Peat Formation Conditions and Peat Properties: a Study of Two Ombrotrophic Bogs in Latvia

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The studies of peat botanical composition and formation conditions have been carried out in two ombrotrophic bogs in Latvia. Despite the small distance between the studied bogs, due to a much differing character of peat development processes, the peat in two selected bogs demonstrate significantly different properties. In this study pollen and peat botanical composition analysis has been used for study of the peat formation process and estimation of peat age. This approach provides better understanding of the properties of peat and bog development processes and their relation to decomposition processes of the living organic matter.

Keywords: peat, botanical composition, decomposition level, pollen.

INTRODUCTION

The interest in peat diagenesis and properties is growing because peat supports and influences bog and wetland ecosystems characterised by unique community structure and high biodiversity (Steiner, 2005), and peat monoliths can serve as an archive that gives information on conditions in past environments (Yeloff and Mauquoy, 2006). Significant amounts of organic carbon are stored in the form of peat; therefore, peat reserves play a major role in the carbon biogeochemical cycling and are of importance to study climate change processes (Borgmark, 2005). The dependence of peat properties on their possible formation conditions as well as the variability of peat composition within peat profiles have not been studied much.

Therefore, the aim of this study is to analyse the development of two ombrotrophic bogs in Latvia to find out the relations between the conditions of peat formation and peat properties with the main attention focusing on the decomposition degree and botanical composition of peat.

MATERIALS AND METHODS

Site Location

The study area includes ombrotrophic bogs located in the central part (Rīga District) of Latvia (Fig. 1). The bogs are located in the lowlands (the Ropaži Plain and the Metsepole Plain), and their origin is similar to the origins of ombrotrophic bogs in Latvia as well as in the north European region. The development of the thoroughly studied bogs is slightly different. The Dzelve-Kronis Bog has developed due to sandy ground paludification in the middle of the Holocene, while the Eipurs Bog developed due to a fill-in of a very shallow basin at the beginning of the Holocene.

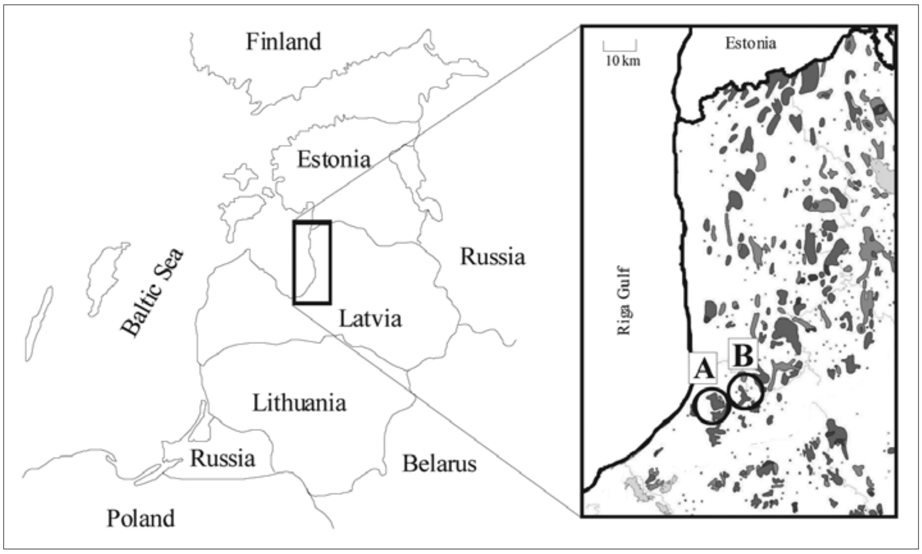

Figure 1. **Sampling sites: A – Dzelve-Kronis Bog; B – Eipurs Bog**

Nowadays these bogs are raised type (moss) bogs; however, a typical raised bog with a number of bog lakes and pools is only the Dzelve-Kronis Bog, which is in semi-pristine condition in spite of peat cutting areas in the north western part. The Eipurs Bog is not influenced by drainage or peat cutting, the largest part of this bog is covered by pine forest.

The characteristics of the Eipurs Bog are as follows (coordinates of the sampling site are 57°14′53.4″N; 24°37′00.3″E). The maximal depth of the peat layer in the bog is 4.70 m. The bog is in the transformation process from a raised bog into a *Pinus sylvestris* forest. The vegetation of the bog is dominated by *Pinus sylvestris* reaching up to 5–6 m height, pines cover up to 35% of the territory of the bog. The territory of the bog is covered by shrubs (dominated by *Calluna vulgaris*, *Ledum palustre*). Among other dominant species *Eriophorum vaginatum, Rubus chamaemorus*, and more rarely, *Cladina* spp. can be mentioned.

Among the mosses *Sphagnum* species (*S. fuscum, S. magellanicum*) dominate. The territory of the bog is surrounded by a vegetation common to transitional mires represented by the presence of *Carex lasiocarpa, Carex rostrata, Andromeda polifolia*, *Oxycoccus palustris*, and dominating *Ledum palustre* and *Eriophorum vaginatum*, whereas in some places *Drosera rotundifolia* can be found.

The Dzelve-Kronis Bog (coordinates of the sampling site 57°13′58.2″N, 24°30′12.2″E) belongs to developing raised bogs and is included in the list of *Natura 2000* protected areas. At the sampling area, the communities' common of a raised bog with knolls covered by *Sphagnum* moss and surrounded by bog pools and small bog lakes can be found. The ground is covered by *Sphagnum* species such as *S. fuscum, S. magellanicum*, more rarely *S. rubellum.* Among higher plants and shrubs, *Eriophorum vaginatum, Oxycoccus palustris, Drosera rotundifolia, Calluna vulgaris* can be found, more rarely *Empetrum nigrum*. The trees are dispersed, and dwarf forms of pines reaching the height of 2–4 m can be found only in a few bog islands. *Betula pubescens* can be found yet more rarely.

