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# GEOMORPHOLOGY AND VEGETATION HISTORY OF THE RYPIENICA CHANNEL, THE DOBRZYŃ LAKELAND, NORTH POLAND

**Abstract:** The article presents the characteristics of the relief of the Rypienica channel (the Dobrzyń Lakeland, North Poland) and the postglacial development of vegetation in this area. The detailed analysis of the organic sediments of the peat-bog vegetation of the Rypienica channel documents the development of vegetation since the beginning of the Holocene until the younger part of the Subatlantic period. Holocene sediments record changes in the local vegetation of this peat-bog brought about by fluctuations in climate, changes in local hydrological conditions and the impact of human activity.

**Key words:** Rypienica channel, river, peat bog, gyttja, geomorphological research, palynological analyses, vegetation history, Holocene

## Introduction

The Rypienica channel is located in the eastern part of the Dobrzyń Lakeland (Fig. 1). This area has a young glacial landscape formed during the ice sheet recession and waning of the Poznań Phase of the Late Weichselian glaciation (Niewiarowski, Wysota, 1995; Wysota, 2002; Wysota et al. 2009; Wysota, Molewski, 2011). In the central part of the Dobrzyń Lakeland, between

Lipno and Rypin, there are the glaciomarginal landforms of Chrostkowo (Nechay, 1927; Liberacki, 1961) developed during a brief ice margin halt in the Kuiavian-Dobrzyń subphase of the last glaciation (Niewiarowski et al., 1995).

Behind the Chrostkowo landforms flat to undulating till plains dominate, interspersed with hills and hillocks of various origins. These plains are cut by numerous, frequently deep subglacial channels bearing rivers or sometimes occupied by lakes (Niewiarowski, Wysota, 1995; Niewiarowski et al., 1995). The Rypienica channel, besides the channels of the Ruziec and Lubianka, is one of the "trunk" valleys in this part of the Dobrzyń Lakeland (Niewiarowski et al., 1995; Lesemann et al., 2010). Besides subglacial channels the morphology of this area features forms unique to the landscape of the last glaciation in Central Europe, namely assemblages of till ridges called the Zbójno drumlins (including Nechay, 1927; Jewtuchowicz, 1956; Lamparski, 1972; Niewiarowski et al., 1995; Olszewski, 1997; Lesemann et al., 2010). The genesis and evolution of the subglacial channels in this area has been the subject of research by Niewiarowski (1986, 1988) and Niewiarowski et al. (1995), and, recently, by Lesemann et al. (2010).

The Dobrzyń Lakeland is characterized by the presence of numerous lakes and peat-bogs. Recognition of the postglacial vegetation history of this landscape started during the 1930s (Fig. 1, Table 1), only a few years after the pollen analysis had been introduced as a completely new method in paleobotanical investigations.

The topic of this article is the geomorphological characteristics of the Rypienica channel and its immediate neighbourhood, as well as a description of the development of vegetation in this area during the Holocene based on palynological analysis and radiocarbon datings of the deposits found in the bottom of the channel.

