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Vegetation response to the climatic and human impact changes during the Late Glacial and Holocene: case study of the marginal area of Baltija Upland, NE Lithuania

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Abstract The results of interdisciplinary investigations reconstructing peculiarities of vegetation development during the late Glacial and Holocene in the marginal area of Baltija Upland, NE Lithuania are presented. The reconstruction is based on pollen survey, plant macroremain investigations, ^{14}C, geological-geomorphological and archaeological data. Natural factors determined flourishing of the Allerød birch/pine wood later replaced by Younger Dryas tundra or forest tundra vegetation during the Late Glacial. Presence of *Picea* macroremains and high pollen representation suggest early-Holocene (about 9400^{14}C BP) immigration of this tree into region where pine had predominated in the local vegetation. The earliest human induced vegetation disturbances were dated back to the Early-Middle Neolithic and continuous increasing woodland clearings with the introduction of cultural activity herbs registered since the Late Bronze Age onwards. Culmination of people initiated vegetation shifts took place at about 2000^{14}C years BP (Early Roman Iron Age) and at about 1000^{14}C years BP (Late Iron Age).

Keywords *Palaeobotany, vegetation history, settlement history, farming, Late Glacial, Holocene, NE Lithuania.*

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INTRODUCTION

The primary aim of this study was to describe vegetation development in the outskirts of the Baltija Upland, NE Lithuania, since the earliest periods of the Late Glacial and to reveal its reaction to natural and human activity by using palaeobotanical, chronological, archaeological and geological-geomorphological data. Juodonys region (Fig. 1) with the varying patterns of the present environment (surface lithology, geomorphology and hydrology) and rich archaeological heritage is an excellent place for the mentioned survey. Continuous sedimentation close to the limit of the maximal distribution of Nemunas (Weichselian) ice sheet seems to be the most representative archives of the Late Glacial and Holocene environment. The reconstruction of regional vegetation pattern obtained on the basis of pollen survey is accompanied by the detailed investigation of the local communities characterized by plant macroremain investigation.

Application of the interdisciplinary approach that has been successfully applied in numerous projects of similar attribution developed in Lithuania and neighboring countries provided a new possibility for the evaluation of the woodland alternation (Berglund 1991, Berglund et al. 1996, Latałowa 1992, Blažauskas et al. 1998, Baltrūnas et al. 2001, Antanaitis-Jacobs et al. 2002, Stančikaitė et al. 2002, Simniškytė et al. 2003).

The Late Glacial and Holocene biostratigraphy, vegetation patterns and agrarian history of the NE

Lithuania have been described by Kabailienė (1993), Kabailienė and Grigienė (1997), Kunskas (1971) and Antanaitis et al. (2000). However, most studied sequences are poorly provided by ^{14}C dates or the latter are lacking. In this study more attention has been paid to the reconstruction of local vegetation successions applying plant macroremain analysis in parallel with microbotanical survey.

STUDY AREA

The reconstruction of vegetation cover is based on the results of the complex investigation done near Juodonys settlement, in the marginal area of the Baltija Upland, NE Lithuania (Fig. 1). Core (55°44'22" N, 25°26'15" E) was collected in the lowest part of the wet plain stretching at a foot of the steep 15-25 meter high slope, which appears to be a striking geomorphological divider

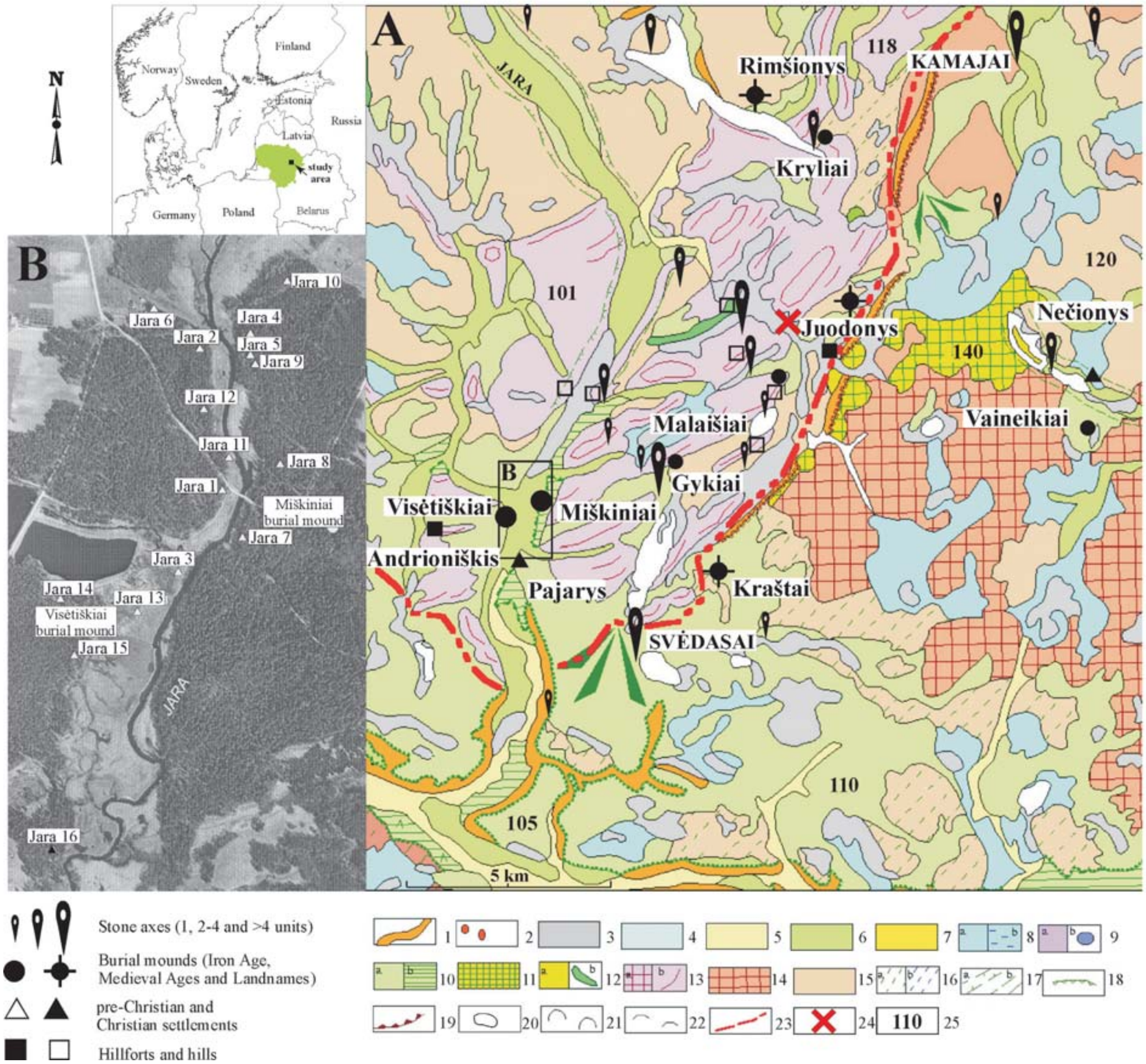

Fig. 1. Location map of study area. A - geomorphological map (compiled by R. Guobytė) and distribution of the archaeological monuments. B - aerial photograph of Jara River valley. Aerial photograph, scale 1:17 000, 1952, depository of the Geological Survey of Lithuania.

Legend of map: *Late Glacial and Holocene*: 1 - slopes; 2 - glaciokarst hole; 3 - bog plains; 4 - lacustrine plains; 5 - flood valley; 6 - glaciofluvial valley; 7 - aeolian relief; *Baltija stage of the Late Weichselian (Nemunas) Glaciation*: 8 - sandy (a) and clayey (b) glaciolacustrine plains; 9 - glaciolacustrine hills (a) and kames (b); 10 - glaciofluvial delta (a) and terrace (b) plains; 11 - kame terrace; 12 - glaciofluvial hills (a) and eskers (b); 13 - morainic hills (a) and ridges on the surface of Middle Lithuania ridge; 14 - hilly till plain; 15 - till plain; 16 - erosional (a) and abrasional (b) plains; 17 - meltwater valleys (a) and tunnel valleys (b); 18 - erosional slopes; 19 - ice-contact slopes; 20 - present lakes. *Other signs*: 21 - maximal extension of the Middle Lithuania oscillation, Baltija Stage; 24 - coring point; 25 - altitudes of the surface topography.

between the Baltija Upland and Middle Lithuania Lowland (Guobytė 2002). East of the slope a hummocky topography characterizes the proximal part of the Baltija Upland. Inter-hilly depressions are filled with silty or peaty sand accumulated in the former lakes. The Middle Lithuanian till plain is complicated by contrasting end-moraine ridges stretching to the west of the slope. The loaf-like NE-SW oriented ridges are stretching 10-20 m higher than the surrounding till and glaciolacustrine plain lying at the altitude of 95-105 m. Marshy plain with the glaciolacustrine sediments on its bottom stretches in between these ridges, and the lowest parts of the plain are occupied by peat deposited in place of remnant lakes after their drainage during the Post Glacial.

