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12 MILLENNIA OF CLIMATIC AND HUMAN INDUCED VEGETATION CHANGES IN THE LOWER SAN VALLEY NEAR JAROSŁAW (SE POLAND) IN THE LIGHT OF POLLEN ANALYSIS

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Abstract

Vegetation changes in the Lower San Valley near Jarosław are reconstructed from the Younger Dryas to the present time on the basis of palynological analysis of the peat core. The pollen profile came from a an old riverbed and was supplemented by radiocarbon datings. The Younger Dryas and early Preboreal vegetation was characterised by a high proportion of forest communities with pine (*Pinus sylvestris* and *P. cembra*) and birch (*Betula*), while patches of open area were dominated by the steppe with *Artemisia*. Climatic amelioration during the Preboreal chronozone led to the rapid spread of elm (*Ulmus*), which was probably a dominant taxon on the lowest terraces of the valley. Terrestrialization of the water body existing in the palaeomeaner and the subsequent beginning of peat accumulation caused a deterioration in pollen preservation. Hence, the interpretation of the profile section spanning the period between the Boreal and Subatlantic chronozones was seriously disturbed due to selective corrosion and the overrepresentation of *Pinus sylvestris* type and Filicales monolete sporomorphs. Between *ca.* 336 and 1152 AD fluctuations in woodland cover were recorded. Important components in those forests, despite the domination of *Pinus sylvestris*, were *Quercus*, *Carpinus betulus*, *Fagus sylvatica* and *Abies alba*. The first pollen grains of cereals (Cerealia type) were found before *ca.* 1605–1414 BC and may be attributed to the agricultural activity of the Neolithic and/or early Bronze tribes. Periods of strong deforestation caused by humans were probably related to the time when the Tarnobrzeska Group of the Lusatian Culture and the Przeworska Culture were active. The first groups of Slavs did not significantly influence the environment, but the subsequent development of those groups led to more visible deforestation, which was triggered after the establishment of Jarosław in the 11th century AD.

Key words: Sandomierz Basin, pollen analysis, vegetation history, Late Glacial, Holocene, human impact, *Ulmus*

INTRODUCTION

The area of the eastern part of the Sandomierz Basin is one of the most important routes of taxa dispersion after the Late Glacial in Poland and so it has been attractive for palynological studies since 1930's. The first studies were carried out by Trela (1934) who analysed two profiles from Grodzisko and Wola Zarczycka. However, the first complete study of vegetation history based on pollen analysis in the Sandomierz Basin was made by Mamakowa (1962). In that paper most profiles came from the eastern part of the region and only the Podbukowina site was located in the San valley, but outside the Sandomierz Basin. Further research was conducted in the palaeomeander in Stubno located south-east of Jarosław. Unfortunately, only its bottom part was studied and at a very low sample resolution (comp. Klimek *et al.* 1997). Other investigated pollen profiles from the Lower San Valley are located north-west of Jarosław, of which Kopki reflects the Late Holocene succession (Bałaga, Taras 2001) and two other profiles, which were collected from Wisłok palaeomeanders in Grodzisko Dolne (Nowe) (Gębica *et al.* 2008) and Grodzisko Nowe (Kołaczek 2010a), reach Late Glacial sediments (Figs 1, 2). Yet another palynological sites which are located outside the Lower San Valley, but relatively close to Jarosław (less than 50 km), come from the Mleczka valley (Klimek *et al.* 2006), Markowa (Mamakowa, Wójcik 1999) and Krasne (Kołaczek 2007).

The main aim of this research is a reconstruction of the vegetation development of the Lower San Valley in the vicinity of Jarosław during the Late Glacial and the Holocene based on pollen analysis supported by radiocarbon dating. The part of results presented in this paper was substantial part of a PhD thesis (Kołaczek 2010b).

Geographical and botanical characteristics of the studied area

The Lower San Valley is a broad erosive rill between the San valley near Przemyśl and its junction with the Wisła near Sandomierz (Kondracki 2002). According to Wojtanowicz (1978) the bottom of the San valley is made of a three-step system of terraces. The highest level, at a height of 10–15 m above the riverbed level, is represented by a terrace built by sands. The second terrace, at a height of 5–10 m above the riverbed, originated during the Holocene. There is also a flood terrace 2–4 m above the riverbed, which is relatively thin and covered by alluvial sands.

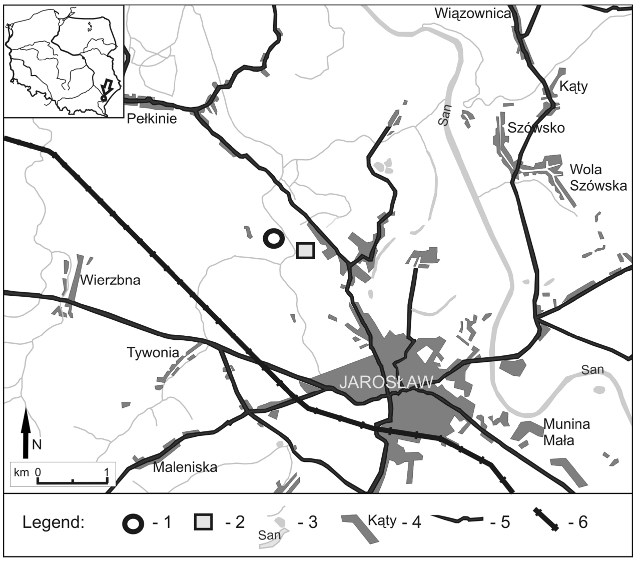

Fig. 1. Map of the Jarosław-Kruchel site location. *1* – place of the profile collection, *2* – location of the archaeological site, *3* – rivers and streams, *4* – villages and towns, *5* – roads, *6* – railways.

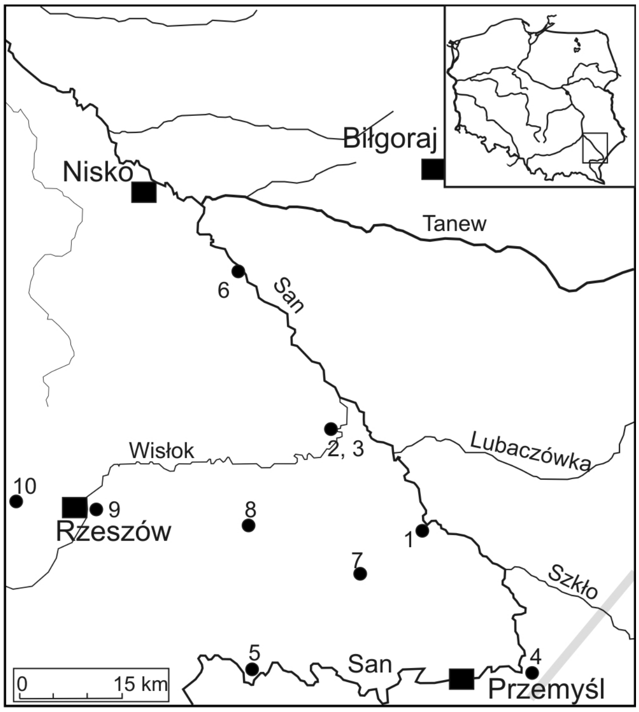

Fig. 2. Map of palynological sites in the eastern part of the Sandomierz Basin cited in the text. 1 – Jarosław-Kruchel (presented in this paper), 2 – Grodzisko Nowe, 3 – Grodzisko Dolne (Nowe), 4 – Stubno, 5 – Podbukowina, 6 – Kopki, 7 – Mleczka, 8 – Markowa, 9 – Krasne, 10 – Świlcza.

Various types of sandy soils *e.g.* podzolic, brown podzolic and acid brown podzolic cover the higher Holocene terrace of the San valley (Kursa *et al.* 1988). Pseudosolic soils and brown soils developed on loamy light sands; peaty and organic rich soils are restricted only to small areas (Bałaga, Taras 2001).

The climate of the Sandomierz Basin was classified by Romer (1949) to the category of piedmont climates of lowlands and basins, and the area of Jarosław is located in more continental zone (Okołowicz 1973–1978). For the period 1996–2000 AD the mean annual temperature for the site was 8°C (17.5°C – mean July temperature, –3°C – mean January temperature), and the mean annual rainfall ranged from 700 to 800 mm (Lorenc ed. 2005).