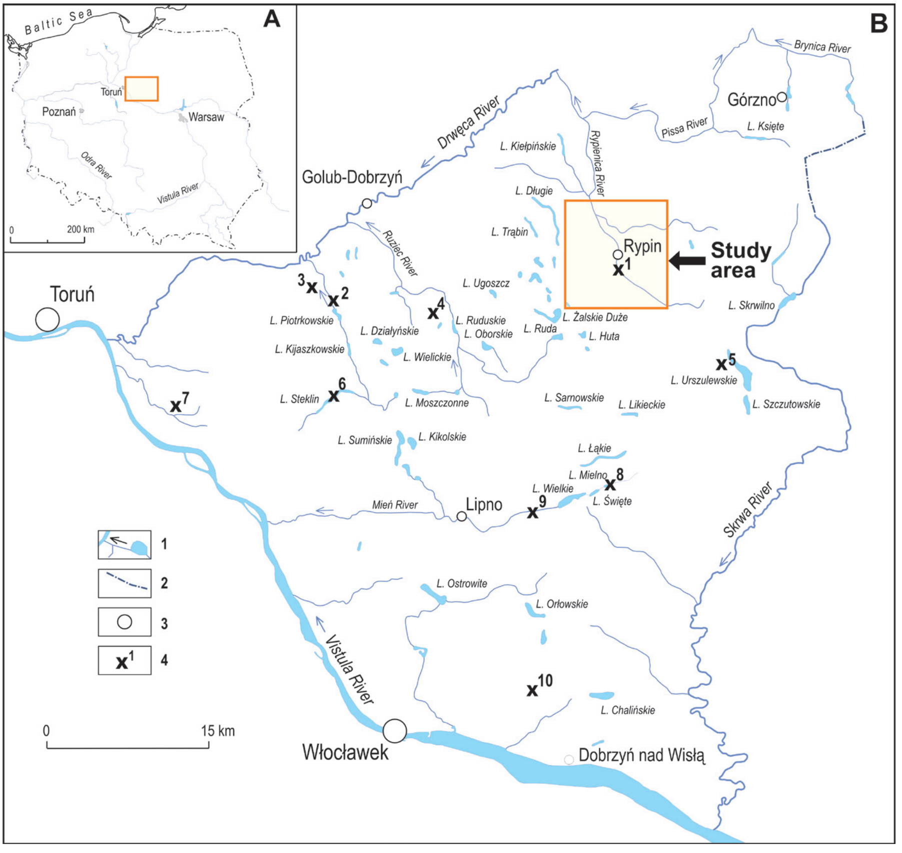


Fig. 1. (A) Location of the Dobrzyń Lakeland in North Poland; (B) Location of the study area in the north-eastern part of the Dobrzyń Lakeland (according to Noryśkiewicz et al., 2010, modified). 1 – rivers and lakes, 2 – section of the watershed, 3 – main towns, 4 – sites with pollen analysis (see table 1): 1 – Rypin (this study), 2 – Piotrkowo, 3 – Rudaw, 4 – Zbójenko, 5 – Urszulewo, 6 – Steklin, 7 – Dzikowo, 8 – Żuchowo, 9 – Mielno/Skępe, 10 – Wylazłowo.

Tab. 1. List of pollen diagrams in the Dobrzyń Lakeland (according to Noryśkiewicz et al., 2010, modified). See fig. 1 for a location of sites.

| No | Name of the site | Author of the pollen analysis | $C^{14}$ Dating | References |
|---|---|---|---|---|
| 1 | Rypin | B. Noryśkiewicz | 4 dates, AMS | Wysota et. al, 2010 |
| 2 | Piotrkowo 1 i 2 | W. Gamrat | – | unpublished |
| 3 | Rudaw | W. Gamrat | – | unpublished |
| 4 | Zbójenko | A.M. Noryśkiewicz, B. Noryśkiewicz | 4 dates, AMS* | Wysota et al., 2010; Karasiewicz et al., 2011 |
| 5 | Urszulewo | K. Lublinerówna | no date | Lublinerówna, 1934 (after Kępczyński, 1965) |
| 6 | Steklin | B. Noryśkiewicz | 1 date | Noryśkiewicz, 1982 |
| 7 | Dzikowo | B. Noryśkiewicz | 1 date | Tomczak, 1987 |
| 8 | Żuchowo | J. Oszast | – | Oszast, 1957 |
| 9 | Mielno/ Skępe | K. Kępczyński | – | Kępczyński, 1960 |
| 10 | Wylazłowo | I. Dąbkowska | – | Dąbkowska, 1935 (after Kępczyński, 1965) |

* AMS radiocarbon ages have not been published yet.

## Study area

The Rypienica is a winding subglacial channel (tunnel valley) up to 1.5 km wide, 20–45 m deep and about 15 km long. It runs from the village of Zakrocz south of Rypin to the village of Kominy west of Brodnica, where it constitutes part of the Drwęca River valley (Wysota et al., 2010). The channel is used by the Rypienica River, which formed several short and narrow gorges north of Rypin. The bottom of the channel consists of peat plains, which in places are covered with alluvial muds (Wysota, Sokołowski, 2009b). The escarpments of the Rypienica channel, especially along its eastern side between Rypin and Osiek, are bisected by many valleys of various origins. Most numerous among them are denudation valleys and small V-shaped valleys and ravines. At the mouths of some of these landforms minor alluvial cones have developed.

The area west of the Rypienica tunnel valley is formed of a flat and undulating moraine plateau at several topographic (plateau) levels: 100–110, 110–120 and 120–135 m a.s.l. (Wysota, Sokołowski, 2009a; Wysota et al., 2010). Here it is bisected by numerous narrow subglacial channels, 4–14 km in length, 10–35 m in depth and 100–800 m in width. They are mostly winding, with numerous narrowings and widenings as well as morphological thresholds and overdeepenings. The subglacial channels are occupied by lakes and peat plains. A few of them have been used and partly transformed by small rivers. The largest are the channels of Lake Kiełpińskie, Lake Długie, lakes Trąbińskie and Czarownica, Lake Ostrowite, Lake Kleszczyńskie and Lake Żalskie Duże. Another characteristic element of the relief of the moraine plateau is kettle holes in the vicinity of Czyżewo, Balin and Kowalki, which mostly contain peat.

