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A Neolithic yew bow in the Polish Carpathians Evidence of the impact of human activity on mountainous palaeoenvironment from the Kamiennik landslide peat bog

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ABSTRACT

A unique artefact — the fragment of a bow made of yew wood, indicating the hunting activity of prehistoric man — was found within the sediments of the landslide peat bog (at the depth of 330 cm) formed on the Mt. Kamiennik (Polish Flysch Carpathians). The datings of this artefact using ^{14}C method at ca 3790–3380 cal BC indicate its connection with the activity of the Neolithic man, related to the Funnel Beaker Culture. In the sequence of the peat bog deposits formed since the Atlantic Phase, the palaeoclimatic changes of the Middle- and Late Holocene, as well as traces of human impact in these and subsequent periods were recorded and analysed using palynological, macrofossils, lithological methods, and dated with radiocarbon. Palaeoenvironmental changes identified in the peat horizon bearing the artefact were marked by the delivery of minerogenic, "high energy" deposits (with charcoal) to the peat bog, as well as distinct changes of plant communities. These phenomena confirm a significant human impact caused by the Prehistoric man on landslide areas. On the other hand, the study confirms significant importance of climatic condition for human activity and proves that landslide peat bog deposits are very sensitive records of palaeoenvironmental changes. The archaeological artefact essentially supplements the results of our interdisciplinary palaeoenvironmental study. It is one of the rare Neolithic bows found in the area of Europe, till now.

1. Introduction

Undrained depressions that can be numerous in the landslide areas, are usually filled with water at the beginning and subsequently get overgrown and gradually pass into fen, soligenic (minerogenic) peat bogs, representing a specific type of landslide peat bogs (Margielewski, 1998, 2006a). Studies of the sediments of these peat bogs indicate that they are very sensitive indicators of the palaeoenvironmental changes in mountainous areas in the Late Glaciation and Holocene (Margielewski, 2006a) similarly to the sediments of high-mountainous lakes (e.g. Kotarba and Baumgart-Kotarba, 1997; Zolitschka and Negendank, 1999; Rubensdotter and Rosqvist, 2003; Sletten et al., 2003; Evans and Slaymaker, 2004). The climatic changes and especially the periodic climate moistening, were recorded in the sediments as apparent lithological changes in their sequences, evidenced by the occurrence of illuvial or mineral horizons within the organic series (Dapples et al., 2002; Kalis et al., 2003; Margielewski, 2006a; Borgatti et al., 2007). Most of these changes represent the results of natural processes, as moistening of climate or natural forest burning (Ali et al., 2005). But part of these changes was evidently generated by economic human activity in the prehistoric time (*see*: Dapples et al., 2002; Kalis et al., 2003; Zolitschka et al., 2003; Tinner et al., 2005, 2007). Charcoal occurring within the lacustrine sediments and usually associated with the mineral horizons, traces of the deforestation as well as pollen of cultivated plants recorded in the pollen diagrams also indicate that extreme changes of the deposition could have been the results of overlapping of climatic and anthropogenic factors (Ralska-Jasiewiczowa, 1977; Starkel, 1988; Berglund, 2003; Zolitschka et al., 2003). Human colonisation, also in prehistoric times, often extended into the colluvial flats of the stabilised landslides in the Carpathians (Margielewski, 2000). Although the existence of prehistoric man in the area of Polish Carpathians was proved by the artefacts found there (e.g. Machnik, 1960; Valde-Nowak, 1988; 1995a), strictly in landslide areas, artefacts indicating an economic activity were not found, so far.

The artefact indicating hunting activity of prehistoric man was found in the sediments of the landslide peat bog situated on the northern slope of the Kamiennik Mt., in the Beskid Wyspowy Mts., in the area of Polish Flysch (Outer) Carpathians (Fig. 1). The artefact is a sharpened fragment of wood ca 10 cm long, occurring within the peat

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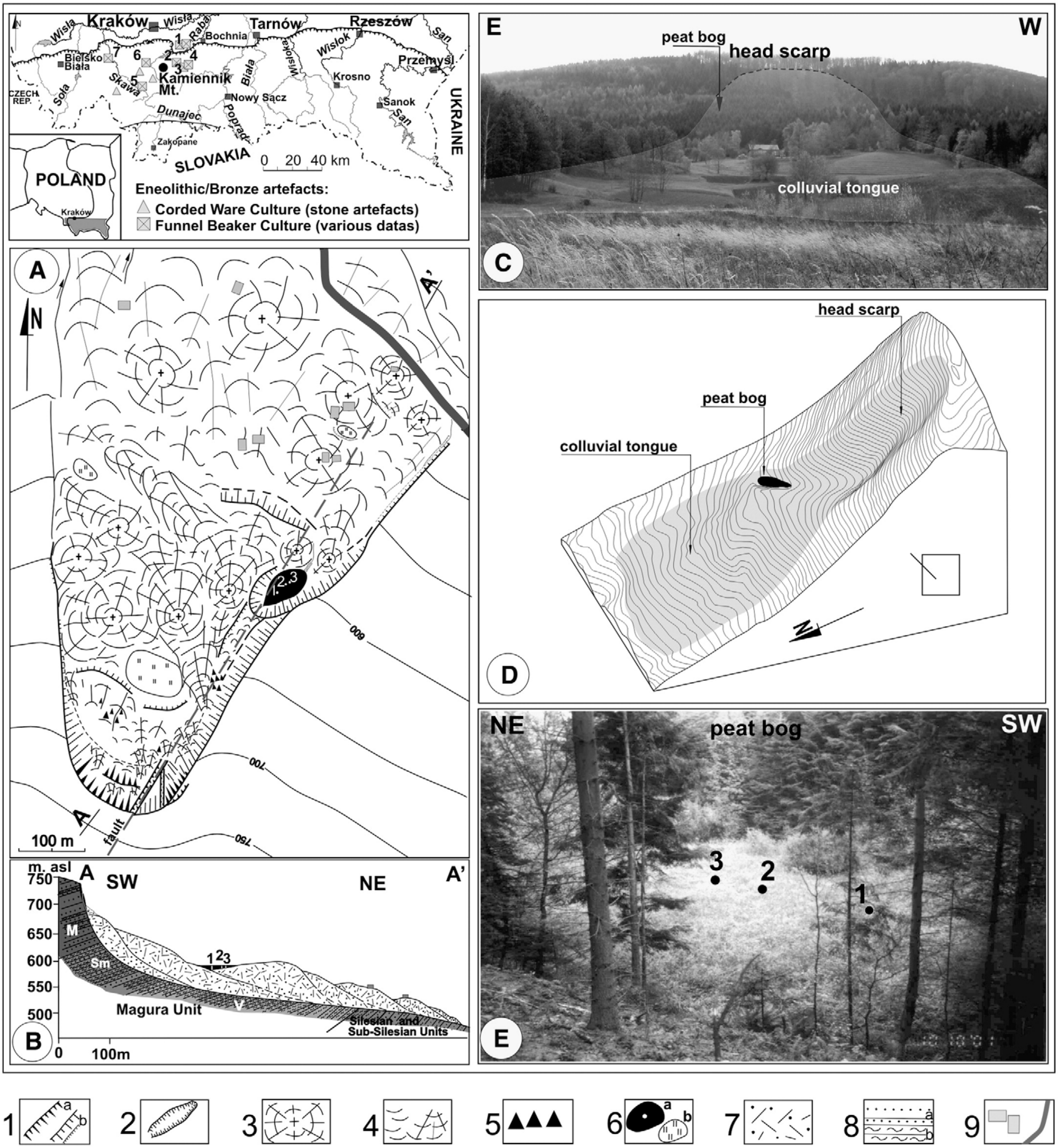

