupulus*) were cultivated in local gardens as early as the 9th century. Among the plants which certainly were grown in Wolin, pulses (*Vicia faba*, *Lens culinaris* and *Pisum sativum*), hemp (*Cannabis sativa*), opium poppy (*Papaver somniferum*) and some fruit trees (*Cerasus vulgaris*, *Prunus domestica* and *P. insititia*) should also been mentioned. Other useful plants such as dill (*Anethum graveolens*), petersil (*Petroselinum crispum*), buckwheat (*Fagopyrum esculentum*), coriander (*Coriandrum sativum*) and walnut (*Juglans regia*), which are alien to the indigenous flora of Wolin Island but were found only as single diaspores, could have grown in local gardens in the town or are traces of imported goods. Some of them may even have been contaminants in imported grain. On the basis of the fossil data it is also difficult to ascertain whether several useful species, indigenous to this area, were planted here already in the early medieval period. The more numerous finds of *Daucus carota* and *Apium graveolens* and regular appearance of large numbers of seeds of *Brassica rapa* suggest that these plants could have been cultivated. Also apple (*Malus* sp.), pear (*Pyrus communis*) and wild cherry (*Cerasus avium*) were planted or grew wild. Single records of *Pastinaca sativa* and *Vicia sativa* (pollen type) constitute a very weak argument for accepting them as cultivated plants. *Setaria italica*, *Spergula arvensis* subsp. *sativa* and *Camelina sativa* probably represent field weeds.

Among field weeds, those typical of rather poor, moderately acid sandy/clayey soils, dominate. This is in accordance with the soil types widespread on Wolin Island. In this context, the presence of a group of field weeds characteristic of fertile, calcareous soils (Caucalidion) is especially interesting, as these species are very rare, or do not occur at all, in the present-day flora of Wolin Island. Their presence points to foreign grain trade.

In the Wolin port deposits, as well as in the peat profile from the fen situated close to the town, palaeohydrological events were recorded. They show a rise in the water table and an increase in water salinity at the end of the 9th century and the beginning of the 10th century. This is probably a reflection of the latest phase of the Baltic Sea transgression.

The Wolin port deposits offer a special opportunity to analyse relationships between pollen and macrofossil data in the specific conditions of an archaeological site. In the culture layers pollen analysis mostly reflects environmental conditions outside the port, as is the case in natural sites such as lakes and mires. On the other hand, it provides an essential complement to data on cultivated plants.

ACKNOWLEDGEMENT

I would like to thank my colleagues at the Department, Wiesław Fałtynowicz and Krzysztof Gos for their invaluable help with field work, Magdalena Jąkalska for preparing some figures, Joanna Jarosińska, Joanna Picińska and Agnieszka Jaworska for preparing plates. I am grateful to Professor Adam Zając from the Jagiellonian University for giving me access to the most recent data on the distribution of some of weed species in Poland and Dr. Odile Poncy from Muséum National d'Histoire Naturelle, Paris for her comment on the *Mucuna*. I am especially thankful to reviewers Professor Krystyna Wasylikowa and Dr. David Robinson for critical reading of the manuscript. David Robinson also improved the English. The work was carried thanks to financial support from the Polish National Committee for Scientific Research (grant no. 6 P04F 038 08) and published due to a grant from the Rector of Gdańsk University (BW/1100-5-0156-9).

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APPENDIX

List of taxa known from macrofossils found in the early medieval deposits (9^{th}–12^{th} century) in Wolin (in alphabetic order) and their occurrence in the recent flora of Wolin Island

Explanations to the list: fossil material – A.A. (Alsleben 1995), M.K. (Klichowska 1961, 1964, 1966, 1972), M.L. (Latałowa, this paper), recent flora – H.P. (Piotrowska 1966a); (+) determination uncertain (cf. or type); if the original macrofossil determination includes more then one taxon (e.g. *Dianthus armeria*/*deltoides*) each of them is listed separately and marked as "uncertain" (+); +* species known only from historical data; cult.– not native cultivated species grown recently and/or in the past; remarks in the last column concerns only the most rare species in the recent flora of Wolin Island

Taxon	A.A.	M.K.	M.L.	Century AD	H.P.	Remarks
Acer sp.		+		9th	+	
Adonis sp.	+			10th	–	
Aegopodium podagraria L.	+			9th–11th	+	
Aethusa cynapium L.	+		+	10th–11th	+	only few localities of *A. cynapium* subsp. *cynapium*
Agrimonia sp.	+			10th–11th	+	
Agrostemma githago L.	+	+	+	9th–12th	+	
Ajuga reptans L.			+	9th–10th	+	
Alisma plantago-aquatica L.	+			10th–11th	+	
Alnus glutinosa (L.) Gaertn.	+		+	9th–12th	+	
Alopecurus geniculatus L.	(+)			10th–11th	+	
Althea officinalis L.	+			10th–11th	–	
Anagallis arvensis L.			+	10th	+	
Anchusa arvensis (L.) M. Bieb.	+			10th–11th	+	
Anethum graveolens L.			+	10th	cult.	ephemerophyte
Anthemis arvensis L.	+		+	9th–12th	+	rare
Anthemis tinctoria L.	(+)		+	9th–11th	+	rare
Apium graveolens L.	+			10th–12th	+*	1 historical locality
Arenaria serpyllifolia L.			+	9th–10th	+	
Atriplex prostrata Boucher ex Dc. subsp. *prostrata*	+		+	9th–11th	+	
Atriplex nitens Schkuhr			+	9th–10th	+	very rare: 1 locality
Atriplex patula L.	+		+	9th–12th	+	
Avena sativa L.	+	+		9th–12th	cult.	
Ballota nigra L.	+		+	10th, 12th	+	
Bellis perennis L.	+			10th–11th	+	
Batrachium sp.			+	9th–10th	+	
Betula pendula Roth			+	9th–10th	+	
Betula pubescens Ehrh.			+	9th–10th	+	
Betula sp.	+	+	+	9th–12th	+	
Bidens cernua L.	+			10th–11th	+	
Bidens tripartita L.	+			10th–11th	+	
Blysmus sp.	+			10th–11th	+	
Brassica nigra (L.) W.D.J. Koch	(+)			9th–12th	cult.	ephemerophyte
Brassica rapa L.	(+)		+	9th–10th	–	
Bromus arvensis L.	+			9th, 12th	+	very rare: 1 recent, 2 historical localities
Bromus hordeaceous L.	(+)		+	9th–10th	+	
Bromus secalinus L.	+			9th–12th	+	
Bromus sterilis L.	+			9th–12th	+	
Bulboschoenus maritimus (L.) Palla			+	10th	+	
Bunias orientalis L.			+	9th–10th	–	
Bupleurum rotundifolium L.	+			10th–11th	–	
Calluna vulgaris (L.) Hull	+			10th–11th	+	

Appendix. Continued

Taxon	A.A.	M.K.	M.L.	Century AD	H.P.	Remarks
Caltha palustris L.			+	9th–10th	+	
Camelina sativa (L.) Crantz	+			10th–12th	+	
Cannabis sativa L.	+	+	+	10th–12th	cult.	
Capsella bursa-pastoris (L.) Medik.			+	9th	+	
Cardamine amara L.			+	9th–10th	+	
Carduus crispus L.	+		+	10th–11th	+	
Carex acutiformis Ehrh.			+	9th–10th	+	
Carex canescens L.			+	10th	+	
Carex cespitosa L.			+	10th	+*	1 historical locality
Carex distans L.			+	9th–10th	+	
Carex disticha Huds.	+		+	10th12th	+	
Carex elata All.			+	9th–10th	+	
Carex elongata L.	(+)		+	9th–11th	+	
Carex flacca Schreb.	(+)			12th	+	rare
Carex flava L.	(+)		(+)	9th–12th	–	
Carex hirta L.	+		+	9th–12th	+	
Carex leporina L.			+	9th–10th	+	
Carex nigra Reichard	+		+	9th–11th	+	
Carex oederi Retz.			(+)	9th–10th	+	
Carex pairae F.W. Schultz			+	9th–10th	+	
Carex panicea L.			+	9th–10th	+	
Carex paniculata L.	(+)			10th–11th	+	
Carex pseudocyperus L.			+	9th–10th	+	
Carex remota L.			+	9th–10th	+	
Carex riparia Curtis	+		+	10th–11th	+	
Carex rostrata Stokes			+	9th–10th	+	
Carex vesicaria L.			+	9th–10th	+	
Carex vulpina L.			+	10th	+	
Centaurea cyanus L	+			9th–12th	+	
Centaurea jacea L.	(+)			9th–12th	+	
Ceralia indet.	+		+	9th–12th	cult.	
Cerastium arvense L.			+	9th–10th	+	
Cerastium holosteoides Fr. em. Hyl.			+	10th	+	
Cerasus avium		+		10th–12th	+	
Cerasus vulgaris	+	+		9th–12th	cult.	
Chaerophyllum temulum L.	+			10th–11th	+	
Chenopodium album L.	+	+	+	9th–12th	+	
Chenopodium ficifolium Sm.			+	10th	–	found in neighbouring Uznam
Chenopodium glaucum L.	(+)		(+)	9th–11th	+	rare
Chenopodium hybridum L.	+		+	9th–11th	+	rather rare
Chenopodium murale L.			+	9th–10th	+	very rare
Chenopodium polyspermum L.			(+)	9th–10th	+	rare
Chenopodium rubrum L.	(+)		(+)	9th–11th	–	rare
Cichorium intybus L.	+			10th–11th	+	
Cirsium arvense (L.) Scop.			+	9th–10th	+	
Cirsium oleraceum (L.) Scop.			+	9th–10th	+	
Cladium mariscus (L.) Pohl			+	9th–10th	+	rare
Coriandrum sativum L.	(+)			10th–11th	cult.	1 historical locality, ephemerop-hyte
Corylus avellana L.	+	+	+	9th–12th	+	
Daucus carota L.	+			10th–11th	+	
Deschampsia caespitosa (L.) P.Beauv.	+		+	9th–11th	+	
Dianthus armeria L.	(+)			10th–12th	+*	1 historical locality