Sampling

Coring and peat sampling has been done with a peat sampler in the cupola area of each bog, where the surface peat layers are clearly elevated up to 2–4 m height beyond the edge of the bog and have not been influenced by peat sliding. The peat samples (50 cm long monoliths) were put in a special cartridge and wrapped in polyethylene film to preserve natural moisture, brought to the laboratory and sliced into 3 cm sections using a stainless steel knife. The outside edges were systematically discarded, as they could have been contaminated during the sampling. The upper layer (+ 3 to 0 cm) corresponds to the material of plants living on the surface of the bog.

Botanical Composition of Peat and the Decomposition Level

Botanical composition of the peat is closely related to plant feeding conditions, characteristics of the bog depression, relief, underlying deposits, and the degree of groundwater mineralisation, which substantially affect the degree of peat decomposition, its moisture and physical-mechanical properties (Tjuremnov, 1976).

The analysis of botanical composition was performed using a Carl-Zeiss light microscope Axiostar with magnification 100–400 times.

The decomposition degree of the peat was determined on the field by von Post pressing method (Parent and Caron, 1993) and afterwards corrected in laboratory by centrifugation method accordingly Lishtvan and Korol (1975).

Pollen Analysis of Peat

Pollen analysis is one of the most important paleoecological techniques. Pollen analysis principally was based on a well-known method described by

B. E. Berglund and M. Ralska-Jasiewiczowa (1985). More detailed information of the method has been obtained from the literature (Faegri and Iversen, 1964, 1975; Moore and Webb, 1978; Birks and Birks, 1980). Carl-Zeiss light microscope Axiostar with magnification 400–1000 times was used for pollen analysis.

Pollen percentage diagrams were constructed for each selected site on the basis of a selection of identified microfossils, expected to be informative of the changing climatic conditions. The pollen zones have been distinguished firstly selected as biostratigraphic units defined purely upon its pollen content, then the results of ^{14}C dating have been applied. Pollen diagrams contribute to the knowledge of biostratigraphy and chronology as well as local and regional environments.

The interpretation of pollen data is focused on the changes in the tree and herb relationship, their ratio variations, presence/abundance of apophytes, changes in tree pollen spectra and finds of spores and microscopic charcoal particles.

Peat Dating

The ^{14}C dating method was used for peat deposits dating. The ^{14}C dating was performed at the Institute of Geology of Tallinn Technical University (Estonia).

RESULTS AND DISCUSSION

The results of the paleobotanical investigations (botanical composition, pollen analysis) in the peat profiles from two ombrotrophic bogs in the central part of the Middle Latvia Lowland indicate both differences and similarities in the development and peat properties of the studied bogs.

After the comparison of pollen diagrams and ^{14}C dating of both mires, it is obvious that the Eipurs Bog is older than the Dzelve-Kronis Bog. The pollen diagram of the Eipurs Bog reflects bogs formation interval from the Preboreal Time up to now (Fig. 2, 3), but the pollen diagram of the Dzelve-Kronis Bog deposits reflects the formation intervals of the bog from the end of the Atlantic Time until the present (Fig. 5, 6).

The deposits dated with the ^{14}C method confirm that peat from the depth interval of 4.62–4.58 m was accumulated about 8960 ± 75 BP years ago – the formation of the Eipurs Bog started during the Late Preboreal. Peat started to accumulate in the shallow wet depression of the Eipurs Bog, which was covered with horsetail and green mosses *Hypnum*, when fen peat formed at the mire depression on sandy clay ground (Fig. 4). The pollen zone ***Betula*** **PB** of this time is distinguished in the diagram in the interval of 4.70–4.42 m, where pollen spectra indicate that deposits have originated during the Preboreal Time too. Pollen spectra of this interval reflect that at that time birch and herbs were widely distributed in the surroundings of the mire (Fig. 2, 3).