Fig. 1. Kamiennik landslide: map (A), cross-section (B), view of the landslide with the colluvial tongue (C), orthogonal projection of hypsometry of the landslide area (D) and view on the landslide peat bog with the location of drillings (1, 2, and 3). Upper left map of Polish Carpathians shows location of the Kamiennik landslide and sites of the finds of artefacts representing the Corded Ware Culture and Funnel Beaker Culture, mentioned in the text, as following: 1 — Książnice and Jawczyce, 2 — Poznachowice, 3 — Szczyrzyc, 4 — Słupia, 5 — Kojszówka, 6 — Mirkowo, 7 — Mucharz. Explanation of symbols: 1 — scarp (a — rocky, b — soil), 2 — trenches, 3 — landslide body, 4 — colluvial tongue, 5 — rock blocs and debris, 6 — peat bog with the location of drillings (a), swamp (b), 7 — colluvial material (on the cross-section), 8 — sandstones (a) and shales (b), 9 — buildings and road. Geology of the Magura Unit on the cross-section: M — Magura beds, Sm — Sub-Magura beds, V — variegated shales and Hieroglyphic beds (geology compiled after: Burtan, 1977, 1978).

at the depth of 330 cm and recovered during drilling with the peat bit. The thorough study indicates that it can be fragment of a bow made of yew wood. The datings of this artefact with the radiocarbon method (^{14}C) prove its connection with the activity of the Neolithic man. The detailed analyses of the peat sediments (palynological and lithological) formed since the Atlantic Phase of the Holocene, enabled the reconstruction of the palaeoenvironmental framework of the bow fragment occurrence as well as the interpretation of the Middle- and Late Holocene climatic changes occurred in this part of the Carpathians.

2. Study site

The studied peat bog is situated within the landslide formed on the northern slope of the Kamiennik Mt. in the Beskid Wyspowy Mts. (49° 48,207′N; 020° 02,980′ E). In the geological terms, the landslide was formed in the marginal zone of the Magura Unit (Siary Subunit), overthrust the Silesian and Sub-Silesian Units (Burtan, 1977, 1978). The landslide lies in the span of altitude 550–750 m a.s.l. Its upper part (head scarp) was formed in the thick-bedded Magura beds (Magura Sandstones), whereas lower segments (landslide body) — in shales and sandstones of the Sub-Magura beds, variegated shales and Hieroglyphic beds of the Magura Unit. The lowermost parts of landslide (colluvial tongue) were formed within Silesian and Sub-Silesian Units (Fig. 1A–B). The landslide represents the rotational landslide type (WP/WLI, 1993; Cruden and Varnes, 1996; Dikau et al., 1996) developed in the opposite direction to the dip of strata (Margielewski, 2006b). The landslide movement formed amphitheatre-like, predominantly rocky head scarp 40 m high and distinct marginal edges with slide troughs developed in some places (Fig. 1A, D). The central part of the head scarp of the landslide is dissected with a transversal, dip-strike, dextral fault, along which erosional gully (cutting head scarp) developed. The landslide body was deposited at the foot of the head scarp in the form of several ramparts, forming landslide steps in some places. In central parts of head scarp foot the extensive flattened area (currently slightly swampy) was formed.

The landslide developed most probably in one event, and the general gravitational movements of main landslide body are not recorded, now. Only secondary, small and local mass movements: rock falls from the head scarp and possible debris flow of material accumulated at the head scarp foot, are observed. Also erosional cutting of the marginal segments of the colluvial tongue by streams initiates local small mass movements. The prominent processes transforming the landslide surface have been slopewash (combined with sheet and rill erosion) transporting mineral material downslope.

In the lower section of the landslide, next to the foot of its eastern side scarp (which is 15 m high) a depression of 60 × 40 m developed. It is situated in the outlet of the trough formed below the side scarp (Fig. 1A, D). Currently it is filled with organic and mineral sediments of the fen type peat bog (Fig. 1E) (Margielewski, 2006a). Its average depth is 4.50 m, but one of the boreholes drilled a small depression of 6.90 m deep (Fig. 2 — log. 1). The lowermost parts of the landslide colluvia are currently deforested and farmed (as pastures and fields) and partly occupied by buildings (Fig. 1C).

3. Materials and methods

Three logs cored in different parts of the peat bog were analysed (Fig. 2). The boreholes were drilled with the peat bit INSTORF (Russian peat sampler), 8 cm in diameter. The loss on ignition analyses at a temperature of 550 °C (Heiri et al., 2001) was carried out for each 2.5 cm long section of the logs. The loss of ignition curves was constructed for every log on the basis of these analyses (Fig. 2).