Appendix. Continued

Taxon	A.A.	M.K.	M.L.	Century AD	H.P.	Remarks
Dianthus deltoides L.	(+)		+	10th–12th	+	rare
Echinochloa crus-galli (L.) P. Beauv.	+		+	9th–12th	+	rather rare
Eleocharis palustris (L.) Roem. & Schult.	+		(+)	9th–12th	+	
Eleocharis uniglumis (Link) Schult.			(+)	9th–10th	+	
Empetrum nigrum L. s.s.			+	9th–10th	+	
Erysimum cheiranthoides L.			+	10th	+	
Eupatorium cannabinum L.	+		+	10th–11th	+	
Euphorbia helioscopia L.	+	+	+	10th	+	rare
Fagopyrum esculentum Moench	+			9th–10th	cult.	ephemerophyte
Fagus sylvatica L.		+		9th	+	
Fallopia convolvulus (L.) Á. Löve	+	+	+	9th–12th	+	
Filipendula ulmaria (l.) Maxim.	+		+	9th–12th	+	
Fragaria vesca L.	+		+	9th–12th	+	
Frangula alnus Mill.			+	10th	+	
Fraxinus excelsior L.	+			10–11th	+	
Fumaria officinalis L.	+			10–12th	+	
Galeopsis bifida Boenn.		+		12th	+	
Galeopsis ladanum L.	(+)		+	9th–12th	+	rather rare
Galeopsis tetrahit L.	(+)	+	(+)	12th	+	
Galium palustre L.			+	9th–10th	+	
Galium spurium L.	+	+	+	9th–12th	–	
Galium uliginosum L.			+	9th	+	
Genista germanica L.		+		12th	+*	1 historical locality
Glaux maritima L.			+	10th	+	
Glyceria fluitans (L.) R. Br.			+	10th	+	
Glyceria maxima (Hartm.) Holmb.	+		+	9th–11th	+	
Hieracium lachenalii C.C. Gmel.			+	10th	+	
Hordeum vulgare L.	+	+	+	9th–12th	cult.	
Hordeum sp.		+		9th–12th	cult.	
Humulus lupulus L.	+	+	+	9th–12th	+	
Hydrocotyle vulgaris L.	+		+	10th–11th	+	
Hyoscyamus niger L.	+			10th–11th	+	very rare: 2 localities
Hypericum perforatum L.	+		+	9th–10th	+	
Iris pseudacorus L.	+	+	+	9th–12th	+	
Juglans regia L.		+		11th	cult.	
Juncus articulatus L. em. K. Richt.	(+)		+	9th–11th	+	
Juncus bufonius L.	+		+	9th–11th	+	
Juncus conglomeratus L. em. Leers			(+)	9th–10th	+	
Juncus effusus L.	(+)		(+)	9th–11th	+	
Juncus gerardi Loisel.	+		+	9th–11th	+	
Knautia arvensis (L.) J.M. Coult.	+		+	9th–12th	+	
Lactuca serriola L.	+			9th	+	rather rare
Lamium amplexicaule L.			+	9th–10th	+	
Lamium purpureum L.	+			10th–11th	+	
Lapsana communis L.	+		+	9th–12th	+	
Legousia speculum-veneris (L.) Chaix	(+)			10th–11th	–	
Lens culinaris Medik.	+			10th–11th	cult.	
Leontodon autumnalis L.	+		+	10th	+	
Leucanthemum vulgare Lam. s.s.	+			9th–11th	+	
Linaria vulgaris Mill.			+	9th	+	
Linum usitatissimum L.	+	+	+	9th–12th	cult.	
Lithospermum arvense L.	+	+	+	9th–12th	+	rather rare

Appendix. Continued

Taxon	A.A.	M.K.	M.L.	Century AD	H.P.	Remarks
Lolium perenne L.	+			10th–11th	+	
Lolium temulentum L.	+			11th–12th	+	very rare
Luzula campestris (L.) DC.	+		+	10th–11th	+	
Lychnis flos-cuculi L.	+		+	9th–11th	+	
Lycopus europaeus L.	+		+	9th–12th	+	
Lysimachia sp.	+			10th–11th	+	
Lythrum salicaria L.			+	9th–10th	+	
Malus sp.	+	+	+	9th–12th	+	
Malva sylvestris Mill.	+		+	9th–11th	+	rare
Medicago lupulina L.	(+)			11th–12th	+	
Melampyrum pratense L.			(+)	10th	+	
Melandrium album (Mill.) Garcke	+	+	+	9th–2th	+	
Melandrium noctiflorum (L.) Fr.	(+)		+	9th–10th	–	
Melandrium rubrum (Weigel) Garcke	+		+	9th–10th	+	
Mentha aquatica L.	(+)		+	9th–11th	+	
Mentha arvensis L.			+	9th–10th	+	
Menyanthes trifoliata L.			+	9th–10th	+	
Moehringia trinervia (L.) Clairv.			+	9th–10th	+	
Molinia caerulea (L.) Moench			+	9th–10th	+	
Mucuna Adans	Filipowiak, Gundlach 1992			12th		
Myosotis arvensis (L.) Hill			+	9th–10th	+	
Myosoton aquaticum (L.) Moench			+	9th–10th	+	
Neslia paniculata (L.) Desv.	+		+	9th–11th	+	very rare: 1 recent. 3 historical localities
Odontites serotina (Lam.) Rchb.	+		+	9th–12th	+	
Oenanthe aquatica (L.) Poir.			+	9th–10th	+	
Origanum vulgare L.			+	9th–10th	+	very rare: 2 recent, 2 historical localities
Panicum miliaceum L.	+	+	+	9th–12th	cult.	
Papaver argemone L.	+		+	9th–11th	+	
Papaver dubium L.	(+)			9th–11th	+	
Papaver rhoeas L.	(+)			9th–11th	+	
Papaver somniferum L.			+	9th–10th	cult.	
Pastinaca sativa L.	+			10th–11th	+	rather rare
Pedicularis palustris L.			+	10th	+	
Petrorhagia prolifera (L.) P.W. Ball & Heywood			+	9th–10th	+	rather rare
Petroselinum crispum (Mill.) A.W. Hill	+			10th–11th	cult.	ephemerophyte
Peucedanum palustre (L.) Moench			+	9th–10th	+	
Phragmites australis (Cav.) Trin. ex Stued.	+	+	+	9th–12th	+	
Pimpinella saxifraga L.			+	9th–10th	+	
Pinus sylvestris L.		+		9th–12th	+	
Pisum sativum L.	+	+	+	10th–12th	cult.	
Plantago lanceolata L.	+		+	10th–11th	+	
Plantago major L.	+		+	9th–11th	+	
Plantago media L.			+	9th–10th	+	
Poa annua L.	+		(+)	9th–10th	+	
Poa compressa L.			(+)	9th–10th	+	
Poa palustris L.			+	9th–10th	+	
Poa pratensis L.	(+)		(+)	10th–11th	+	
Poa trivialis L.	(+)		(+)	10th–11th	+	
Polygonum aviculare L.	+	+	+	9th–12th	+	

Appendix. Continued

Taxon	A.A.	M.K.	M.L.	Century AD	H.P.	Remarks
Polygonum calcatum Lindm.			+	9th–10th	+	very rare
Polygonum hydropiper L.	+		+	9th–11th	+	
Polygonum lapathifolium L. s.l.	+		+	9th–12th	+	
Polygonum lapathifolium subsp. *lapathifolium* (With.) Fr.			+	9th–10th	+	
Polygonum lapathifolium subsp. *pallidum* (With.) Fr.			+	9th–10th	+	
Polygonum persicaria L.	(+)	+	+	9th–12th	+	
Polypodium vulgare L.		+		9th	+	
Potamogeton rutilus Wolfg.			+	10th	+	very rare: 1 recent, 1 historical locality
Potentilla anglica Laichard	(+)			10th–11th	+	rather rare
Potentilla anserina L.	+		+	9th–11th	+	
Potentilla argentea L.	(+)		+	9th–11th	+	
Potentilla erecta (L.) Raeusch.	+		+	9th–12th	+	
Potentilla norvegica L.	(+)			10th–11th	–	
Potentilla recta L.	(+)			10th–11th	+	rare
Potentilla reptans L.			+	10th	+	
Potentilla supina L.	(+)			10th–11th	–	
Prunella grandiflora (L.) Scholler			+	9th–10th	+*	few historical localities
Prunella vulgaris L.	+		+	9th–11th	+	
Prunus domestica L.		+		9th–11th	cult.	
Prunus insititia L.	+	+		10th–11th	cult.	
Prunus spinosa L.		+		11th	+	
Pteridium aquilinum (L.) Kuhn			+	10th	+	
Puccinellia distans (Jacq.) Parl.	+			12th	+	
Pyrus communis L.			+	10th	+	
Pyrus sp.	+			10th–12th	+	
Quercus petraea (Matt.) Liebl.		+		9th	+	
Quercus sp.		+		9th–12th	+	
Ranunculus acris L.	(+)		+	9th–12th	+	
Ranunculus bulbosus L.			+	10th	+	
Ranunculus flammula L.			+	9th–10th	+	
Ranunculus repens L.	+		+	9th–10th	+	
Ranunculus sardous Crantz			+	9th–10th	+*	1 historical locality
Ranunculus sceleratus L.	+		+	9th–12th	+	
Raphanus raphanistrum L.	+			10th–12th	+	
Rosa sp.		+	+	9th–10th	+	
Rubus caesius L.	+		+	9th–12th	+	
Rubus fruticosus L.	(+)		(+)	9th–12th	+	
Rubus idaeus L.	+	+	+	9th–12th	+	
Rubus saxatilis L.			+	10th	+	
Rumex acetosa L.	+		+	9th–11th	+	
Rumex acetosella L.	+	+	+	9th–12th	+	
Rumex conglomeratus Murray			+	9th–10th	+	very rare
Rumex crispus L.	(+)	+	+	11th	+	
Rumex hydrolapathum Huds			+	10th	+	
Rumex maritimus L.	+			10th–11th	+	rather rare
Rumex obtusifolius L.			(+)	9th–10th	+	
Rumex sanguineus L.			+	9th–10th	+	
Salix cinerea L.		+		9th	+	
Sambucus nigra L.		+	+	12th	+	
Schoenoplectus lacustris (L.) Palla			+	9th–10th	+	