Coniferous and hardwood-spruce forests, swampy meadows and fens characterize the investigated area. The forest habitats are various depending on the complicated relief and diversity of soil-hydrological factors. Spruce-pine forest accompanied by spruce forest with oak or pine forest with the hazel bush layer predominated in area where woodlands are in minority in our days. Paludified meadows with *Carex* as predominating species are common in the herb cover widely spread on peat enriched soils (Laasimer et al. 1993).

Small villages such like Juodonys and Malaišiai together with several farms are situated in the surroundings.

SETTLEMENT HISTORY

Traditional archaeological typology and written sources were used as a primary tool for the chronological subdivision of the human history periods in the investigated region. A few ^{14}C dates supported the conclusions dealing with the Migration period only.

3000 – 2000 BC. The first inhabitants took up occupation of the north-eastern Lithuania during the Stone Age. Abundant archaeological materials of this period have been discovered in Jara River microregion (Fig. 1, B). There are more than 15 archaeological sites mostly from the Stone Age, and three of them (Jara 1, 2, 3) were excavated more widely (Girininkas 1977, 1978, 1986). For the meantime, Lake Jara microregion is the only known densely inhabited island in the whole North Eastern Lithuania's region during the Stone Age.

The surroundings of Jara appeared to have been inhabited since the Early-Middle Neolithic. Abundant ceramic complex and flint collection belong to Narva Culture (Girininkas 1977, 1978, 1986, Brazaitis 2002). The subsistence strategy of Narva people has been based on fishing and hunting, and the conditions for this kind of activity have been favourable in the Jara lakeside.

Simultaneously, new groups of people reached the microregion in the 3rd millennium BC. At the settlement of Jara 1, complex A, besides the material of the Narva Culture, sherds ornamented by cord were found and earlier attributed to the Corded Ware Culture (Girininkas 1977). After a careful revision it appeared

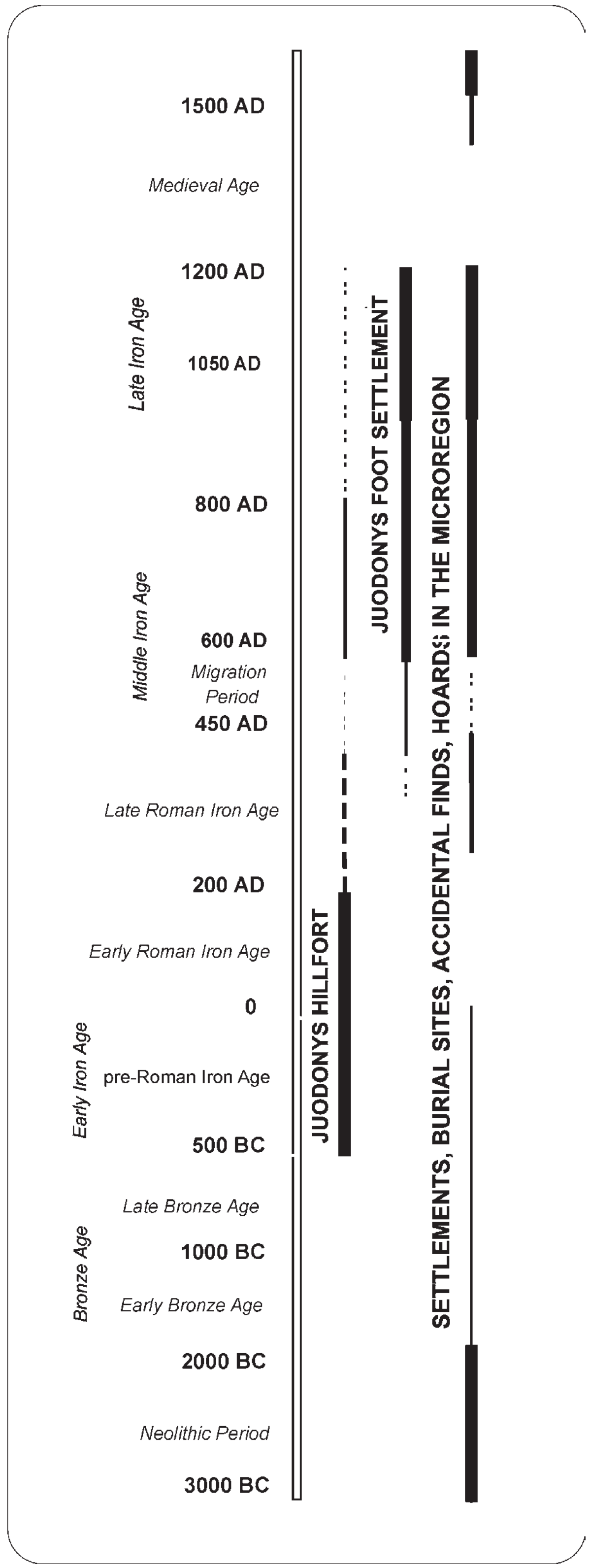

Fig. 2. Chronology of the archaeological monuments in the investigated region.

that a part of material belongs to the Globular Amphora Culture (Brazaitis 2000, Girininkas 2002). In Jara 1 settlement site the pot sherds of the Globular Amphora Culture were related mainly to Narva material, which is chronologically a bit earlier. This could be explained as cultural changes: bearers of new culture have displaced the Narva culture people (Brazaitis 2002). Mixed type of subsistence, including animal husbandry and fishing, could be assumed as proper explanation for the economical situation in the second half of the 3rd millennium BC, which was one of the most intensive cultural stages in the Jara lakeside.

2000 – 1000 BC. The settlement of Jara area continued to exist. The investigation of the Visėtiškiai Iron Age burial mound (Fig. 1, B) provided rather big amount of pottery and flint artifacts, which definitely originated from much older times. Majority of decorated pottery with crushed granite differ from the ceramic of the Late Narva Culture and the Corded Ware Culture. This type of ceramic was named ”a post-Corded Ware pottery“ (Brazaitis 2000). The suggestion was made that the earliest tumuli of Visėtiškiai barrow cemetery could have been erected in the Bronze Age (Brazaitis 2000).

1000 BC – 200 AD. The second half of the Bronze Age coincides with the formation of the Brushed Pottery Culture, which continued until the first ages AD. During the 1st millennium BC fishy shores of Lake Jara and the Jara River were still economically and culturally attractive for local communities. A few find spots with stroked pottery are known to be located close to the river (Andrioniškis, Visėtiškiai, Jara). Some tumuli in Visėtiškai barrow cemetery (Fig. 1, B) could have been erected in this period (Brazaitis 2000).

The 1st millennium BC was the period of human expansion in a spatial point of view. There are more than 60 stonework - axes from 20 locales near the research point (Fig. 2). These are generally stray finds. Distribution of numerous axes indicates the territorial zones of human activity. Most of them were found westward of the proximal slope, on the plain complicated by the moraine ridges. These hills do not have any features of the past settlement, but with no doubt, they were under the influence of human activity. Juodonys Hillfort is the only known place in the microregion where permanent settlement occurred. Systematic excavations of the area covering 228.5 sq. m were carried out in 1986-1987 (Grigalavičienė 1992). It appeared that the resident population in Juodonys occurred in the second half of the 1st millennium BC and, due to the intensive activity, a thick cultural layer was formed. Settlement has continued for more than a half of millennium until the reorganization occurred in 200/300AD.

The Bronze Age and Early Iron Age was the time of agriculture expansion. However, not until the next stage cereal agriculture has taken the dominant role in economic system. Husbandry has remained the main branch of subsistence of the eastern Lithuanian communities in the 1st millennium BC (Luchtan 1986, Luchtanas 1992, Grigalavičienė 1995). The domestic animals: cattle (27.91%), horse (25.58%), pig (11.63%), sheep/goat (4.65%) and dog bones (11.63%) composed 81.39% of the total amount of all identified bones in Juodonys Hillfort (Daugnora & Girininkas 1996, Fig. 51). Animal herds of local communities implied the main wealth, that needed to be protected, and this was an important reason to have fortified hillforts (Luchtan 1986).