The organic sediments were identified by Dr. K. Lipka from the Agriculture University in Cracow, basing on the peat classification

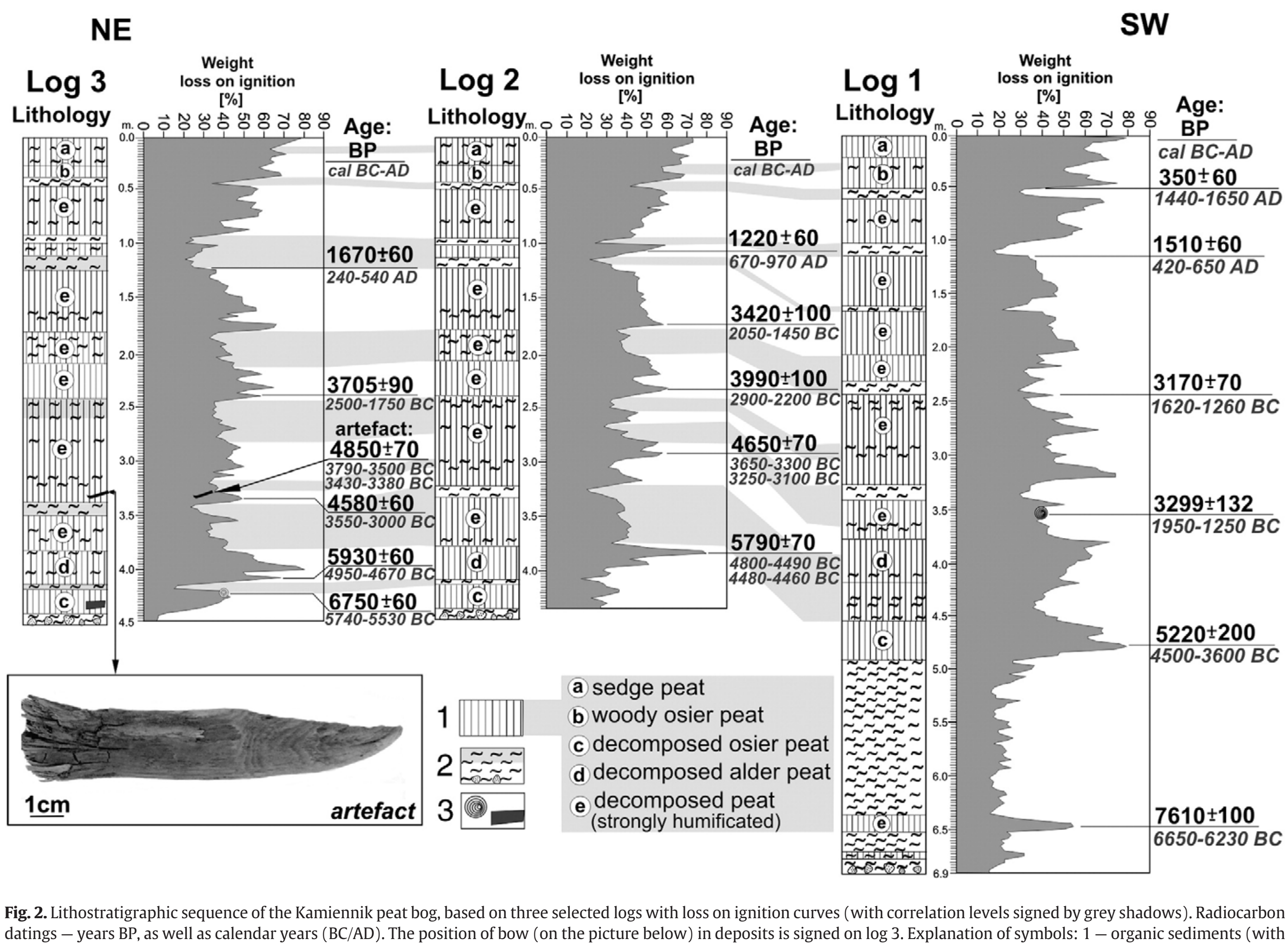

Fig. 2. Lithostratigraphic sequence of the Kamiennik peat bog, based on three selected logs with loss on ignition curves (with correlation levels signed by grey shadows). Radiocarbon datings — years BP, as well as calendar years (BC/AD). The position of bow (on the picture below) in deposits is signed on log 3. Explanation of symbols: 1 — organic sediments (with types of peat), 2 — mineral sediments, and 3 — tree trunk.

