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Composition of Atlantic forest in northern Carpathian foothills, from a charcoal record from a Neolithic domestic site at Żerków (Poland): The relevance of oak and hazel

MAGDALENA MOSKAL-DEL HOYO

W. Szafer Institute of Botany, Polish Academy of Sciences, Lubicz 46, 31-512 Kraków, Poland;
e-mail: m.moskal@botany.pl

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ABSTRACT. A study of firewood remains from the foothills of the Western Carpathians in Poland yielded information about the history of forest communities growing in the vicinity of human settlements in the Atlantic period. The anthracological material was collected at Żerków, a Neolithic site of the Linear Band Pottery culture, situated on the highest parts of a hill covered by fertile soil. The anthracological assemblage was dominated by *Quercus* and *Corylus avellana*, followed by *Acer* and Maloideae, suggesting that those taxa probably were significant constituents of the local forest during the Atlantic period. Based on the ecological requirements of the identified taxa, such communities occupied areas of more open canopy, but it is unclear whether the material reflects the composition of the primeval forest or rather the presence of open canopy created by human impacts on local ecosystems during the period of settlement.

KEYWORDS: Atlantic woody flora, oak-hazel-dominated forest, anthracology, Neolithic, Carpathian foothills, Poland

INTRODUCTION

Palynological analyses have enabled researchers to reconstruct past vegetation cover and to better understand the history of plants in Poland (e.g. Ralska-Jasiewiczowa & Latałowa 1996, Ralska-Jasiewiczowa et al. eds. 2004), but some regions of the country still await comprehensive palaeobotanical study due to the lack of pollen evidence. In these regions, plant remains found at archaeological sites are especially important sources of information about past vegetation. The Wiśnicz foothills (Pogórze Wiśnickie), part of the Western Carpathian foothills (Starkel 1988), are such a region. Recent archaeological excavations in the central part of the Dunajec River valley in southern Poland (Kienlin et al. 2011, Valde-Nowak 2014) have opened an opportunity for the first systematic archaeobotanical studies in this area (Lityńska-Zając et al. 2014, Moskal-del Hoyo et al. 2015). However, the majority of the sites date to the Bronze Age; the only site that produced archaeobotanical material dating to the Early Neolithic was site 106-63/65 at Żerków in Gnojnik municipality. This material contained mostly charcoal remains, which offer palaeoethnographic information on the different uses of wood; potentially it also holds palaeoenvironmental information, but only if the charcoal assemblage originated from domestic fuel and represents long-term deposition. This kind of assemblage, derived from dispersed charcoal, is characterised by high diversity of taxa, since wood collection then depended on its availability in the ancient woodlands as well as its ease of gathering. From that material an image of the local woodlands can be obtained, and changes in the forest composition can be observed on a micro-regional scale (e.g. Chabal 1988, 1997, Ntinou 2002, Asouti & Austin 2005, Théry-Parisot et al. 2010).

The investigated region is hilly terrain, with average elevation of 350–550 m a.s.l. (Starkel 1988, Kondracki 2002). The climate is moderately warm, with average annual temperature of 6–8°C. Temperature varies with the topography, differing between the hills and the valleys (Obrębska-Starklowa & Leśniak 1988). The archaeological site is at the top of a hill covered with fertile loess. The good edaphic conditions have made this area attractive to human groups since the beginning of agriculture in Poland (Kienlin & Valde-Nowak 2008). Currently, field camps are located in the area of settlement. The natural vegetation is oak-hornbeam forest (*Tilio-Carpinetum stachyetosum*, *Tilio-Carpinetum typicum*), and in humid habitat willow-poplar forest (*Salice-Populetum*) with alder carrs (*Circaeo-Alnetum*, *Carici remotae-Fraxinetum*, *Carici elongate-Alnetum*). Beechwoods (*Dentario glandulosae-Fagetum*), fir and spruce forest (*Abieti-Piceeteum*), and mixed oak-pine forest (*Pino-Quercetum*) appear occasionally (Towpasz 1988). In terms of potential natural vegetation, oak-hornbeam forest communities (*Tilio-Carpinetum*) and acid oak forests (*Luzulo luzuloidis-Quercetum*) are the most characteristic ones for this region (Matuszkiewicz 2008). The forest communities in the Atlantic period most likely were different, since the establishment of the communities dominant nowadays probably was completed at ca 2500 BP (Ralska-Jasiewiczowa et al. 2004). The characteristic species of present-day oak-hornbeam forests and beechwoods, such as hornbeam *Carpinus betulus*, beech *Fagus sylvatica*, and fir *Abies alba*, are late-arriving trees in Poland, which began to be more widespread in the Subboreal period (Ralska-Jasiewiczowa et al. 2004). In view of this, the anthracological materials collected from that archaeological site, dated to the period preceding the Subboreal phase, may offer an insight into the composition of the forest before that time.

The archaeological site at Żerków is located at 348 m a.s.l, ca 10 km from the Dunajec River (Fig. 1). Judging from the potential flow paths of a digital terrain model, the distance to the nearest stream in the period of the first farming activity was ca 300 m (Cappenberg

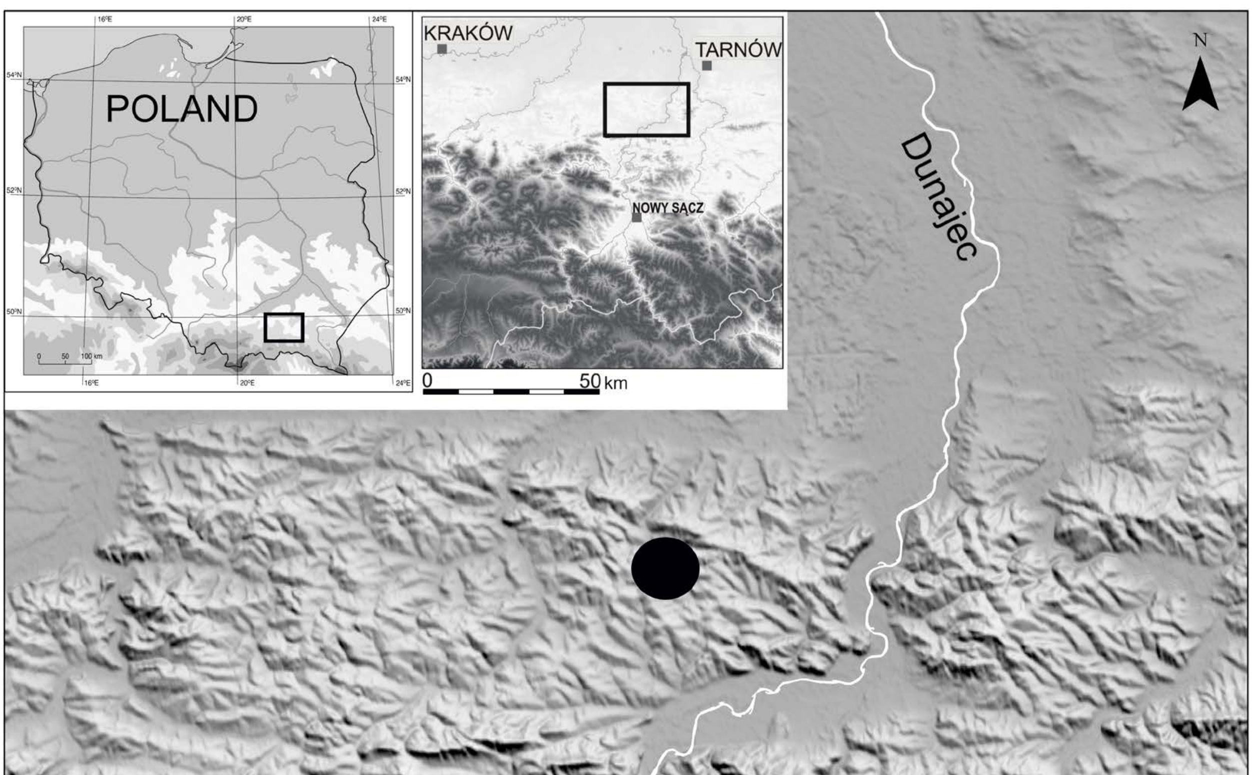

Fig. 1. Location of the Żerków archaeological site in the Carpathian foothills. Prepared by K. Cappenberg. Map of Poland by M. Wysocki & J. Wieser