The distribution of forest communities in the Sandomierz Basin area is mainly determined by the terraced morphology of the valleys. Fragments of beech-fir and mixed forests *e.g. Fagetum carpaticum*, *Querco-Carpinetum*, *Pino-Quercetum* and *Carici elongatae-Alnetum glutinosae* in damp depressions and near streams survived on the highest levels of the geomorphological units. The Pleistocene terrace is occupied by *Vaccinio myrtilli-Pinetum* forests, *Pino-Quercetum* forests and various meadow and mire plant communities. The Holocene terraces are periodically flooded so that meadows and willow thickets are the main communities in this area (Szafer 1972).

Settlement history

The main source of information about the past settlement in the vicinity of the palaeomeander is the archaeological site discovered in 2008 near the Kruchel Pełkiński Street in Jarosław. This site records findings from the Neolithic epoch until the Modern Period (Bobak, Pelisiak unpubl.). The first information about human activity in the Jarosław environs goes back to the times of settlement of the Malicka Culture which lasted until 3600 BC and which was a part of the Lengeyel-Polgar Cultural Cycle. Findings of this culture were represented by 22 structures, mainly small hollows and postholes. The economy of these people was dominated by agriculture in the valleys supplemented by animal breeding (Czopek 2003).

The Bronze Age at this site is revealed by distinct traces of the people of the Mierzanowicka Culture. These artifacts are the most numerous among the whole archaeological collection. The younger period of this epoch is represented by occurrences dating back to the time of the development of the Tarnobrzeska Group of the Lusatian Culture. What is more, 10 objects related to the Scythians were found. This is probably an effect of contacts and cultural exchange between the indigenous tribes and the Scythians who occupied south-eastern Europe (Bobak, Pelisiak unpubl.).

In the youngest phase of the period of the Tarnobrzeska Group of the Lusatian Culture (5th–4th century BC) an abrupt settlement crisis took place and lasted until 1st–2nd century AD (Czopek 1998).

The Roman Period brought an economic and demographic revival, which is reflected in numerous occurrences of the Przeworska Culture at the archaeological site (Bobak, Pelisiak unpubl.). A very broad spectrum of data about settlement during this period was provided by surveys of the archaeological site at the Saint Nicholas Hill (Wzgórze Świętego Mikołaja). The collection of artifacts contains pottery, fragments of a glass goblet, a fibula and a Trajan denar minted in 1st century AD (Kieferling 1999). The decline in the Przeworska Culture in south-eastern Poland was abrupt and occurred after strong economic and settlement development (Godłowski 1985).

In the time before the reign of the Piast dynasty the area of Jarosław was occupied by the Lendians tribe and this area was under the control of the rulers from Bohemia, Poland and Russia. In 1031, according to tradition, Yaroslav I The Wise – the Grand Prince of Novgorod and Kiev established fortified settlement there (http://www.jaroslaw.pl/historia-miasta). Contemporary settlement had been developing on St Nicholas Hill, but in 1375 it was transferred into a town on a neighbouring hill (Kieferling 1999). The first information about municipal status granted to the town come from 1323 (the period of Russian rule). The full and well-documented establishment of the town under the Magdeburgian law was granted by prince Władysław Opolczyk in 1375. The town of Jarosław was located on the crossroads of trade routes from Silesia to the Rus' and from Gdańsk (Danzig) to Hungary and at the beginning of the 15th century it was a significant trade and craft centre. The greatest prosperity of the town between the 16th an 17th century was connected with the fairs which were the most splendid in the whole of Poland (http://www.jaroslaw.pl/historia-miasta). Nowadays, Jarosław is a local government centre and covers an area of 34.46 km^2 within the Podkarpackie voivodship.

MATERIAL AND METHODS

Collecting of the profile from Jarosław-Kruchel was done in 1998 by A. Wójcik using an Instrorf (Russian type) sampler during preparations of the 'Detailed Geological Map of Poland 1:50000, Jarosław sheet' (Malata, Wójcik 1998). The place where the profile was collected was at an altitude of 183 m a.s.l. (50°02'25"N, 22°39'03"E), within a palaeomeander of the San. The remains of the core, after sampling at intervals of 5 cm, were destroyed and the author received material only as 1 cm^3 samples from Prof. K. Szczepanek.

59 samples (1 cm^3 each) were selected and prepared with standard preparation procedure and then acetolysis was applied (Berglund, Ralska-Jasiewiczowa 1986). To every sample a weighed *Lycopodium* tablet was added for further calculations of pollen concentration (Stockmarr 1971). More than 500 arboreal pollen grains (occasionally 200 in samples with low pollen concentrations) per sample were counted at 400× and 1000× magnification.

The pollen taxa were determined with the assistance of the modern pollen slide collection of the Władysław Szafer Institute of Botany, Polish Academy of Science, and special keys and atlases (Beug 2004, Reille 1992, Moore *et al.* 1991, Punt 1975). The taxa were identified to the lowest possible level and the nomenclature used follows the mentioned keys and manuals. The percentage values of individual taxa were calculated in the ratio to AP+NAP excluding Poaceae undiff., telmatophyte (with Cyperaceae) and limnophyte pollen, as well as the spores of cryptogams. Poaceae undiff. were excluded from the total pollen sum because of their high numbers in the Preboreal chronozone and the problem with distinguishing *Phragmites australis* type from this group. The percentages of excluded taxa were calculated in the ratio to AP+NAP+taxon. During the pollen analysis every graminaceous grain which had a diameter >37 µm and a minimum diameter annulus of 8 µm was taken, according to Beug's (2004) suggestion, to be pollen of Cerealia type. The high proportions of Poaceae undiff. grains with a diameter of between 21 and 26 µm, which were detected especially in the Preboreal section of the profile, caused problems with their classification as *Phragmites australis* type. Despite discrepancies with the diagnosis of this type (compare Faegri, Iversen 1989, Beug 2004), a maximal grain diameter of 23 µm was accepted for grains of *Phragmites australis* type. Pollen diagrams were plotted using POLPAL software (Nalepka, Walanus 2003).

RESULTS

Lithology of the profile

The analyzed core has been described by A. Wójcik (Fig. 3a, b). Unfortunately, small amount of material obtained by the author were insufficient for more detailed description.
0–100 cm strongly decomposed peat, black
100–160 cm decomposed peat, dark brown
160–170 cm lacustrine marl
170–180 cm strongly decomposed peat, dark brown
180–190 cm gyttja with an admixture of peat
190–225 cm decomposed peat with numerous findings of molluscs
225–235 cm decomposed peat, brown
235–240 cm decomposed peat with admixture of silt
240–295 cm decomposed peat, brown
295–310 cm decomposed peat, brown, lighter with molluscs' shells
310–360 cm decomposed peat, brown
360–370 cm strongly decomposed peat, dark brown, black
375–400 cm strongly decomposed peat, black
400–430 cm decomposed peat, brown (wood fragments?)
430–438 cm strongly decomposed peat, dark brown
438–450 cm decomposed peat, light brown
450–495 cm strongly decomposed peat, brown and black with marble structure
495–500 cm decomposed peat, brown, strongly compressed
500–510 cm strongly decomposed peat, black
510–603 cm calcareous gyttja with numerous findings of molluscs
603–621 cm calcareous silt
621–626 cm silt, dark
626–627 cm sand.

Radiocarbon dating

Radiocarbon dates were obtained in the Poznań Radiocarbon Laboratory and were calibrated using the OxCal program v 4.1 (Bronk Ramsey 2009) according to the calibration curve IntCal 09 (Reimer *et al.* 2009). The results are presented in Table 1.

Radiocarbon dates Poz-26439 and Poz-27937 were clearly not representative, so they were excluded from the profile interpretation. It is likely that unidentified plant remains which were chosen for the Poz-26439 dating which had seemed to be the stems of the herbaceous plants were in fact fragments of roots. A fragment of bark selected for the Poz-27937 dating was probably rebedded by the river during a flood or by erosion processes from the higher elevation of the neighbouring loess foothills.

Table 1

Radiocarbon dates from the Jarosław-Kruchel profile

Lab. No	Depth (cm)	Material	Age (^{14}C BP)	Calibrated age 95.4% probability
Poz-26441	45	Unidentified fragment of leaf (monocotyledons)	1005±30	977AD (76.4%) 1050AD 1082AD (14.5%) 1125AD 1136AD (4.5%) 1152AD
Poz-30514	215	Unidentified fragment of leaf (monocotyledons)	1640±30	336AD (77.7%) 471AD 476AD (17.7%) 534AD
Poz-26440	265	Unidentified fragment of leaf (monocotyledons)	3215±35	1605BC (4.3%) 1576BC 1536BC (91.1%) 1414BC
Poz-26439	530	Unidentified plant remains	3135±35	1496BC (83.9%) 1370BC 1356BC (11.5%) 1316BC
Poz-27937	540	Fragment of bark	11860±100	11976BC (95.4%) 11492BC

The other radiocarbon dates which are cited in the paper were also calibrated in accordance with the above-mentioned method.