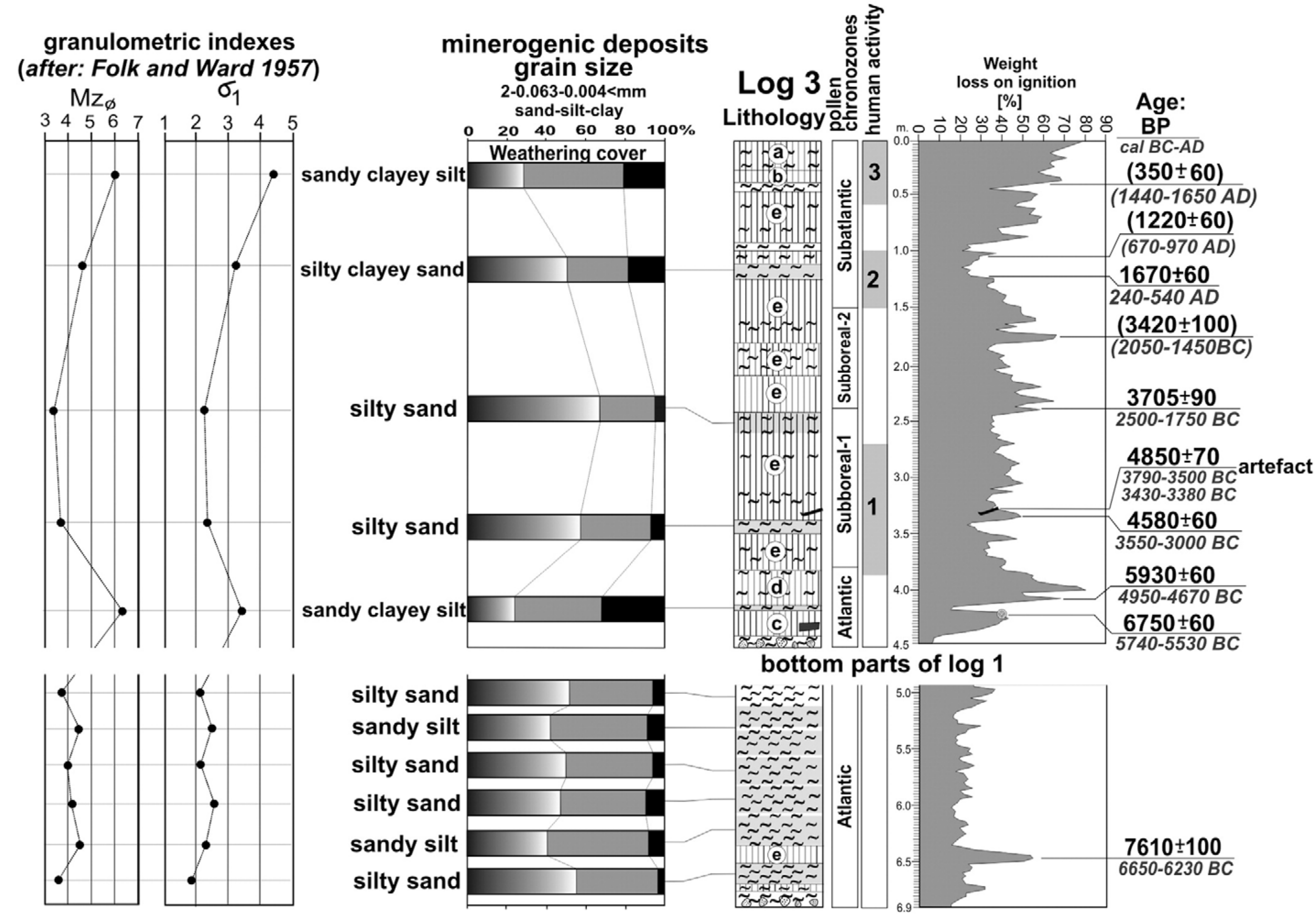

Fig. 3. Lithostratigraphic sequence of the Kamiennik peat bog, showing types and grain size composition (areometry) of minerogenic sediments, and loss on ignition curve of sediments. Granulometric indexes of minerogenic sediments after: Folk and Ward (1957). Age (BP and calendar years: BC/AD) exposed for the presented logs and for correlation horizons of other logs (in brackets). Pollen chronozones and stages of human activity according to pollen diagram (Fig. 4). Explanation of symbols — see Fig. 2.

according to Tołpa et al. (1971). The analyses of the peat were accompanied with the description of plant macroremains.

Mineral sediments occurring within the peat bog were described on the basis of the Bouyoucos–Casagrande aerometric analyses modified by Prószyński (Mycielska-Dowgiałło and Rutkowski, 1995). The identification of these sediments was conducted according to the Pettijohn classification (Pettijohn, 1975; Battaglia et al., 2002) using Wentworth's scale of the grain size (Wentworth, 1922). The granulometric indexes: mean grain size (Mz) and standard deviation (σ_1), were calculated for analysed mineral sediments (see Folk and Ward, 1957) (Fig. 3).

Conventional (BP) radiocarbon (^{14}C) datings reported in the article were carried out in the Radiocarbon Laboratory of the Ukrainian Academy of Sciences in Kiev (Ki-signature) and at the Radiocarbon Laboratory of the National Academy of Sciences of Belarus in Minsk (IGSB-signature). One AMS dating was made in the Poznań radiocarbon Laboratory in Poland (Poz-signature). The calibration of the radiocarbon datings (expressed as cal yr BC/AD time intervals with probability 95%) were made using the calibration data set of Stuiver et al. (1998), using OXCAL (version 3.9) computer program (Bronk Ramsey, 2001, 2003). Generally, within the described peat bog 18 radiocarbon datings were made, among which were two datings of the archaeological artefact (Table 1).

The comprehensive palynological analyses in 10 cm long intervals were made for one of the deepest log (Fig. 4). During the subsequent investigations, when the local depression was found within the bottom of the basin, supplementary palynological analyses of several samples taken from the lowermost part of the sediment sequence were made (Figs. 2 and 4). Totally, 42 samples of the sediments from logs of the Kamiennik site were submitted to the palynological analyses. These samples were prepared according to Erdtman's (1943) acetolysis procedure. The results of these analyses are presented as a percentage pollen diagram. The calculations are based on the sum AP + NAP including trees, shrubs and herbs, excluding spores and aquatic plant pollen. Sporangia of fern, fungi hyphae, *Pinus* stomata and charcoal particles were occasionally found during the palynological analyses.

Two samples of the recovered artefact were dated by radiocarbon, one of them using AMS method (Fig. 5A, B). The artefact was also submitted to the dendrological and dendrochronological analyses in the Dendrochronological Laboratory of the AGH University of Science and Technology in Cracow. The measuring equipment DendroLab 1.0 was used for tree-ring measurement (with 0.01 mm accuracy). The taxonomic analysis of wood was conducted on the basis of macroscopic and microscopic photographs taken in the scanning microscope (type: FEI Quanta 200 FEG) in the laboratory of the AGH University of Science and Technology in Cracow.

4. The landslide peat bog sedimentary records

The organic sediments filling the peat bog basin are characterised by an advanced stage of humification (mainly decomposed peat), as well as a significant participation of mineral material, which occasionally forms mineral inserts within the peat sequence (Fig. 2).

Table 1
Radiocarbon datings of the Kamiennik peat bog, calibration using OxCal v. 3.9 (Bronk Ramsey, 2003) on the basis of Stuiver et al., 1998, calibration curve.