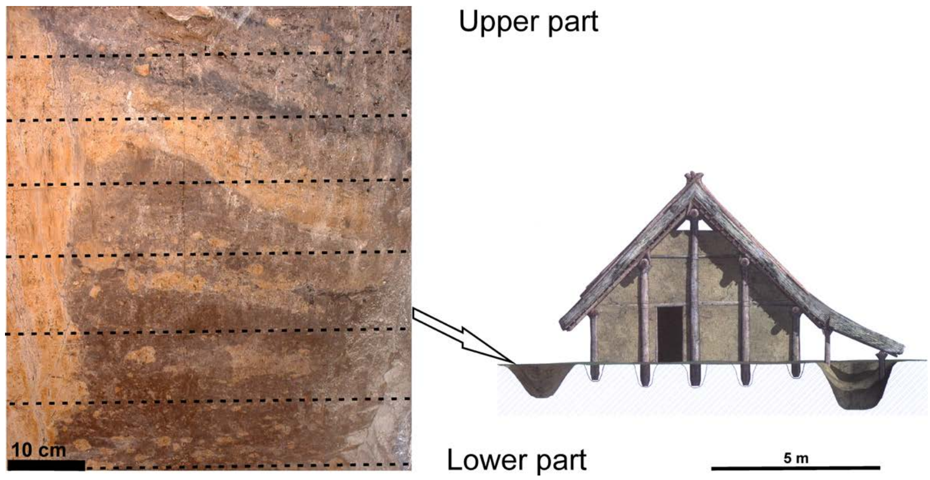

Fig. 2. Profile of pit 17A. Photo by M. Moskal-del Hoyo. Central building according to Czekaj-Zastawny 2008

2014). The archaeological site can be dated to the Linear Band Pottery culture (*Linearband-keramik*, LBK), the first Neolithic culture in Poland (Kaczanowski & Kozłowski 1998). This site was discovered in 1994 and later excavated by Prof. P. Valde-Nowak of the Jagiellonian University in Kraków (Poland). During two archaeological field projects in 2006 and 2007, 23 pits belonging to a typical long house were discovered. Eight of them are larger pits situated along the house, which in the case of LBK settlements are usually described as clay extraction pits. The majority of the layers found in these pits are interpreted as refuse areas, since remains of charcoal, lithic objects and pottery were the main material detected. The bottom of these pits did not contain any archaeological material, but some dispersed charcoal fragments were found. The rest of the features correspond to post-holes. In the settlement, the youngest phase of LBK culture (Želiezowce) was the main phase detected, confirmed by radiocarbon dating (6210 ± 40 BP, Poz-18662; 5160 cal. BC) (Valde-Nowak 2008, 2014). This site was perhaps connected to another LBK settlement found at Łoniowa (site 106-63/80). This centre of occupation gave new evidence of Neolithic routes along the Dunajec and Poprad rivers. The location on the top of the hill is unique in the LBK culture, since the majority of such settlements have been found in lowland near rivers. Such an unusual site may have been selected because the climate in the foothills was better on the hills than in the valleys (Valde-Nowak 2014). The Neolithic occupation of this site corresponds to the Atlantic period in the European Holocene Blytt-Sernander subdivision (Roberts 1998) and the Polish chrono-climatostratigraphy (Starkel et al. 2013).

MATERIALS AND METHODS

Soil samples were systematically collected at the Żerków archaeological site in 2007. Following the established procedure for collecting charcoal from large pits associated with a former house, frequently described as clay pits (2A, 2B and 17A), samples were taken from artificial layers 10 cm thick, from different areas and depths of the archaeological features. Samples containing ca 10 litres of sediment were taken from each layer. Often the artificial layers did not correspond to the natural layers of the filling (Fig. 2). In total, ca 290 litres of sediment were processed by flotation (mesh: 0.2 mm, 1.0 mm). Some concentrations of charcoal were recovered manually, mainly from post-holes (Moskal 2010).

The anatomical structure of wood is preserved in charcoal, enabling identification. Each charcoal fragment, as an observation unit, was manually broken along three anatomical sections: transverse (Pl. 1, fig. 1), longitudinal tangential (Pl. 1, fig. 2), and longitudinal radial (Pl. 1, figs 3, 4). The fragments were observed using reflected light microscopy. Fragments were identified by comparing them with anatomical atlases (Schweingruber 1982, 1990) and with the modern reference collection at the University of Valencia in Spain. A Hitachi S-4100 scanning electron microscope was employed for more detailed study of the fragments and to prepare micrographs of the prehistoric wood. Most taxa were determined to genus, and to species if only one taxon exists in the present-day vegetation of the region (Lityńska-Zając & Wasylikowa 2005). The level of identification also depends on fragment size, the anatomical structure of the wood, and the state of preservation of charcoal fragments (Schweingruber 1982, Chabal et al. 1999). The charcoal fragments from Żerków generally were badly preserved, showing incrustation by clayey sediment particles and also vitrification (e.g. Pl. 1, figs 8, 9). Because of this, a larger group of charcoal fragments was classified to major taxonomic groups such as the broadleaved flora group (Tab. 1, 2).

Table 1. Absolute and relative frequency of charcoal fragments found in post-holes in Żerków

Żerków: post-holes	Post-holes											
Features	3		8		13		24		29		30	
Taxa	N	%	N	%	N	%	N	%	N	%	N	%
Corylus avellana							1	4.8			2	18.2
Pinus sylvestris	2	3.5										
Quercus sp.	52	91	31	100	1	33.3	15	71.4	5	80	1	9.1
Betulaceae											1	9.1
Broadleaved					1	33.3	4	19	1	20	4	36.4
Coniferous								4.8				
Indeterminable	3	5.2			1	33.3	1				3	27.3
Sum of fragments	57	100	31	100	3	100	21	100	6	100	11	100
Minimum number of taxa	2		1		1		2		1		2	

Table 2. Absolute and relative frequency of charcoal fragments found in pits in Żerków. **LP** – lower part of pit, **UP** – upper part of pit