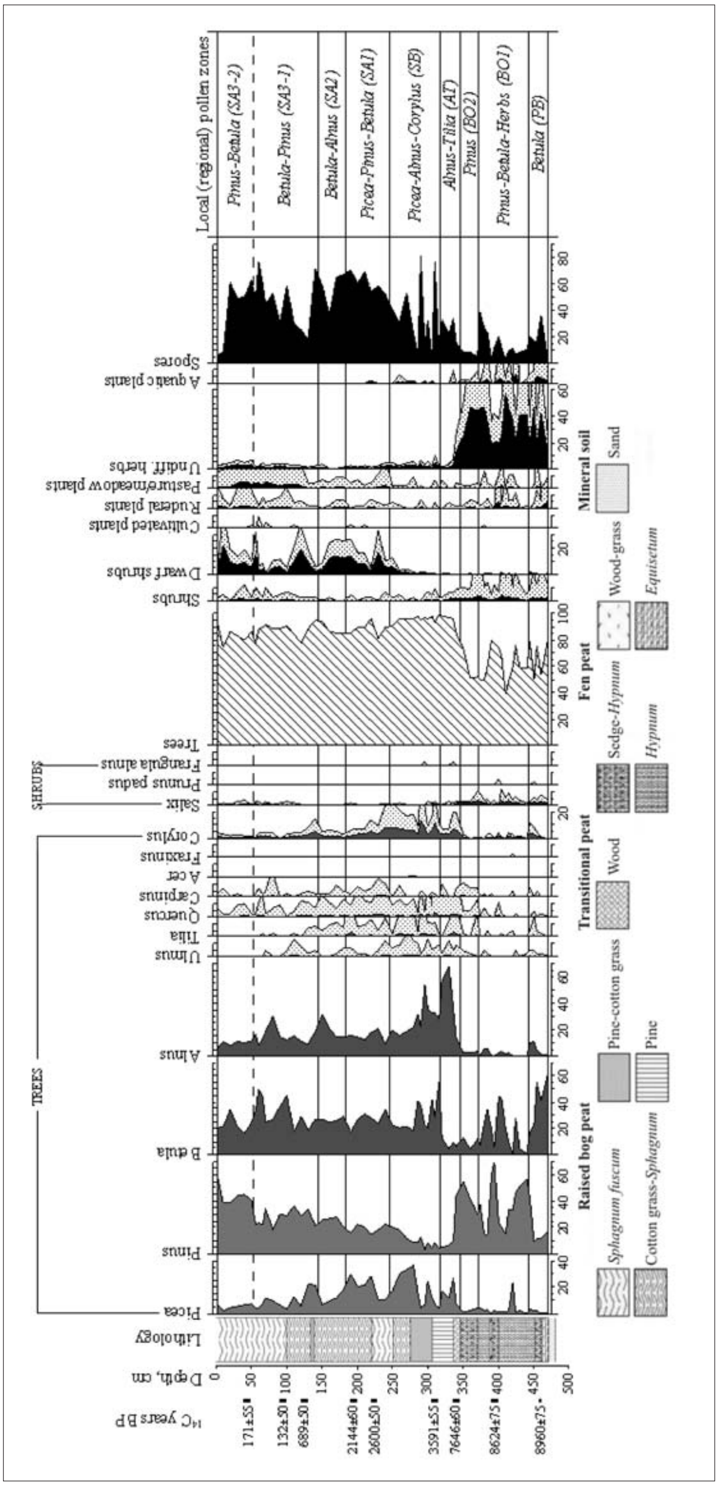

Figure 2. **Pollen percentage diagram from of the Eipurs Bog**

Next pollen zones – ***Pinus-Betula-Herbs*** **BO1** and ***Pinus*** **BO2** – cover the deposit depth interval of 4.42–3.45 m. Pollen spectra are characterized by a sharp rise of the pine curve, which reaches its maximum and is characteristic of the Boreal Time. The botanical composition of peat reflects typical fen peat vegetation – *Hypnum* moss (~ 65%) and different sedge species (~ 30%) like *Carex lasiocarpa, C. diandra, C. appropinquata, and C. teretiuscula* that grew in the depression and formed the fen *Hypnum* and sedge-*Hypnum* peat, which was averagely decomposed (Fig. 4). Subsequently, *Hypnum* decreased in the peat composition and reached 25% and were replaced by well-decomposed wood remains. Changes of plant species of fens such as *Hypnum* and sedge in the peat composition can be explained by frequent humidity changes during the Boreal Time. These species are also characteristic of the second part of the Boreal Time (BO2), when they still were the main peat forming plants and the averagely decomposed (25–30%) *Hypnum* and sedge-*Hypnum* peat layer was deposited, which is not characteristic of the Boreal Time. It can be explained by the high groundwater level in the Eipurs Bog during that time. The only exception is the very well-decomposed layer (56%) of wood-grass fen peat, which obviously indicates significant environmental changes.

The zone ***Alnus-Tilia*** **AT** covers the depth interval of 3.45–3.17 m. The deposits dated with the ^{14}C method confirm that peat from the depth interval of 3.45–3.35 m was accumulated in about 7643 ± 60 BP. Pollen spectra show that coniferous trees have been replaced by deciduous trees. Alders comprise the main part of tree pollen, more lindens appear. Such pollen composition is characteristic of the vegetation of the Atlantic Time. During that time in the development of the vegetation of the Eipurs Bog is marked by a sharp transition from fen type vegetation to vegetation characteristic of a raised bog. Deposited peat layers reached 1.25 m thickness since the time of formation of the bog up to the Atlantic Time, which determined changes in plant feeding from groundwater rich in minerals from precipitation. Further peat formation and bog development is related to the appearance of raised bog species like Cotton grass (*Eriphorum vaginatum*), Sphagnum (*Sphagnum fuscum*), and pine. A raised bog pine peat layer approximately 0.25 m thick formed during the Atlantic Time, which was well decomposed (58%) under climatic optimum conditions. Herb pollen diagram (Fig. 3) very well reflects the transition from fen to transition bog at the depth of 3.50–3.40 m dated with ^{14}C to 7646 ± 60 years.

The pollen zone ***Picea-Alnus-Corylus*** **SB** in the depth interval of 3.17–2.45 m of the diagram is subdivided according to pollen spectra, which characterise the vegetation of the Subboreal Time by an increase of the pollen curves of deciduous trees and the maximum of hazels. The curve of spruces reaches its maximum. The deposit layer in the depth interval of 3.15–3.05 m dated with the ^{14}C method indicates the deposition of the layer 3591 ± 55 BP years ago. This zone can be compared with the lower part of the Subboreal zone. Cotton grass became more