Palynological analysis

The pollen diagram (Fig. 3a, b) was divided into local pollen assemblage zones (L PAZ) according to Birks (1979, 1986) and Janczyk-Kopikowa (1987). The chronology of the profile was established on the basis of radiocarbon dating and correlation with radiocarbon dated profiles from the Lower San Valley and the neighbouring area (Kołaczek 2007, 2010, Gębica *et al.* 2008, Klimek *et al.* 2006, Bałaga, Taras 2001). The diagram was also divided into the chronozones proposed by Mangerud *et al.* (1974). The results are presented in Table 2.

DISCUSSION

Vegetation history in the vicinity of Jarosław and palaeomeander development

Younger Dryas chronozone (~10700–9550 BC)

JK-1a. *Pinus-Betula* (*Artemisia*). The area of the valley was overgrown by *Pinus-Betula* forests and/or steppe-forests. Important elements in these were *Pinus cembra* and *Larix* – a taxon, according to Jankovská (1995), strongly indicative of its *in situ* occurrence. In open areas there were also patches of steppe vegetation where the dominant *Artemisia* coexisted with *Plantago major* and *P. media*, and members of the Chenopodiaceae family, *Anthemis* type and *Helianthemum oelandicum* type. The second important kind of open communities were *Juniperus* thickets. Patches of tundra with *Betula nana*, as well as *Salix* thickets may have occurred in more humid sites and in the surroundings of the oxbow lake. The littoral zone of the water body was dominated by *Myriophyllum verticillatum* together with members of *Potamogeton* subgen. *Eupotamogeton*, and Lemnaceae, while *Hydrocharis morsus-ranae* covered the water table.

Preboreal chronozone (~9550–8250 BC)

JK-1b. *Pinus-Betula* (*Pinus cembra*). Climatic and edaphic amelioration connected with the beginning of the Preboreal caused the spread of woodlands in which *Pinus cembra* maintained its occurrence which is a unique phenomenon in the area of the San valley (see Kołaczek 2010, Klimek *et al.* 1997). On the contrary *Larix* probably disappeared there. *Populus*, *Picea abies* and *Alnus* may have occurred as additional elements on the lower terrace of the valley. Light demanding communities with *Artemisia*, Chenopodiaceae, *Pleurospermum austriacum* and *Juniperus* visibly retreated. The wetter open habitats were covered by communities with *Filipendula* and *Thalictrum*. The depth of the oxbow lake decreased, which enabled *Hippuris vulgaris* to expand.

JK-2. *Betula-Ulmus*. Birch and elm probably spread over the previously open areas. The latter most likely occupied the lowest levels of the valley where it may have been a dominant element and a substantial component of woodlands in the upper terraces of the valley as well. On the other hand, *Populus* might have played an important role in these communities and its low percentage curve may confirm the more numerous occurrence of this rather poorly represented taxon in the pollen spectra (Filbrant-Czaja *et al.* 2004). Characteristic components of that riparian forest were *Humulus lupulus* and *Urtica*. The presence of *Lilium martagon*, a taxon nowadays indicative of the *Fagetalia silvaticeae* order (meso- and eutrophic deciduous forests of middle and Eastern Europe) suggests that woods with *Ulmus* may have been a primary habitat of this lily after the Late Glacial in Central Europe. According to Matuszkiewicz (2005) the *Alno- Ulmion* alliance – containing riparian forests with *Ulmus minor* – is the only one belonging to *Fagetalia sylvaticeae* where elm is an important component of forests. Fragments of steppe vegetation with *Artemisia*, Chenopodiaceae and *Pleurospermum austriacum* were still present, as well as taxa associated with tundra *e.g. Betula nana* and *Dryas octopetala*. Light-demanding thickets with a relic population of *Hippophaë rhamnoides* together with *Rhamnus catharticus* occupied the sun-exposed slopes of the valley. *Nympahaea alba* and *Nuphar luteum* probably displaced *Myriophyllum verticillatum* and limited the occurrence of members of *Potamogeton* subgen. *Eupotamogeton* in the water body. A decrease in the water table level enabled *Phragmites australis* to expand on the surface of the basin.

Table 2

Jarosław-Kruchel. Description of local pollen assemblage zones (L PAZ)

L PAZ. Depth	Description of pollen spectra	Top boundary description
JK-5. *Pinus*-NAP. 75-1 cm	Stable values of *Pinus sylvestris* type, decrease in *Fagus sylvatica*, *Abies alba*, *Alnus* undiff. and *Ulmus*. The strongest increase in NAP; Cerealia type (5%), *Secale cereale* (4%), Brassicaceae undiff. (11%), Cichorioideae (6.5%), Chenopodiaceae (1.9%), *Centaurea cyanus* (2%) have the highest percentages in diagram among them; appearance of *Fagopyrum esculentum* type. Low percentage curves of *Anthoceros* and *Phaeoceros*; increase in *Sphagnum*; drop in Filicales monolete. *Potamogeton* subgen. *Eupotamogeton* are more frequent. Maximum values of *Pediastrum duplex* var. *rugulosum* (1.7%) and *Botryococcus* undiff. (4.3%). Corroded sporomorphs: 16-45.5%.	
JK-4. *Pinus-Quercus-Alnus*. 320-75 cm	Fluctuation in high values of *Pinus sylvestris* type and *Quercus*; the highest values of *Alnus* undiff.	Beginning of stable rise in NAP
JK-4f. *Fagus*. 95-75 cm.	Increase in *Fagus sylvatica* (max. 9.5%) and *Pinus sylvestris* type; fall in *Betula* undiff., *Quercus* and *Carpinus betulus*. Rise in Cyperaceae undiff., decrease in Poaceae undiff., continuous low-percentage curve of Cerealia type. Drop in *Phragmites australis* type *Pediastrum* undiff, *Pediastrum integrum* (max. 3.2%), *Pediastrum duplex* var. *rugulosum* and *Botryococcus* undiff. occur.	
JK-4e. *Quercus* 125-95 cm	Sharp rise in *Quercus* (28.5%); maximum frequency of *Abies alba* (4.5%); increase in *Betula* undiff., *Carpinus betulus* and *Fagus sylvatica*; decrease in *Pinus sylvestris* type. Decrease in Cyperaceae undiff., *Artemisia*, Cerealia type, Cichorioideae, *Cirsium*/*Carduus*, *Thalictrum* and *Filipendula*; rise in Poaceae undiff., *Rumex acetosa* type, Brassicaceae and *Caltha*. Rise in *Phragmites australis* type. Fall in corroded sporomorphs: 19-23.5%.	
JK-4d. *Pinus*. 155-125 cm	Rise in *Pinus sylvestris* type; drop in *Carpinus betulus*, *Fagus sylvatica*, *Quercus*, *Corylus avellana* and *Fraxinus excelsior*. Decrease in Cyperaceae undiff., increase in Poaceae undiff., maximum values of *Cirsium*/*Carduus* and *Thalictrum*; continuous curve of Cerealia type, higher percentages of Cichorioidae, slight increase in *Artemisia*; decrease in *Rumex acetosa* type and *Plantago lanceolata*. Regular curves of Filicales monolete and *Pteridium aquilinum*, disappearance of *Equisetum*. Single cenobia of *Pediastrum* undiff. and *Pediastrum duplex* var. *rugulosum*. Corroded sporomorphs: 32.5-49.5%.	
JK-4c. *Carpinus-Fagus*. 195-155 cm	Distinct increase in *Carpinus betulus* (max. 19%), first peak of *Fagus sylvatica*, maximum values of *Alnus* undiff. (11%); continuous curve of *Abies alba*. Decrease in *Urtica*, maximum frequency of *Rumex acetosa* type (2%) and *Plantago lanceolata* (1.5%); Cerealia type in most of spectra. Decline in *Typha latifolia* and cf. *Cyperus*. Continuous curve of *Equisetum* (max. 6.5%, in the lower part). Single *Botryococcus* undiff. Corroded sporomorphs: 12-40.5%.	
JK-4b. *Picea*. 265-195 cm	Increase and decrease in *Pinus sylvestris* type; rise in *Picea abies* (max. 6%), the highest values of *Tilia cordata* type (3.2%), *Carpinus betulus*, *Fagus sylvatica* and *Salix* undiff.; decrease in *Corylus avellana*, *Quercus* and *Ulmus*; stable occurrence of *Acer* in the upper part of the subzone. Rise in *Urtica* and *Aster* type (max. 10%); Cerealia type, *Rumex acetosa* type and *Plantago lanceolata* form continuous curves. Among telmatophytes cf. *Cyperus* dominates (0-17%), maximum values and continous curve of *Typha latifolia* (2%), disappearance of *Alisma* type; regular curve of *Potamogeton* subgen. *Eupotamogeton*, the highest values of *Lemna* type (1.3%) in the upper part of the subzone. Decline in Filicales monolete and *Pteridium aquilinum.* Singular *Pediastrum boryanum* var. l*ongicorne* and *Botryococcus* cf. *neglectus* in the bottom part. Corroded sporomorphs: 24.5-42.5%.	
JK-4a. *Corylus*. 320-265 cm.	Decline in *Pinus sylvestris* type; rise in *Quercus* (up to 25%), *Corylus avellana*, *Alnus* undiff., *Fraxinus excelsior* and *Picea abies*; appearance of *Fagus sylvatica* and *Carpinus betulus*. High frequency of Cyperaceae undiff., fall in Asteroideae undiff., slight increase in *Artemisia*. Appearance of *Alisma* type (max. 1.6%), *Potamogeton* subgen. *Eupotamogeton* almost in each spectrum. Decrease in Filicales monolete, regular curve and maximum frequency of *Pteridium aquilinum* (5.5%). Fall in values of corroded sporomorphes.	
JK-3. *Pinus*. 507.5-320 cm	Domination of *Pinus sylvestris* type and Filicales monolete	Rise in *Quercus*
JK-3c. Asteroidae. 380-320 cm	Decline in *Corylus avellana* and *Betula* undiff (min. 2%). Maximum and fluctuation in Asteroidae undiff. frequency (17.5%), fall in Poaceae undiff, fluctuation in Cyperaceae undiff. High percentages of Filicales monolete; regular curve of *Pteridium aquilinum* (1.5-4%). Maximum values of corroded sporomorphs (62.5%).	
JK-3b. *Corylus*. 455-380 cm	Fluctuation of *Pinus sylvestris* type; increase in *Corylus avellana* (5.5-11.5%), *Quercus* and *Alnus* undiff.; maximum of *Fraxinus excelsior* in the upper part (9.5%); Cyperaceae undiff. rise in the upper part to its maximal values (48.5%); fluctuation in Poaceae undiff. curve. In the lower part of the subzone high percentage peaks of *Menyanthes trifoliata* (max. 5%) values coincided with occurrence of *Utricularia*. Fluctuation and maximum of Filicales monolete (74%), disappearance of *Thelypteris palustris* curve in the upper part of subzone; singular spores of *Pteridium aquilinum*.	
JK-3a. Poaceae 507.5-455 cm	Maximum values of *Pinus sylvestris* type (76%); sharp fall in *Betula* undiff., *Ulmus* and *Populus*, increase in *Picea abies*, *Corylus avellana* and *Quercus*. After maximum decrease in Poaceae undiff. percentages (max. 52.5%); rise in Cyperaceae undiff. and *Galium* type. Decrease in *Phragmites australis* type; singular grains of limno- and telmatophytes. Sharp rise in Filicales monolete and *Thelypteris palustris* (max. 55.5%) percentages, declining trend of the latter. Corroded sporomorphs are visibly more frequented.	