Depth [cm]	Material	Lab. code	Age ^{14}C (yrs BP)	Calendar age 2σ (cal yr BC–AD)	Context of datings
Log 1					
49–50	Wood	Ki-11711	350 ± 60	1440–1650 AD	Mineral horizon deposition
114–120	Peat, wood	Ki-11841	1510 ± 60	420–650 AD	Mineral horizon deposition
244–246	Peat	Ki-11842	3170 ± 70	1620–1260 BC	Series of mineral horizons deposition
350–360	Tree trunk	IGSB-1033	3299 ± 132	1950–1250 BC	Mineral horizon deposition
468–480	Peat	IGSB-1088	5220 ± 200	4500–3600 BC	Start of mineral horizon deposition
640–647	Peat	Ki-13852	7610 ± 100	6650–6230 BC	Start of peat level accumulation
Log 2					
107–113	Wood fragment	Ki-11138	1220 ± 60	670–970 AD	Peat between two minerogenic horizons
170–178	Peat with wood	Ki-11712	3420 ± 100	2050–1450 BC	End of mineral horizon deposition
230–237	Peat with wood	Ki-11716	3990 ± 100	2900–2200 BC	Mineral horizon deposition
282–290	Peat with wood	Ki-11843	4650 ± 70	3650–3300 BC 3250–3100 BC	Start of mineral horizon deposition
383–387	Wood fragment	Ki-11139	5790 ± 70	4800–4490 BC 4480–4460 BC	First maximum of peat accumulation
Log 3					
120–122	Peat with wood	Ki-10807	1670 ± 60	240–540 AD	Thick mineral horizon deposition
235–245	Peat with wood	Ki-11713	3705 ± 90	2500–1750 BC	End of mineral horizon deposition
330	Yew artefact	Ki-11525	4850 ± 70	3790–3500 BC 3430–3380 BC	Archaeological artefact yew bow
330	Yew artefact	Poz-21566	4830 ± 30	3700–3680 BC 3670–3620 BC 3600–3520 BC	Archaeological artefact yew bow; AMS date (second dating)
330–340	Peat with wood	Ki-10897	4580 ± 60	3550–3000 BC	Series of mineral horizon deposition
408–410	Bark, Peat	Ki-10898	5930 ± 60	4950–4670 BC	Start of peat accumulation
423–431	Tree trunk	Ki-10146	6750 ± 60	5740–5530 BC	Formation of landslide depression

Ki — Kiev Radiocarbon Laboratory (Ukraine).
IGSB — Minsk Radiocarbon Laboratory (Belarus).
Poz — Poznań Radiocarbon Laboratory (Poland) (AMS date).

In the deepest part (small depression) of the peat basin, in the interval 6.90–5.00 m the mineral–organic sediment was deposited: silty sand (Mz: 3.6–4.5 φ), poorly and very poorly sorted (σ_1: 2–2.5) (Fig. 3). The thin horizon of peat, occurring in the lower part of this mineral unit was dated at 7610 ± 100 BP (6650–6230 cal BC). It is the oldest radiocarbon date measured in this peat bog (Fig. 2 — log 1).

In the main log (Fig. 2 — log 3) above the bottom mineral sediments, in the interval 4.40–3.50 m massive peat occurs (in places recognised as humificated osier and alder peat). It is composed mainly of the wood and bark of *Alnus glutinosa* and *Salix* sp. with small admixture of the sedge *Carex* sp. and moss *Bryales* sp. Directly above the floor, within the decomposed osier peat a tree trunk, 10 cm in diameter, was drilled. It was dated with radiocarbon at 6750 ± 60 BP (5740–5530 cal BC) (Fig. 2 — log 3). The horizon bearing the trunk is overlain with the thin layer of minerogenic sediment, defined as sandy clayey silt (Mz: 6.3 φ) very poorly sorted (σ_1: 3.3), similar to the weathering covers occurring in the landslide areas (Fig. 3). The thin horizon of the decomposed alder peat (ranging 80% loss on ignition), occurring above this layer, was dated at 5930 ± 60 BP (4950–4670 cal BC) in this log and at 5790 ± 70 BP (4800–4490 and 4480–4460 cal BC) in the neighbouring log (Fig. 2). Upwards, the peat gets more decomposed and contaminated with mineral material. The peat unit is overlain with a mineral layer, 10 cm thick. The layer comprises silty sand with the significant participation of sand grains (Mz: 3.8 φ) (Fig. 3). Above the mineral layer a massive peat horizon occurs. Its bottom was dated at 4580 ± 60 BP (3550–3000 cal BC) (in the neighbouring log the date is very similar: 4650 ± 70 BP, that its 3650–3300 and 3250–3100 cal BC). Within this massive peat, at the depth of 3.30 m, the archaeological artefact was found — a fragment of a bow made of yew tree and dated at 4850 ± 70 BP (3790–3500 and 3430–3380 cal BC) (Ki-11525) (Fig. 2, photo). Additionally, the youngest tree-ring of the artefact's wood was dated using radiocarbon AMS method. The result, 4830 ± 30 BP (3700–3680, 3670–3620, 3600–3520 cal BC) (Poz-21566), indicates that the dates are identical within the error limits. Moreover, the dates are analogous to the dates carried out of the organic sediment occurring in the same level. Their significance is confirmed also by the palynological analysis, suggesting the early Subboreal as the period of its accumulation (Figs. 2 and 4). Thus, the fragment of bow was undoubtedly recovered from an *in situ* location.

Above the peat unit bearing the artefact, in the interval 3.30–1.60 m, a unit of massive peat with the remnants of *A. glutinosa*, *Salix* sp., *Carex* sp., *Scirpus caespitosus* and *Scirpus* sp., *Equisetum* sp., *Bryales* sp. occurs. Within this unit two inserts of the mineral material occur (recorded as drops of loss on ignition curve). Silty sand layer at the depth of 2.60–2.40 m, represents high-energetic sediment, very poorly sorted (σ_1: 2.3) with high content of sand fraction (Mz: 3.4 φ). Its top was dated at 3705 ± 90 BP (2500–1750 cal BC) and 3990 ± 100 BP (2900–2200 cal BC), which indicate the Subboreal Phase as the time of the deposition of this sediments (Figs. 2 and 3).

From the depth of 1.60 m (horizon dated at 3420 ± 100 BP), within the highly decomposed wood peat bearing macroremains of *Scirpus* sp. and *Bryales* sp., the successively increased delivery of the mineral material is observed. This tendency is finalised with the deposition of mineral horizon at the depth of 1.30–0.90 m, formed of silty clayey sand (Mz: 4.6 φ) and very poorly sorted (σ1: 3.2). This mineral horizon represents undoubtedly the Subatlantic Phase, because it was dated with radiocarbon in various logs at 1670 ± 60 BP (240–540 cal AD), 1220 ± 60 BP (670–970 cal AD) and 1510 ± 60 BP (420–650 cal AD) (Figs. 2 and 3).

The uppermost unit of the massive peat (0.90–0.40 m) is overlain by a thin (5 cm) layer of mineral sediment, above which the osier peat (with the predomination of *Salix* sp. and *A. glutinosa* wood) and sedge peat (with the predomination of *Carex* sp. and small participation of *Phragmites communis* and *Bryales* sp.) occur.