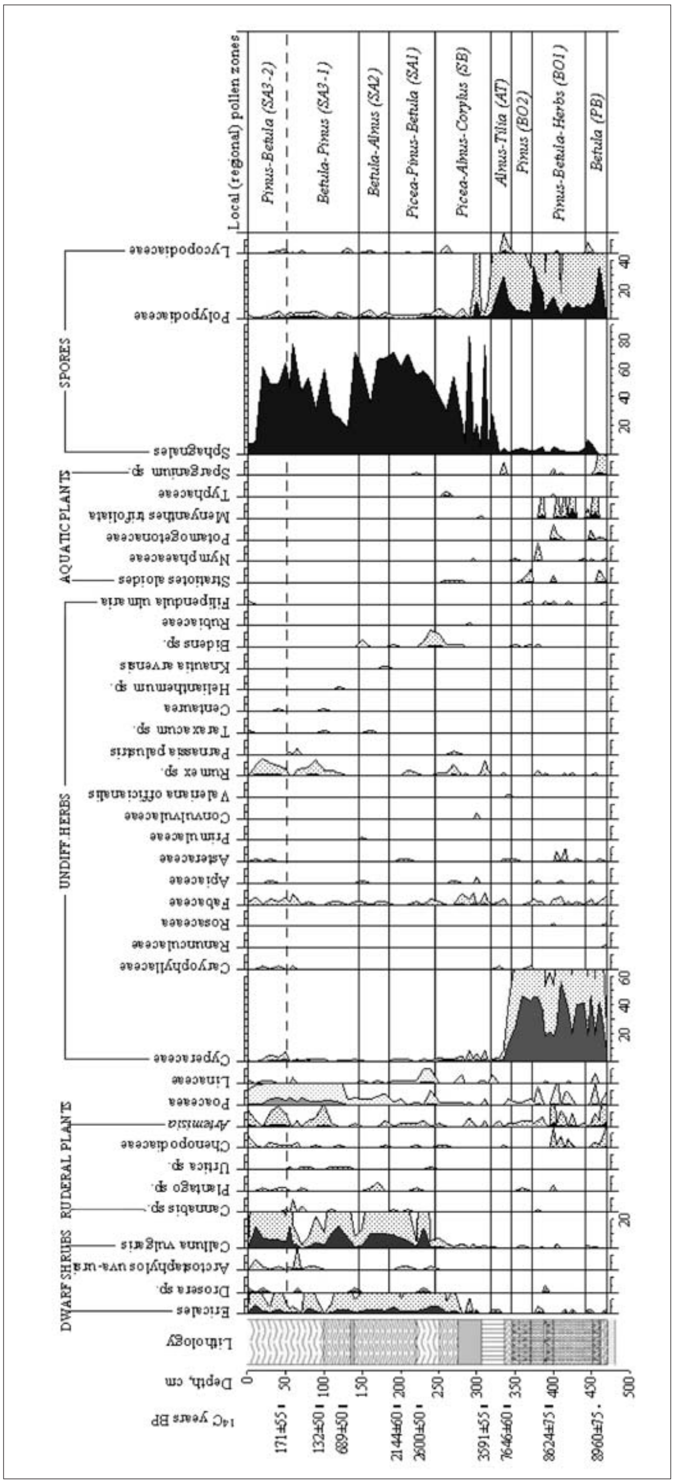

Figure 3. **Herb pollen percentage diagram from the Eipurs Bog. (legend of the deposits see in Fig. 2).**

important in the peat composition at the beginning of the Subboreal Time. The number of the *Sphagnum* species increased – *Sphagnum magellanicum* and *Sphagnum angustifolium* formed the complex of *Sphagnum* mosses characteristic of the central and peripheral part of the bog. Well-decomposed (40%) pine-Cotton grass and Cotton grass-Sphagnum peat was deposited during the comparatively dry and warm climate of the Subboreal Time.

The thickest layer of peat deposits is characteristic of the Subatlantic Time. It covers deposits from the depth interval of 2.50 m to the upper layer. That layer is subdivided into zones of the lower, middle, and upper part of the Subatlantic Time.

The lower zone ***Picea-Pinus-Betula*** **SA1** of the Subatlantic Time divided in the depth interval 2.45–1.85 m is distinctive by sharp decrease of spruce, which replaces pine. Changes in peat botanical composition during the Subatlantic Time decreased. Remains of *S. fuscum* prevailed (~ 50%), cotton grass was also abundant (~ 20%). The peat decomposition level decreased to 15% due to climate deterioration. A significant portion of cotton grass remained because it is more resistant to decomposition in comparison with *Sphagnum*.

Similar climatic conditions also prevailed during the middle part of the Subatlantic Time, when Cotton grass-Sphagnum peat (averagely decomposed, 30%) continued to form. The pollen zone ***Betula-Alnus*** **SA2** covers a deposit layer in the depth interval of 1.85–1.45 m and is characterised by a decline of spruces and a repeated increase of pine, as well as birch, alder, and dwarf shrub pollen.

The uppermost part of the Subatlantic Time is subdivided into two local and regional pollen zones. In the zone ***Betula-Pinus*** **SA3–1** in the interval of 1.45–0.51 m, pine and birch curves rise again. The dating with the ^{14}C method also indicates that peat from the depth interval of 1.30–1.20 m is accumulated during the time 689 ± 50 BP years ago.