Table 2 continued

L PAZ. Depth	Description of pollen spectra	Top boundary description
JK-2. *Betula-Ulmus*. 590-507.5 cm	Gradual increase in *Ulmus* to its maximum (22%); after maximum values of *Betula* undiff. (52%) decrease in percentages; stable occurrence of *Populus* (max. 2%); singular findings of *Betula na*na type. The lowest percentages of Cyperaceae undiff. (min. 1.5%), high values of Poaceae; maximum values of *Humulus*/*Cannabis* (0.7%), decrease in *Urtica* and *Filipendula*..Among telmato- and limnophytes domination of *Phragmites australis* type (max. 37.5%); appearance of *Nuphar* (max. 3%), gradual increase in *Nymphaea alba* (max. 5%); disapearance of *Hippuris vulgaris* and *Myriophyllum vericillatum*, decline in *Potamogeton* subgen. *Eupotamogeton.* Stable curves of *Thelypteris palustris* and Filicales monolete, maximum frequency of *Dryopteris filix-mas* (1.2%).	Sharp decrease in *Betula* undiff. and *Ulmus*, rise in *Pinus sylvestris* type
JK-1. *Pinus-Betula*. 635-590 cm	Domination of *Pinus sylvestris* type (35-55.5%), *Betula* undiff.(24.5-35.5%), high percentages of *Pinus cembra* type. Among limnophytes *Myriophyllum verticillatum* dominates.	Sharp decrease in *Pinus cembra* type
JK-1b. *Pinus cembra*. 612.5-590 cm	Stable values of *Pinus cembra* type; decrease in *Juniperus* and *Larix*; slight increase in *Populus*, *Ulmus* and *Picea abies*; High percentages of Poaceae undiff.; rise in *Urtica* and *Filipendula* (max. 3%); fall in *Artemisia*; regular occurrence of *Pleurospermum austriacum*. Visible increase in *Phragmites australis* type; maximum values of *Hippuris vulgaris* (11 %); increase in *Typha latifolia*; After peak of curve fall in *Myriophyllum verticillatum*, decrease in *Potamogeton* subgen. *Eupotamogeton*.	
JK-1a. *Artemisia*. 635-612.5 cm	The highest values of *Pinus cembra* type (7.5%), *Larix* (1.85%) and *Juniperus* (1.6%) in profile; stable decrease in *Salix* undiff.; regular but not numerous grains of *Betula nana* type; Maximum values of *Artemisia* (12.5%) and Apiaceae undiff. (7.5%). Visible increase in Poaceae undiff.; regular values of Chenopodiaceae, *Plantago major* and *P. media*. After maximum, sharp decrease in *Myriophyllum verticillatum* (down from 22.5%), maximum values of *Potamogeton* subgen. *Eupotamogeton* (5.7%); *Ranunculus trichophyllus* and *Lemna* type in most of spectra. Singular spores of Filicales monolete.	

Boreal chronozone (~8250–6950 BP)

JK-3a. *Pinus* (Poaceae). Rapidly expanding pine, which displaced birch and elm from most of their sites, probably built homogeneous communities which dominated in the landscape, similarly to the site from Grodzisko Nowe (Kołaczek 2010). Spruce was an important component of remains of forests located in wetter places, where it coexisted with elm. The percentage values of *Picea abies* are compatible with isopollen maps for the older part of Boreal chronozone (Obidowicz *et al.* 2004). A rapid decrease in the frequency of water correlated with the expansion of *Thelypteris palustris*, as well as Poaceae undiff. suggests terrestrialization of the water body. A rapid decrease in elm might have also been an effect of deterioration of pollen preservation on the JK-2/JK-3a boundary, so a rise in pine could have been caused by easier identification of its corroded sporomorphs in comparison with other taxa.

JK-3b. *Pinus* (*Corylus*). Hazel (*Corylus avellana*) spread in the understorey of pine forests in which oak (*Quercus*) was more frequent. Ash (*Fraxinus excelsior*) became more common in riparian forests existing on the lowest terrace. Moreover, its pollen frequency exceeds visibly patterns presented in the isopollen maps (comp. Tobolski, Nalepka 2004). On the surface of the fen, *Menyanthes trifoliata* together with Polypodiaceae (Filicales monolete) occurred during the older part of the subzone. A decrease in the frequency of *Thelypteris palustris* spores may have been caused by the corrosion of perispores. Simultaneously, the curve of Filicales monolete reaches very high levels. Small eutrophic water body (or bodies) was overgrown by *Utricularia*, *Potamogeton* subgen. *Eupotamogeton* and *Nymphaea alba* in this part of the subzone.

Atlantic chronozone (~6950–3750 BC)

JK-3c. *Pinus* (Asteroideae). The highest frequency of corroded sporomorphs, the strong decomposition of peat and the lack of water taxa pollen suggest a fluctuation in the water table level, or even the disappearance of water body(ies). Bracken (*Pteridium aquilinum*) expanded probably on the desiccated parts of the mire. Members of Asteroideae were an important component of the herbal flora overgrowing the fen surface. High values of *Pinus sylvestris* type may be the effect of the domination of this taxon in woodlands as well as an effect of strong and selective sporomorphs' corrosion, which favours grains of *Pinus sylvestris* type. Although pollen grains of this taxon are rather weakly resistant to compaction (Campbell 1999), they are easy to identify even when badly destroyed (personal observ.). Similar situation was observed in profiles from Krasne (Kołaczek 2007) and Grodzisko Nowe (Kołaczek 2010). The fact of strong corrosion of pollen material prevents from a reliable reconstruction of vegetation history in this part of the profile.