Appendix. Continued

Taxon	A.A.	M.K.	M.L.	Century AD	H.P.	Remarks
Schoenoplectus tabernaemontani (C.C. Gmel.) Palla			+	9th–10th	+	
Scirpus sylvaticus L.	+		+	9th–12th	+	
Scleranthus annuus L.	+		+	9th–12th	+	
Scrophularia sp.	(+)			9th–10th	+	
Secale cereale L.	+	+	+	9th–12th	cult.	
Setaria italica (L.) P. Beauv.	+		+	9th–10th	–	
Setaria pumila (Poir.) Roem. & Schult.	+	+	+	9th–12th	+	
Setaria viridis (L.) P. Beauv.	+	+	(+)	9th–12th	+	rather rare
Setaria verticillata (L.) P. Beauv.			(+)	9th–10th	+*	2 historical localities, ephemerophyte
Silene gallica L.	+		+	9th–11th	+*	*S. gallica* var. *silvestris*, 1 historical locality (garden)
Silene nutans L.	+		+	9th–11th	+	rather rare
Silene vulgaris (Moench) Garcke	(+)		+	9th–12th	+	rather rare
Sinapis arvensis L.		+		10th–11th	+	
Sisymbrium sp.	+			12th	+	
Solanum dulcamara L.			+	9th–10th	+	
Solanum nigrum L. em. Mill.	+	+	+	10th–11th	+	
Sonchus palustris L.	+			10th–11th	+	
Sorbus aucuparia L. em. Hedl.			+	9th–10th	+	
Sorbus torminalis (L.) Crantz			(+)	10th	+	very rare: 1 locality
Sparganium erectum L. em. Rchb. s.s.			+	9th–10th	+	
Spergula arvensis L. s.l.	+		+	9th–12th	+	
Spergula arvensis subsp. *maxima* (Weiche) O. Schwarz	+		+	9th–12th	–	
Spergula arvensis subsp. *sativa*			+	9th–10th		
Spergula arvensis subsp. *vulgaris*			+	9th–10th		
Stachys annua (L.) L.			+	9th–10th	+*	very rare: 3 historical localities
Stachys arvensis (L.) L.	+		+	10th	–	
Stachys recta L.			+	10th	+	rare
Stachys sylvatica L.			+	10th	+	rather rare
Stellaria graminea L.			+	10th	+	
Stellaria media (L.) Vill.	+		+	9th–12th	+	
Stellaria palustris Retz.			+	10th	+	
Thalictrum flavum L.			+	10th	+	
Thalictrum minus L.			(+)	10th	+	
Thlaspi arvense L.	+		+	9th–12th	+	
Trapa natans L. s.l.	+	+		9th–10th	–	
Trifolium pratense L.	+			10th–11th	+	
Triglochin maritimum L.	+		+	12th	+	
Triticum aestivum L. s.l.	+	+	+	9th–12th	cult.	
Triticum compactum Host (=*T. aest.* grex *aestivo-compactum* Schiem.)	+	+		9th–12th	cult.	
Triticum dicoccon Schrank	+			9th–12th	cult.	
Triticum spelta L.	+			9th–12th	cult.	
Triticum sp.		+		10th	cult.	
Typha sp.	+		+	9th–11th	+	
Urtica dioica L.	+		+	9th–12th	+	
Urtica urens L.	+		+	9th–10th, 12th	+	rather rare
Vaccinium myrtillus L.	+		+	10th–12th	+	
Vaccinium vitis-idaea L.	+		+	10th–12th	+	
Valeriana sp.			+	9th–10th	+	
Valerianella dentata (L.) Pollich	+		+	9th–12th	+*	2 historical localities

Appendix. Continued

Taxon	A.A.	M.K.	M.L.	Century AD	H.P.	Remarks
Verbascum sp.	+			9th–10th	+	
Veronica hederifolia L.			(+)	10th	+	
Viburnum opulus L.	+	+	+	10th–11th	+	
Vicia angustifolia L.	+			9th–11th	+	
Vicia faba L.	+	+		9th–10th		
Vicia hirsuta (L.) S.F. Gray	+		+	9th–11th	+	
Viola arvensis Murray	(+)		(+)	9th–10th	+	
Viola canina L.	+			10th–11th	+	
Viola tricolor L.	(+)		(+)	9th–12th	+	
Xanthium strumarium L.		+		12th	+*	known only from few historical localities
Zannichellia palustris subsp. *palustris* (Wahlenb. & Rosen) Hegi			+	9th–10th	+	
Zannichellia palustris subsp. *pedicellata* (Wahlenb. & Rosen) Hegi			+	9th–10th	+	

PLATES

Plate 1

1. *Polygonum lapathifolium* subsp. *pallidum*
2. *Polygonum lapathifolium* subsp. *lapathifolium*
3. *Fallopia convolvulus*
4. *Polygonum hydropiper*
5. *Rumex hydrolapathum*
6–7. *Polygonum aviculare* (two specimens)
8. *Polygonum calcatum*
9. *Rumex acetosella*
10. *Urtica urens*
11. *Cannabis sativa*
12. *Humulus lupulus*

Scale bars equal 1 mm

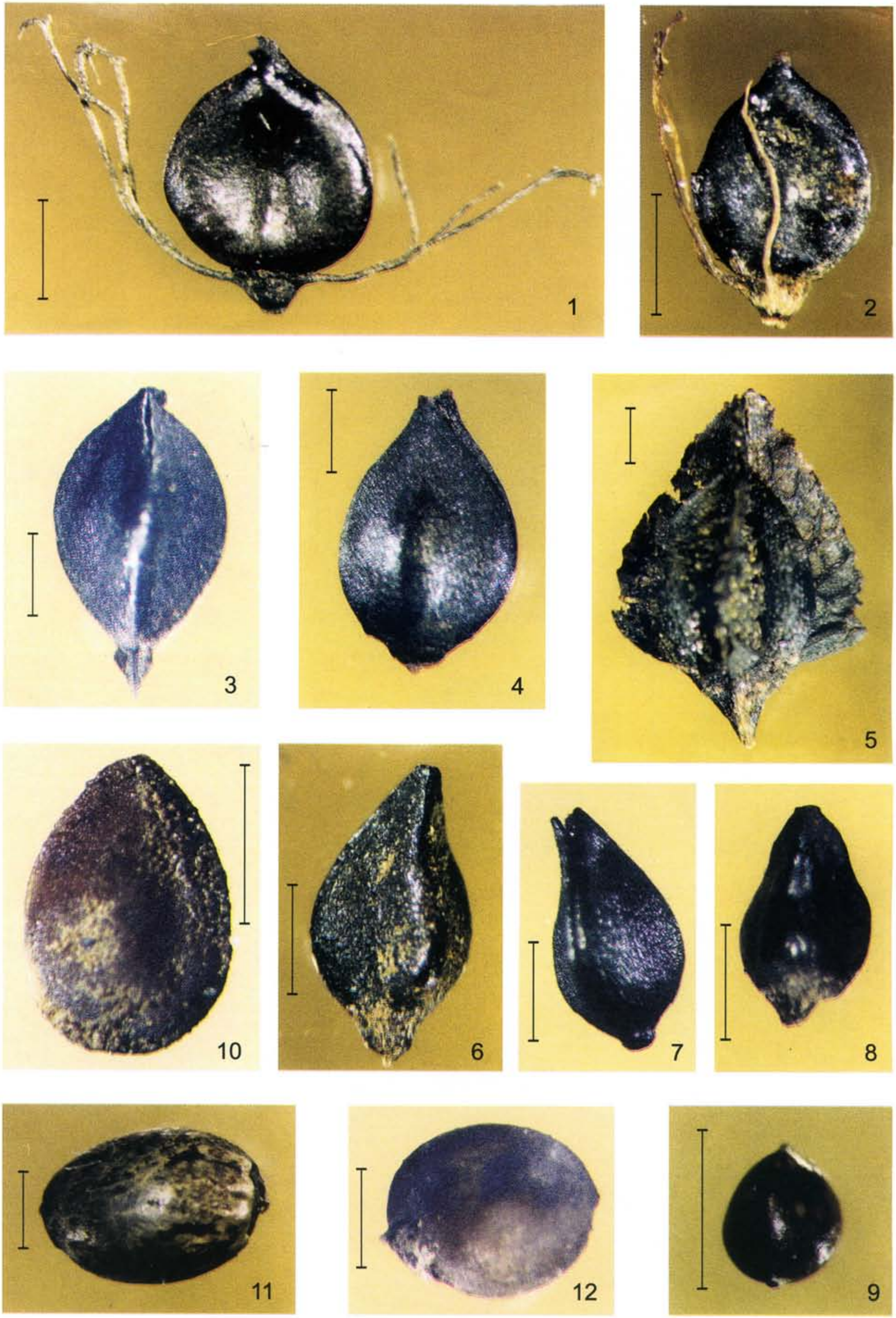
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Plate 2

1. *Agrostemma githago* (mineralised)
2. *Melandrium album*

3–4. *Melandrium rubrum* (two specimens)

5. *Melandrium noctiflorum*
6. *Silene inflata*
7. *Silene nutans*
8. *Silene gallica*
9. *Scleranthus annuus*
10. *Cerastium arvense*
11. *Cerastium holosteoides*
12. *Arenaria serpyllifolia*