Żerków: pits	2A – LP		2B – LP		17A – LP		2A – UP		2B – UP		17A – UP	
Taxa	N	%	N	%	N	%	N	%	N	%	N	%
Cornus sanguinea							1	0.6			4	0.5
Corylus avellana	7	15.2			5	2.9	28	16.2	68	22.8	106	13.6
Fraxinus excelsior			1	3.1			4	2.3	8	2.7	46	5.9
Pinus sylvestris			1	3.1	4	2.3					4	0.5
Viscum album							4	2.3				
Acer sp.	8	17.4	3	9.4			16	9.2	27	9.1	143	18.4
Acer sp. cf. *A. campestre*	2	4.3					6	3.5	20	6.7	39	5.0
Quercus sp.	13	28.3	16	50.0	144	84.2	35	20.2	6	2.0	248	31.8
Salix sp./*Populus* sp.											1	0.1
Tilia sp.	1	2.2			2	1.2			9	3.0		
Ulmus sp.							7	4.0	37	12.4	13	1.7
Betulaceae: *Corylus avellana* or *Carpinus betulus*	1	2.2			1	0.6	3	1.7	1	0.3	22	2.8
Betulaceae	7	15.2	1	3.1	2	1.2	41	23.7	27	9.1	40	5.1
Maloideae	2	4.3	1	3.1			15	8.7	63	21.1	20	2.6
Broad-leaved	5	10.9	6	18.6	12	7.0	11	6.4	30	10.1	79	10.1
Coniferous			2	6.2	1	0.6						
Indeterminable			1	3.1			2	1.2	2	0.7	14	1.8
Sum of fragments	46	100	32	100	171	100	173	100	298	100	779	100
Minimum number of taxa	5		5		4		8		7		9	

Due to the poor state of preservation of the charcoal collected at Żerków, an abundant group of taxa was identified only as Betulaceae. In transverse section these fragments showed wood characteristics similar to those of *Corylus avellana*, but it was not possible to confirm the presence of typical anatomical features that can be seen in sections of well-preserved wood, such as the scalariform perforation plate in *Corylus avellena* (Pl. 1, fig. 6). Charcoal fragments were classified as Betulaceae when it was impossible to determine the type of perforation plates present and to confirm that the vessels contained fine spiral thickenings (Pl. 1, fig. 7). They were identified as *Corylus avellana* or *Carpinus betulus* when spiral thickenings were observed. Within the Betulaceae, three taxa may be considered: *Corylus avellana*, *Carpinus betulus*, and *Alnus* sp. It is more likely that the fragments belong to *Corylus avellana*, since *Carpinus betulus* probably did not occur in the Polish Carpathians during the sixth millennium cal. BC (Ralska-Jasiewiczowa et al. 2004), and *Alnus* sp. did not appear in the charcoal assemblage from Żerków. Another botanical identification requiring a brief explanation is that of *Acer*, where the species *A. campestre* is identified based on its wood characteristics, in which mainly 2- and 3-seriate rays appeared (Pl. 1, figs 10, 11) (Schweingruber 1982, 1990). Moreover, if a species is documented in a given sample/unit (e.g. *C. avellana*), the calculation of the number of taxa (Minimum number of taxa) in that sample/unit will include that species but will not include fragments identified only to a higher rank of that particular species (e.g. Betulaceae for *C. avellana*).

Some of the fragments are identified as tree parts such as trunks, branches and twigs. Classification of wood of small calibre is based on ring curvature (Schweingruber et al. 2006, Marguerie & Hunot 2007). Also, evidence of the presence of xylophagous organisms (indicating the use of deadwood) usually is noted. These observations provide additional information about wood gathering (Théry-Parisot 2001, Moskal-del Hoyo et al. 2010). In Żerków only a few fragments of small-size wood were found (Pl. 1, fig. 9; Pl. 2, fig. 2). Some evidence of biodeterioration was found (Pl. 2, fig. 3) but this may be due to the poor state of preservation of the charcoal.

The quantitative data are based on counts of charcoal fragments (Chabal 1997) and given as absolute (N) and relative frequency (%) of taxa (Tab. 1). No differences in charcoal fragmentation between taxa have been observed in experiments on fragmentation and mass reduction during combustion. A law of fragmentation has been formulated to determine the relative proportions of large and small fragments, independent of the species (Chabal 1988, 1997, Chabal et al. 1999). Any over-representation of some species may be controlled by using appropriate sampling methods and by analysing enough fragments, at least 400 per archaeological unit, regardless of their size (Chabal 1988, 1997, Aouti & Austin 2005).

The material from the three pits was taxonomically diverse. Taxonomic curves (Chabal 1988, 1997, Badal 1992) were applied to the assemblages of each pit in order to confirm their dynamics. These curves demonstrate the dynamics of the appearance of new taxa (Y axis) during the analysis of charcoal fragments (X axis). Samples from dispersed charcoal usually show high taxonomic diversity and a rapid dynamic of the curve at the beginning, although later some new taxa may still be found. The most abundant taxa appear in the first analysed fragments. This method helps establish the number of charcoal fragments needed to reach maximum detection of taxonomic diversity (e.g. Chabal 1988, Badal 1992, Ntinou 2002, Carrión 2005, Moskal-del Hoyo 2014). In the samples from the three pits the majority of taxa appeared in the first 150 fragments analysed, indicating the number of charcoal fragments needed for maximum detection of taxonomic diversity (Fig. 3A). In the material from pit 17A, the richest assemblage, taxonomic diversity did not increase much with the number of charcoal fragments analysed, but the relative frequency curves of the most abundant taxa for pit 17A (Fig. 3B) indicated that at least 500 charcoal fragments per pit needed to be analysed in order to stabilise the curves. For pits 2A and 2B the final values of the relative frequency of taxa should be treated with some caution, as the number of charcoal fragments needed for this aspect of the analysis was not found.

RESULTS AND DISCUSSION

The post-holes contained a small amount of charcoal documenting three taxa: hazel *Corylus avellana*, Scots pine *Pinus sylvestris*, and oak *Quercus* sp. (Tab. 1). Oak was ubiquitous and was more frequent than the other taxa. Oak is one of the most important construction materials in prehistory (e.g. Lityńska-Zając & Wasylikowa 2005). It was not possible to determine if these charcoal fragments were from posts or another part of the building, but some suggestions can be made. The charcoal was preserved in small fragments. No evidence of a post burnt *in situ* was found, as documented at other sites (e.g. Moskal-del Hoyo et al. 2015a). With the exception of pit-hole 13, the charcoal contained at least two different taxa, indicating that those fragments did not represent a single post. Along with charcoal it is common to find remains of cultivated plants and wild herbaceous plants in the filling of small pits interpreted as post-holes of LBK houses (e.g. Lityńska-Zając et al. 2014). In the present work they usually were not abundant; it is likely that they resulted from cleaning activity during which the material fell around the posts. Based on the available data from Żerków, it is difficult to maintain that the charcoal found in the post-holes was originally part of construction material.

The charcoal assemblage from the pits shows higher taxonomic diversity, as evidenced by the finding of 12 taxa (Tab. 2). Several were identified to species (field maple *Acer campestre*, common dogwood *Cornus sanguinea*, common hazel *Corylus avellana*, ash *Fraxinus excelsior*, Scots pine *Pinus sylvestris*, mistletoe *Viscum album*); others were identified to genera (maple *Acer*, oak *Quercus*, lime *Tilia*, elm *Ulmus*, willow *Salix*, poplar *Populus*) and one subfamily (Maloideae) (Pl. 1, 2). The charcoal definitely represents secondary contexts and probably is firewood remains. This is suggested by its taxonomic diversity but also can be inferred from analysis of the archaeological material, mostly pottery fragments, found with the charcoal (Valde-Nowak 2014). These three pits were associated with one long house and were external to it. Although it is usual to describe them as clay extraction pits or clay pits, their original function is not yet clarified. They were filled with refuse that was scattered around the house, but natural runoff could have carried it to the places where it was found (Kvetina & Končelová 2013, Czekaj-Zastawny 2014). Charcoal from pits that finally served as refuse areas mainly contain remains of firewood. Anthracological studies have demonstrated that charcoal fragments found in archaeological