Subboreal chronozone between ~3750 and ~1500 BC

JK-4a. *Pinus-Quercus-Alnus* (*Corylus*). Oak visibly expanded into the pine forests, while on the lowest terraces alder became the more frequent taxon. A new element of the woodlands were probably hornbeam (*Carpinus betulus*) and beech (*Fagus sylvatica*). An increase in the water table level led to the revival of small water body(ies) occupied by members of *Potamogeton* subgen. *Eupotamogeton*.

Younger Subboreal and the older part of Subatlantic chronozone (~1500 BC–400 AD)

JK-4b. *Pinus-Quercus-Alnus* (*Picea*). Simultaneously to the increase in the distribution of spruce (*Picea abies*), hornbeam and fir (*Abies alba*) became more common in woodlands. The spread of spruce in forest communities caused a decrease in the availability of light in the understorey of the forests and a retreat of *Corylus avellana* (comp. Miotk-Szpiganowicz *et al.* 2004). During this subzone visible forest clearings caused by human activity were recorded. Arable fields with pastures and/or mown meadows were a more common element of the landscape. These processes led to stronger nitrification and the development of communities with *Urtica*. Improvement of water conditions on the fen caused the enlargement of water body(ies) and the subsequent spread of *Potamogeton* and members of the Lemnaceae family. Cyperaceae (from the *Cyperus* genus) and *Typha latifolia* became more numerous in belts of rushes.

Subatlantic chronozone between ~400 and ~1050 AD

JK-4c. *Pinus-Quercus-Alnus* (*Carpinus-Fagus*). Hornbeam (*Carpinus betulus*) expanded rapidly and probably colonized fallow lands. The same habitats might have enabled beech (*Fagus sylvatica*) to spread. Although open areas were reduced, arable fields, pastures and mown meadows were present in the landscape of this part of the San valley. An increase in the water level and its fluctuation are visible in the conversion of peat into a mix of lacustrine chalk, peat and gyttja, yet this is correlated with the disappearance of communities from the Potametalia class. Only single findings of Lemnaceae and *Botryococcus* undiff. indicate the existence of a water body, so it suggests a rather strongly eutrophic or dystrophic character of the pool (Jankovská, Komárek 2000) and/or insufficient conditions for the preservation of the water taxa pollen. Telmatic members of *Equisetum* were an important component of vegetation surrounding this water basin.

JK-4d. *Pinus-Quercus-Alnus* (*Pinus*). A fall in the level of the water table caused a deterioration of sporomorphs preservation. Moreover, this phenomenon was simultaneous with anthropogenically-induced deforestation, which was less serious in the areas covered by alder carrs and riparian forests. Dryer conditions on the fen enabled the spread of taxa related to wet meadows *e.g. Cirsium/Carduus*, *Thalictrum*, *Valeriana officinalis* type and *Filipendula*. Temporal fluctuations in the water level are visible in the presence of the cenobia of *Pediastrum* undiff. and *Pediastrum duplex* var. *rugulosum*.

JK-4e. *Pinus-Quercus-Alnus* (*Quercus*). During this subzone, a revival of woodlands in which oak (*Quercus*) played an important role, took place and it probably replaced pine from some communities. Its percentage values significantly exceed those presented in the isopollen maps for this period (Milecka *et al.* 2004). Abandoned arable fields were probably colonized by birch and hornbeam. Fir (*Abies alba*) together with beech might have formed fragments of forests on the highest terrace of the valley and the neighbouring summits of the Rzeszów Foothills. The mire was characterised by rather dry conditions confirmed by the lack of water taxa and/or algae specimens. This probably contributed to the spread of *Phragmites australis* on the fen surface.

JK-4f. *Pinus-Quercus-Alnus* (*Fagus*). Gradual deforestation considerably affected forests dominated by oak. Moreover, the simultaneous extension of beech distribution may confirm the selective cutting down of *Quercus* specimens. Seasonal fluctuations in water table depth and/or the existence of temporal water bodies are confirmed by the presence of single grains of *Lemna* type and *Utricularia* as well as members of the *Pediastrum* and *Botryococcus* genera.

Younger part of Subatlantic chronozone (younger than ~1050 AD)

JK-5. *Pinus*-NAP. An increase in anthropogenic activity triggered the strongest deforestation recorded over the whole Holocene which affected every type of woodlands in the neighbouring area. Arable fields, pastures and mown meadows were the most widespread component in the landscape. The water bodies recovered and were colonized by members of the *Eupotamogeton* subgenus among which *Nymphaea alba* and *Nuphar* (and maybe *N. pumila*) grew periodically. The eutrophic conditions of these reservoirs enabled the occurrence of algae *e.g. Pediastrum duplex* var. *rugulosum* and *Botryococcus* (Jankovská, Komárek 2000).

Analysis of settlement phases during the Holocene in the vicinity of Jarosław in a regional context

The first gramineous pollen grain with dimensions of Cerealia type was detected at a depth of 620 cm in the Preboreal chronozone (Fig. 3b). It probably came from one of the wild grass genera *e.g. Glyceria*, whose members occur in humid or wet habitats and produce this kind of pollen (Beug 2004).

In Phase A (265–340 cm, AT/SB transition, Fig. 4) the first single grains of Cerealia type, which were probably the effect of human activity, were detected. An increase in the number of bracken (*Pteridium aquilinum*) spores simultaneous with a slight increase in charcoal concentration may suggest the occurrence of local fires. Soil acidification after fires favours germination of these spores, so that young plants appear in great numbers on soils fertilized by ash (Oberdorfer 1990, Page 1986). The occurrence of *Artemisia*, *Trifolium repens* type and *Rumex acetosa* type may confirm the existence of patches of deforested area. These processes were probably connected with human activity from the Neolithic and/or Early Bronze cultures of which the oldest traces found at the archaeological site came from the Malicka Culture (Neolithic) (Bobak, Pelisiak unpubl.). However, the most numerous findings came from the Mierzanowicka Culture (Early Bronze). Unfortunately, the pollen material in this section of the profile is highly corroded, so that there may possibly be several discontinuities. Palynological traces of the probable agricultural activity of Neolithic tribes were detected in Krasne but the few radiocarbon datings in this profile prevented a more detailed correlation with specific cultures (Kołaczek 2007).

Phase B (265–245 cm) shows more visible deforestation revealed in the expansion of open ground herbs. The cultivation of cereals seems to have been more extended, and ruderal communities with *Polygonum aviculare* and *Urtica*, which could also exist in riparian forests, were more common than in the previous phase. A slight increase in *Rumex acetosa* type and *Plantago lanceolata* might point to the extension of areas exploited as mown meadows and/or grazing areas (comp. Makohonienko *et al.* 1998). In this phase the first rise in *Carpinus betulus* and *Fagus sylvatica* could have been connected with anthropogenic disturbances to forest communities (comp. Latałowa *et al.* 2004, Ralska-Jasiewiczowa, Van Geel 1998). Those processes may be affected by the activity of the Tarnobrzeska Group of The Lusatian