The morainic plateau east of the Rypienica tunnel valley rises to a height of 130–150 m a.s.l. (Fig. 2). The upland fragment directly adjacent to the Rypienica channel lies at an altitude of 110–120 m a.s.l., where there is a flat morainic plateau. It is bisected by side valleys of varying origins which are especially numerous to the north of Rusinowo and between Rypin and Dylewo. More to the east the morainic plateau is hummocky, and in places rises above 150 m a.s.l. (at 154.3 m a.s.l., the high point to the south of the village of Kretki Małe is the highest point in the vicinity of Rypin). The landscape here also has numerous kettle holes as a characteristic feature. To the southeast of Rypin there are glaciomarginal landforms related to the stagnation of the ice sheet during the Kuyavian-Dobrzyń subphase of the last glaciation (Niewiarowski, Wysota, 1995; Niewiarowski et al., 1995). These are small hills of accumulative end moraine which determine the limit of this subphase in the vicinity of Huta Nadróż and east of the village Godziszewy (Wysota, Sokołowski, 2009a, b). They also include the sandur plain, stretching out to the east of Sitnica and Huta Nadróż and to the south of Zakrocz and Dylewo. It constitutes a section of the proximal part of the vast lower level of the Dobrzyń sandur (Wysota, 1992, 1999). The surface of the sandur plain is at an altitude range of 138–130 m a.s.l. (on the border of the moraine plateau in the vicinity of Sitnica and Huta Nadróż) to

130–125 m a.s.l. (in the surroundings of Zakrocz and Dylewo). It is diversified with numerous and often extensive dead ice depressions, which are mostly filled with peat and gyttja.

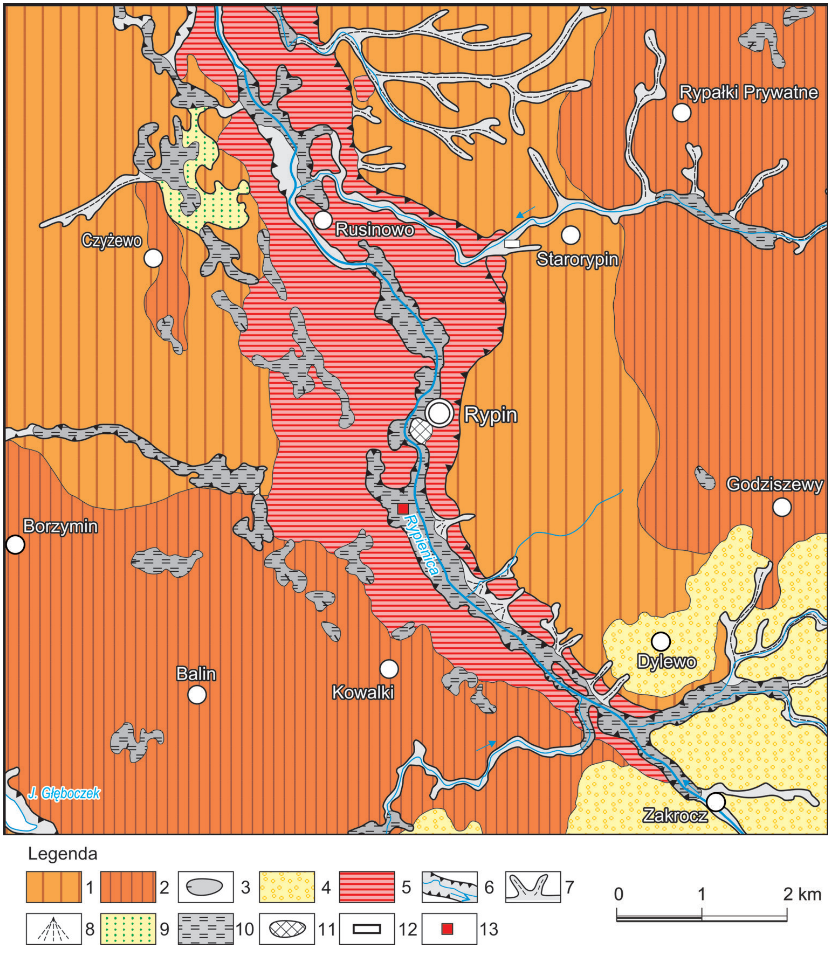


Fig. 2. Geomorphological map of the Rypienica channel and its surroundings (according to Wysota, Sokołowski 2009a, modified)

Explanations:1 – flat till plain; 2 – undulating till plain; 3 – kettle holes; 4 – sandurs; 5 – kames, 6 – subglacial channels; 7 – side valleys of various origin (denudation valleys, small V-shaped valleys and ravines), 8 – alluvial cones, 9 – lacustrine plains, 10 – peat plains, 11 – embankments, 12 – fortified settlements, 13 – location of the profile in the Rypienica channel peat-bog.