5. Analysis of the yew bow artefact

The artefact is the one-sidedly sharpened fragment of the wood stick, ca 10 cm long, oval in the transversal cross-section, 16–20 mm in diameter (Fig. 5A, B). The macro- and microscopic analyses of its surface excluded the connection of its shape with animal (e.g. beavers) activity. Its anthropogenic origin is unequivocally confirmed by the

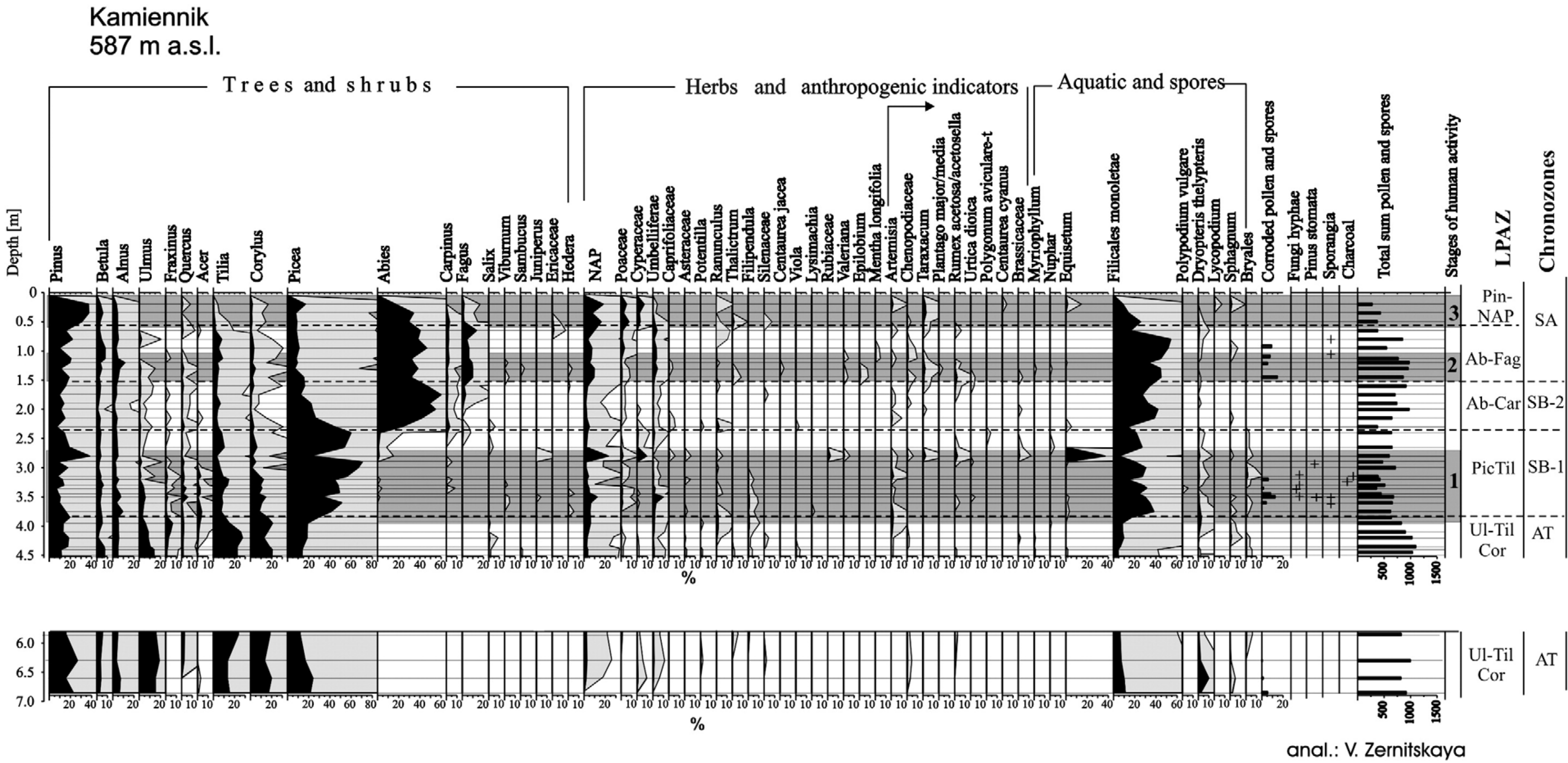

Fig. 4. Percentage pollen diagram of the Kamiennik peat bog sequence (log 3 — see Fig. 2) supplemented (below) by pollen analysis of the bottom part of the deepest log (log 1 — Fig. 2). Explanation of symbols — see Fig. 2.