The zone ***Pinus-Betula*** **SA3–2** covers the depth interval of 0.51–0.01 m. Pollen amount of pine and birch continues to rise with fluctuations. Pine reaches its second maximum, the curve of spruces decreases. The amount of *Calluna vulgaris* rises again. The composition of the subdivided pollen zone pertains to the ending part of the Subatlantic Time. Bog development during the Late Subatlantic Time is similar than previously; however, some short-time, but sharp changes, which probably were related to local conditions, can be observed. Changes in the botanical composition of peat took place, the numbers of *S. fuscum* decreased from 40% to 5%, but pine increased and reached 20% of the peat botanical composition. Other species preserved their positions. These sharp changes are also reflected by the decomposition level (48%) of pine-Cotton grass peat of the raised bog in the depth interval of 1.39–1.34 m (Fig. 4). The reason for such sharp (even catastrophic) and short-term changes probably is an intense and swift process, possibly a fire, that destroyed the ground vegetation of bog. Perhaps the extreme drought period took longer time, because the degree of decomposition of deposits formed during this time interval is relatively high (~ 40–30%). Bog vegetation was represented mainly by pine trees and heather (*Calluna vulgaris*), reached high values among shrubs (Fig. 3). Heather may indicate the presence of dry pine forests and burning, because the species have adapted to growth in nutrient-poor conditions.

Such rapid change is not observed in peat deposits formed during that time interval of the Late Subatlantic Time in the other surrounding bogs, as well as in the Dzelve-Kronis Bog (Fig. 4, 7). This feature would suggest fire in the Eipurs Bog during that time and reflects local conditions in the bog. Thereafter bog ecosystem became balanced when Cotton grass-Sphagnum and *S. fuscum* peat layers were deposited. Sphagnum, including *S. fuscum* (over 50%), *S. magellanicum, S. angustifolium*, and Cotton grass became the main plants in bog vegetation, which is characteristic of raised bogs under acidic conditions and poor in nutrients. The uppermost peat layers are slightly decomposed (up to 10%) and are not impacted yet.

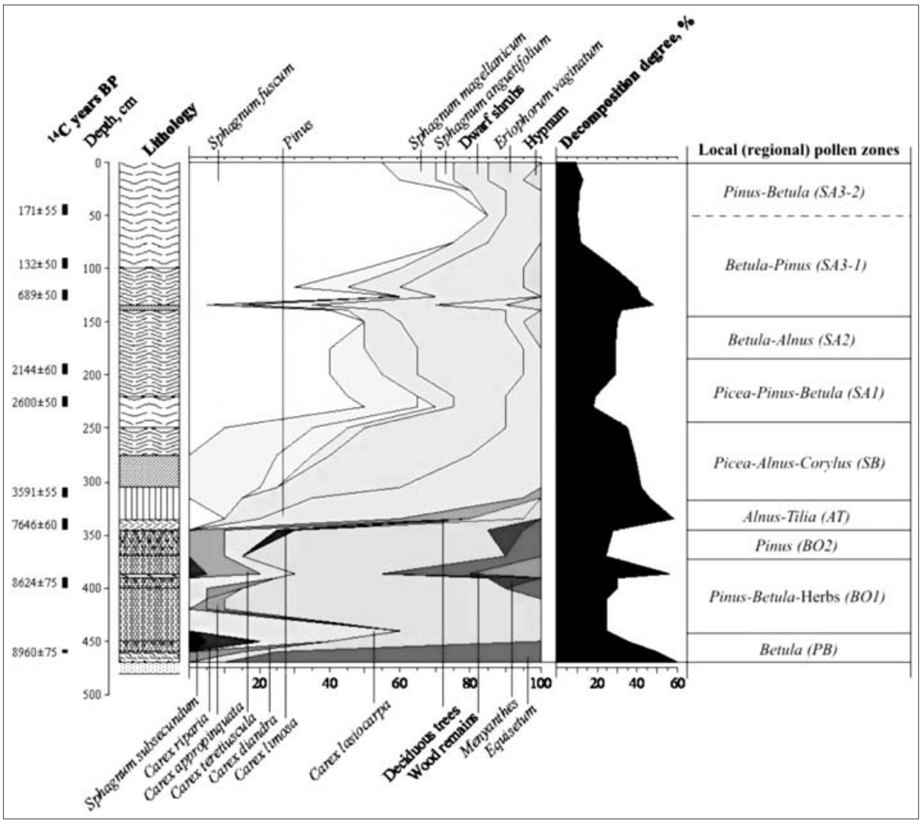

Figure 4. **Peat botanical composition and decomposition degree of the Eipurs Bog (see legend of the deposits in Fig. 2)**