Scale bars equal 1 mm

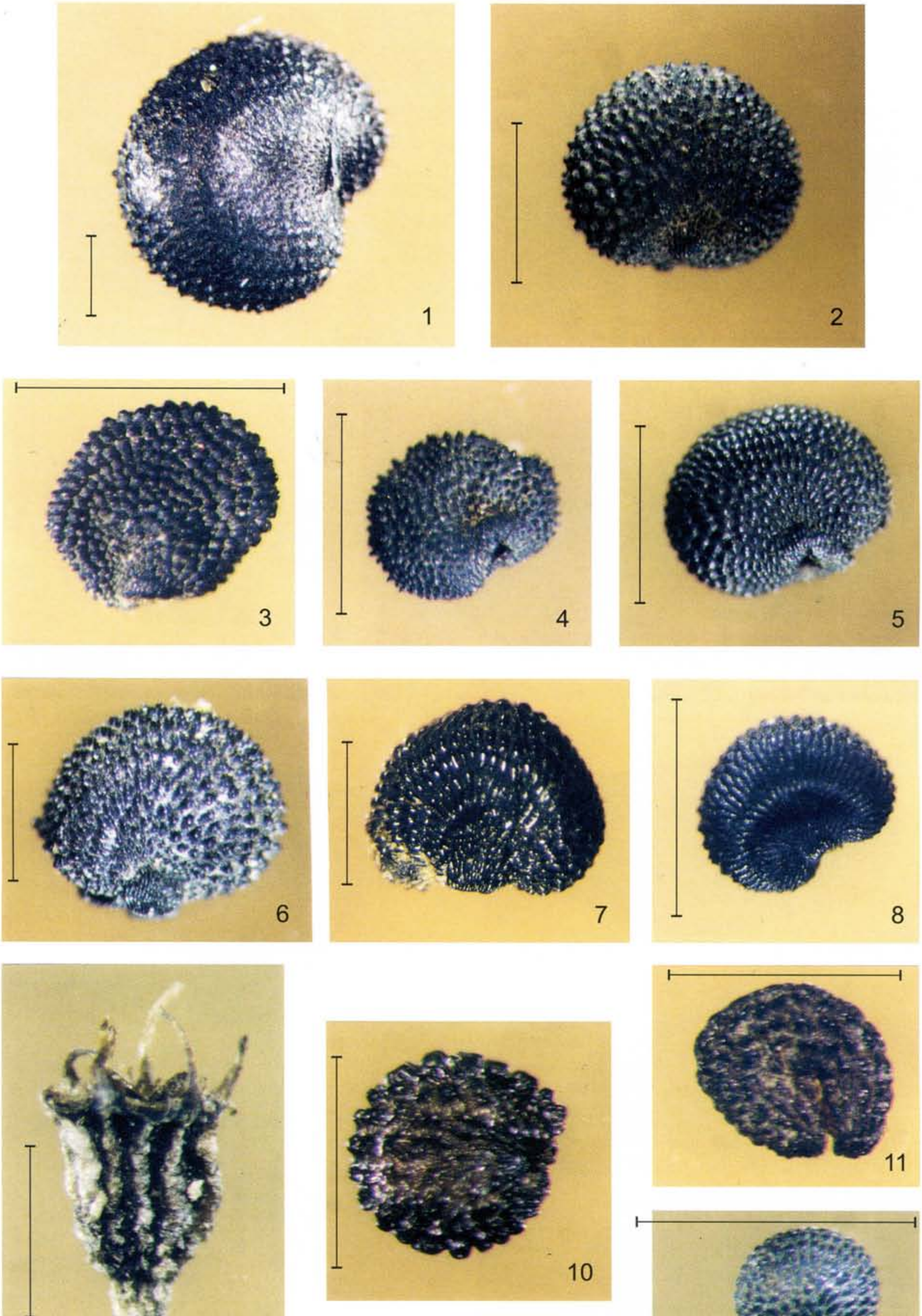
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Plate 3

1–2. *Petrorhagia prolifera* (seed from ventral (1) and dorsal (2) sides)
3. *Moehringia trinervia*
4. *Stellaria media*
5. *Stellaria palustris*
6. *Spergula arvensis* subsp. *maxima*
7. *Hypericum perforatum* (charred)
8. *Plantago lanceolata*
9. *Plantago major*
10. *Plantago media*
11. *Viola arvensis/tricolor*
12. *Glaux maritima*

Scale bars equal 1 mm

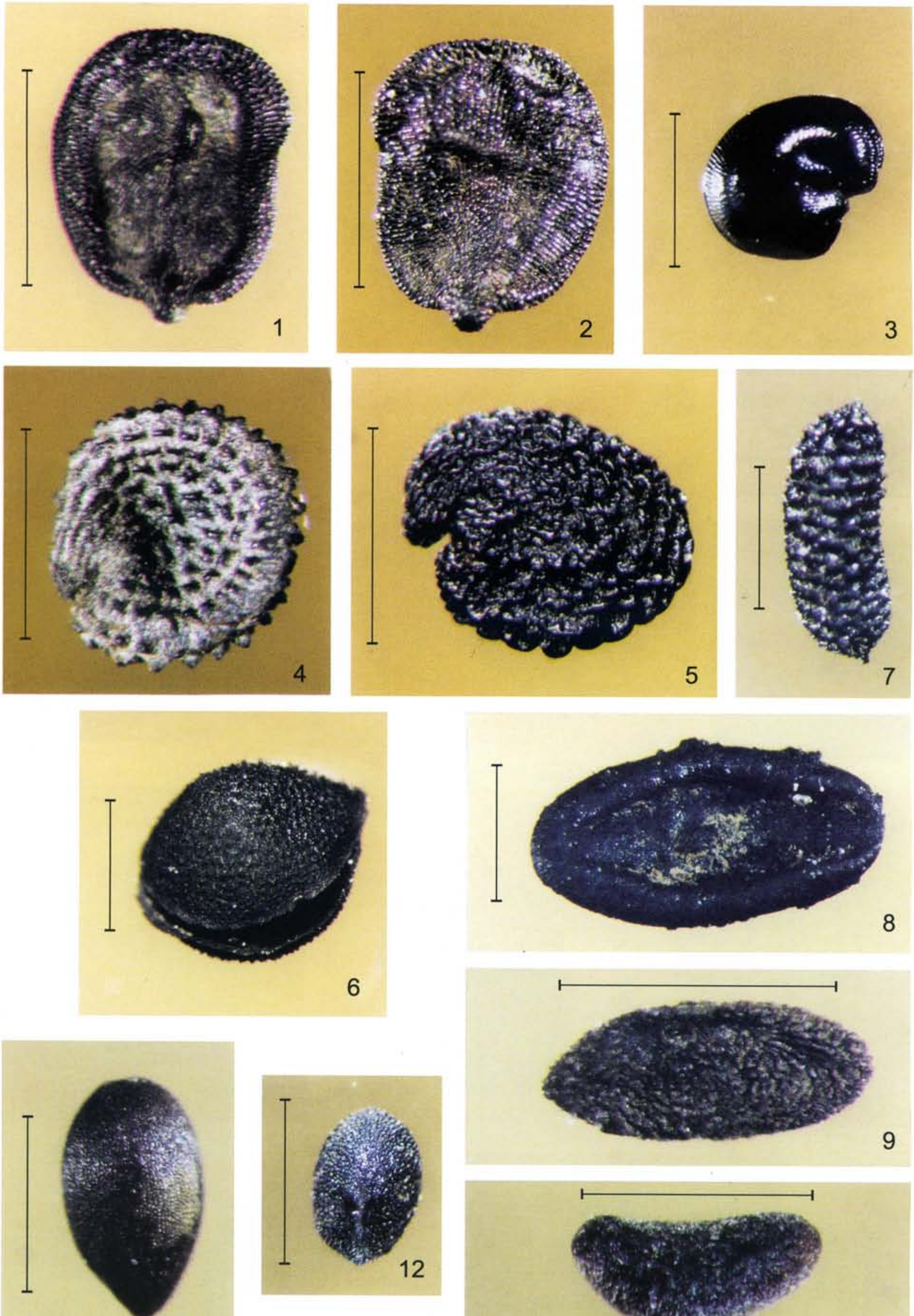
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Plate 4

1. *Ranunculus acris*
2. *Ranunculus bulbosus*
3. *Ranunculus sceleratus*
4. *Batrachium* sp.
5. *Ranunculus repens*
6. *Ranunculus sardous*
7. *Ranunculus flammula*
8. *Thalictrum flavum*
9. *Myosotis arvensis*-type
10. *Euphorbia helioscopia*
11. *Linum catharticum*
12. *Vicia hirsuta* (charred)

Scale bars equal 1 mm

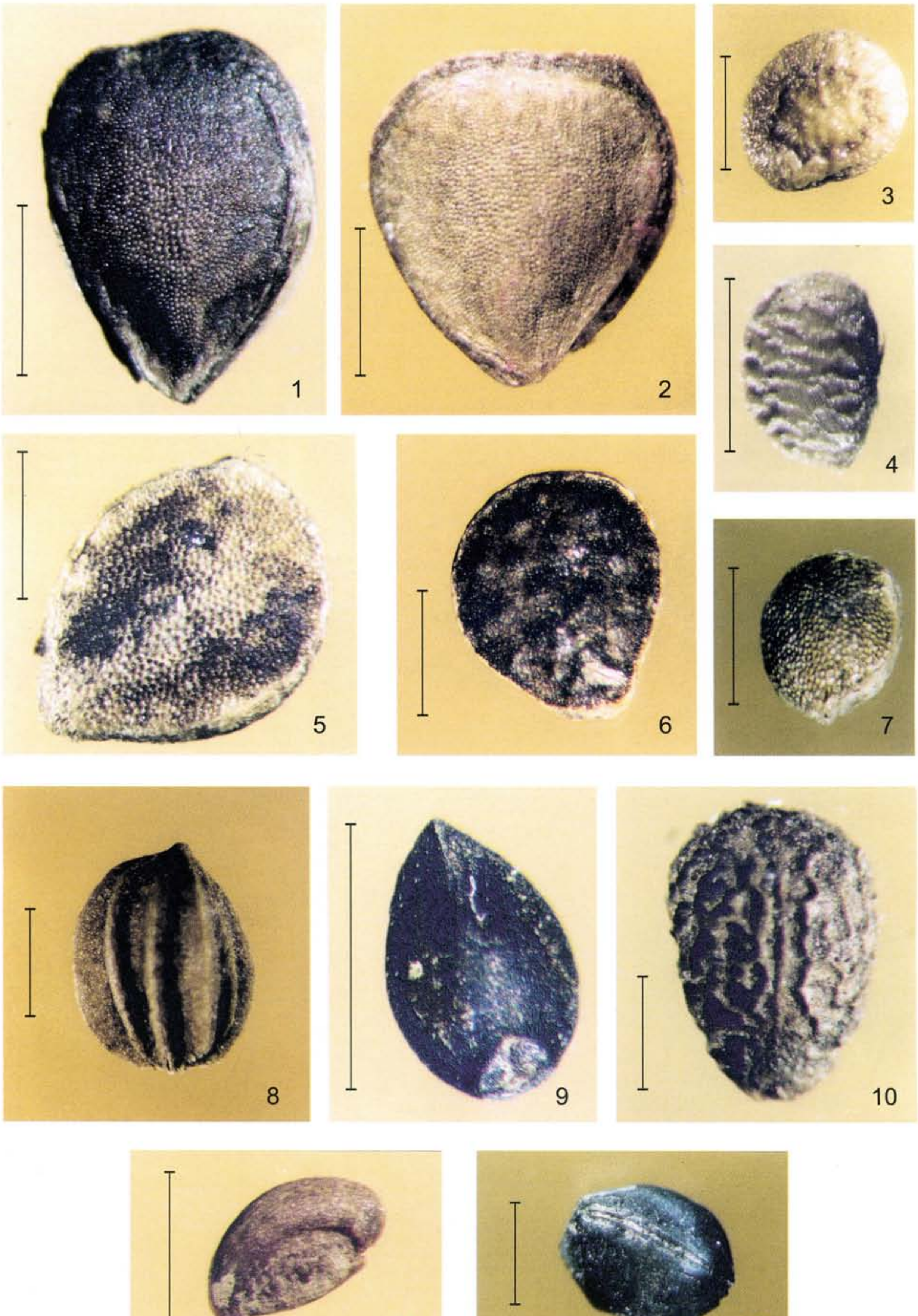
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Plate 5