In the Rypienica channel and the adjacent upland moraine there are numerous accumulative landforms associated with the retreat and stagnation of the last ice sheet. The largest area is taken by kames. They occupy compact and hilly areas, diversified by kettle holes, which form a belt of 0.5–3.0 km wide along the Rypienica channel (Wysota, Sokołowski, 2009a, b; Wysota et al., 2010). Extensive kame hills and a 15-m-high plateau are located south of Radzynek and near Ruda. Small, isolated kame hills 5–10-m-high occur in the vicinity of Ostrowite, Wąpielsk, Sumówko and Dzierżno.

Presently, the Dobrzyń Lakeland area is mainly farmland and built-up areas, while only 13.5% of the surface is covered by forests. Patches of the Dobrzyń Lakeland forests are very unevenly distributed. They cover the areas unsuitable for agriculture and are mostly located in channels and river valleys, on sandur plains and around lakes. The increase in the intensity of settlement and the related deforestation in this area began in the late phase of the Early Middle Ages, i.e. the $11^{th}$–$12^{th}$ century (Chudziak, 1996).

Nowadays, the basic types of forest in the Dobrzyń Lakeland are pine forests. Deciduous and mixed forests play a minor role, and often they are protected areas, such as nature reserve „Sources of the Skrwa". A larger forest complex, part of the Górzno-Lidzbark Landscape Park, is located on the north eastern boundary of the lakeland. Over 70% of its area is occupied by multiform forests, which often resemble the primeval forest landscape. In the northern part there are mainly deciduous and mixed forests while the south features mixed and pine forests.

The most important forest-building component in the lakeland is pine (*Pinus sylvestris*) which occurs mainly in sandy areas, less favourable for crops. Trees of fertile habitats such as hornbeam (*Carpinus*), linden (*Tilia*), elm (*Ulmus*), sycamore or maple (*Acer*) and ash (*Fraxinus*) seldom occur in the forest stand. Alder (*Alnus*) plays an important role in wet habitats, in the depressions surrounding watercourses and lakes. In the Rypin region there are also small natural stand positions of European beech (*Fagus sylvatica*). This species occurs in small patches as an admixture of deciduous and mixed forests on the eastern border of its natural range. Also noteworthy are the natural stands of spruce (*Picea abies*) and yew (*Taxus bacata*) on the sandur plain, and patches of Polish larch (*Larix*) on the till plain. Spruce, yew, and Polish larch grow beyond their closed range. Forests constitute only 5–10% of Rypin county, which is a much lower proportion than for the entire Kuyavian-Pomeranian Voivodeship (23%).

## Methods

The study was carried out in the wide bottom of the Rypienica channel close to Rypin (Fig. 2). Detailed geomorphologic and geologic field mapping at a scale of 1:25,000 was used to examine the composition and origin of glacial landforms of this area (Wysota, Sokołowski, 2009a, b). The vegetation history was studied in a core which was taken from the peat-bog in the Rypienica channel about 1 km south of Rypin (Noryśkiewicz, 2009). The core was taken from the western part of the peat-bog to a depth of 10.30 m, using a Więckowski probe (1961). Samples for pollen analysis were taken with a volumetric sampler of 1 cm$^3$. The deposits containing $CaCO_3$ were treated with 10% HCL. Carbonate-free and peat deposits were prepared by a standard procedure: 10% KOH and Erdtman's acetolysis method (Berglund, Ralska-Jasiewiczowa, 1986). The samples containing silica were treated with cold 40% HF. The concentration of pollen grains in 1 cm$^3$ of the sediment was calculated by the method described by Stockmarr (1971). Two *Lycopodium* tablets were added to each sample of profile (Fig. 5).

The percentage pollen diagrams were constructed using the sum of AP+NAP, without limnophyta, telmatophyta and spores. Chemical analyses were defined according to the method recommended by Bengtsson, Enell (1986). The organic content, carbonate and mineral residue were defined based on the loss at ignition at the temperatures of 550°C and 925°C. The results of analyses are presented in the pollen diagram. All calculations and drawing diagrams were done with the POLPAL programme (Walanus, Nalepka 1999).