200 – 450 AD. The beginning of Late Roman Iron Age (LRIA) was marked by a remarkable decrease of human activity in the Juodonys Hillfort itself. There are only few artifacts that could be dated to the Roman period (e.g. knife-sickle) (Grigalavičienė 1992, Fig. 8:1). However, the regression of human activity has nothing to do with cultural crisis or ”depopulation“. LRIA was the period of the expansion of the burial mounds with stone circle culture (Michelbertas 1986, Vasks 2001). Tumuli culture people preferred different ecological conditions within the hilly and more contrasting landscape than previous inhabitants. Vaineikiai barrow cemetery 5 km eastward of Juodonys is situated at the opposite side of the marginal slope in the hummocky landscape of Baltija Upland. Before it‘s destruction the cemetery had been one of the biggest barrow cemeteries in north-eastern Lithuania. We do not know how settlements of the people buried in the burial mound look like. Nevertheless, it could be assumed that single farms and small irregular hamlets have been scattered across the landscape.

The cultural changes have signalized the transformation of social and economic situation. Favourable conditions for individual farming have occurred after. Therefore, the spread of burial mounds in cultural landscape contemporized with the dispersion of the settlement pattern. The large extensive hillfort families have been replaced with individual families, which set up farmsteads in new places located some distance away from hillforts.

450 – 600 AD. The Migration Period was one of the most diverse periods in the Baltic lands (Myhre 1992, Näsman 1978, 1998, Stenberger 1955, Šimėnas 1992, Žulkus 2004). The sociocultural changes have not bypassed Juodonys microregion. Due to significant decrease in burial the idea about the presumed abandonment of the area has been raised (Simniškytė 2002). However, the traces of “empty period” have been detected at the foot of the hillfort after a careful revision of Juodonys material and additional excavations (Simniškytė et al. 2003). The role of new foot settlement in the settlement system remains difficult to assess. The recovered layer was poor in terms of both quality and quantity. There were no signs of settlement hierarchy or subordination. It is unlikely that the process of settlement contraction started in the Migration Period. It seems as if a part of dispersed population had returned to old places and took up ordinary occupation at the hillfort‘s foot with low level of farming activity. However the action of moving should has been connected with general sociocultural transformation.

600 – 950 AD. At about the transition from 6th to 7th centuries AD the second expansion phase of the human activity started in Juodonys. It was the very beginning of a new ”hillfort-and-foot settlement“ system, where the centre of craft, trade and ideology occurred (Simniškytė et al. 2003). Thick peaty cultural layer with abundant archaeological collection started to accumulate above previous meager horizon at the foot of Hillfort. Juodonys became the focal settlement for the local communities with growth activity. Rising amount of the archaeological material discovered in the surroundings indicates settlement expansion. Some more traces of dwelling sites are known from this period (Jara, Zoviškiai, Nečionys). Unfortunately, only a few potsherds, predominately coarse ceramic, testify the existence of these sites. Burial monuments became widespread at both sides of the marginal slope. Burial rites have revived in Vaineikiai and a new burial mounds have been erected in Visėtiškiai and Miškiniai barrow cemeteries (Kazakevičius 2000a, 2000b). None of these burial monuments provide an immediately information about economical system. Nevertheless, it is correct to assume that human intervention became more active and many-sided.

950 – 1200/1300 AD. Formation of the Juodonys centre started at the beginning of the Middle Iron Age and reached its heyday in 10th - 11th c. AD. The frequency of artifact groups from 900–1200/1300 AD five times outnumbers the groups of previous period. Economical surplus could have been produced under the favourable conditions. Friction among the societal groups has become sharper. Many of the previous burial monuments continued to exist: Visėtiškiai, Miškiniai, Kryliai. However, under the influence of rivalry some groups split off. As a result new burial places with extremely rich graves occurred close to the hillfort (e.g. Gykiai).

In historical documents of 13th century, the territorial centre of Sėla – *Maleysine, Maleisine* – was mentioned, thus reinforcing the importance of this region.

1200/1300 – up to present. No archaeological data confirming activity during Medieval Ages in the immediate vicinity of Juodonys archaeological complex were discovered. The only one Kalviai stray find from the times of battles with Livonian Order is known. The next time span of 100–200 years archaeologically is ”empty“ for the whole North-East Lithuania. New traces of habitation reappeared in 15th – 16th c. AD. New villages and cemeteries have been founded mostly on the edge of previous Juodonys microregion: Svėdasai (1503), Kamajai (1541), cemetery of Kraštai, Rimšionys and Pajarys manor (Simniškytė et al. in press). The prehistorical settlement pattern has been completely altered.

METHODS OF INVESTIGATION

Coring and sampling. Samples for the palaeobotanical survey and ^{14}C dating were taken from the peat bog (Fig. 1) using a *Russian* sampler. Samples were taken after 2-5 cm for all mentioned investigations.

Pollen investigations. Pollen preparation followed the standard procedure described by Grichuk (1940) and Erdtman (1936) with the improvements suggested by Stockmarr (1971). More than 1000 terrestrial pollen grains were counted for each level and AP+NAP sum based the percentage calculation of the spectra. The pollen and plant macrofossils spreadsheets as well as percentage diagrams were plotted with the TILIA (version 2) and TILIA-GRAPH (version 2.0 b.4) programs (Grimm 1991). Chronostratigraphical zonation of the diagrams is based on the results of ^{14}C dating and changes in local pollen assemblage zones (LPAZ). LPAZ have been correlated with those established for Lithuania and chronozones of Late Glacial and Holocene (Mangerud et al. 1974, Kabailienė 1998). Pollen and spore identifications were based on Fægri and Iversen (1989), Moore, Webb and Collinson (1991) and Moe (1974) in conjunction with the reference collection of the Department of Geology and Mineralogy, Vilnius University.

The construction of the human impact diagram follows the groups of taxa established by Behre (1981, 1986), Berglund and Ralska-Jasiewiczowa (1986), Veski (1998) and Poska and Saarse (1999).

Plant macroremain analysis. 61 samples with a volume of 230 cub. cm were sieved through screens with a mesh size of 0.25 mm and material left on screens analyzed using dissecting microscope. The identification of plant macrofossils was based on Beijerinck (1947), Berggren (1969, 1981) and Grigas (1986) in combination with the plant macrofossil and modern seed collections (Institute of Geology and Geography, Vilnius). The taxa have been sorted into habitat classifications to aid interpretation and reconstruction of the vegetation.

RESULTS

Chronology. Chronology of the investigated sequence has been supported by five conventional ^{14}C dates (Table 1). Samples were dated at the Radioisotope Laboratory of the Institute of Geology and Geography, Vilnius, and Kiev Radiocarbon Laboratory, and calibrated using the program REV 3.0.3 (Stuiver and Reimer 1993).

Three upper dates reveal the age of the vegetation changes related to the different periods of the human interference and two lower have stratigraphic significance. However, ^{14}C age of the lowermost sample (Ki-10952) contradicts to the results of the pollen stratigraphy and for this reason could be accepted with a big limitation. Linear interpolation between the closet

Table 1. Uncalibrated ^{14}C (BP) and calibrated (cal AD/cal BC) dates from Juodonys core.

Depth, cm	Uncalibrated ^{14}C years BP	Calibrated time (1σ range)	Lab. code	Dated material	Dating object
60–65	1020±70	AD 965-1054	Ki–1029	Peat with gyttja	Rise in human interference
102–107	2147±164	378 BC-AD 5	Vs–1365	Peat with gyttja	Culmination of human activity
175–180	5919±590	4792 BC	Vs-1378	Gyttja	Start of the continuous presence of apophytes
265–275	9410±310		Vs-1433	Plant remnants	Early *Picea* culmination
322–326	12170±180	–	Ki-10952	Peat	Rise in NAP representation

dates was used for the reconstruction of the time scale. Discussing the age of the vegetation changes as well as the periods of human history, uncalibrated ^{14}C years before present (BP) are used.

Pollen stratigraphy. Pollen diagram (Fig. 3) has been divided into twelve local pollen assemblage zones (LPAZ). Determination of the LPAZ was based on the presence and absence of the taxa together with the results of CONISS zonation (Grimm 1991).

LPAZ 1, ~ 11900 ^{14}C BP, *Pinus–Betula*–Cyperaceae (341–339 cm). Determination of this zone is based on predominance of *Pinus* (89%) in pollen spectra. Total AP sum reached 95% in this zone. Herbs are dominated by Cyperaceae (~2%) and *Artemisia* (0.2%). Charred particles reached up to 12% at the beginning of the zone and pollen concentration varies around $88*10^3$ grains /cm^3.