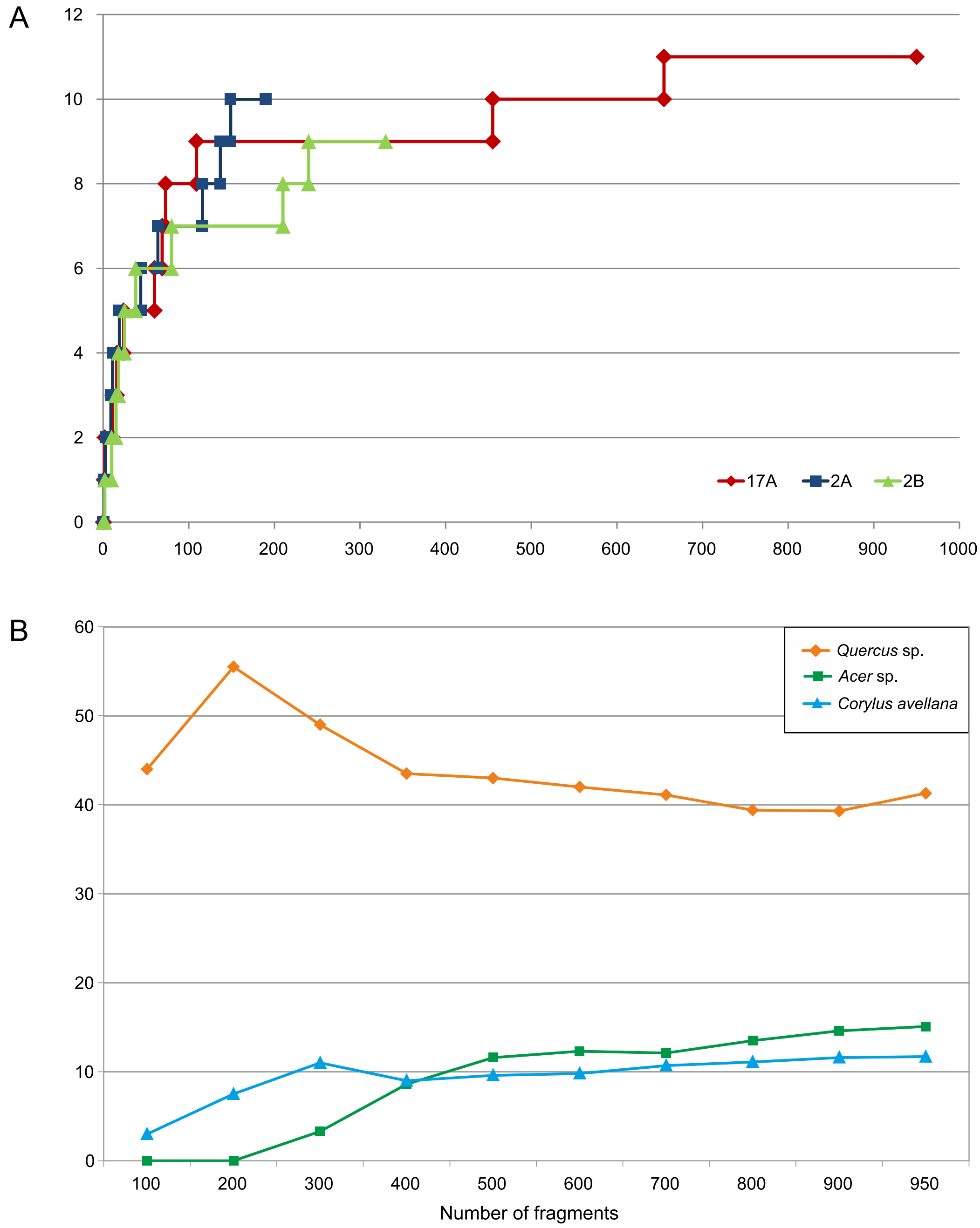

Fig. 3. **A**. Taxonomic curves of the charcoal assemblages from the pits. **B**. Relative frequency curves of taxa from pit 17A

structures with waste context have characteristics similar to dispersed charcoal. The pits probably were filled in with sediment and material from the surface around the site, where charcoal had been deposited over a longer period. Past environmental conditions may be inferred from such material, and ancient forest communities may be reconstructed (e.g. Chabal 1988, Bernabeu & Badal 1992, Ntinou 2002, Lityńska-Zając et al. 2008, Moskal-del Hoyo 2013, Moskal-del Hoyo et al. 2015).

Interestingly, two different types of filling can be distinguished in Żerków. At the bottom of the pits was a muddy type of sediment which did not contain any archaeological material. Some charcoal was found, but it appeared only after flotation and was not seen during excavation work. The upper parts of the pits had typical filling of various layers documenting dumping activity (Fig. 2). This pattern suggests that the pits remained open at first, probably to hold water dropping from the roof or for some other purposes, and later were filled with refuse and sediment from nearby. It also indicates that the charcoal was deposited by two different processes: by natural runoff in the lower part of the pits, and with refuse in the other part. In view of this, I present the charcoal analysis results separately for the lower and upper parts of the pits, though both sediments generally reflect one period of occupation at the settlement.

Table 2 presents the results of charcoal analysis for the upper and lower parts of the three pits (2A, 2B, 17A). The following taxa were found in the lower parts: *Corylus avellana*, *Fraxinus excelsior*, *Pinus sylvestris*, *Acer* sp., *Quercus* sp., *Tilia* sp., and Maloideae. Oak was ubiquitous and was the most frequent taxon, but hazel and maple were also somewhat abundant. Other taxa were less frequent but some of them were found in different features (Maloideae, *Pinus sylvestris*, *Tilia* sp.). More taxa were documented from the upper parts of the pits (Tab. 2). Taxa such as oak and hazel were similarly common, and maple and Maloideae were very frequent. Elm and ash were also found in all upper parts of pits. Other taxa were scarce. In general the charcoal found in the two different parts of the pits were similar qualitatively but differed quantitatively, especially in regard to their dominant taxa (Tab. 2). In the lower parts, oak was conspicuously predominant, and the second most frequent taxon was hazel. In the upper parts, hazel predominated and was more abundant than oak, although taxa of the Betulaceae were not taken into account. Among the other taxa, maple was somewhat common in the lower parts, whereas Maloideae, *Acer* sp., and *Acer campestre* were both frequent and abundant in the upper parts. *Tilia* sp., *Fraxinus excelsior*, and *Ulmus* sp. were also more frequent in the upper parts. Despite the significant differences between the lower and upper parts of the pits, they should not be interpreted as indicating different phases of occupation.

As mentioned before, the material found in the pits might be used for reconstruction of the former forest communities if it originated from firewood. In the material from Żerków, the diversity of taxa and the similarities in taxonomic composition between all three pits strongly suggest that these assemblages reflect collection of fuelwood. As previously commented, however, the final relative frequency of the taxa may not be quantitatively representative; only general tendencies in the occurrence and abundance of taxa should be inferred. The analysis indicates that the nearby vegetation probably was dominated by forest with oak and hazel. *Acer* species probably were common constituents of these communities, accompanied by lime and Scots pine. Different species of the Maloideae subfamily apparently formed part of the undergrowth or grew in forest clearings or in hedges. Two different riparian forest communities probably developed in the vicinity of the site: elm-ash-oak woods (*Ulmus* sp., *Fraxinus excelsior*, *Quercus* sp., *Cornus sanguinea*, Maloideae) in places with good water supply, and willow-poplar forest (*Salix* sp., *Populus* sp.) near rivers or creeks. The latter community probably was more distant, since it is represented by only one charcoal fragment.