Four samples from the Rypin profile were radiocarbon dated by the AMS method at the Poznań Radiocarbon Laboratory, Poland (Tab. 2, Fig. 4).

## Results

The upper part of the sediments in the analyzed profile contains black peat 610 cm thick. At a depth of 235–290 cm there is an insert of dark grey gyttja with small fragments of mollusc shells. Below the peat layer there is grey gyttja to the depth of 971 cm, which at the base turns into beige with a layer of snail and mussel shells (Fig. 3). This gyttja covers a 10-cm-thin layer of peat at a depth of 992–1,002 cm which contains a fragment of pine wood. At the bottom of the biogenic sediments there is light grey, sandy silt.


Fig. 3. (A) Hand drilling made in the Rypienica channel peat-bog; (B) Beige gyttja with shells of snails and mussels, and underlying peat layer with pine wood remnant in the bottom part of the "Rypin" profile; (C) and (D) Extracted shells from lacustrine sediments: (C) single specimen of snail mussel found in the gyttja; (D) crumbled specimens of *Unionidae* forming a 1-cm-thick layer.

The pollen spectra of the analysed profile, besides recording the history of the forest vegetation, also register changes in the local vegetation that occurred directly on the studied peat-bog (Fig. 4). The bottom radiocarbon date from the depth of 998–996 cm, which is 10,230 ± 60 $C^{14}$ BP (11,968 ± 111 cal BP[1]), and the pollen record in this profile show that since that time forests have predominated in the area (Fig. 4). At the beginning

[1] Conversion to calendar years was based on the Fairbanks calibration computer program: http://radiocarbon.ldeo.columbia.edu/research/ radiocarbon.htm

of the Holocene, continental climate and generally poor soil encourage the spread of pine and pine-birch forests in the Preboreal period (*Pinus* and *Betula-Pinus* L PAZ). An alternating dominance of pine and birch was characteristic in the forests of the early Holocene, when the climate of relatively high but oscillating temperatures and significant continental features was in a state of imbalance with the forming vegetation.

During the Boreal period (*Corylus-Ulmus-Alnus* L PAZ) hazel (*Corylus*) spread massively on young soils with higher fertility, superseding birch communities. Gradually, other mesophilous species spread, such as elm, oak, linden, and then finally, ash. In the wetland areas, forest communities developed in which the tree stand consisted mainly of alder.

Further succession led to the development of stable, mixed deciduous forests in the Atlantic period (*Corylus-Alnus-Quercus, Alnus-Tilia-Fraxinus* and younger part of *Poaceae* L PAZ). Their main component was oak, linden, elm and ash. At that time, forest communities stabilized. They achieved a balance between the climatic conditions and habitat, forming a climax community. At the peat-bog and in its vicinity this state continued almost until the end of the Atlantic period.

Some part of the sediment, which stratigraphically refers to the end of the Atlantic period and the beginning of the Subboreal period (*Poaceae* and *Corylys-Quercus* L PAZ), shows local changes in the peat-bog in question. The invasion of bog fern (Polypodiaceae) resulted in the overgrowing of the reservoir, and this is reflected in its heavy presence in the pollen diagram (Fig. 4). The groundwater level was probably unstable, resulting in the drying of the bog, the selective distribution of sporomorphs and, perhaps, a hiatus.

It is difficult to determine whether the observed changes were caused by a break in peat sedentation or whether they are secondary (i.e. the accumulated peat was partially destroyed as a result of dehydration). A variable groundwater level appears be proven by, inter alia, the occurrence and then disappearance of rush plants at the time that fern spores were at their maximum, and the variable presence of algae (*Pediastrum*). This assertion is further supported by the large fluctuations in quantities of alder pollen overtaking wet habitats and the characteristic succession of telmatic and shallow-water plant communities.