LPAZ 2, 11900 – 11300 ^{14}C BP, *Betula*–Cyperaceae (339–326 cm). AP value dropped down to 47% and *Betula* (24%) predominated in this zone. Apart *Pinus* (39%), *Populus* (5%) and *Juniperus* (0.5%) AP species are mostly represented sporadically. Cyperaceae culminates reaching 47% and Chenopodiaceae together with *Artemisia* are registered continuously. Other grasses appeared in the separated spectra only. The same is true for Polypodiaceae, *Sphagnum*, *Botrychium* and *Selaginella selaginoides* spores. Increasing value closer to the upper limit of the zone has changed drop in pollen concentration.

LPAZ 3, 11300 – 10900 ^{14}C BP, *Pinus* (326–311 cm). This zone is characterized by rising value of *Pinus* (78%), together with a decrease in *Betula* representation. AP species (*Alnus*, *Picea* and *Populus*) have low continuous curves starting in this zone. Due to the lowering of Cyperaceae value, NAP sum decreased remarkably if compared to the previous zone. Spores are rare in this zone. Pollen concentration is the highest throughout whole diagram ($206*10^3$ grains /cm^3).

LPAZ 4, 10900 – 10200 ^{14}C BP, *Betula–Juniperus–Artemisia*–Cyperaceae (311–289 cm). Rise in *Betula* (14%) representation and *Juniperus* culmination (6%) is characteristic for the spectra. Simultaneously, value and frequency of the NAP pollen increased. Culmination of Chenopodiaceae (~3%) is followed by *Artemisia* peak (~5%) and abundant representation of Cyperaceae (28%) in this LPAZ where occurrence of Brassicaceae, *Filipendula*, Polygonaceae and Caryophyllaceae noted. Charcoal curve shows 15% and pollen concentration decreased ($12*10^3$ grains /cm^3) at the end of the zone.

LPAZ 5, 10200 – 9100 ^{14}C BP, *Picea–Pinus* (289–255 cm). In this zone culmination of *Picea* curve (40%) and some rise of *Pinus* value (76%) coincides with especially low representation of *Betula*. AP sum increased to 97% and NAP is represented by low number of Cyperaceae, *Artemisia* and Poaceae. LPAZ contains the beginning of the continuous Polypodiaceae and *Sphagnum* curves. Charcoal value varies from 10 to 17% and pollen concentration gradually increased.

LPAZ 6, 9100 – 6000 ^{14}C BP, *Pinus* (255–182 cm). *Pinus* representation rises to 92% and stays high throughout this zone. At the same time *Picea* nearly diminished from the pollen spectra. *Ulmus*, *Populus*, *Salix* and *Acer* are registered in spectra, which show rising number of *Betula* and *Alnus*. NAP is low in this LPAZ where Cyperaceae, *Artemisia* and Poaceae are registered continuously. Charcoal value is minor and pollen concentration stays rather steady throughout this zone.

LPAZ 7, 6000 – 3200 ^{14}C BP, *Betula*–Cyperaceae (182–148 cm). Re-increase in *Betula* representation (16%) coincides with the rising number of NAP (8 %) and Cyperaceae (15%) particularly. An appearance of *Artemisia*, *Plantago lanceolata*, Brassicaceae and *Galium* is more frequent in this zone. LPAZ contains the beginning of the continuous representation of *Corylus*. *QM* is registered in mostly spectra attributed to this zone. Sudden rise of the pollen concentration ($102*10^3$ grains /cm^3) coincides with increasing number of the charred particles (38%).

LPAZ 8, 3200 – 2000 ^{14}C BP, *Picea–Pinus–Alnus* (148–112 cm). *Picea* increased up to 9% and *Pinus* varied from 54.5 to 86.9% in this zone. Number of *QM* pollen stays minor and erratic representation of the rest AP species is noted. The pollen spectra of this zone contain higher percentage and variety of NAP species. *Cerealia*, *Rumex acetosa/acetosella*, *Aster*. Sect. *Aster*, *Urtica*, *Taraxacum*, *Artemisia* and Chenopodiaceae occurred. Number of charcoal particles reaches up to 41% in this zone. Pollen concentration increased up to 197*10^3 grains/cm^3 in the middle of the LPAZ but lowered close to the limits of the zone.

LPAZ 9, 2000 – 1500 ^{14}C BP, *Pinus–Betula* (112–79 cm). This zone is characterized by the increasing representation of *Pinus* (~85%) and *Betula* (~10%) pollen together with the gradual lowering of NAP value. However, some species of non-arboreal pollen, such like *Cerealia* (2%), culminated or increased in representation in this zone. Lowering of charcoal number coincides with the increasing pollen concentration.

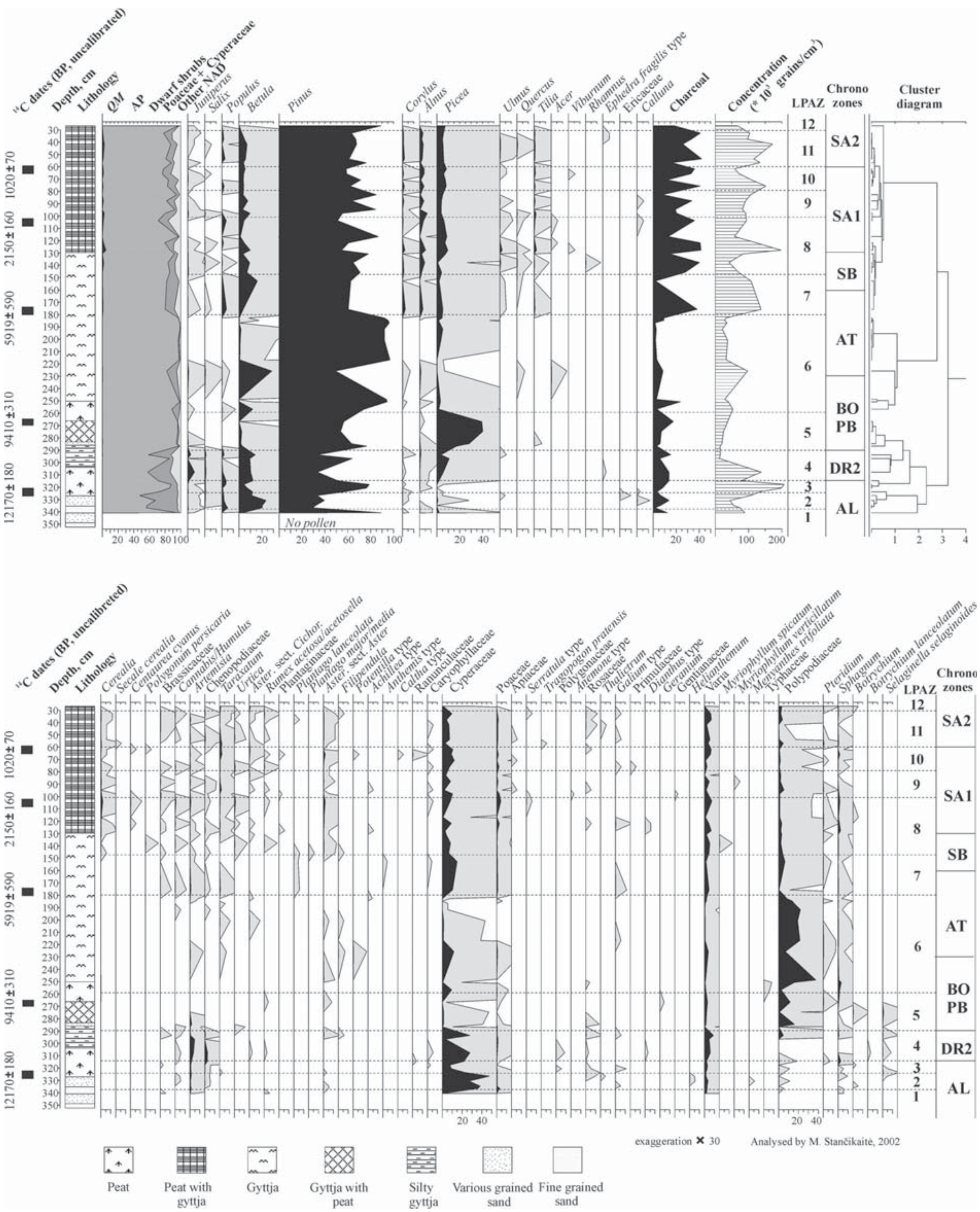

Fig. 3. Pollen diagram of Juodonys core.