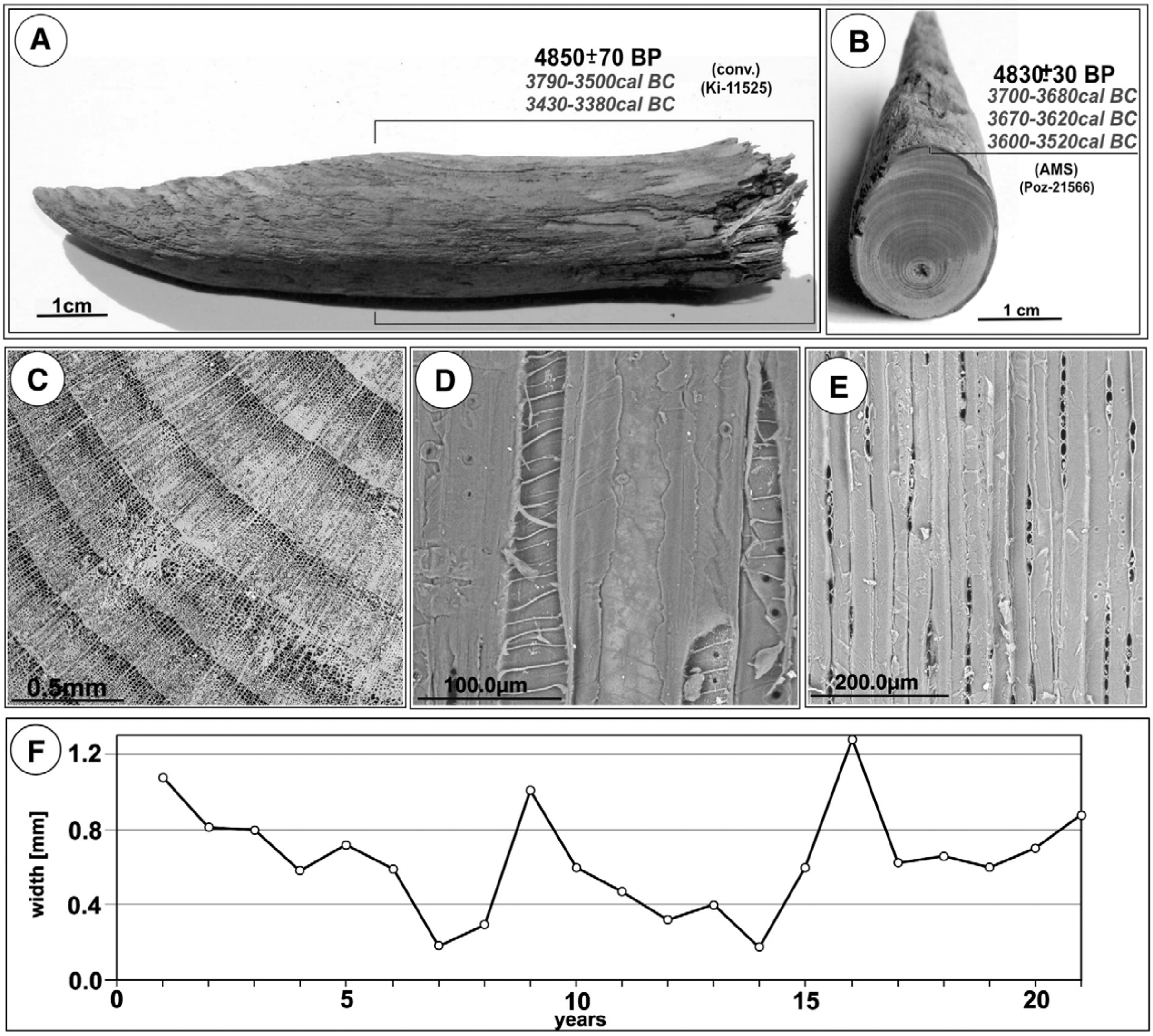

Fig. 5. Dendrological analysis of the yew bow fragment found in the Kamiennik peat bog (log 3 — Fig. 2). A — macroscopic photograph of the bow fragment with the section sampled for the conventional radiocarbon dating; B — cross-section of the bow with the segment sampled for AMS radiocarbon dating; C–E — scanning microscopic photographs of the bow cross-sections: C — transversal, D — ray, E — tangential; F — dendrochronological curve of the yew bow.

precision of shaping as well as deconcentric core position of the wooden stick well visible on the cross-section (Fig. 5B). Small and shallow incisions visible in the longitudinal profile of the sharpened part of the stick could be related to string's fastening.

5.1. Microscopic analysis

The artefact was made of the narrow ring wood originated from the heartwood part of the trunk. In order to assess the taxonomic designation of the wood, its anatomic structure of the tree, perpendicular to each other cross-sections were analysed using the scanning microscope. On the transversal cross-section distinct annual growth rings of slightly wavy shape were observed. The transition from the early to the late wood is gradual. The thick-wall tracheids are found both in the early and late wood (Fig. 5C).

On the longitudinal and transversal cross-sections the spiral thickenings on the tracheid walls are clearly visible (Fig. 5D). The wood rays are one-row and homogenous, formed mainly of the parenchyma. Their height ranges from 5 to 10 cells (Fig. 5E). The rays are without tracheids. The pits are cupressoid. These features unequivocally indicate that the analysed wood fragment represents *Taxus* genus, most probably the *Taxus baccata*, which has been the only species of yew occurring in this region.

5.2. Dendrochronology

The dendrochronological measurements evidenced 23 annual growth rings in the analysed artefact. The mean width of the rings is 0.645 mm, whereas the ring width varies from 0.17 mm to 1.08 mm (Fig. 5F). These values are similar to the currently growing yew trees in Poland (Cedro and Iszkuło, 2008). The extremely narrow rings visible on the dendrogram, were probably caused by the low temperature in the winter seasons (December–March), which was identified as the predominating factor controlling the activity of the yew cambium growing in the area of Poland and, supposedly, Central Europe. In turn, the formation of wide rings, apart from the thermal conditions in winter, could have been stimulated by more frequent or heavier rainfalls during summer, mainly in June and July (Cedro, 2005). Taking into account the above formulated remarks, it can be supposed, that the yew tree of the artefact grew in the area, in which cold winters but also warm winters and humid summers happened each several or more years.

6. Reconstruction of the palaeoenvironmental changes in the Kamiennik site

Kamiennik site represents characteristic small peat bog. In the small basins situated within the densely forested areas, the local pollen components are definitely predominant (Tauber, 1967, 1977). Such location of the peat bog enables the detailed determination of the floristic changes in the close neighbourhood of the basin, caused e.g. by the local human impact, which could have generated also the lithological changes in the sequence of the peat-bog sediments.

6.1. Vegetation history

The pollen diagram is divided into the Local Pollen Assemblage Zones (LPAZ) on the basis of the visual analysis of individual pollen curves (Fig. 4). The subdivision of the Holocene sediments is based on the climatic–stratigraphic scale proposed by L. Starkel (1977, with later changes: Starkel, 1999). The method of recognition of human activity using the pollen indicators was applied after Behre (1981) and Ralska-Jasiewiczowa (1982).

6.1.1. LPAZ Ulmus–Tilia–Corylus (depth: 6.90–3.80 m)

According to the pollen diagram interpretation and radiocarbon dates, the sediments in the interval 6.90–3.80 m were accumulated in the second part of the Atlantic Chronozone, between 6700–4800 BP. The watering of the depression was connected with the increase in the climatic humidity. The occurrence of aquatic plants pollen (*Myriophyllum* and *Nuphar*) suggests that the depth of the lake filling the basin was not less than 3 m. The neighbouring area was covered by a mixed, deciduous–coniferous forest composed of *Ulmus*, *Tilia*, *Picea* with the admixture of *Fraxinus*, *Acer* and *Corylus* growing on wet ground. Dry patches of ground were covered by pine-oak forest.