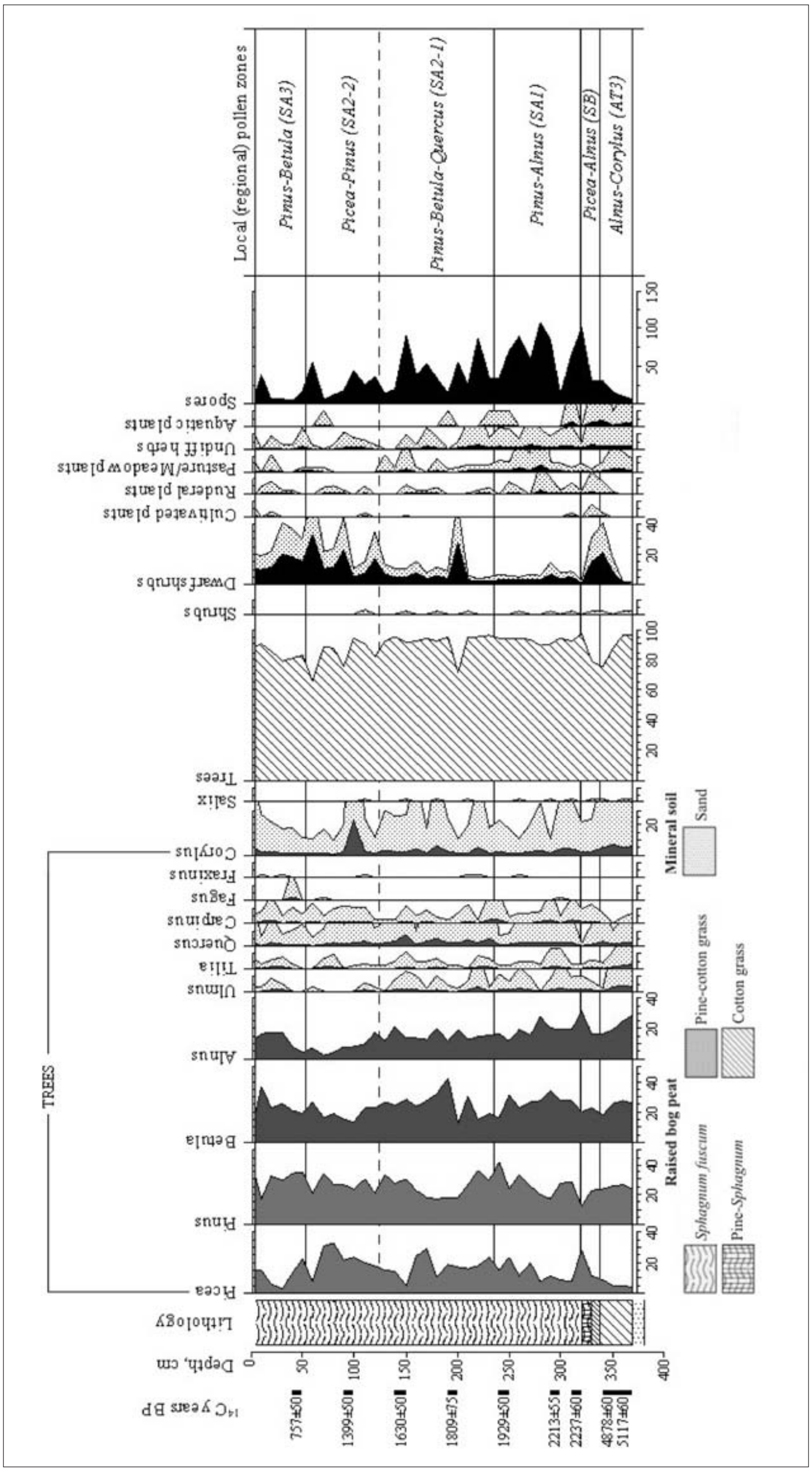

Figure 5. **Pollen percentage diagram of the Dzelve-Kronis Bog**

Six local and regional pollen zones are distinguished in the diagrams of the Dzelve-Kronis Bog on the basis of pollen spectrum changes and the results of peat deposit dating with the ^{14}C method (Fig 5, 6). The Dzelve-Kronis Bog has formed in the process of paludification of sandy ground as a result of increase of the level of groundwater and wet conditions. Very well decomposed (60%) raised bog cotton grass peat has formed on the small depression of the bog at the end of the Atlantic Time (AT3) (Fig. 7). The ^{14}C dating of peat from the depth interval of 3.70–3.50 m indicates peat accumulation over 5000 BP years ago. During that time the Eipurs Bog entered the phase of a raised bog and accumulated a deposit layer more than 1.20 m thick.

The first pollen zone ***Alnus-Corylus*** **AT3** of the Dzelve-Kronis Bog confirms that broad-leaved trees were widely distributed in the surroundings of the bog, but hazels reached their maximum during the formation of the layer. The dominant species of peat deposits is cotton grass (*Eriophorum vaginatum*), reaching 70%, *S. fuscum* occupies a smaller part – 15 %, and pine (*Pinus*) – 10 %; there are dwarf shrubs as well.

The next pollen zone ***Picea-Alnus*** **SB** is distinguished in the depth interval of 3.38–3.18 m and pollen spectra are characterized by a rapid rise of the spruce curve almost reaching the maximum. The values of alder pollen increase. The pollen zone reflects vegetation conditions characteristic of the Subboreal Time. Peat deposits formed during that time have a similar botanical composition, but with different proportions. Cotton grass composes 20%, *Sphagnum fuscum* – 30%, and pine – 20% of the deposits. Changes of local vegetation are also reflected in peat types: pine-Cotton grass and pine-Sphagnum peat was deposited during the Subboreal.

Bog development during the Subatlantic Time is homogeneous and persistent. Representatives of typical raised bog vegetation prevail: *Sphagnum* compose up to 60% of the total botanical composition, including *S. magellanicum* and *S. rubellum*, as well as cotton grass and dwarf shrubs. Only low decomposed (12–15%) raised bog type *S. fuscum* has been deposited in the Dzelve-Kronis Bog since the beginning of the Subatlantic Time. The pollen zone ***Pinus-Alnus*** **SA1** covers the deposit depth interval of 3.18–2.35 m. Pollen spectra show changes in the composition of conifers – spruces have been replaced by pines that gradually reach the maximum. The zone conforms to the beginning of the Subatlantic Time. Dating with the ^{14}C method indicates the same, peat from the depth interval of 3.20–3.10 m accumulated 2237 ± 60 BP (in the lower part of the zone). Herb pollen diagram reflects the largest herb species diversity in the deposits formed during the early Subatlantic Time (Fig. 6).

The zone ***Pinus-Betula-Quercus*** **SA2–1** in the depth interval of 2.35–1.25 m indicates that the rise of the birch curve continues. The number of oaks and alders also increases. The pollen composition of the zone conforms to the beginning of the middle part of the Subatlantic Time.