LPAZ 10, 1500 – 1000 ^{14}C BP, *Picea*-Cyperaceae (79–60 cm). Rise in *Picea* (8%) percentage and imperceptible lowering of *Pinus* together with *Betula* registered. Cyperaceae (12%) is the best represented NAP species, whereas lower percentages of Poaceae, *Artemisia* and *Cerealia* are registered. *Taraxacum* culminates reaching 1.4%. The beginning of this LPAZ corresponds to high value of the pollen concentration (153*10^3 grains /cm^3) that lowered afterwards.

LPAZ 11, 1000 – 300 ^{14}C BP, *Betula–Pinus* (60–30 cm). High percentage of *Pinus* (76%) and rising number of *Betula* (7.0%) is characteristic for the spectra. *Alnus* and *Populus* are noted in all spectra and some rise of *QM* seen. NAP reaches 11% approaching the upper limit of the zone and Cyperaceae, Poaceae, *Taraxacum* and *Aster*. sect. *Aster*. are the best represented. Peak of the pollen concentration (164*10^3 grains /cm^3) registered in the middle of the LPAZ coincides with the drop in charcoal value.

LPAZ 12, <300 ^{14}C BP, *Pinus* (30–27 cm). Sudden jump in *Pinus* (89%) representation coincides with the increasing AP percentage. At the end of the zone mostly rest AP species diminished from the pollen spectra and the same is true for the NAP. Only a few species, such like *Taraxacum* and *Aster*. sect. *Cichor*. increased in representation. LPAZ contains progressive drop in charcoal and pollen concentration curves.

Plant macroremain zones. 338 remains of plants belonging to 36 taxa have been found after the analysis of macrobotanical samples. Predominantly those were fruits and seeds of plants as well as *Picea* needles, *Chara* oospores and *Selaginella* megaspores. The identified species by their ecological characteristics have been categorized into several ecological groups (Fig. 4). Most of the remains belong to wetland and bog plants that characterize the dominant ecological conditions in the investigated area. The group of woodland plants is of poor species diversity, but it makes it possible to judge about the forest type, which used to exist in area throughout the different periods of accumulation. Plants indicating human habitation and economical activity were subsumed in anthropochores group. However many of these plants can also be related to the plant communities, which were formed under natural conditions. Discovered diaspores are unevenly distributed in the section. The quantitative proportion between ecological groups is also changing. According to discussed data section has been divided into six zones.

Zone I, >10200 ^{14}C BP, (305–290 cm). In the lower part of the section the low number of the macroremains is registered. Plants of the wet habitats – such as *Carex, Menyanthes trifoliata* L., and *Selaginella selaginoides* (L.) Link – comprise one of the most abundant groups. The latter species imply humid severe climatic conditions and open type of the habitat. The plants like *Trifolium repens* L. and *Urtica dioica* L. that are attributed to anthropochores in the diagram represent natural vegetation growing in the nitrogen-enriched soil in this part of the section.

Zone II, 10200 – 8800 ^{14}C BP, (290–260 cm). This interval abounds in macroremains of plants typical for wood and wetland habitats (41 and 37 %) (Fig. 4). At the time of sediments formation spruce and birch predominated in the forest composition. *Fragaria vesca* L. that belongs to the natural vegetation of sunny, open or shadowed slopes or wood outskirts is common in the deposits (Hamet-Ahti et al. 1998). Eight species predominated by sedges are representing the group of wetland and coastal plants. *Selaginella selaginoides* (L.) Link megaspores are still found in the sediments implying cool and semi-humid climatic conditions prevailing. Although some species of this zone usually are attributed to the anthropochores they cannot be taken as letters in this interval. For example, *Urtica dioica* L. as nitrophilous species, characterize the edaphic conditions in this case.

Zone III, 8800 – 7000 ^{14}C BP, (260–210 cm). The changes of environmental conditions are fixed in the deposits ascribed to this zone. In the area previously occupied by wetlands the monodominant plant community of *Menyanthes trifoliata* L. has developed – it is a semiaquatic plant, which grows in the shallow water (Bennike 2000). The plants of wet habitats account for 82 % of remains in this interval (Fig. 4) that indicates rising humidity. The wood communities have changed as well. Only the remains of *Betula* sect. *Albae* fruits were found in the deposits. Presumably the woodland communities existed in a distance from the investigation point and fruits of birch were scattered by the wind.

Zone IV, 7000 – 3000 ^{14}C BP, (210–140 cm). In this zone sediments are poor in plant macroremains. They are even absent in the middle part (160–190 cm) of the zone. The rest part of the interval is predominated by anthropochores (*Stellaria graminea* L., *Urtica dioica* L.) though the diversity of the spectra is rather small. The rest part of the finds belongs to the plants of wet habitats (*Lychnis flos-cuculi* L., *Cirsium palustre* L., *Menyanthes trifoliata* L.).

Zone V, 3000 – 300 ^{14}C BP, (140–35 cm). Seeds and fruits of 28 taxa were identified in the deposits. 2% finds represent the wood elements, including birch and pine. The poor tree remains show that forest was growing in a distance from the site of sedimentation. Twelve identified species belong to the plants of wetlands and shores (44% of all finds). Different species of *Carex* (*C. rostrata* Stokes*, C. diandra* Schrank, *C.* cf. *pseudocyperus* L.), *Ranunculus sceleratus* L., *Lychnis flos-cuculi* L. are predominating. The presence of the water plant *Batrachium* sp. at a depth of 35–130 cm may suggest an imperceptible decrease of the water table, which was not reflected in the lithology composition. There are plenty of anthropochores (about 35% of finds) within

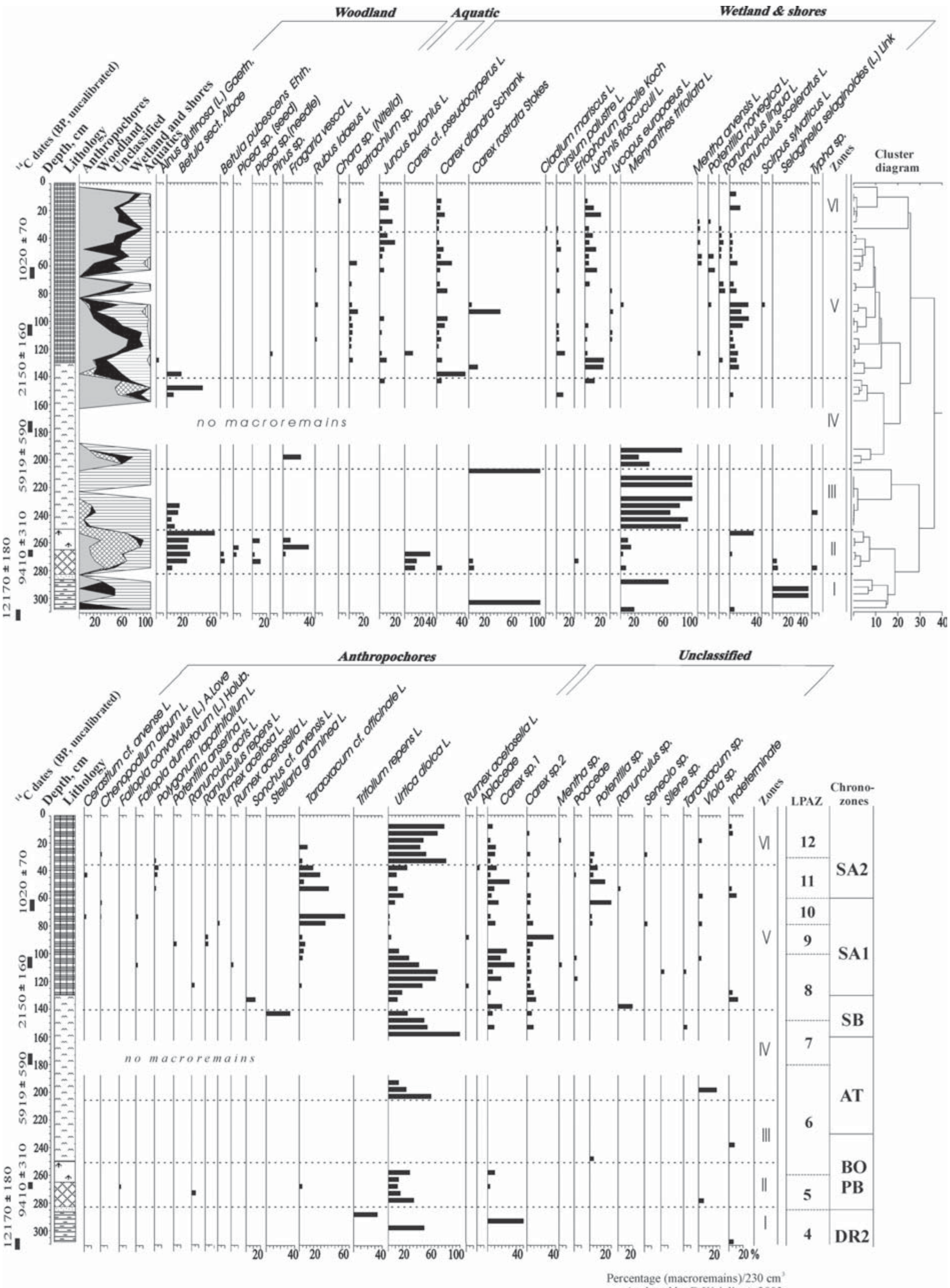

Fig. 4. Macrofossil remains from Juodonys core deposits.

the interval 35–145 cm and *Urtica dioica* L. predominates among them. This species indicates anthropogenic impacted nitrogen-rich soil (Antanaitis et al. 2000). Presence of *Taracxacum* cf. *officinale* L.*, Stellaria graminea* L., *Ranunulus repens* L. and *Potentilla anserina* L. may suggest anthropogenic activity (Vourela et al. 2001) and existence of the cultivated fields.