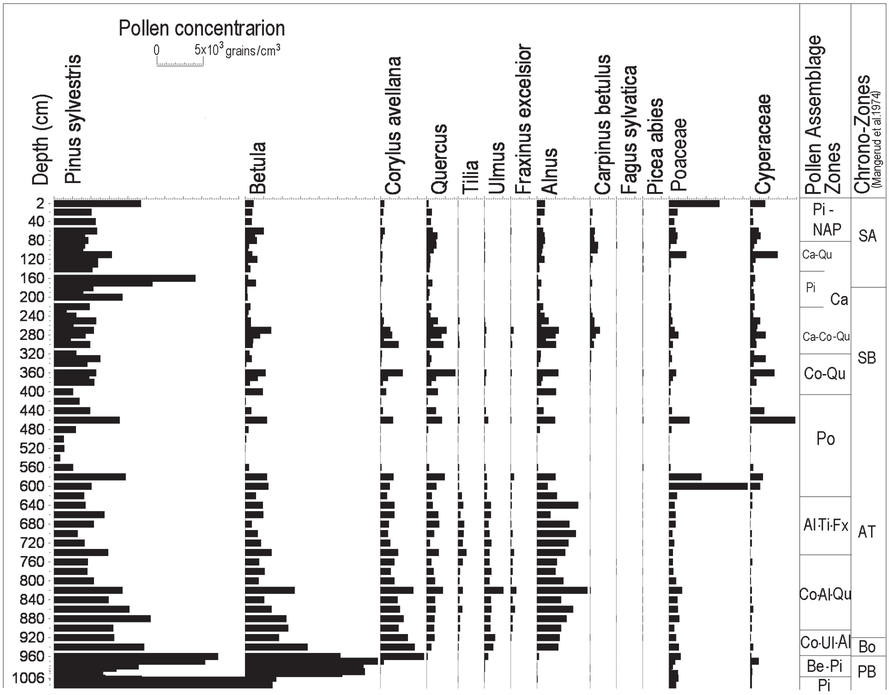


Fig. 5. Concentration pollen diagram of the selected pollen taxa from the Rypin peat-bog

The Rypienica River is fed by a number of small tributaries, but largely by groundwater. A large hydrological variability can be observed in the analyzed peat-bog until modern times. However, it cannot be excluded that the reason for hydrological change was not only climate but also human activity. In the Rypin county there exist traces of Neolithic settlements (Żurowski, 1967), which could have had an impact on the forest cover and, indirectly, on the water level in the bog.

With the passage of time, the stable climax forests of the Atlantic period underwent transformations due to deteriorating weather conditions, the progressive impoverishment of soils and the influence of human activity on the environment. These changes have exerted an influence on the species composition of forests. During the Subboreal period (the younger part of the *Carpinus* L PAZ) the share of elm, linden and ash in deciduous mixed forests decreased, and gradually hornbeam and beech spread. Beech at that time was probably an admixture of deciduous forest or appeared in small patches in the fertile soils. As today, spruce in the vicinity of Rypin was outside the boundary of its natural range and probably in dispersal. At approximately 3,510 ± 35 $C^{14}$ BP (3,788 ± 56 cal BP) there was a dynamic development of deciduous mixed forests with a large share of hornbeam in the study area. However, at the turn of the Subatlantic and Subboreal periods in the surroundings of the Rypienica channel, pine was already a dominant species. At the same time herbaceous plants of anthropogenic origin spread.

Tab. 2. AMS radiocarbon ages from Rypin profile carried out at the Poznań Radiocarbon Laboratory, Poland.

| No. | Sample no. | Depth, cm | Lab. no. | Radiocarbon age BP | Calibrated age BP* |
|---|---|---|---|---|---|
| 1 | Rypin 90 | 90–91 | Poz–26621 | 1,220 ± 30 | 1,147 ± 48 |
| 2 | Rypin 290 | 290–291 | Poz–26622 | 3,510 ± 35 | 3,788 ± 56 |
| 3 | Rypin 610 | 610–611 | Poz–26624 | 5,700 ± 40 | 6,475 ± 48 |
| 4 | Rypin 996 | 996–998 | Poz–26682 | 10,230 ± 60 | 11,968 ± 111 |

* Conversion to calendar years was based on the Fairbanks calibration computer program: http://radiocarbon.ldeo.columbia.edu/research/ radiocarbon.htm

The destruction of deciduous forests in the vicinity of the peat-bog was brought about by two factors. In addition to fluctuations in water level caused by climate change, the second important factor was human activity (Fig. 4, 6). The presence of settlements from the Bronze Age and early Iron Age (the peoples of the Lusatian culture) is confirmed by the remains of open settlements recorded during the surface archaeological investigations with an (AZP) test in numerous villages surrounding Rypin. However, in 2009 at the archaeological site in the Starorypin settlement, about 4 km NE of the location of the profile, the remains of a Pomeranian-culture settlement was uncovered (Lewandowska, 2010). In Rypin itself, Roman coins from the years 248–251 AD (Kubiak, 1979) and other archaeological findings of the Wielbark culture were found (Żurowski, 1967). The weakening of the settlement, and perhaps depopulation of the area, resulted in a distinct phase of forest regeneration. The maximum share of hornbeam in those forests falls to the level dated with radiocarbon at 1,220 ± 30 $C^{14}$ BP (1,147 ± 48 cal BP) (the younger Subatlantic period). Archaeologically, it was the Migration Period and the beginning of the early Middle Ages in which the weakening, or even depopulation, of the settlement took place.