The higher frequency of oak and hazel in material from other LBK settlements has been interpreted as evidence of their use as construction material (Kreuz 1992, 2010/2012, Kirleis & Willerding 2008). Were oak and hazel, dominant in the Żerków assemblage, similarly selected for their uses? Oak is an important source of timber, while hazel can be used for construction of walls in wattle work (Kirleis & Willerding 2008), so such an interpretation might be suggested for the Early Neolithic settlement in Żerków. However, the oak and hazel remains in the samples occurred along with other taxa and did not clearly represent any construction parts such as burnt wood found in association with daub fragments, or posts. Oak wood may frequently be over-represented in firewood remains, since its preparation for use as timber leaves behind many smaller branches which can be burned as fuel later. Thus the need for a good sampling protocol that takes scattered charcoal samples from different archaeological layers spanning a long period of deposition, to reduce the likelihood of over-representation of taxa and controlling for "human filters" such as selection of particular species (Asouti & Austin 2005). It should also be stressed that the shares of taxa found in a charcoal assemblage are not directly related to the quantitative relations between the different trees and shrubs that appeared in nearby woodlands (Lityńska-Zając & Wasylikowa 2005).

OAK AND HAZEL

In the Atlantic period, oak and hazel were the main components of the forest that developed in the vicinity of the Żerków site. The present-day vegetation of the Carpathian foothills contains two species of *Quercus* (*Q. robur*, *Q. petraea*) and only one *Corylus* species (*Corylus avellena*). Oak woodlands are well-insolated forests having broken canopy which permits a rich understorey to develop (Medwecka-Kornaś et al. 1972, Polunin & Walters 1985, Ellenberg 1988, Matuszkiewicz 2005). *Corylus avellana* is a very important constituent of these communities but may also occur in mixed deciduous forest, coniferous forest, and open brushwood. It prefers moderately humid soils but also tolerates different edaphic conditions (Miotk-Szpiganowicz et al. 2004, Seneta & Dolatowski 2004). In general, the high frequency of hazel, especially when counted together with the taxa identified as Betulaceae (Fig. 4), suggests that this forest probably has no present-day analogue, so it is difficult to infer its ecological requirements during the Atlantic period.

During the eighth millennium BP, mixed deciduous forest with *Ulmus*, *Tilia*, *Quercus*, and a high frequency of *Corylus* occurred in the foothills of the Western Carpathians (Obidowicz et al. eds 2013). In the Atlantic period, hazel is also interpreted as an important component of forests of the lower montane zone. Isopollen maps show that in the Carpathian region hazel reached 20–25% frequency, and in particular profiles even 50% locally (Miotk-Szpiganowicz et al. 2004, Obidowicz & Nalepka 2013). The Żerków site is located in the Carpathian foothills, part of the region that includes the West Beskidy Mts. and forelands according to the subdivision of Polish palaeobotanical type regions (Ralska-Jasiewiczowa & Latałowa 1996). Recent studies in this area found dominance of hazel, which was a characteristic feature of the vegetation in the older phase of the Atlantic period, as observed in the peat bog at Pcim Sucha 1 (480 m a.s.l.) (Margielewski 2006, Margielewski et al. 2010). A similar hazel-dominated pollen zone was reported at Szymbark (465 m a.s.l.) in the Low Beskidy Mts. (Ralska-Jasiewiczowa & Latałowa 1996, Szczepanek 1989, Wacnik et al. 2001). Both of these zones are not far from Żerków but are not necessarily comparable, as they lie at higher elevation. Mixed deciduous woodland with a higher proportion of hazel has been reported from other localities in southern Poland (e.g. Harmata 1987, Ralska-Jasiewiczowa & Latałowa 1996, Nalepka 2003).

At the beginning of the Holocene the spread of hazel was promoted by its tolerance of a large range of climatic and edaphic conditions, its high seasonality, and its ability to compete against birch and pine trees, which prevailed in the early Holocene vegetation (Tallantire 2002, Finsinger et al. 2006). In the

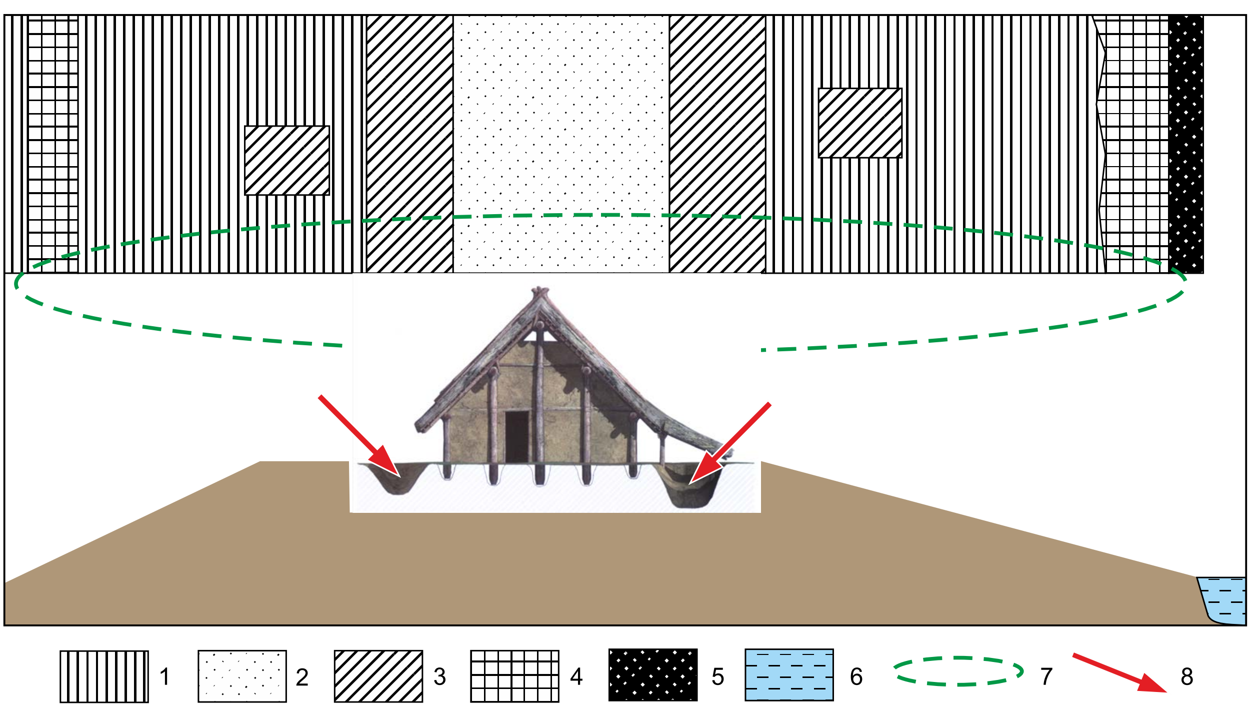

Fig. 4. Reconstruction of the palaeovegetation of areas near the Neolithic settlement of Żerków. Central building (according to Czekaj-Zastawny, 2008). **1**. Oak-hazel-dominated forest with maple, Maloideae, lime and Scots pine; **2**. Deforested zone of the settlement; **3**. Hedge/scrub; **4**. Mixed deciduous forest with elm and ash; **5**. Willow-poplar forest; **6**. Stream; **7**. Area of wood gathering; **8**. Clay pits with archaeological charcoal

Western Carpathians a hazel phase in the pollen spectra has been noted, especially between 8000 and 7500 BP but possibly continuing to 7000 BP or beyond, since the first significant reduction of hazel pollen is at ca 4500 BP (Obidowicz & Nalepka 2014). The pollen data seem to be in line with the anthracological data from archaeological sites dated to the Bronze Age in the Wiśnicz and Rożnów foothills (Moskal-del Hoyo et al. 2015b). *Corylus avellana* was found only sporadically, and oak together with *Carpinus betulus* and *Fagus sylvatica* were the most abundant and frequent taxa. For this reason, significant changes in forest communities of the Carpathian foothills are indicated for the Subboreal period. The continuous reduction of hazel pollen may be related to the expansion of *Carpinus betulus*, which shows a rapid increase in pollen values (Szczepanek 1989, Ralska-Jasiewiczowa et al. 2004, Margielewski et al. 2010). This tree has ecological requirements very similar to those of hazel, appearing in oak forest and riverine communities. It is also a very competitive species, capable of very rapid colonisation, especially in disturbed forests (Ralska-Jasiewiczowa et al. 2004).