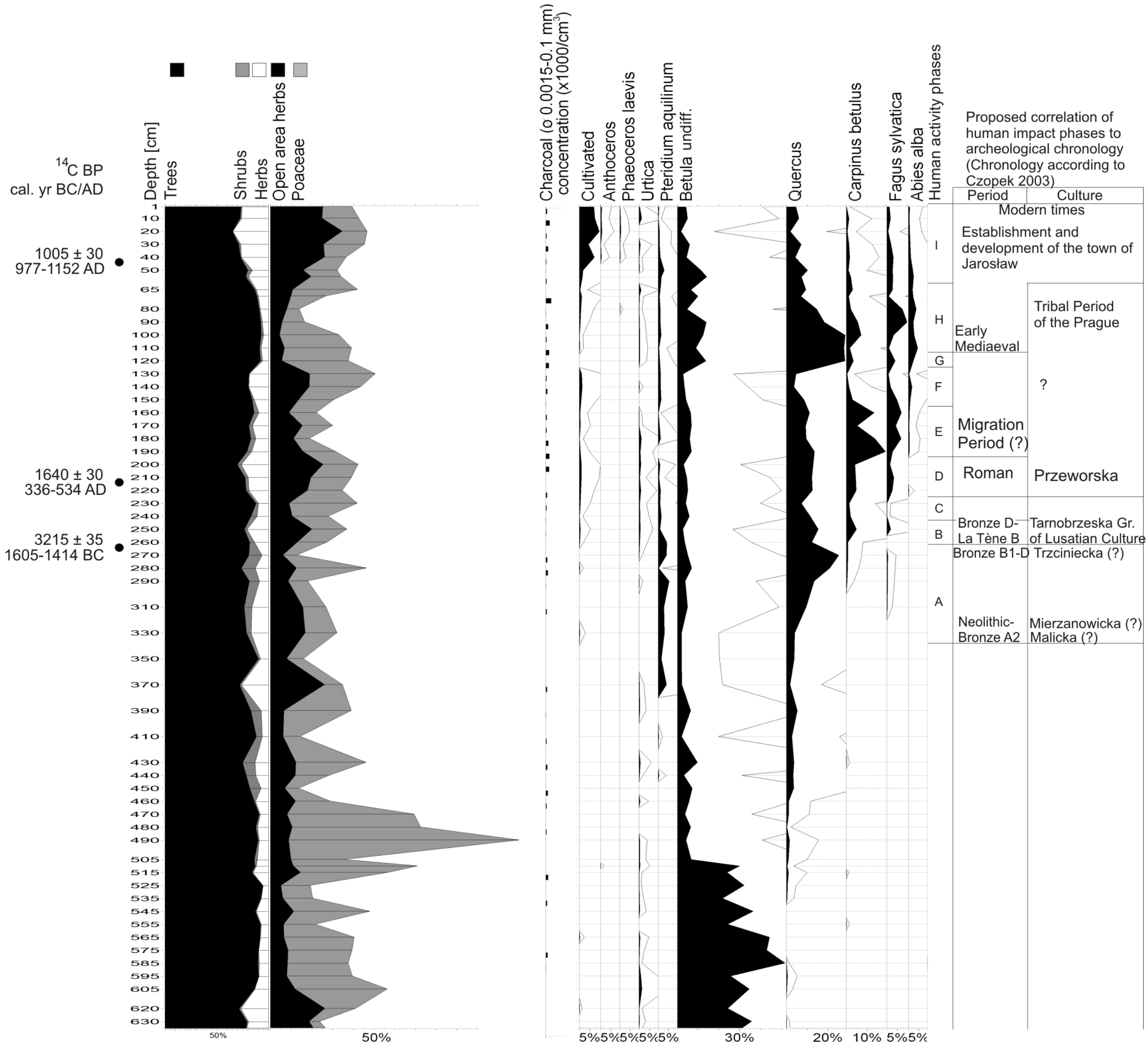

Fig. 4. Summary diagram of human impact from the Jarosław-Kruchel site.

Culture. The period of these people's settlement in the Grodzisko Nowe (Kołaczek 2010) as well as in the Kopki (Bałaga, Taras 2001) profile was characterized by higher values of hornbeam, especially a distinct peak (>15%) which is recorded in the profile from Kopki.

Phase C (245–225 cm) reflects the recovery of woodland cover. However, the taxonomical composition of open area herbs similar to Phase B as well as occurrences of Cerealia type pollen confirms human activity. Moreover, *Pinus sylvestris* type is the only arboreal taxon that increased in this period and this is correlated with a rise in the frequency of corroded sporomorphs, so this may suggest selective corrosion as the main factor in the composition of the pollen spectra in this section of the profile. Phase C is probably related to the period of the domination of the Tarnobrzeska Group of the Lusatian Culture and/or the beginning of the settlement discontinuity between this group and the Przeworska Culture (comp. Czopek 2003). The second of these time intervals was characterised by a decline in the number of weeds and ruderals together with the lack of cereal pollen in the Kopki profile (comp. Bałaga, Taras 2001).

Radiocarbon dating indicates that the deforestation reflected in the Phase D (235–195 cm) was a result of the activity of Przeworska Culture. During this phase agriculture visibly developed and was more extended than in Phase B. Broader parts of the area of the valley were probably exploited as mown meadows and pasturelands (an increase in *Plantago lanceolata*, *Trifolium pratense* and *T. repens* types and *Centaurea jacea* type). This period was also recorded in the Kopki site where the deforestation level was probably like the one in the Jarosław-Kruchel site, but the occurrence of cereal grains was much lower (comp. Bałaga, Taras 2001).

In Phase E (195–155 cm) woodland recovery was detected, in which *Carpinus betulus* with *Fagus sylvatica* played a very important role. Despite the weakening of human activity, arable fields, pasturelands and mown meadows still existed in the contemporary landscape. In this period maxima of the frequency of *Plantago lanceolata* and *Rumex acetosa* type were detected. The occurrence of the former is nowadays connected with ploughed meadows, arable fields and fallow lands (Makohonienko *et al.* 1998), which seems to confirm the hypothesis that *Plantago lanceolata* is an indicator of early agriculture (Groenman-van Waateringe 1986, Latałowa 1992). This species preference for mown meadows stems from the fact that this plant is able to produce seeds before its inflorescences are cut off, whereas grazing and/or early mowing prevent this species from flowering (Court-Picon *et al.* 2006, Hjelle 1999, Gaillard *et al.* 1992).

Phase F (155–125 cm) points to an economic revival demonstrated in the development of agriculture in the area previously occupied by mixed forest with *Quercus*, *Fagus sylvatica* and *Carpinus betulus*. The newly cultivated cereal was *Secale cereale*. The increase in Cichorioideae values was probably the effect of greater exploitation of the San valley for mown meadows and pastures.

Phase G (125–115 cm) reflects an economic collapse which brought a decline in the cultivation of cereals and the strongest forest recovery since the beginning of the first agricultural activities. The time interval which spans Phases E, F and G corresponds to the Migration Period (comp. Czopek 2003), but in contrast to the Kopki profile it is not reflected in any decrease in NAP values correlated to the lack of agricultural indicators (comp. Bałaga, Taras 2001). In the vicinity of the Jarosław-Kruchel site an area abandoned by one of the groups from the Przeworska Culture was probably subsequently colonized by other groups retreating from different areas. However, there are no clear archaeological traces to support this hypothesis (S. Czopek personal comm.).

Despite the high percentages of arboreal taxa, in Phase H (125–60 cm), the pollen spectra suggest the existence of cereal cultivation. A rapid decrease in Poaceae with a high and rather stable level of arboreal pollen point to the initial transformation of grasslands into cultivated fields (instead of claiming the area for agriculture by deforestation). These changes may be ascribed to the first Slavs' activity who appeared in the area of the Sandomierz Basin in small groups (Czopek, Podgórska-Czopek 2007) and at the beginning they occupied open areas which had not been overgrown by expanding forest communities.

Phase I (60–1 cm) reflects vegetation changes caused by the gradual development of the Jarosław town from medieval times up to now. Human-induced forest retreat as well as the development of the cultivation of cereals is the strongest one over the whole profile. This is also confirmed by the regular occurrence of *Centaurea cyanus* as well as *Anthoceros* and *Phaeoceros* – hornworths, which are contemporarily recorded on ploughed stubble fields in autumn (Rejment-Grochowska 1966). A new component in cultivation was buckwheat (*Fagopyrum esculentum*). The highest values of Brassicaceae undiff. in the profile could have been caused by the dispersion of weed species from this family and/or the appearance of rapeseed (*Brassica napus*) cultivation. A maximum of Cichorioideae and high values of *Plantago lanceolata* simultaneous with a decrease in *Alnus* suggests exploitation of the lowest terraces of the valley as mown meadows (comp. Makohonienko *et al.* 1998).

Early Holocene expansion of elm (*Ulmus*) in the eastern part of the Sandomierz Basin

One of the most characteristic features of the pollen profile from Jarosław is the very high frequency of *Ulmus* pollen, which exceeds 20% (after the exclusion of Poaceae undiff. pollen) in the Preboreal chronozone (JK-2 zone), which is significantly inconsistent with patterns presented in the isopollen maps (Zachowicz *et al.* 2004). Unfortunately, radiocarbon datings from the JK-2 zone showed discrepant results and were excluded from the interpretation. Additionally, high percentages of *Betula* undiff. and the simultaneous lack of *Corylus avellana*, *Tilia cordata* type and other pollen taxa related to the Boreal and Atlantic chronozones claim against the existence of sediment discontinuity between the Younger Dryas and the Holocene Climatic Optimum. The percentage values of lime and hazel are similar to the patterns presented in the isopollen maps for 9500±100 ^{14}C BP (9216–8575 BC) (Kupryjanowicz *et al.* 2004, Miotk-Szpiganowicz *et al.* 2004). The composition of pollen spectra in the JK-2 zone is almost identical to the *Pinus-Betula-Ulmus* zone from the Mleczka valley profile, where elm reached its first maximum (up to about 15%) in the Preboreal chronozone (Fig. 5, comp. Klimek *et al.* 2006). Radiocarbon datings obtained from this zone showed 9250±100 ^{14}C BP (8728–8284 BC) and 9290±100 ^{14}C BP (8772–8292 BC). The expansion of *Corylus avellana* in the Mleczka valley took place not earlier than 8350±250 ^{14}C BP (8170–6658 BC). The high percentage values of elm in the Preboreal period were also detected in the profile from the palaeomeander in Stubno (near Przemyśl) and the age of the beginning of its expansion was approximated to 9840±140 ^{14}C BP (9862–8826 BC) (Klimek *et al.* 1997). Unfortunately, in this profile palynological analysis was carried out as a survey, and no radiocarbon dating has been done. The age was approximated by a comparison based on the lithology of this core with a well-dated core collected from the very close vicinity (personal observation based on Klimek *et al.* 1997).