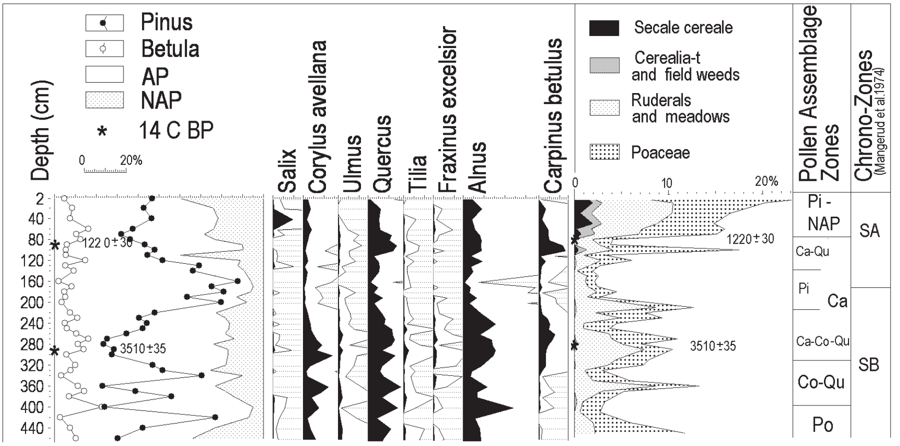


Fig. 6. Synthetic pollen diagram of human activity for the upper part of the Rypin profile

According to the archeological findings, re-colonization took place in the early Middle Ages. The fortified settlements in Starorypin and Radziki in the northern part of the Dobrzyń Land were dated at the 11th–12th century (Grześkowiak, 1967; Grążawski, 1996). Favourable conditions for the development of metallurgy in the northern part of the Dobrzyń Land encouraged further destruction of the natural environment. The remains of the metallurgical settlement located on the Rypienica River prove the use of local ores from the 12th century (Guldon, 1974; Andrzejewska, 2004).

Since the late Middle Ages pine has been the main component of the depleted forests, which survive in poor soils. Mixed forests consist of pine together with oak and hornbeam. The non-forested surfaces are occupied mainly by crops, pasture and built-up areas. This is reflected in the large proportion of herbaceous plants, which in the upper part of the profile exceeds 40% (Fig. 4).

## Conclusions

The research carried out within the Rypienica channel confirms earlier opinions (e.g. Błaszkiewicz, 2005) that in a specific palaeogeographic situation it was possible for the blocks of buried ice to have been preserved until the Late Glacial/Holocene transition.

Palynological and sedimentological analysis of the peat-bog sediments provide data on the history of vegetation in the Rypienica channel since the beginning of the Holocene until the youngest part of the Subatlantic period. The sediments record changes in the local vegetation brought about by climate fluctuations, dynamics of hydrological conditions and the impact of human activity.

Local pollen assemblage zones (L PAZ) distinguished in the pollen diagram (Fig. 4) reveal the following most important features of the vegetation history in the Rypin peat-bog and its surroundings during the Holocene.

In *Pinus* and *Betula-Pinus* L PAZ (the Preboreal period) the continental climate and generally poor soils caused an expansion of pine and pine-birch forests.

During the *Corylus-Ulmus-Alnus* L PAZ, hazel spread out on young soils with higher fertility, massively superseding birch communities. Gradually, other mesophilous species increased in number such as elm, oak, linden, and then finally ash. The wetland communities were still dominated by *Alnus*.

The further succession led to the development of stable, mixed deciduous forests in the *Corylus-Alnus-Quercus* L PAZ*, Alnus-Tilia-Fraxinus* L PAZ and the younger part of *Poaceae* L PAZ. They consisted mainly of oak, linden, elm and ash.

The part of the sediment in the analyzed peat (*Poaceae* L PAZ and *Corylys-Quercus* L PAZ) which stratigraphically refers to the end of the Atlantic period and the beginning of the Subboreal period shows local changes. The overgrowing of the reservoir caused the invasion of fern (Polypodiaceae – Fig. 4) on the bog. The groundwater level was probably unstable, thus affecting the drying of the bog, selective destruction of sporomorphs and, perhaps, a hiatus in a pollen record.