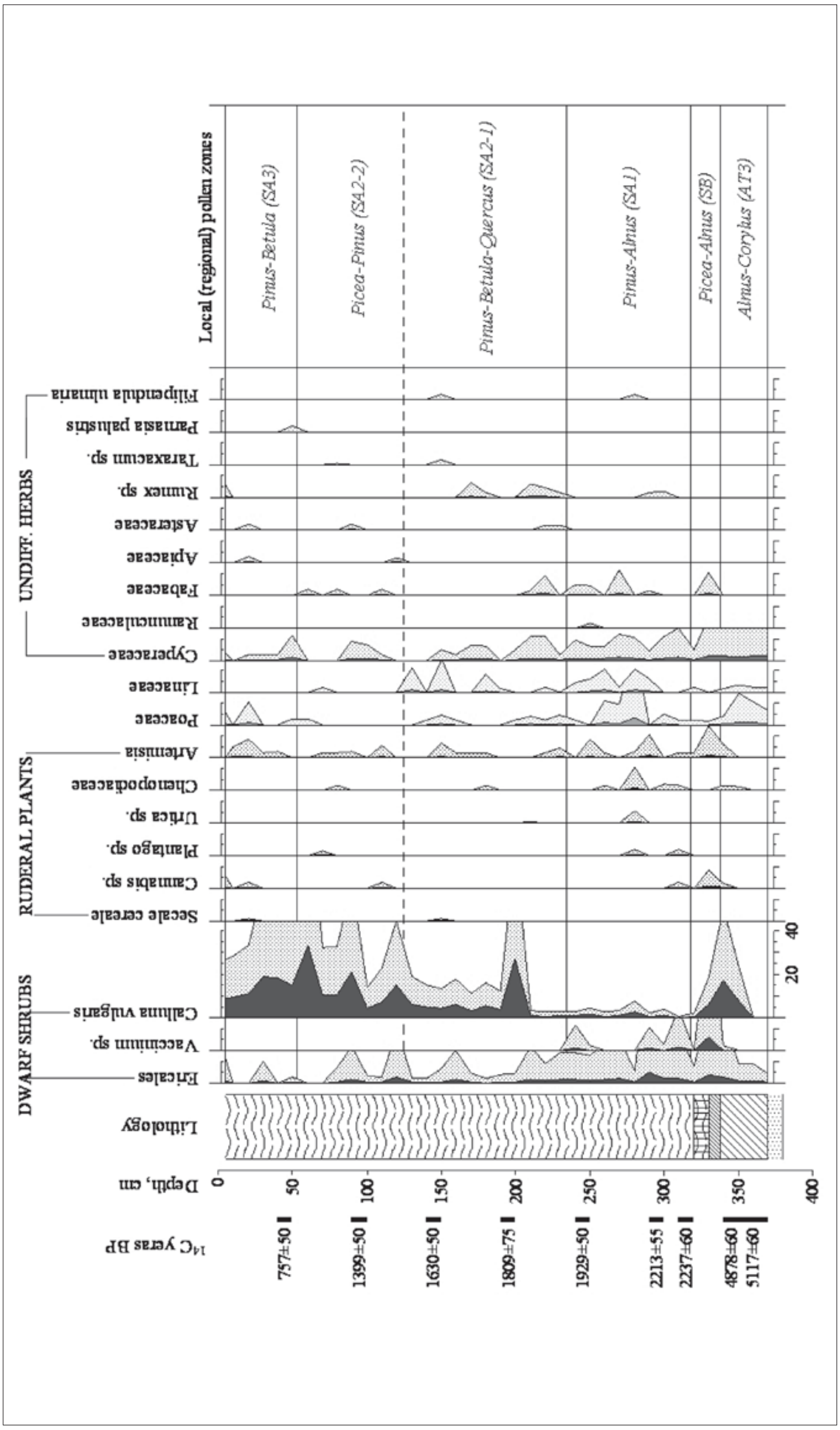

Figure 6. **Herb pollen percentage diagram of the Dzelve-Kronis Bog** (see legend of the deposits in Fig. 5)

The pollen zone ***Picea-Pinus* SA2–2** is distinguished in the depth interval of 1.25–0.53 m, and is characterized by a gradual increase, reaching the maximum of pine and spruce values. Birch and alder pollen curves decrease. With small fluctuations, curves of pollen of deciduous trees gradually decrease and lose their importance. The composition of the pollen zone conforms to the middle part of the Subatlantic Time.

The uppermost zone ***Pinus-Betula* SA3** covers the deposit layer in the depth interval of 0.53–0.05 m. After a small fall of the pine curve it rises again. A sharp rise of the birch curve up to the maximum is observed. Rise of the pollen curve of *Calluna vulgaris* also continues. The zone conforms to the last part of the Subatlantic Time.