Two other profiles from the San valley were collected from the Podbukowina peat bog, located south of the Sandomierz Basin. Both of them seem to have established the Younger Dryas/Preboreal boundary incorrectly, because the Preboreal maxima of *Ulmus* were ascribed by the author to the Boreal chronozone (Mamakowa 1962) (Fig. 6). The beginnings of the expansion of elm in many pollen profiles in the Sandomierz Basin are strongly correlated with the decline in *Artemisia* (Fig. 7), which is related to the end of the Younger Dryas (Kołaczek 2010). In the Podbukowina 2 profile the occurrence of high percentages of elm is simultaneous with high values of *Betula*, which is similar to the Mleczka profile. The same situation was recorded in the Markowa S profile (25 km west of Jarosław, outside the San valley), where high percentages of *Ulmus* (exceeding 20%) were ascribed to the Preboreal/Boreal chronozone (Fig. 6) (Mamakowa, Wójcik 1999).

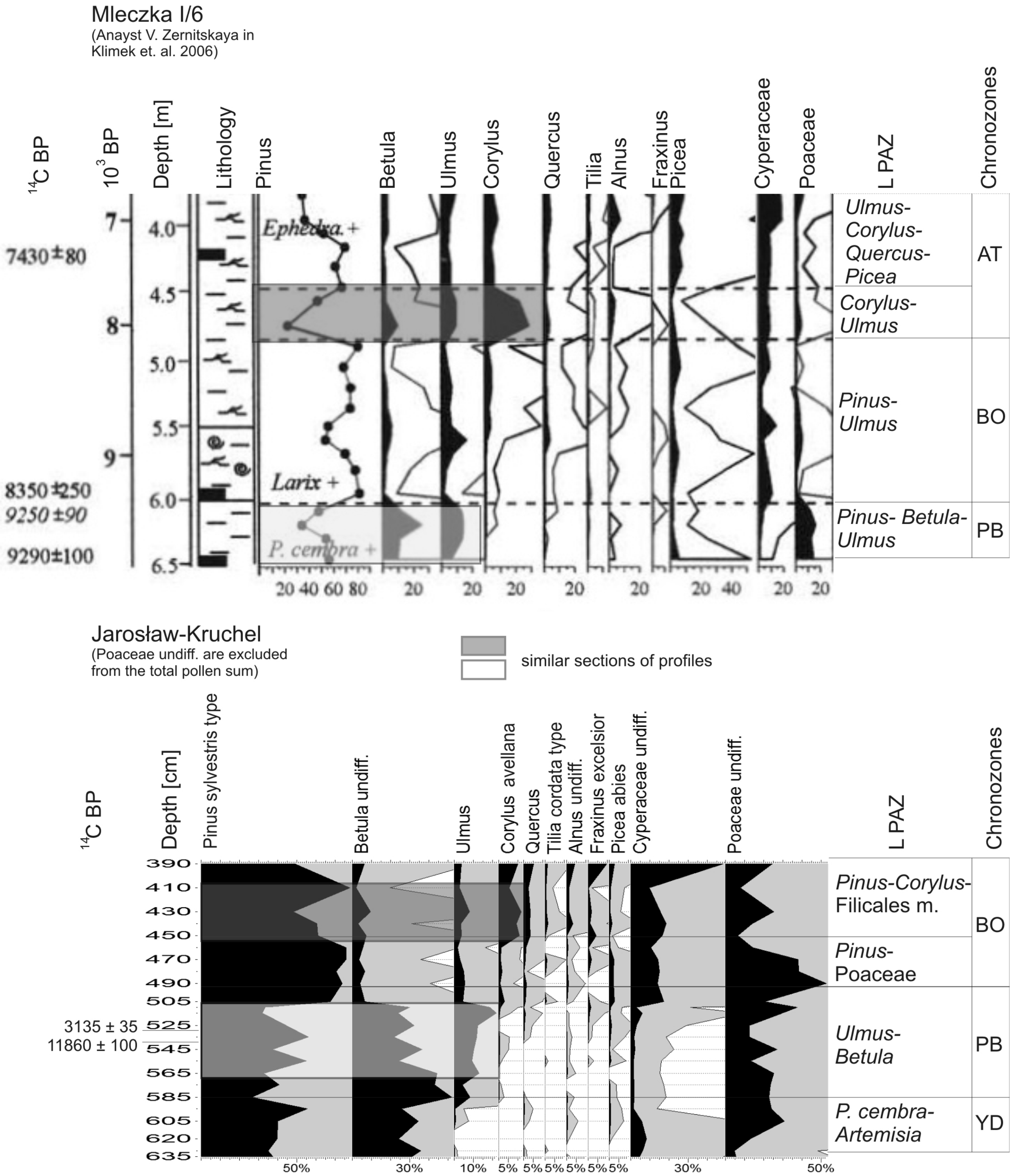

Fig. 5. Similarities between the Younger Dryas–Boreal section of the Jarosław-Kruchel profile and the Preboreal-Atlantic section of the Mleczka I/6 profile (based on Klimek *et al*. 2006, figure slightly changed).

A different pattern during the Preboreal chronozone is observed in the Grodzisko Nowe profile (located north-west of Jarosław). Pine rapidly displaced birch from most of its sites in the early Preboreal chronozone and prevented elm from spreading in that area. However, in this profile *Ulmus* recorded a small distinctive peak on the percentage curve (about 2%) in the Preboreal chronozone (Kołaczek 2010). The probable reason for the wrong identification of the Younger Dryas sections in the above-mentioned profiles carried out by Mamakowa (1962) was a contemporary opinion which treated elm as a main indicator of the Holocene Climatic Optimum, or even of the Atlanic period (comp. Dyakowska 1959). This opinion may be logically explained by the fact that elm does not have the features of a pioneer taxon