1. *Brassica rapa*
2. *Berteroa incana*
3. *Thlaspi arvense*
4. *Neslia paniculata*
5. *Bunias orientalis* (mineralised)
6. *Pedicularis palustris*
7. *Linaria vulgaris*
8. *Valerianella dentata*

9–10. *Papaver argemone* (seed from lateral (9) and ventral (10) sides)

11. *Papaver somniferum*

Scale bars equal 1 mm

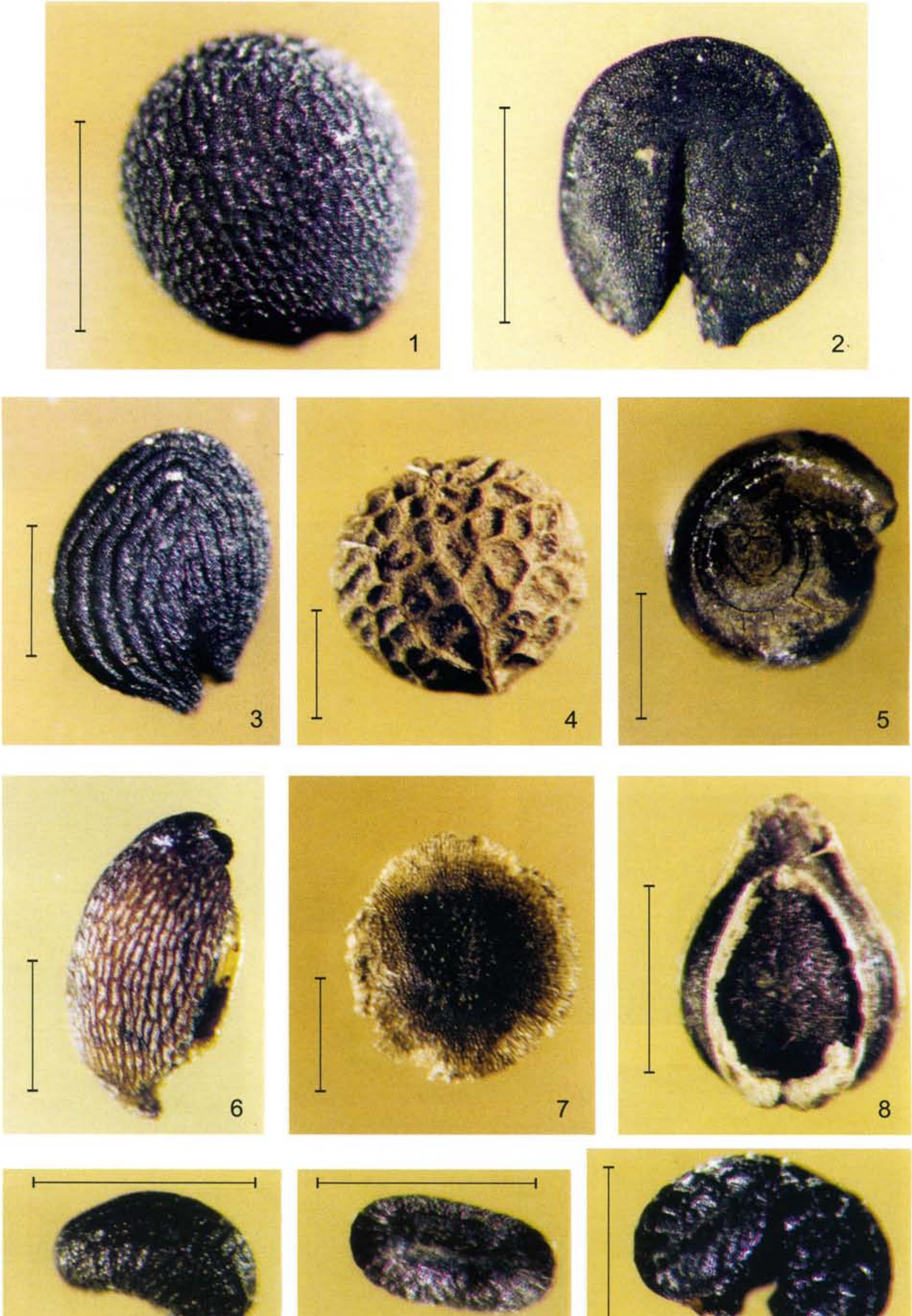
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Plate 6

1. *Malus* sp.
2. *Pyrus communis*
3. *Sorbus* cf. *torminalis* (fragment of a pipe)
4–5. *Sorbus aucuparia* (pipe from both sides)
6. *Rubus caesius*
7. *Rubus fruticosus*-type
8. *Rubus idaeus*
9. *Fragaria vesca*
10. *Potentilla argentea*
11. *Potentilla reptans*
12. *Potentilla erecta*

Scale bars equal 1 mm

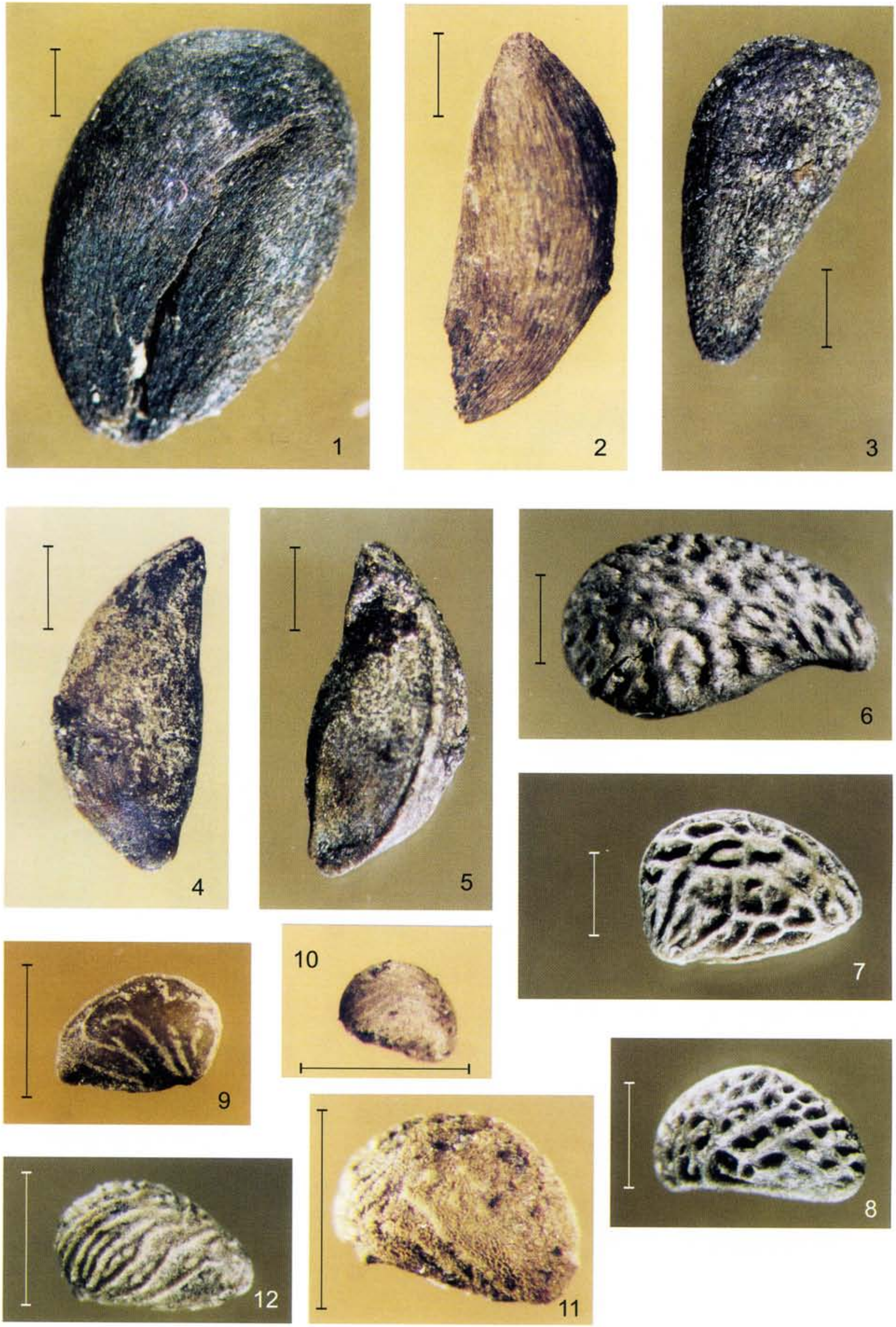
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Plate 7