Zone VI, <300 ^{14}C BP, (35–0 cm). The upper part of the poorly decomposed peat is predominated by *Urtica dioica* L. and remains of plants typical for wetland habitats. *Cladium mariscus* L., as a calciphilous, indicates the increasing amount of calcium in sediments (Bennike et al. 2000).

Anthropogenic phases sensu palaeobotanical data. Eight consistent phases of the human activity have been distinguished representing the land-use since the Mesolithic onwards (Fig. 5). The main features of those zones are discussed in this chapter while the detailed study of the human history including agriculture development is available in Simniškytė et al. (2003).

A - Mesolithic (7000-6000 ^{14}C years BP). The earliest small-scale signs of human interference appear in the sediments dated back to Mesolithic time. Increasing representation of the light-demanding or early successional taxa, such like *Betula*, *Salix*, *Acer, Juniperus* and *Populus* in separated spectra could be related to the artificial disturbances of the forest cover. Spread of the ruderal plants and apophytic taxa at the same level points to the formation of the local forest openings. Despite the minor charcoal representation spores of *Pteridium* confirms fire activity in area.

B - Neolithic - Early Bronze Age (6000-3400 ^{14}C years BP). Increasing intensity of the human activity was noted in the pollen spectra of the investigated sequence. Rising representation of the ruderal plants, *Artemisia*, *Taraxacum* and Chenopodiaceae particularly, confirms intensive soil erosion at the time of the high fire activity that also coincides with the thinning of the forest cover. *Plantago lanceolata* pollen are assumed as indirect evidence of the animal grazing even at the beginning of the period.

C - Late Bronze Age (3400-2500 ^{14}C years BP). Introduction of the arable farming shown by the appearance of the *Cerealia* pollen together with the presence of *Polygonum persicaria* typical for the fallow land communities took place at the second half of the Bronze Age. High frequency of the microscopic charred particles indicates intensive forest burning and development of the open grassland communities suitable for the animal husbandry. Grazing in light dry forest was also common.

D - Pre-Roman Iron Age (2500-2000 ^{14}C years BP). Continuous presence of the *Cerealia* pollen accompanied by the different weeds, including species typical for the winter crop (*Centaurea cyanus*), coincides with the rise of the ruderal representation in this zone. Obviously agriculture became important part of the local economy and entered in to establishment phase. Due to the rising intensity of the farming practices vast areas of the forest were burned and numerous microscopic charred particles deposited. Significant increase in the number and variety of the ruderal species noted in this zone coincides with the

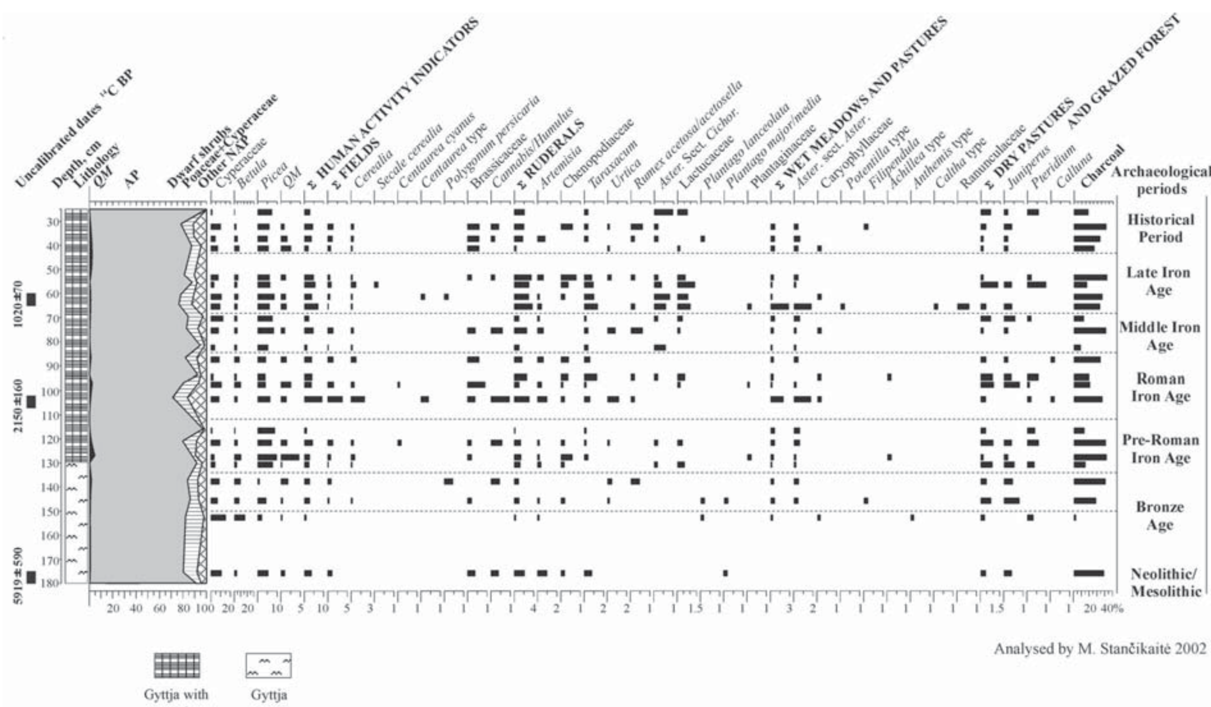

Fig. 5. Human impact diagram of Juodonys core.

prosperity of the archaeological monuments investigated around.

E - Roman Iron Age (2000-1500 ^{14}C years BP). The most prominent human pressure on the environment has been registered in this zone. Culmination of the *Cerealia* curve together with the maximum presence of the mostly weeds including species typical for the permanent fields suggest introduction of the new agriculture system. Ruderal plants flourished both in the fallow land and close to the settlement itself. Opening of the landscape is confirmed by AP/NAP ratio and high number of charred particles.

F - The Middle Iron Age (1500-1200 ^{14}C years BP). Regression of the human activity is observed throughout the Middle Iron Age in investigated region. Reforestation if region is followed by the gradual lowering of crop representation. However the presence of the weeds together with indicators of dry and wet pastures confirms animal husbandry on abandoned fields.

G - Late Iron Age (1200-800 ^{14}C years BP). Pollen record of the Late Iron Age suggests increasing intensity of the human interference. Numerous plants typical for the agriculture fields and pastures accompany the onset of the extensive clearance. Especially high number of the ruderals, *Aster*. sect. *Cichor*., Lactucaceae and *Taraxacum* coincide with the intensive settlement phase and predominance of the permanent fields. Existence of the permanent fields and possible winter sowing has been confirmed by the appearance of *Secale cerealia* pollen grains together with *Centaurea cyanus*.

H - Historical period (800 - present ^{14}C years BP). Some imperceptible regression of the human activity followed by the phase of high intensity is characteristic for this zone. Crops, weeds and ruderals are frequent in vegetation composition where open tree-less communities predominated. Forest decline coincides with the rise of charcoal representation and flourishing of the plants typical for the disturbed soils.

REGIONAL AND LOCAL VEGETATION DEVELOPMENT

Investigated core contains a complete vegetational record from the Late – Glacial until today (Fig. 3). The palynological record starts in the Allerød, which has been subdivided into three local pollen zones on the basis of the AP composition mainly. Because the boundaries of this period have not been dated accurately, recourse was had to the term, which refers to the biostratigraphic unit *sensu* Mangerud et al. (1974) (11.9–10.9 x 10^3 ^{14}C years BP). Registered peak showing the local presence of *Pinus* tree at the beginning of the chronozone is difficult to explain on the available data. Formed in the layer with predominating mineroclastic deposits spectra could survive intensive redeposition or input of the older material. The same reasons could be given explaining the discrepancy between biostratigraphic and ^{14}C results.