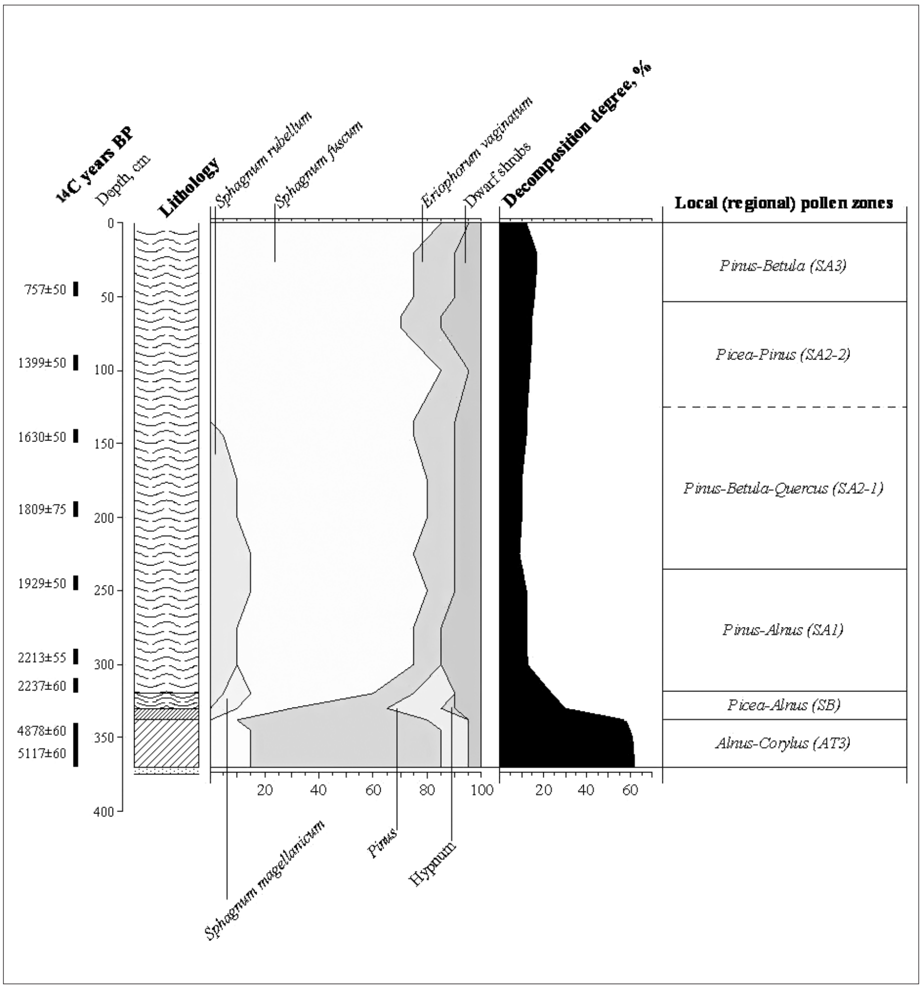

Figure 7. **Peat botanical composition and decomposition degree of the Dzelve-Kronis Bog (see legend of the deposits in Fig. 5)**

Data on botanical studies of peat confirm the similar character of peat formation during the Subatlantic Time (the last 2800 years); however, larger decomposition of peat in the Eipurs Bog suggested dryer conditions (probably a lower groundwater level). There are significant differences between peat layers formed in both bogs during the Subboreal and Atlantic Time which can be explained by the local conditions, as well as with the fact that the Dzelve-Kronis Bog started to form almost 4000 years later under different climate conditions (Fig. 4, 7).

CONCLUSIONS

The studies of peat botanical composition and formation conditions carried out in two ombrotrophic bogs in Latvia confirm the different character of peat development processes and significantly different properties.

The pollen data accompanied with ^{14}C datings indicate start of peat formation in the Eipurs Bog during the Preboreal Time, when birch trees and different herbs were widely distributed in the bog depression. Conditions were favourable for fen peat formation and good decomposition. Fen peat formed in the Eipurs Bog up to the Atlantic Time when transition from fen to transition bog and later to raised bog took place. Peat formation also started in the depression of the Dzelve-Kronis Bog during the Atlantic Time, indicating the conditions for raised bog development were favourable and did not depend significantly on the age of the bog. However, the obtained data point to different hydrological conditions in the two bogs. Data on the peat botanical composition and the decomposition degree of peat layers from the Eipurs Bog reflect dryer and more changing conditions than in the Dzelve-Kronis Bog, where the peat properties only slightly change.

The study of these two closely located ombrotrophic bogs demonstrates the significant influence of regional and local conditions on the peat formation process and properties.

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REFERENCES

Berglund B. E., Ralska-Jasiewiczowa M. (1986) Pollen analysis and pollen diagrams. In: Berglund B. E. (ed.) *Handbook of Holocene Palaeoecology and Palaeohydrology*. John Wiley & Sons, pp. 455–484.

Birks H. J. B., Birks H. H. (1980) *Quaternary Palaeoecology*. London: Edward Arnold, 289 p.

Borgmark A. (2005a) Holocene climate variability and periodicities in south-central Sweden, as interpreted from peat humification analysis. *Holocene*, 15 (3), 387–395.

Borgmark A. (2005b) The colour of climate: changes in peat decomposition as a proxy for climate change – a study of raised bogs in South-central Sweden. PhD thesis, Stockholm: Stockholm University.

Faegri K., Iversen J. (1964) *Textbook of pollen analysis*. Copenhagen: Munksgaard.

Lishtvan I. I., Korol N. T. (1975) Basic Properties of Peat and Methods for Their Determination. Minsk: *Nauka I Teknika*, 320 p. (in Russian)

Moore P. D., Webb J. A. (1978) *An illustrated guide to pollen analysis*. London: Hodder and Stought. 133 p.

Parent L. E., Caron J. (1993) Physical properties of organic soils. In: Carter M. R. (ed.) *Soil sampling and methods of analysis*. Canadian Society of Soil Science. LEWIS Publisher, pp. 159–441.

Steiner G. M. (ed.) (2005) *Moore von Siberien bis Feuerland.* Linz: Biologiezentrum der OÖ Landesmuseum.

Tjuremnov S. N. (1976) Peat deposits and their exploration. Moscow: Nedra.

Yeloff D., Mauquoy D. (2006) The influence of vegetation composition on peat humification: implications for paleoclimatic studies. *Boreas*, 35, 662–673.