1. *Oenanthe aquatica*
2. *Peucedanum palustre*
3. *Aethusa cynapium*
4. *Hydrocotyle vulgaris* (half of a fruit)
5. *Anthemis tinctoria*
6. *Anthemis arvensis*
7. *Leontodon autumnalis*
8. *Eupatorium cannabinum*
9. *Lapsana communis*

10–11. *Cirsium arvense* (two specimens)

12. *Solanum nigrum*
13. *Solanum dulcamara*
14. *Knautia arvensis*

Scale bars equal 1 mm

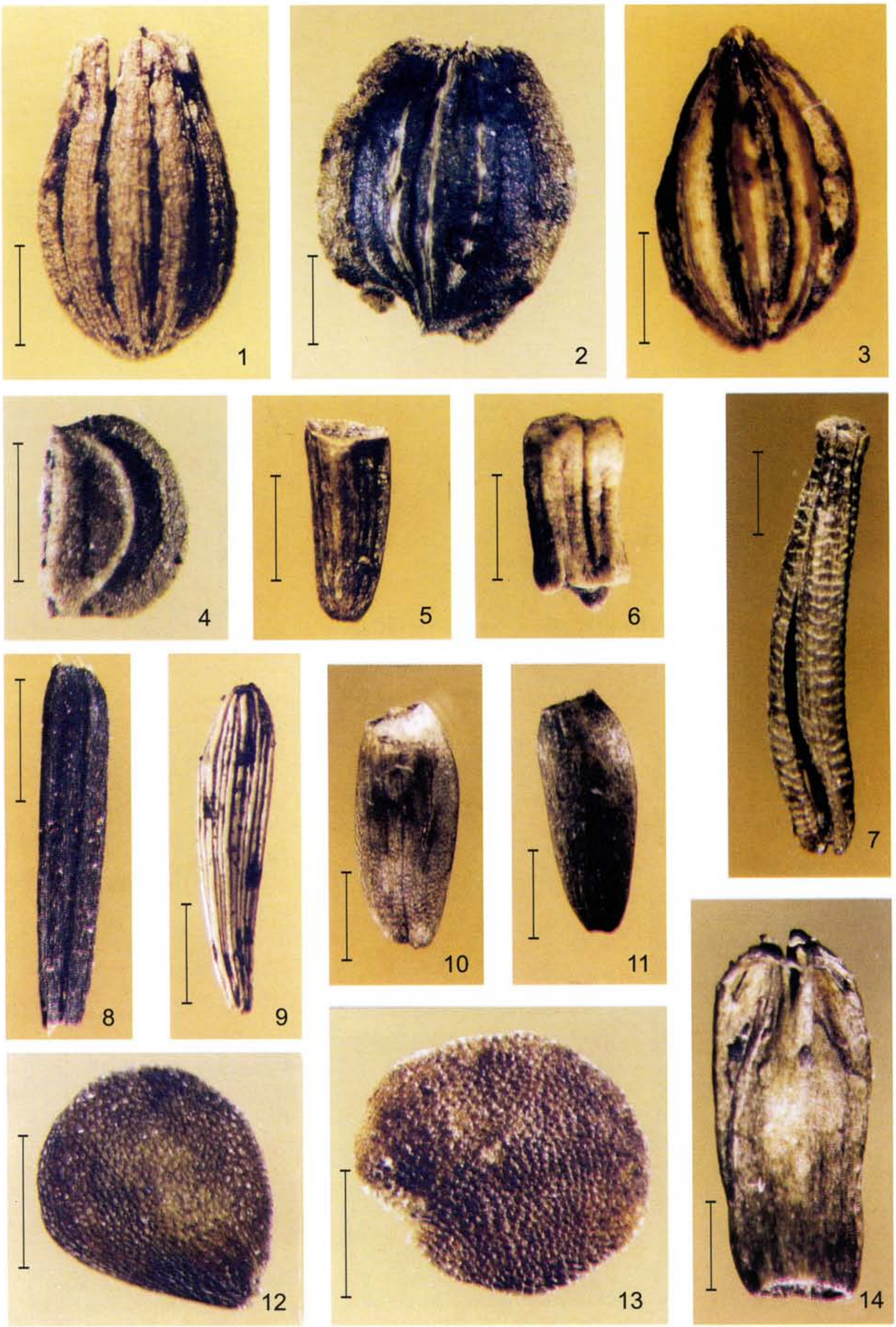
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Plate 8

1. *Galeopsis tetrahit*-type
2. *Galeopsis ladanum*
3. *Lycopus europaeus*
4. *Ajuga reptans*
5. *Stachys arvensis*
6. *Stachys annua*
7. *Stachys recta*
8. *Prunella grandiflora* (fruit without the outer layer of pericarp)
9. *Prunella vulgaris*
10. *Lamium album*

11–12. *Galium spurium* (fruit from ventral (11) and dorsal (12) sides)

Scale bars equal 1 mm

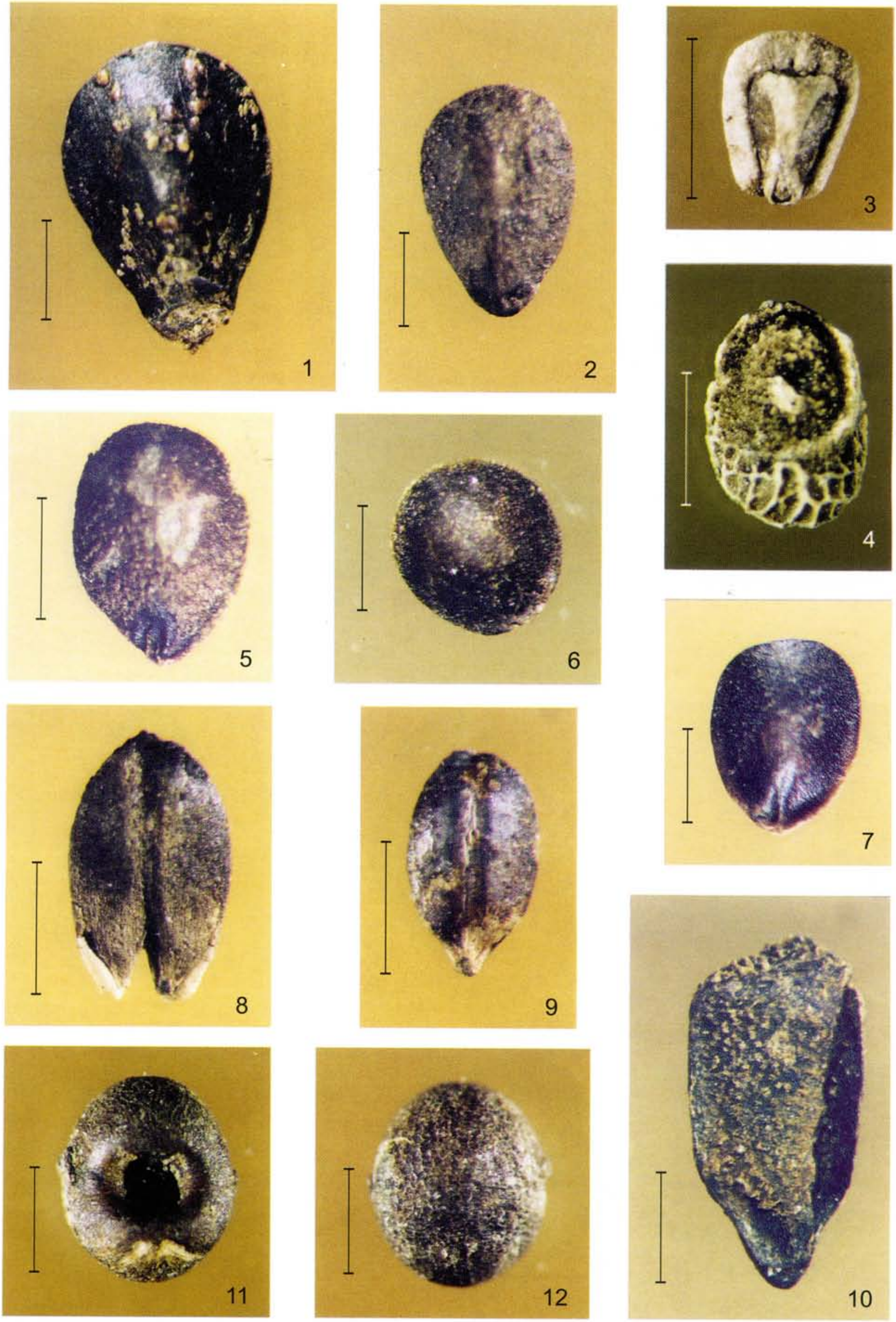
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Plate 9

1. *Bulboschoenus maritimus*
2. *Schoenoplectus lacustris*
3. *Schoenoplectus tabernaemontani*
4. *Cladium mariscus*
5. *Scirpus sylvaticus*
6. *Carex nigra*
7. *Carex elata*
8. *Carex remota*
9. *Carex leporina*
10. *Carex elongata*
11. *Carex vulpina*
12. *Carex pairae*
13. *Carex paniculata*