High representation of *Betula* pollen (24%) together with other light–demanding taxa points towards the formation of birch forest throughout the first half of the Allerød. Before that *Populus* may have been favored as a pioneer tree as it was registered during the former investigations (Ammann et al. 1994). According to Huntley and Birks (1983) *Betula* pollen values over 25% can indicate local birch dominated woodland. The optimum mean July temperature necessary for the development of *Betula pubescens* Ehrh. woodland is 12°C (Birks 1993). High representation of *Pinus* suggests the local growing of this tree being a significant component in the vegetation successions. Number of the pine pollen registered in the first half of the period exceeded the rational limit of 20%, indicating that tree was actually growing locally, because below values of 15-20% the presence of *Pinus* in the region cannot be assumed (Lang 1994, Ammann et al. 1994). Contemporaneous pinewood has been discovered and dated back to 11880±150 ^{14}C BP in SE Lithuania (Stančikaitė et al. 1998). Birch and pine dominated forest out competed mostly of herbs and grasses. Continuous low representation of *Artemisia,* Poaceae and Chenopodiaceae indicates the presence of treeless patches most probably, near the sedimentary basins, on the slopes of the hills and eroded plots. Appearance of the Cyperaceae peak is due to the local flourishing of these grasses. Transition from the minerogenic to the organogenic sedimentation could be related to the remarkable changes of the water level and progressive extension of the habitats suitable for sedges. Otherwise some moistening of climatic conditions before the middle Allerød that have been dated by Polish scientists (Goslar et al. 1999) can also be assumed as the reason for Cyperaceae spread.

During the second half of the Allerød, LPAZ 3, *Betula* pollen suddenly decreases in favor of *Pinus* (Fig. 3) pointing the predominance of the latter in the regional vegetation. Huntley and Birks (1983) conclude that pollen values >50% indicate local dominance of the pine. The associated rise in AP is mainly caused by pine increase as well as especially high pollen concentration. In some cases *Pinus* expansion may indicate increasingly severe conditions particularly in winter, i.e. an increase in continentality (Walker 1995), while some increase of precipitation and humidity since the middle of the Allerød has been suggested (Goslar et al. 1999). Decreasing representation of herbs and grasses together with the general rise of AP indicates progressive closing of the forest. Various pollen spectra registered at the beginning and approaching the end of the Allerød chronozone suggests climatic fluctuations took place in region. Generally, proxy records from Europe show major contrasts in terms of climatic history throughout Allerød chronozone (Lowe et al.

1994). Both, longitudinal and latitudinal gradients appear to have existed between investigated sites representing different parts of the continent (Lemdahl 1991, David 1993, Birks et al. 1994, Berglund et al. 1994). Several climatic oscillations registered all around the Europe suggest an increasing soils erosion, decline in AP representation and an increase in open-habitat herbaceous taxa at about ca. 11.8 ka BP (southern Sweden, Denmark and British Isles, Berglund et al. 1994, Walker et al. 1994), ca. 11.7 ka BP (northern French Alps, David 1993), ca. 11.75 ka BP and ca. 11.4 ka BP (southwest Norway, Paus 1988), 11.4±0.2 ka BP (Great Britain and Luxembourg, Walker & Harkness 1990, Guiot & Couteaux 1992) and shortly before 11.0 ka BP ('Gerzensee Oscillation', Lotter et al. 1992).

The beginning of the Younger Dryas (10.9–10.0x10^3 ^{14}C years BP *sensu* Mangerud et al. 1974) is marked by the increasing proportion of herbs and other plants typical for the dry and cool climate in the investigated profile. Clear evidence of the climatic deterioration that coincides with the sharp drop of *Pinus* curve and rising number of *Artemisia* together with other NAP is registered in LPAZ 4 (Fig. 3). Herb communities dominated by *Artemisia* and Chenopodiaceae gained more ground responding to the thinning of the forest cover. Prior to the birch asp and later juniper outspread into new opened habitats as it was registered in the pollen spectra. Contemporaneously spores and macroremains of typical tundra plant *Selaginella selaginoides* (L.) Link. appear. Retreating of the pine/birch forest cover and formation of forest tundra landscape is also proved by the increasing proportion of the mineroclastic deposits in the investigated sequence. Regardless of the drying of the climate the abundance of Cyperaceae pollen and macroremains of *Carex* sp. 1 and *Carex rostrata* Stokes (Fig. 3, 4) indicates moist conditions prevailing in the investigated site. Presence of *Urtica dioica* L. seeds is particularly interest from the point of environmental reconstruction because these plants require mean July temperature at least 8°C (Kolstrup 1980, Aalbersberg & Litt 1998, Bos 1998). In the western Poland reconstruction of the minimum July temperatures showed at least 12°C during the Younger Dryas (Walker 1995).

Vegetation changes registered during the second half of the Younger Dryas e.g. increasing AP, appearance of *Filipendula*, drop in heliophytic shrubs and herbs, could be discussed as the possible signs of the climatic amelioration that has also been reported from other sites in Europe and dated back to about 10.5 x10^3-10.4 x10^3 ^{14}C BP (Goslar et al. 1993, Birks et al. 1994, Berglund et al. 1994). Vegetation pattern points to a gradual reforestation of the investigated region. Similar subdivision of the Younger Dryas chronozone into cold first half and warmer and wetter second half have been reported from some other European sites (Goslar et al. 1993, Birks et al. 1994, Pokorny 2002).

The Late-Glacial—Holocene transition is reflected in the proxy records from all regions around the North Atlantic by an abrupt and significant climatic warming. Due to the rising temperature and humidity formation of the forest communities with especially high representation of pine and presence of spruce started at the beginning of the Holocene in investigated region. The presence of *Picea* sp. needles, seeds (Fig. 4) and macrofossils indicates that spruce was growing at about 9.4 x10^3 ^{14}C BP here. The high number of pollen grains also confirms the local presence of this plant because according to Krementski et al. (1999) "spruce is considered to have been presented in the area when its pollen curve is continuous and the percentage is more than 5%". High representation of the *Picea* pollen in layers dated back to Preboreal—Boreal chronozones was also noted in eastern Latvia, Lubana Plain (Seglinš et al. 1999). However, for the biggest part of the Lithuania flourishing of the *Betula* woodland later replaced by *Pinus* was typical for Preboreal—Boreal (Kabailienė 1998, Stančikaitė 2000). In the area under investigation, the local appearance of the *Betula* sect. *Albae* and *Betula pubescens* Ehrh. has been confirmed by the presence of the plant macroremains although pollen grains nearly absent. Increasing density of the vegetation cover is confirmed by the rising pollen concentration, while the low variety of pollen spectra should be stressed. That can be related to the local conditions, such like intensive soil leaching confirmed by the flourishing of the *Urtica dioica* L., widely represented among macroremains. Instability of the environmental conditions including climate is also proved by the appearance of *Selaginella selaginoides* (L.) Link macroremains and spores. Considerable evidence for a cold climatic event dated back to about 8200 cal BP have been collected from whole North Atlantic region (Rosen et al. 2001).

Vegetation pattern of LPAZ 6 correlated with the Atlantic chronozone (8.0-5.0 x10^3 ^{14}C years BP *sensu* Mangerud et al. 1974) differs from frequently registered in Lithuanian territory. Instead of *QM* pine is abundant in palynological record. Over representation of *Pinus* pollen could be related to its strong pollen production and air transportation. Except *Betula*, pollen grains of other trees are sporadically represented and the same is true for herbs. Flourishing of rather dense wood with high representation of pine and small patches of herbs is recorded during Atlantic in discussed area. High representation of *Menyanthes trifoliata* L., typical semiaquatic plant, points to the predominance of the wet habitats that have been determinated by high precipitation established from different data sets in the first half of Atlantic chronozone. Investigated profile gives some indications of early forest clearing possibly related with the human activity. Synchronous appearance of the ruderal taxa, light-demanding shrubs, pioneer trees and increasing representation of microscopic charred particles suggest fire activity and subsequent overgrow of burned plots at about 5900 ^{14}C BP. Pollen grains of *Plantago lanceolata*, *Taraxacum* and *Artemisia* indicate the possible agriculture activity and existence of the fallow land in the surroundings. Simultaneous appearance of the agriculture indicators have been registered in the southeastern Lithuania, Dūba and Pelesa Lakes (Stančikaitė et al. 2002).