It remains unclear whether the forest communities with high oak and hazel values inferred from the charcoal from Żerków represent primeval forest or rather reflect forest vegetation that developed due to the human presence in the area. Supporting the first interpretation, the high frequency of hazel in the Atlantic forests, documented by pollen analysis, can be interpreted as resulting from natural development of woodlands in the Holocene. As mentioned above, *Corylus avellana* is one of the most important components of the pollen of Atlantic forests in the Western Carpathians. However, this does not necessarily mean that it was one of the most important forest constituents during the Atlantic period. It is difficult to estimate its real frequency in ancient woodlands because hazel produces abundant pollen and also has an early pollination period, before that of the majority of other trees and shrubs (Miotk-Szpiganowicz et al. 2004). As hazel was significantly more frequent in this period than in later periods of the Holocene in the foothill zone, probably it was not merely a second canopy or woodland edge component of Atlantic forests. The higher proportion of hazel may represent natural vegetation formed on sunny southern slopes of the Carpathian foothills. *Corylus avellana* is likely to have played an important role in Atlantic woodlands, especially in the foothill zone. Its high frequency in the charcoal from Żerków generally correlates well with the pollen assemblage values.

The other explanation maintains that these woodland communities with high shares of oak and hazel appeared in the vicinity of the Neolithic settlement as a result of anthropogenic effects associated with deforestation or cutting of forest clearings. Such activities by Neolithic people would have affected the local vegetation and might have led to the development of open scrub. In a later period (5000–3000 BP), in central Poland the existence of ecologically unstable scrub-forest communities with hazel is interpreted as a consequence of the activities of Neolithic people (Ralska-Jasiewiczowa et al. 2003, Miotk-Szpiganowicz et al. 2004). At the Żerków archaeological site only one occupation phase was revealed, so a more detailed chronological sequence cannot be given. However, there was no evidence of early stages of secondary succession in the forests, such as high frequency of pioneer *Betula* trees or light-demanding *Pinus sylvestris*. It is likely that on a microscale the charcoal assemblage from Żerków reflects some disturbance of the local forests due to human occupation, consisting mainly in successive opening of the forest which created mosaic-like communities with forest and hedges as an important transitional vegetation group at the woodland margins (Kreuz 1992). This process, possibly also connected with the role of large wild herbivores capable of creating canopy gaps in the woods, may have been enhanced by the presence of domesticated animals kept near the Neolithic settlement (Vera 2000, Birks 2005, Kreuz 2008).

Oak-hazel-dominated forests probably were rather open and therefore easier for the Neolithic people to exploit. The question of the density of the primeval forests encountered by the first Neolithic settlers arriving in Central Europe is of great interest to researchers (Ellenberg 1988, Vera 2000, Svenning 2002, Birks 2005, Vera et al. 2006, Kreuz 2008, 2010/2012). Recent studies have reported evidence of more open woodland during this period (Vera et al. 2006, Kreuz 2008, 2010/2012), supported especially by the presence of light-demanding taxa as well as the dominance of hazel and oak in forests (Kreuz 2008). Light is critical to oak and hazel regeneration; neither genus can survive in closed, densely wooded areas (Vera 2000, Tallantire 2002, Vera et al. 2006, Kreuz 2008). It is difficult to establish whether the forests of the Carpathian foothills were semi-open, but this anthracological study confirms that this kind of community developed on the hills occupied by Neolithic farmers.

The presence of other taxa such as *Acer* sp. and Maloideae also suggests that these communities with oak and hazel formed semi-open forests, scrub or hedges. As stated before, this community has no present-day analogue. However, it can be compared to well-insolated present-day oak forests of the *Quercion petraeae* alliance with *Quercus pubescens*, *Acer campestre*, and *Corylus avellana*. According to several authors, anthropopression probably played an important role in their formation and maintenance (Szafer & Zarzycki 1972, Ralska-Jasiewiczowa et al. 2003, Matuszkiewicz 2005). *Viscum album*, also documented at Żerków, is a heliophilous species which had its maximal expansion between 7000 and 6000 BP (Granoszewski et al. 2004, Seneta & Dolatowski 2004).

Acer species are shade-tolerant but the younger trees require a good amount of sunlight. Three species of *Acer* are common in Polish forests today: *A. campestre*, *A. pseudoplatanus*, and *A. platanoides* (Noryśkiewicz et al. 2004). In oak-hornbeam forests of the studied area, *A. campestre* is more commonly found (Towpasz 1988). Based on wood anatomy, *Acer* is represented in the charcoal from Żerków mainly by *A. pseudoplatanus–A. platanoides*-type and perhaps also *A. campestre*-type trees. Juvenile wood of the former has characteristics similar to those of *A. campestre* (Schweingruber et al. 2006). That type of charcoal may have originated from trees that grew in well-insolated places, since, like young *Acer* trees, field maple is a light-demanding species. Even if the higher frequency of *Acer* in the charcoal assemblage may somehow be due in part to over-representation, the data from the Żerków charcoal clearly indicate that *Acer* is strongly underrepresented in pollen assemblages from the Atlantic period. *Acer* species are insect-pollinated and do not produce abundant pollen (Noryśkiewicz et al. 2004). At Pcim Sucha 1, during the Atlantic period *Acer* exhibited a continuous curve and also reached its highest peak (Margielewski et al. 2010). This tree does not appear in the pollen diagram of Szymbark (Szczepanek 1989).

Other insect-pollinated plants such as those of the Maloideae subfamily were also very frequent in the charcoal from Żerków. Taxa belonging to that subfamily are not usually found in pollen diagrams from the Atlantic period. The Maloideae remains may indicate the presence of more open woodland, edge vegetation and hedges in the zones near the Neolithic settlement. In general, the various fruit trees and shrubs of the Maloideae subfamily do not grow nor regenerate well in dense forest (Vera 2000). Based on anatomical features it is generally not possible to differentiate members of the Maloideae subfamily (Schweingruber 1990). All of them are very vulnerable to the effects of growing in dense forest canopy and easily disappear from closed forest, especially *Malus sylvestris*, *Pyrus pyraster*, *Pyrus communis*, *Crataegus* species, *Sorbus torminalis*, *S. aria*, and *S. domestica*. These trees occur in dense forests only at their margins (Vera 2000, Vera et al. 2006). Since only one occupation phase was identified at the Żerków archaeological site, it is not possible to relate the presence of Maloideae to human occupation of the area. In recent studies of charcoal found at LBK settlements in Belgium, however, an increase of heliophilous post-pioneer taxa such as Maloideae was observed in the second occupation phase; this means that agro-pastoral activity significantly influenced the development of more open forest communities (Salavert et al. 2014). The presence of Maloideae has also been linked to human impacts in the Early and Middle Neolithic of Germany (Kreuz 1992, 2008, 2010/2012, Jansen & Nelle 2014). More open forests and hedges favour the spread of fruit trees, including the Rosaceae and *Corylus avellana*. These trees probably were an important food source in the ancient diet. Collection and consumption of *Malus sylvestris* was confirmed at Gwoździec, a Neolithic LBK settlement also situated in the Carpathian foothills (Bieniek & Lityńska-Zając 2001). Openings in local woodland would have been of benefit to Neolithic people, and eventually they created open areas.