Scale bars equal 1 mm

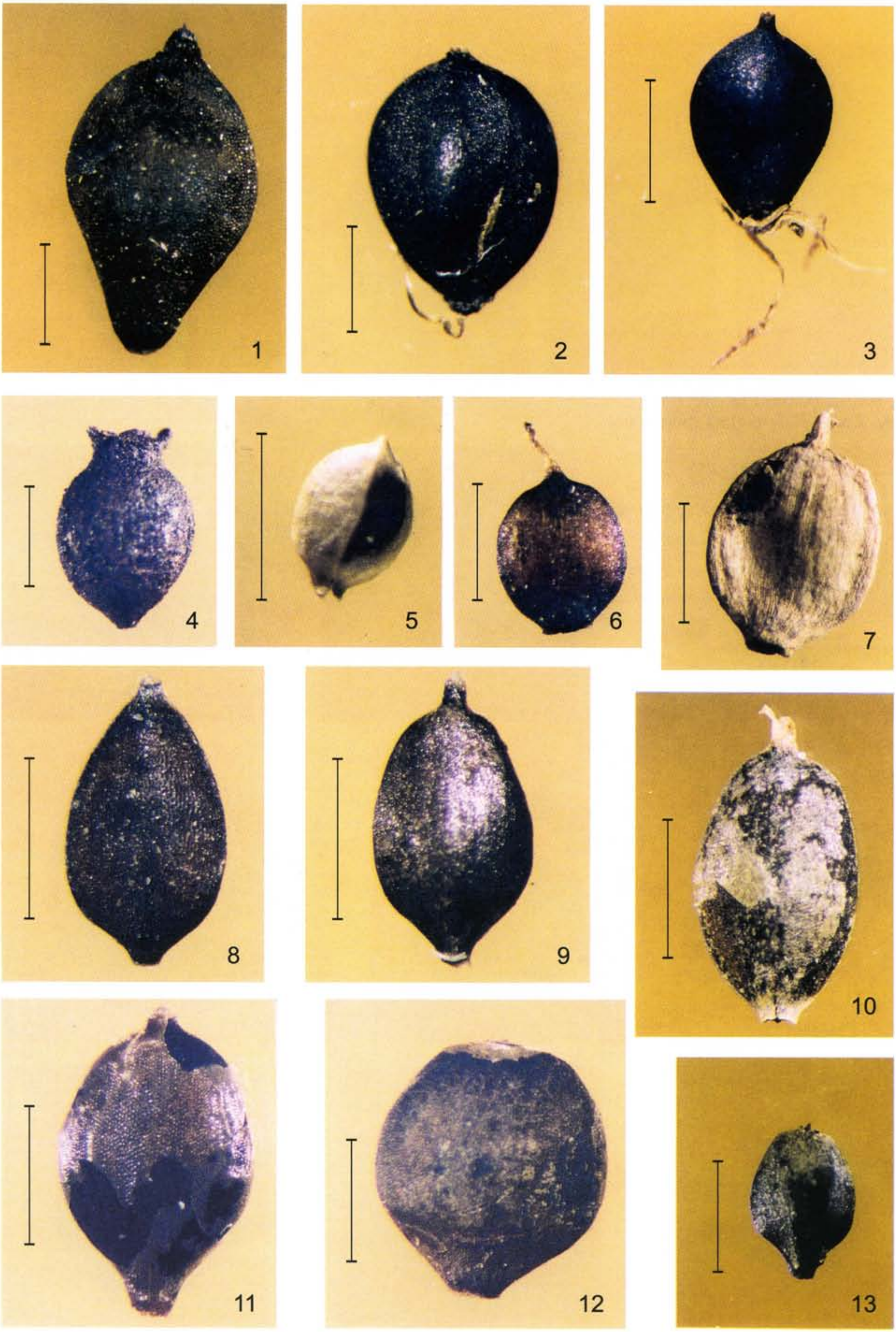
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Plate 10

1–2. *Carex riparia* (utriculus (1) and achene (2))

3. *Carex flava/oederi*

4. *Carex pseudocyperus*

5–6. *Carex distans* (two specimens)

7. *Carex panicea*

8. *Atriplex patulum*

9–10. *Atriplex prostrata* subsp. *prostrata* (two specimens of different types)

11. *Chenopodium hybridum*

12. *Chenopodium polyspermum*-type

13. *Chenopodium rubrum/urbicum*

Scale bars equal 1 mm

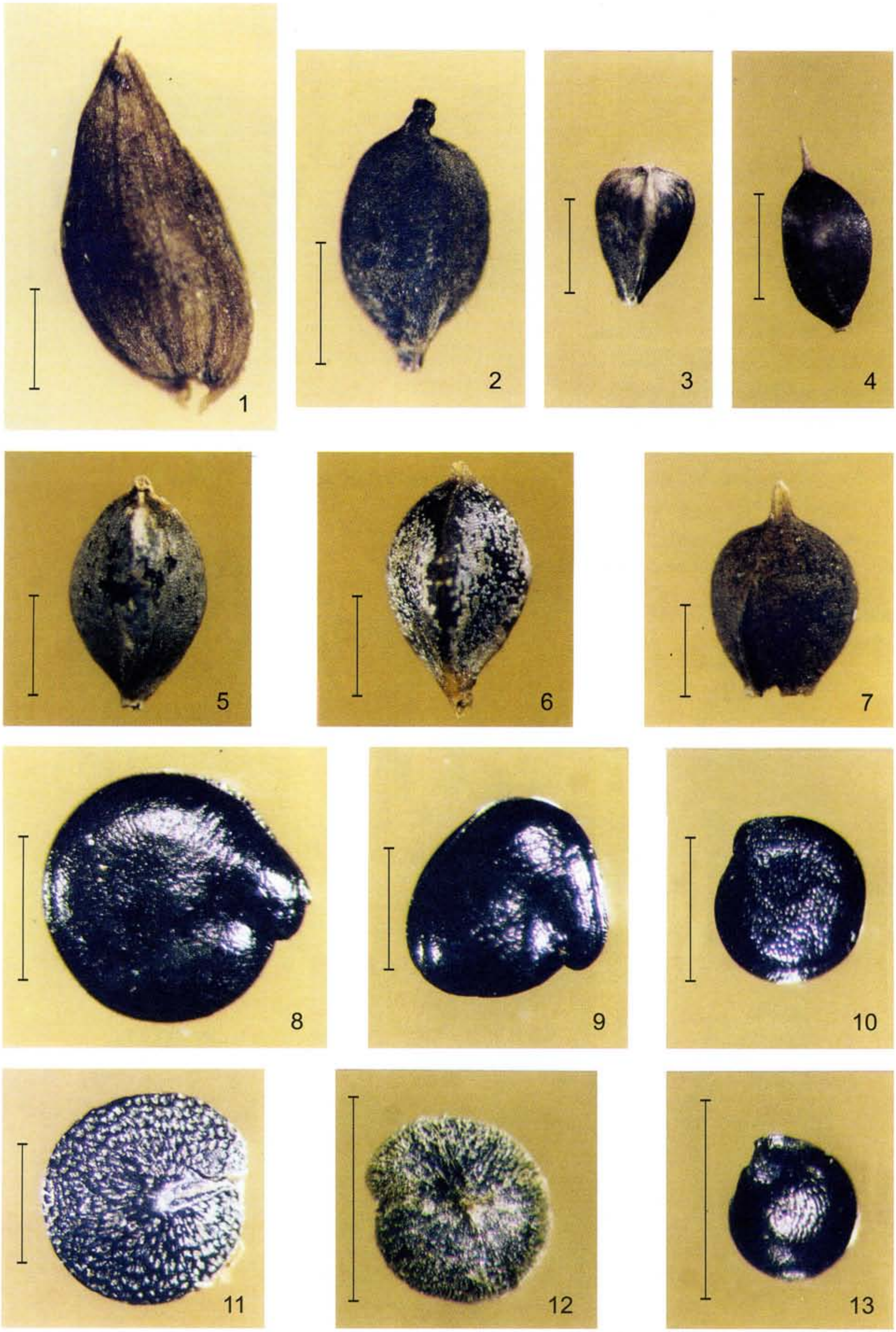
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Plate 11

1. *Panicum miliaceum* (dorsal side)
2. *Echinochloa crus-galli* (dorsal side)
3. *Setaria pumila* (dorsal side)
4. *Setaria italica* (carbonised, ventral side)
5. *Setaria viridis / verticillata* (dorsal side)

6–7. *Triticum aestivum* s.l. (mineralised, specimen from ventral (6) and dorsal (7) sides)

8. *Triticum aestivum* s.l. (charred)
9. *Secale cereale* (charred)
10. *Hordeum vulgare* subsp. *vulgare* (charred)

Scale bars equal 1 mm

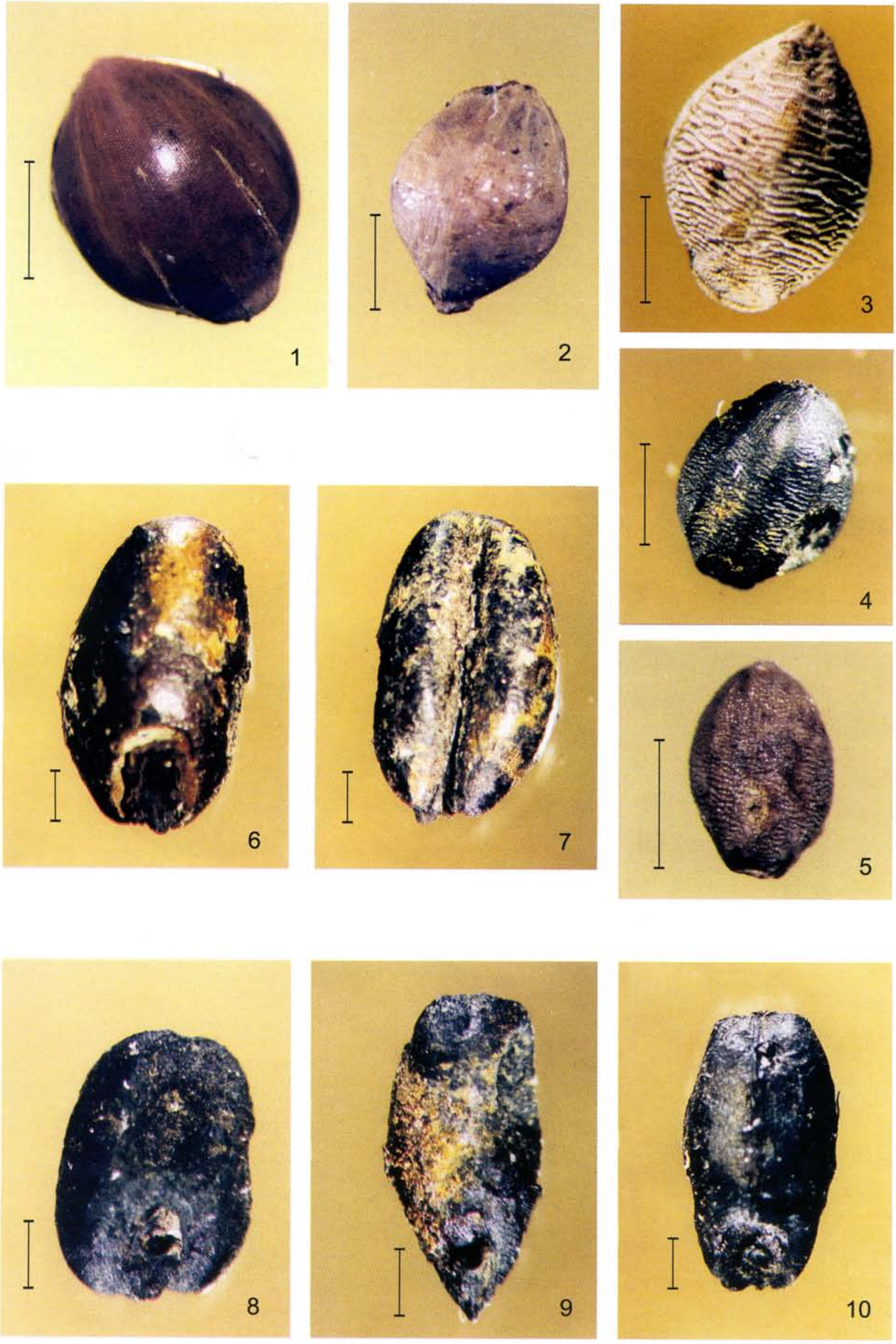
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Plate 12