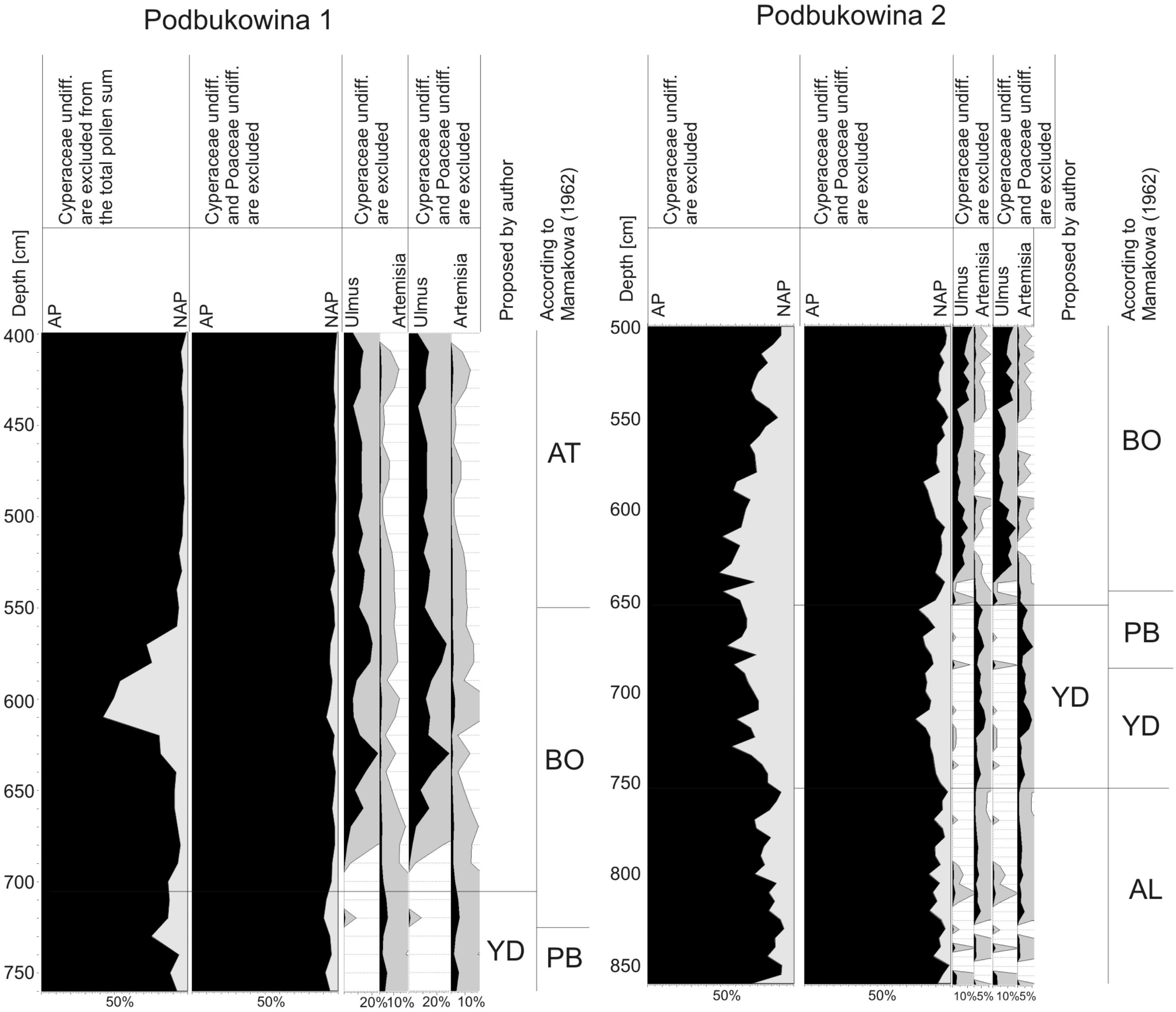

Fig. 6. Percentage values of AP, NAP, *Ulmus* and *Artemisia* from the Podbukowina 1 and 2 profiles, redrawn with the exclusion of Cyperaceae and both Cyperaceae and Poaceae from the total pollen sum.

(comp. Zachowicz *et al.* 2004), but the relative proximity of the San valley to its probable glacial refugium in the southern part of the Carpathian Mts. (Feurdean *et al.* 2007, Björkman *et al.* 2003) may have been a deciding factor in such rapid expansion.

CONCLUSIONS

The pollen profile from Jarosław presents vegetation changes from the Younger Dryas up to the modern period. The succession of the Late Glacial and beginning of the Holocene is characterized by the high proportion of birch-pine forests and/or steppe-forests with a visible addition of *Pinus cembra* in forest communities. During the Preboreal chronozone a rapid expansion of *Betula* and *Ulmus* took place; especially the values of the latter taxon significantly exceed those in patterns of regional vegetation for the eastern part of the Sandomierz Basin. This phenomenon was also recorded in a few sites from the San valley, but in some profiles it was attributed to the Boreal chrononozone. Terrestrialization of the oxbow lake took place in the Boreal chronozone and together with a change of deposits into peat pollen preservation rapidly deteriorated. This fact probably caused more numerous identifications of the pollen of *Pinus sylvestris* and Filicales monolete spores, which are the dominant taxa in the most corroded section of the profile. So then, there is no basis for the exact reconstruction of vegetation in those parts of the profile. Fluctuations in woodland cover were typical of the Subatlantic period, in which *Quercus*, *Carpinus betulus*, *Fagus sylvatica* and *Abies alba* occurred more frequently. Especially the expansion of the oak was distinct during the period 1800–600 yr cal. BP.

The first traces of human activity recorded in the pollen diagram date back to the age before *ca.* 1605–1414 BC and may point to the occupation of this area by tribes of Neolithic and/or Early Bronze cultures. From this period traces of the Malicka, Mierzanowicka and Trzciniecka Culture were found on the adjacent archaeological site. Other intensifica-

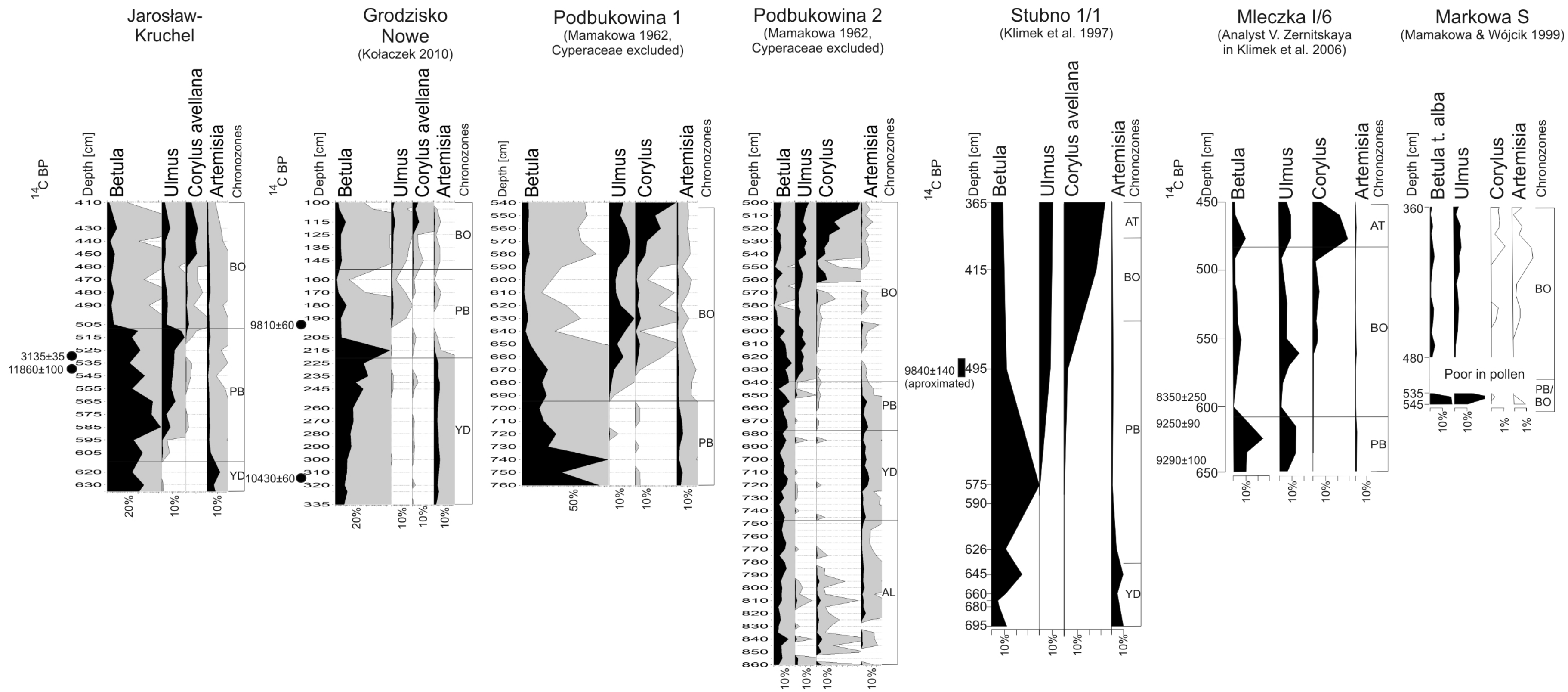

Fig. 7. Changes of the percentage values of *Betula*, *Ulmus*, *Corylus avellana* and *Artemisia* from the Younger Dryas to Boreal and/or Atlantic chronozones in the profiles from the San valley and its western surroundings.

tion of human activity was probably connected with the presence of the Tarnobrzeska Group of the Lusatian Culture and the Przeworska Culture. Palynological evidence shows two maxima of human impact on the environment around the Migration Period; the first one is connected with the activity of the Przeworska Culture, the second one after the recovery of woodland areas was probably caused by temporal settlement by a group(s) which immigrated there during the Migration Period. The appearance of first Slavs in the area of Jarosław did not have a significant influence on the environment. Relatively small groups of newcomers probably settled on previously occupied areas which were not overgrown by forests. An increase in the population of these groups led to the necessity of deforestation to claim new areas for cultivation. The establishment of the Jarosław town in the 11th century AD and its subsequent development caused the most significant deforestation in the whole period studied.

The low resolution of radiocarbon datings prevented the author from establishing a detailed chronology of the profile and from providing exact correlation between phases of human activity and the archaeological chronology. This fact made it also impossible to detect all sediment discontinuities which are likely to be present in the fragments with the strongest decomposition of peat material.

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