Other trees such as *Ulmus*, *Fraxinus excelsior*, and *Tilia* were also important components of pollen assemblages of the Polish Western Carpathians from the Atlantic period (Obidowicz et al. eds 2013). *Ulmus* Pollen grains had 5–10% shares in the mountains and their foothills; these trees are likely to have been important taxa in the lower montane zone (Zachowicz et al. 2004, Kołaczek & Nalepka 2013). Three species of elms are native trees of Poland: *Ulmus minor* (smooth-leaved elm), *U. laevis* (fluttering elm), and *U. glabra* (wych elm). They are components of deciduous and riverine forests. All of them grow in moderately warm to moderately cool climate and prefer moist, rich, deep soil (Seneta & Dolatowski 2004, Zachowicz et al. 2004). The frequency of *Ulmus* was above 20% in the pollen diagram for Szymbark (Szczepanek 1989), and below 10% for Sucha Pcim 1 (Margielewski et al. 2010). This taxon was not very abundant in the charcoal from Żerków, reaching a maximum of 4.3%. *Fraxinus excelsior* had a similar low share but it was better correlated with the pollen assemblages (Tobolski & Nalepka 2004). The frequency of ash was ca 10% at Szymbark (Szczepanek 1989), and lower at Pcim Sucha 1 (Margielewski et al. 2010). These anthracological results suggest that elm and ash trees were not dominant constituents of the Atlantic forests that developed on the highest parts of the Carpathian foothills. Probably they grew on more humid slopes.

Pollen diagrams from the south of Poland also show *Tilia* to be a very important element of mid-Holocene forests, although this is an insect-pollinated tree, usually underrepresented in pollen assemblages (Kupryjanowicz et al. 2004, Wacnik et al. 2013). This taxon includes two species in Poland: *Tilia cordata* and *T. platyphyllos*. *Tilia* also appeared in the pollen diagrams from Szymbark and Pcim Sucha 1, reaching shares of ca 10% (Szczepanek 1989, Margielewski et al. 2010). In the charcoal assemblage from Żerków it was found in only a few fragments, suggesting its lower frequency in local forests of the lower foothills. Kreuz (1992, 2008) reported the absence of *Tilia* in anthracological assemblages from Germany, and attributed that finding to cultural practices, as its wood was not typically selected for fuel. That finding goes against the general trend documented in charcoal assemblages originating from fuelwood, which show taxonomic diversity based on local availability. Fuelwood was not commonly considered good or bad based on its species (Chabal 1988, 1997), especially since the gathered firewood was deadwood (e.g., Chabal 1988, Asouti & Austin 2005, Carrión 2005). For these reasons it can be concluded that the low frequency of *Tilia* in the charcoal is due mostly to its lower share in the forests near this Neolithic settlement.

In the pollen diagrams from Pcim Sucha 1 and Szymbark, *Pinus sylvestris* reached values slightly above 10% (Szczepanek 1989, Margielewski et al. 2010). On isopollen maps from the Carpathian foothills this tree shows a large decline relative to early Holocene pollen sequences, and does not appear frequently (Latałowa et al. 2004). With its fewer climatic requirements and its adaptedness to continental climate, *Pinus sylvestris* is a ubiquitous species. Due to competition from other species it is not usually found on rich soil, which promotes broadleaved trees and shrubs (Polunin & Walters 1985, Latałowa et al. 2004). In the foothills, Scots pine now occurs in mixed oak-pine forest (*Pino-Quercetum*) together with two oak species (*Q. robur*, *Q. petraea*), silver birch (*Betula verrucosa*), and *Sorbus aucuparia* and *Corylus avellana* in the undergrowth (Towpasz 1988). *Pinus sylvestris* also may indicate open landscape or disturbed habitats, since it is a pioneer tree (Latałowa et al. 2004). Overall, the remains of *Pinus sylvestris* were sparse in the charcoal, suggesting that it was present in local forests but did not dominate in the foothills.

CONCLUSIONS

This analysis of charcoal from the Żerków archaeological site indicates that open-canopy oak forests developed near a human settlement in the Carpathian foothills during the Atlantic period. The area closest to the settlement on the top of a hill probably was deforested and covered partly by scrub and hedges, which promoted the spread of light-demanding fruit trees and shrubs (Fig. 4). These trees and shrubs may also have developed in oak forest, where together with hazel they would have formed the undergrowth. *Acer* species also seem to have been important forest constituents. This community probably has no present-day analogue but may resemble open-canopy oak forests of today. Due to the absence of different occupational phases at the archaeological site, it is not possible to state whether this kind of semi-open forest was local primeval woodland on the highest foothills or rather developed as a consequence of human activities. However, other anthracological studies of Neolithic settlements in Central Europe suggest that open-canopy forests were penetrated by people in search of firewood, and that, as a consequence of human agro-pastoral activity, mosaic-like forest communities developed, including open forests and transitional hedge vegetation at the woodland border. This paper contributes to the reconstruction of Atlantic plant communities in the Carpathian foothills, adding findings from a microscale study of one settlement area. To increase the reliability of palaeoecological reconstructions of the region, new anthracological studies from this area are needed.