From the Subboreal onwards increasing importance of the human activities in the vegetation development should be stressed. Although the onset of this period coincides with the remarkable climatic shifts, human interference has played an important role for the formation of both local and regional vegetation.

Pine remained the dominant tree taxon throughout the Subboreal (5-2.5 thousand ^{14}C years BP *sensu* Mangerud et al. 1974) in the NE Lithuania. At the same time advance of birch and spruce is accompanied by the increasing representation of hazel and alder. Wet habitats or lake sites were overgrowing by *Carex*, *Juncus bufonius* L., *Lychnis flos-cuculi* L. Short-lasting flourishing of light-demanding trees and shrubs coincide with the formation of open plots where herbs, including cultural plants, spread. The earliest remarkable rise of the charred particles curve that coincides with the appearance of ruderals and pronounced expansion of herbs took place at about 5000 ^{14}C years BP or during the Middle Neolithic when numerous archaeological sites of the Neolithic Narva and Globular Amphora Cultures existed in Jara region (Fig. 1, B). The opinion prevails that the Globular Amphora Culture people used to live in small groups and based their economy on half-nomadic husbandry. On the basis of the archaeological data is assumed that the development of stockbreeding and agriculture, the beginning of farming economy in eastern Lithuania likely resulted from the relationship between local groups and members of the Globular Amphora Culture (Daugnora & Girininkas 1998). However the progressive closing of the forest has changed mentioned peak of the human interference.

Successive changes of the vegetation cover has been registered in the sediments dated back to the second half of the Subboreal, 3000–3200 ^{14}C years BP. Appearance of the *Cerealia*, *Polygonum persicaria* L. and *Plantago lanceolata* L. together with the high representation of charcoal dust confirm continuous agriculture practices in surrounding territories during the Late Bronze Age. Numerous stone axes discovered in the surroundings of the Juodonys were attributed to the Bronze Age also. Stone axe – an indicator of the slush-and burn agriculture – were used to cut trees and bushes in the course of clearance for agriculture (Vasks 2003). Intensive disturbances of the vegetation cover caused intensive soil leaching and flourishing of nitrophilous plant, such like *Urtica dioica* L.

The Subatlantic (2.5–0 thousand ^{14}C years BP *sensu* Mangerud et al. 1974) begins with an obvious spruce advance registered all over the territory of Lithuania (Kabailienė 1993) and the same is true for the investigated region. Simultaneously, some retreat of the pine has been registered. Frequency of *Juniperus, Salix* and *Alnus* increase along with NAP taxa. Pollen infers a mixed forest of conifers and birch that gradually becomes more open predominated in the regional vegetation. Open wet habitats predominated around the investigated site were overgrown by different *Carex* and *Ranunculus* species, *Circium palustre* L. and *Lycopus europaeus* L.

There are few phases of most prominent vegetation changes related both to the human interference and climatic variations registered throughout the Subatlantic. Beginning of the period coincides with the cool and wet climatic phase named "Subatlantic Pessimum" which lasted until 300 BC (Hass 1996). At the beginning of pre-Roman Iron Age, at about 2500 ^{14}C years BP, human impact into environment has been registered both in archaeological and palaeobotanical data. Deforestation reflected in the AP/NAP ratio was followed by the increasing number of the charred particles and appearance of *Pteridium*, indicator of the forest fires (Behre 1981, Berglund 1985, Peglar 1993). These changes could be related to development of slash–and–burn cultivation also confirmed by high representation of *Taraxacum* pollen and seeds, Lactucaceae and *Aster*. sect. *Cichor* that suggest the formation of the permanent fields nearby. Predominance of the domestic animal bones in the osteological material (Daugnora & Girininkas 1996) proved the importance of the animal husbandry for the local communities that increased pressure on vegetation even more.

Human inferred vegetation changes culminated during the Roman Iron Age (about 2000–1500 ^{14}C years BP) when above mentioned climatic deterioration has been changed by generally warm climatic period that lasted until 400 AD and often called Roman Climate Optimum (Hass 1996). Prospering of the Juodonys Hillfort was dated back to the 378 BC–5AD when the most prominent vegetation disturbances occurred. Gradual lowering of the *Picea* curve coincides with the increasing frequencies of the pioneer (*Betula* and *Alnus*) and light-demanding (*Populus* and *Acer*) trees suggesting the extensive opening of the vegetation. Numerous charred particles discovered in the sediments could refer to the use of fire for the land clearing. Culmination of the *Cerealia* curve and appearance of the *Centaurea* pollen as well as the fruits of *Fallopia convolvulus* (L.) A.Love suggests the existence of the permanent agriculture fields. Agriculture has become much more efficient after the rise of local black metallurgy. Therefore during the second half of the Roman Iron Age (200–450 AD) forest expansion into open areas started and some drop in the human activity occurred. According to the archaeological data this regression was the result of extensive dispersion of earlier concentrated intensive activity.

Gradual lowering of the human interference approaching the end of the Roman Iron Age has prolonged during the first half of the Middle Iron Age or during Migration Period (400/450–600 AD), time of increasing moisture and decreasing temperatures (Hass 1996). Expansion of the trees including spruce and pine confirms the development of the tree-covered areas. Despite the continuous appearance of the *Cerealia* and presence of the weeds, including those typical for the permanent fields (*Fallopia convolvulus* (L.) A. Love, *Chenopodium album* L. and *Cerastium* cf. *arvense* L.) the degree of the human induced vegetation changes declined. In the neighboring countries regression of the human inferred vegetation disturbances was also registered at about A.D. 500 (Engelmark & Wallin 1985, Veski 1998) that coincides with the mentioned climatic deterioration.

The second period of the most prominent human activity in Juodonys was dated back to the beginning of the Late Iron Age (about 1000 ^{14}C years BP) and can be roughly correlated with the Medieval Warm Period (approximately 1080–1350 AD), the mildest period since the Holocene climatic optimum (Hass 1996). Simultaneously the second expansion of the human activity in Juodonys started. Progressive opening of the woodlands has been accompanied by the sharp increase in ruderal representation, rising frequency of the cereals (*Secalia cerealia*) and weeds (*Polygonum persicaria* L., *Centaurea cyanus* L. and *Polygonum lapathifolium* L.). An iron hoe and sickle – indicators of farming activity – were found among numerous adornments and outwork tools within Juodonys foot settlement collection. The domestic animals: pig (41.1%), cattle (22.1%), sheep/goat (11.6%), horse (7.2%), and dog (1.5%) bones composed 83.5% of total amount of all identified bones in Juodonys foot settlement. Among wild animals the bones of elk were in the majority (49.1%), beaver (16.2%), wild boar (14.5%), aurochs (9.8%), and bear (8.1%) (1958–1959 data from foot settlement were analyzed by K. Paaver). Development of new technology (e.g. the appearance of broad blade axes, perfection of sickles) determined the rising farming efficiency (Kuncevičius & Luchtanas 1997). Both palaeobotanical and archaeological data reflects an open, strongly cultivated landscape with arable fields and meadows in between the mixed forest existed.

The youngest phase of the vegetation history corresponds with the gradual lowering of the human activity signs and some expansion of the woodlands. Due to the lack of detailed time model the chronological description of this period is rather complicated but according the linear interpolation of the available dates it coincides with the climatic deterioration phase called "Little Ice Age" which started at about 1200/1300 AD and recorded from various data sets (Karlen 1976, Kullman 1995, Rosen et al. 2001). Abandoned fields were overgrown by various herbs and colonized by birch later. Flourishing of the pine in the upper pollen samples is related with the more modern forest management.

CONCLUSIONS

Palaeobotanical survey has provided the vegetation history since the Allerød onwards. Flourishing of the birch/pine wood later replaced by the pine/birch forest was recorded at the beginning of the core formation. Appearance and expansion of the cold tolerant plants coincides with the Younger Dryas cooling. Early Holocene immigration of *Picea* to the region (about 9400 ^{14}C BP) has been confirmed by palynological and plant macroremain data. The earliest traces of the human initiated vegetation changes pointing to the development of local forest openings and possible animal husbandry occurred during the Early-Middle Neolithic (about 5900 ^{14}C BP). Continuous increasing pressure on vegetation including formation of arable plots and pastures started since the Late Bronze Age (3200 ^{14}C BP) and increased considerably during the Roman Iron Age (378 BC-AD 5) when, according to archaeological data, cultural activity culminated in region. The second peak of the human initiated vegetation disturbances coincides with the first half of the Late Iron Age or Middle Ages (AD 965–1054).

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