1. *Viburnum opulus*
2. *Sambucus nigra*
3. *Frangula alnus*
4. *Alnus glutinosa*

5–6. *Vaccinium myrtillus* (two specimens)

7. *Vaccinium vitis-idaea*

Scale bars equal 1 mm

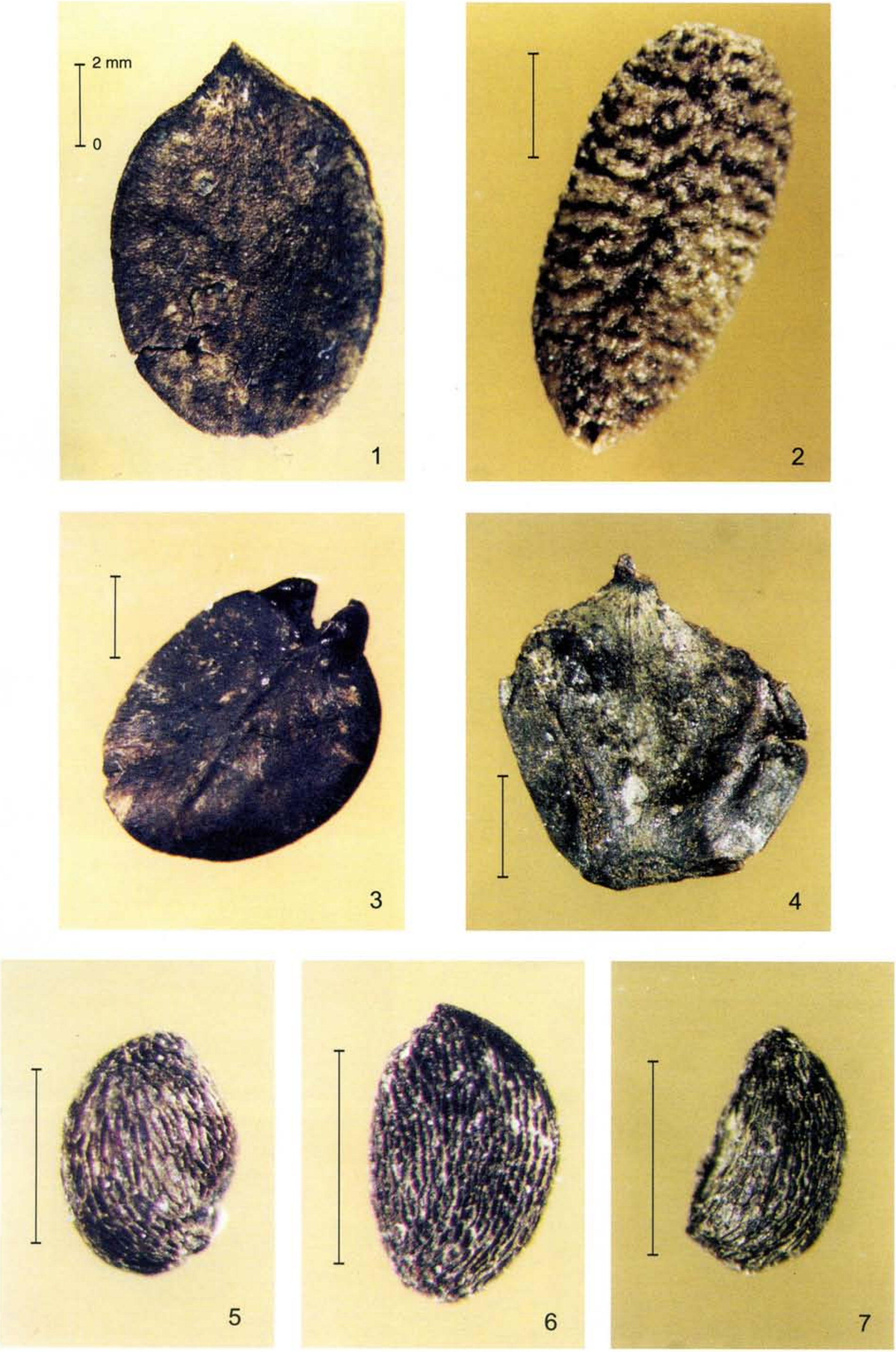
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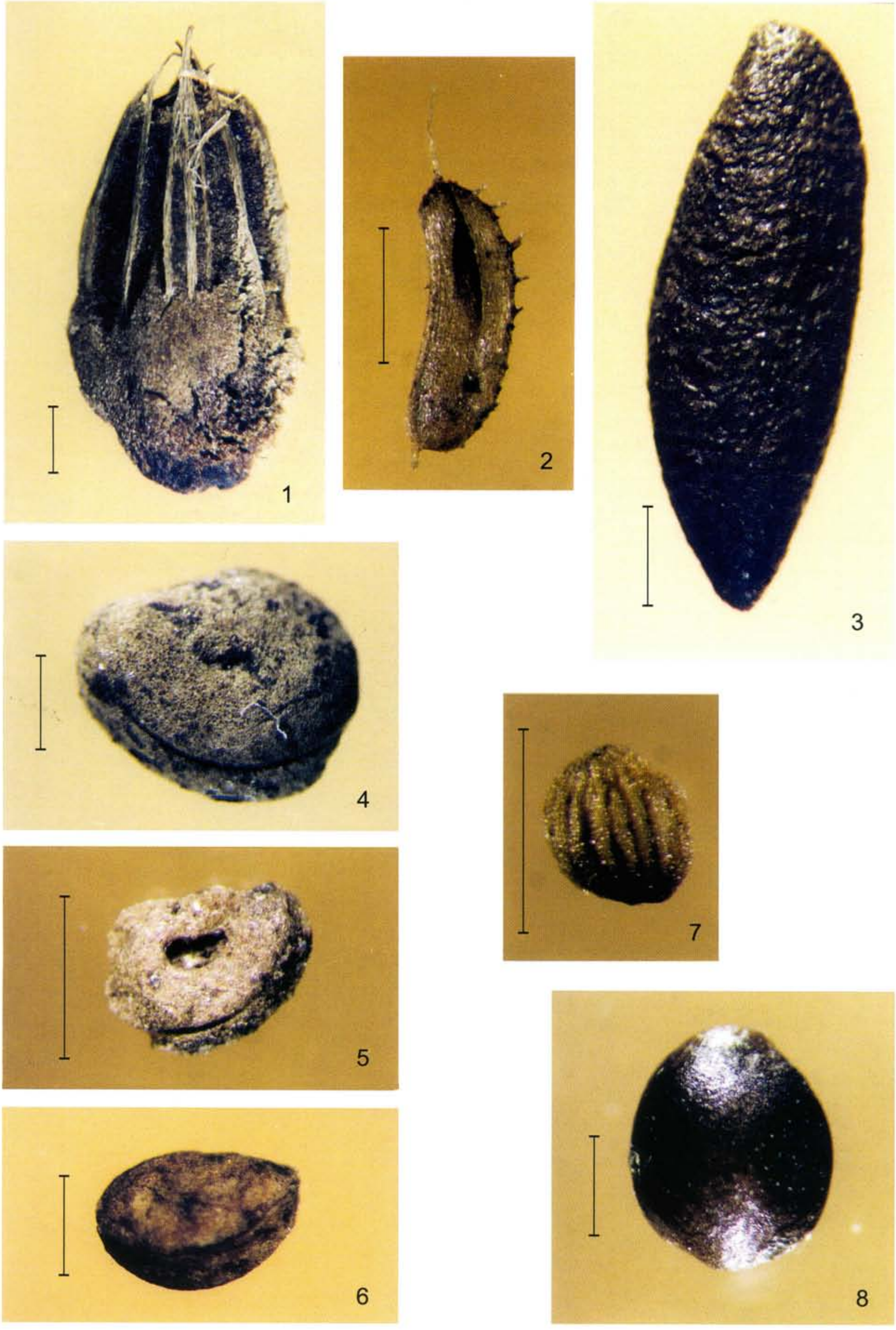
Plate 13

1. *Sparganium erectum*
2. *Zannichellia palustris* subsp. *pedicellata*
3. *Najas marina*
4. *Potamogeton natans*
5. *Potamogeton coloratus*
6. *Potamogeton pusillus*
7. *Lemna trisulca*
8. *Menyanthes trifoliata*

Scale bars equal 1 mm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