A variable groundwater level appears to prove the occurrence and then disappearance of rush plants during the time of the maximum amount of fern spores, and variable presence of algae (*Pediastrum*). This is demonstrated by the large fluctuations in quantities of alder pollen overtaking wet habitats and characteristic succession of telmatic and shallow-water plant communities. A high degree of changeability in hydrological conditions up to present times has been observed in the analyzed peat-bog.

The absolute maximum of *Carpinus* pollen (the younger Subatlantic period) was dated with a radiocarbon age at 1,220 ± 30 $C^{14}$ BP (1,147±48 cal BP).

Traces of the settlement history were extremely difficult to identify on the basis of pollen analysis of peat deposits because of the poor state of sporomorph preservation and hiatuses. Single pollen grains of cereals were found in the Subboreal period, and correlate with the Bronze Age and the early Iron Age (the peoples of the Lusatian culture).

Signs of intense human activity, well visible in the younger part of the Subatlantic period, have been associated with the intensive development of early medieval settlements (XI–XII century) in the area.

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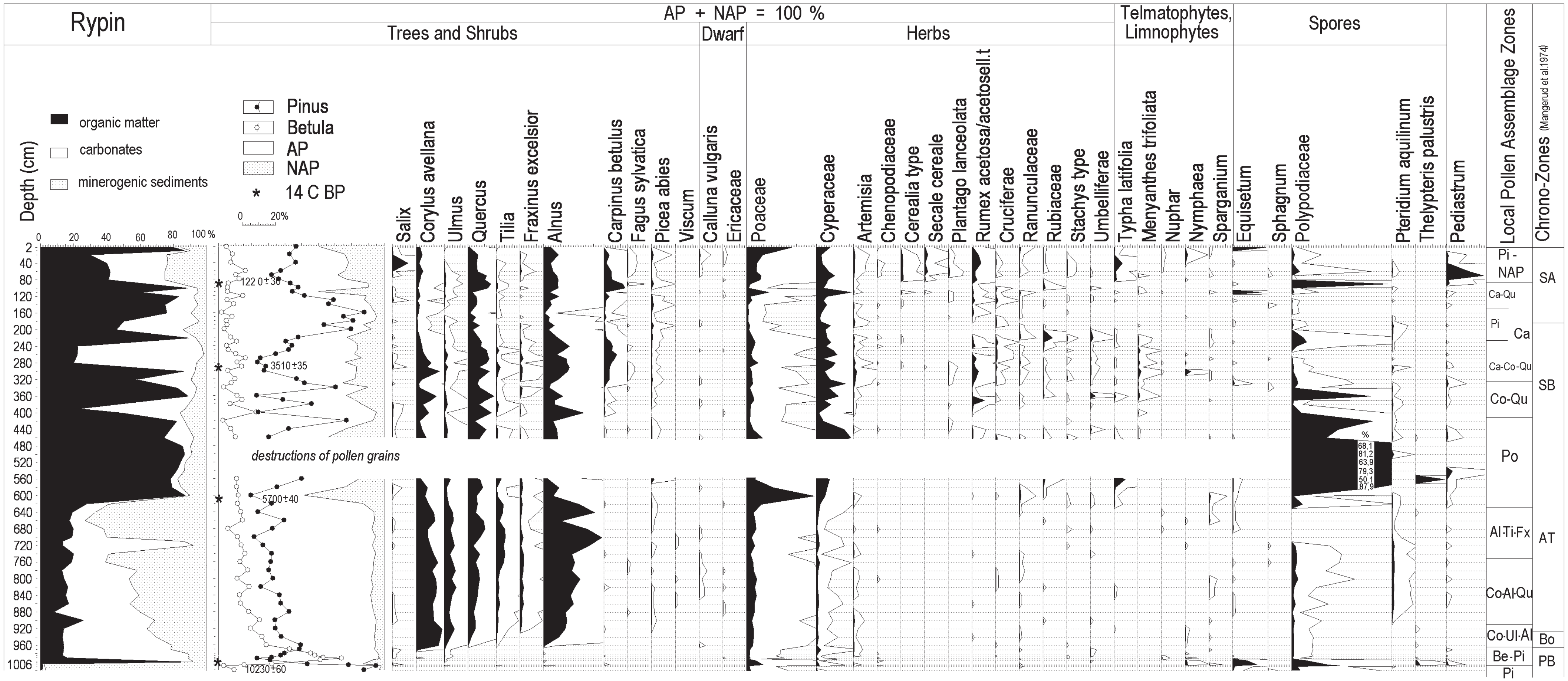


Fig. 4. Percentage pollen diagram of the selected pollen taxa from the Rypin peat-bog