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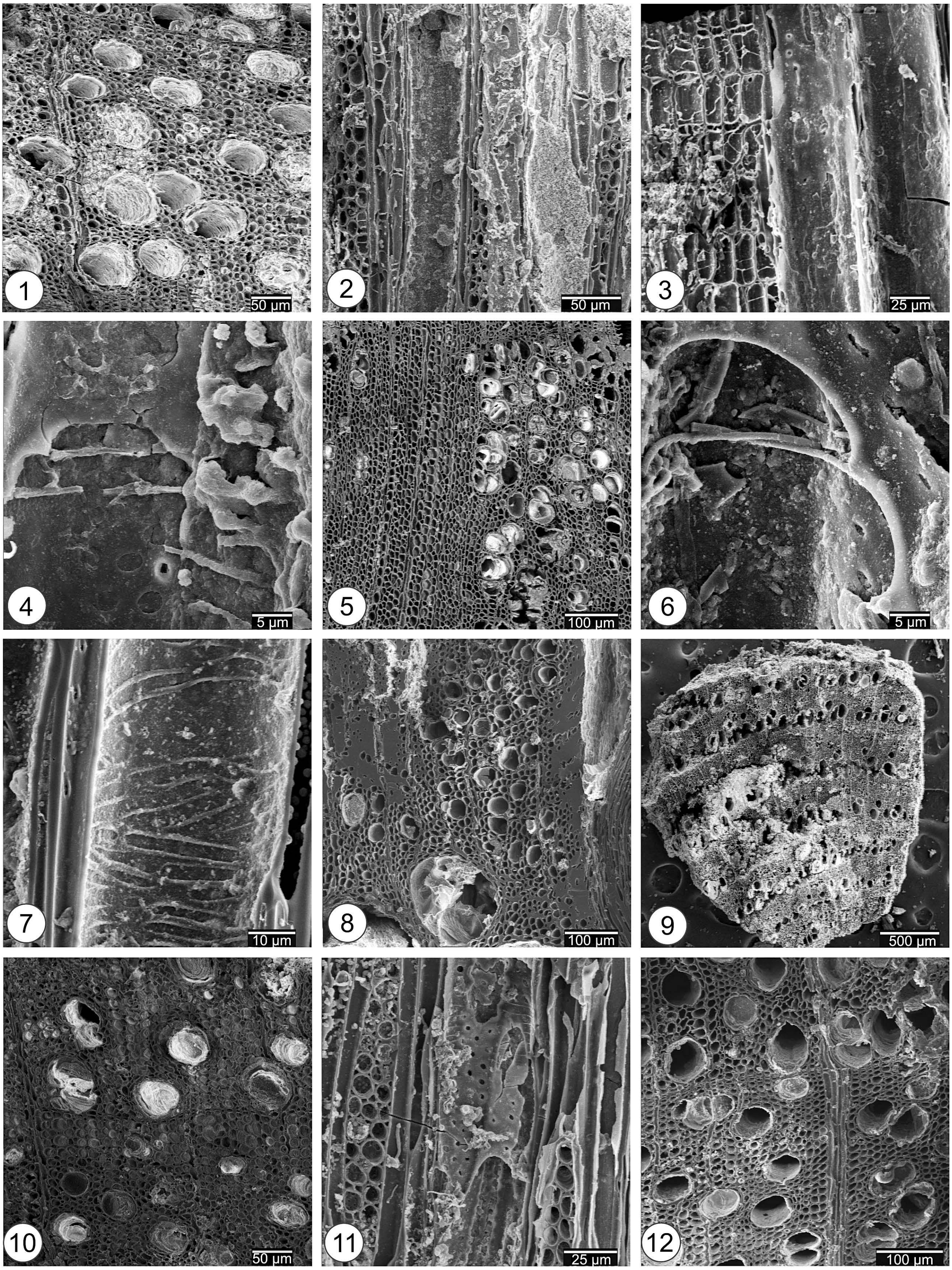
PLATES

Plate 1

Selected charcoal samples from Żerków:

1. *Cornus sanguinea*, transverse section
2. *C. sanguinea*, longitudinal tangential section
3. *C. sanguinea*, longitudinal radial section
4. *C. sanguinea*, longitudinal radial section
5. *Corylus avellana*, transverse section
6. *C. avellana*, longitudinal radial section
7. *C. avellana*, longitudinal radial section
8. *Quercus* sp., transverse section
9. *Ulmus* sp., transverse section
10. *Acer* sp. cf. *A. campestre*, transverse section
11. *Acer* sp. cf. *A. campestre*, longitudinal tangential section
12. *A. pseudoplatanus*-*A. platanoides*-type, transverse section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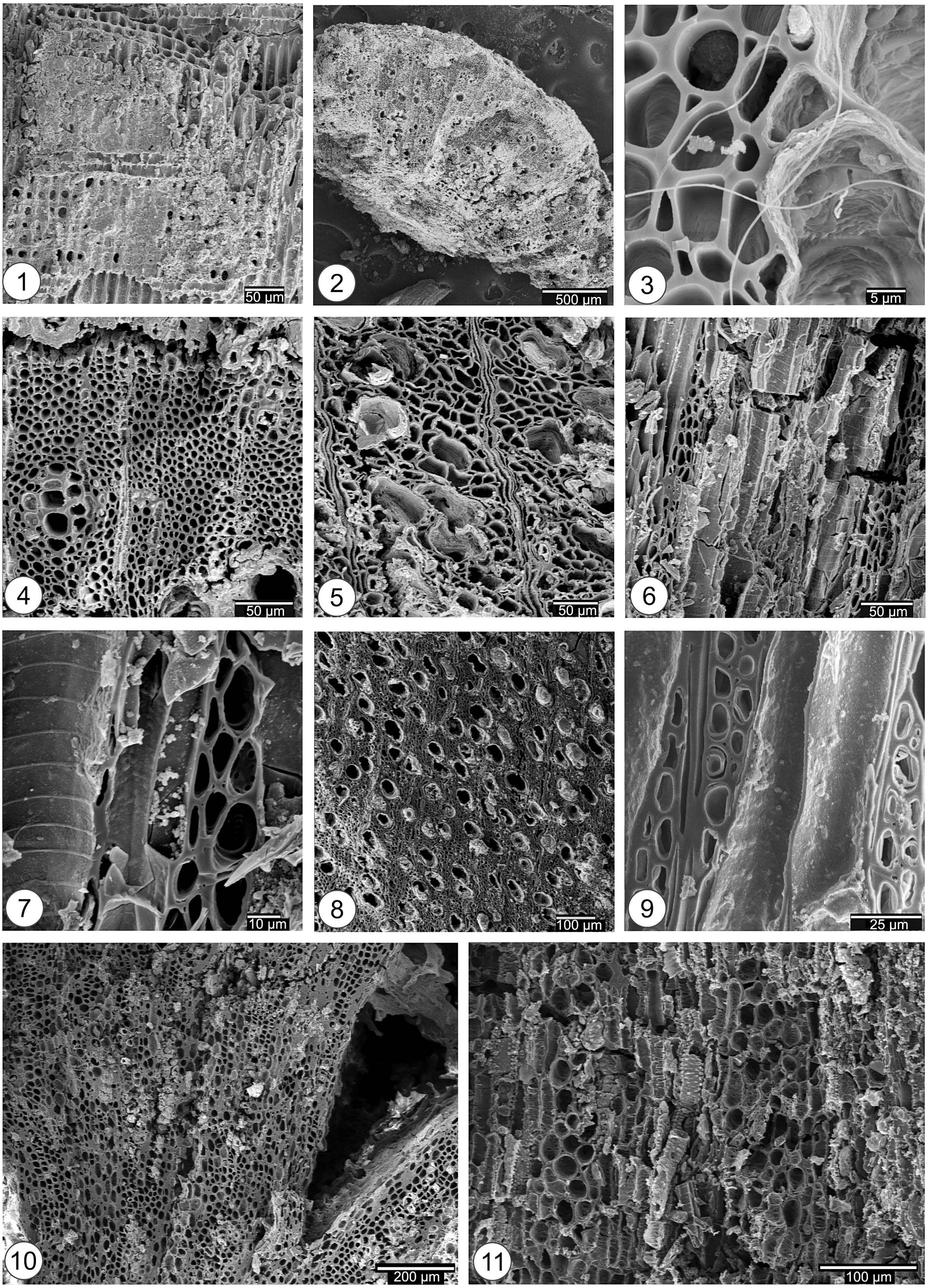
10
50 µm
11
25 µm
12
100 µm

Plate 2

Selected charcoal samples from Żerków:

1. *Pinus sylvestris*, transverse section
2. Broadleaved, transverse section
3. Broadleaved, transverse section, fungal hyphae in the charcoal
4. *Fraxinus excelsior*, transverse section
5. *Tilia* sp., transverse section
6. *Tilia* sp., longitudinal tangential section
7. *Tilia* sp., longitudinal tangential section
8. Maloideae, transverse section
9. Maloideae, longitudinal tangential section
10. *Viscum album*, transverse section
11. *V. album*, longitudinal tangential section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