6.1.2. LPAZ Picea–Tilia (depth: 3.80–2.35 m)

At the beginning of the Subboreal Phase (ca 4800–4200 BP) the participation of *Quercetum mixtum* in the deciduous–coniferous forest started to decrease. The spruce trees (*Picea*) predominated in this forest, whereas the deciduous trees were represented mainly by *Tilia*, *Quercus* and *Corylus*. According to the pollen maps of *Picea abies* (Obidowicz et al., 2004a) the maximum predomination of the spruce trees in the studied region took place between 5000 and 4000 BP. At that time, due to the early Subboreal climate cooling and moistening, the extension of *P. abies* in the lower forest belt in the Carpathians was recorded (Gil et al., 1974; Starkel, 1995).

In the lower layer of the forest, shrubs *Viburnum* occurred. The fern was growing within the undergrowth of the spruce and mixed forests and on the wet (boggy) sites of the depressions together with the moss (*Bryales*). At the depth of 3.60–3.48 m the fern sporangia was also found. The findings of *Pinus* stomata (3.48 and 3.35 m) indicate that pine grew near this place, too. The open areas were covered by light-demanding herbaceous plants, such as Umbelliferae, Poaceae, Asteraceae, *Filipendula*, Ranunculaceae.

At the depth of 3.80–2.60 m, the first traces of human activity are evidenced. It is proved by the appearance of the ruderal plants: *Rumex acetosa/acetosella*, *Urtica*, *Taraxacum*, *Artemisia*, Chenopodiaceae, Brassicaceae, which usually grow along paths (in trodden sites), in the vicinity of human settlements. The small charcoal particles occurring at the depth of 3.35 m, could be related to the local forest fire, generated by human activity. The presence of the corroded microfossils and fungi hyphae (redeposited with other macroremains to the basin by erosive processes) suggests the oxidation of the material and formation of soils (Andersen, 1986), probably within the flat area situated above the peat bog (Fig. 1A). The existence of man in this area and during this period is also obviously confirmed by the yew bow found at the depth of 3.30 m. Lack of *T. baccata* pollen in these sediments proves that the artefact was a matter of import.

A very distinct stage of deforestation was recorded at the depth of ca 2.70 m, where the considerable drop of the pollen curves of trees and the raise of the curves of herbs (Cyperaceae, Rubiaceae, *Valeriana*, *Equisetum* and ruderal plants) are observed. In this horizon (2.80–2.60 m) increased percentage of pine trees and juniper shrubs is also noticed.

6.1.3. LPAZ Abies–Carpinus (depth: 2.35–1.50 m)

In the late Subboreal chronozone the studied area was covered by the fir (*Abies*) forest with pine and spruce trees The maximum of the predomination of the fir trees in the forest composition fall on the period 3500–2500 BP (Obidowicz et al., 2004b). The other components of this forest were as follows: *Carpinus*, *Tilia*, *Quercus* and *Fagus*. In the treeless areas the fern prevailed, while the ruderal plants occurred occasionally.

6.1.4. LPAZ Abies–Fagus (depth: 1.50–0.50 m)

In the early Subatlantic Chronozone, the character of the forest communities did not considerably change, but within the tree assemblage the amount of beech (*Fagus*) and hornbeam (*Carpinus*) increased. Such a forest was probably growing during 2100–1000 BP, because the maximum participation of these trees in forest structure was noticed at about 1500 BP (Latałowa et al., 2004; Ralska-Jasiewiczowa et al., 2004). More humid conditions were marked by an increase in the amount of the alder (*Alnus*), hazel (*Corylus*) trees and of the appearance of the aquatic plants (*Myriophyllum* and *Nuphar*). At the beginning of this phase (at the depth of 1.50–1.10 m) the second stage of human impact is recorded with open areas occupied by herbaceous plants representing the Umbelliferae family, *Thalictrum* and *Centaurea jacea* are noticed. The increase in the participation of *Rumex acetosa/acetosella*, *Urtica*, *Taraxacum*, Chenopodiaceae indicates the expansion of ruderal habitats and pastures. The presence of corroded pollen and spores can be related to accelerated erosive processes. The stage of deforestation is marked by an increase in the amount of birch trees and shrubs recorded at the depth of 1.25–0.90 m. The appearance of sporangia in the interval 1.00–0.55 m indicates that the fern was growing in the vicinity of the peat bog.

6.1.5. LPAZ NAP–Pinus (depth: 0.50–0.00 m)

During the youngest stage of the Subatlantic Phase (ca 1000 BP–present day) a significant change of vegetation was noticed. The pine-woods with the admixture of fir, spruce, birch and alder (the latter on the wet ground) have predominated in this area. The open areas have been the grasslands overgrown by Cyperaceae, Poaceae, *Ranunculus*, *Taraxacum*, which are indicators of pasturelands. The content of the ruderal and cultivated plants (weeds) in the pollen diagram is not high enough, so as to state significant increase of human impact. Therefore, the changes of the vegetation reflect rather the climate cooling than the anthropogenic influence (Fig. 4).

6.2. Depositional responses to the palaeoenvironmental changes

The analysis of the loss on ignition curves of all logs of the Kamiennik site indicates that the deposition in this peat bog was characterised by the periodical delivery of mineral material to the basin during periods of climate moistening, which are also identified by the pollen analysis and defined in the time scale by radiocarbon datings (Figs. 2 and 4). These phenomena are shown on the loss of ignition curves in the form of long regressions (curve deepenings). They reflect the long-lasting and gradual increasing of the mineral material delivery to the basin (due to the continuous slopewash, surface run-off or a linear erosion), formation of the thick illuvial horizon within peat and, finally, deposition of the minerogenic layer during the maximum of the humid climate phase (phase of frequent downpours or continuous rains) (Figs. 2 and 3). Human activity (forest burnout, cultivation) usually accelerated these processes.

The first gradual increasing of the delivery of the mineral material to the peat bog, finalised with the mineral horizon (silty sand) at the depth of 3.50–3.40 m, was apparently connected with the distinct moistening of climate at the beginning of the Subboreal Phase (see e.g. Starkel, 1995; Magny, 2004). It is related to the sequence between the horizons dated at 5.9–4.5 ka BP (log 3) and 5.7–4.6 ka BP (log. 2 — Fig. 2). The local increase of the concentration of pollen of plants preferring open habitats (*Rumex* sp., Poaceae, occasionally Cyperaceae), occurring next to this horizon, indicates deforestation of anthropogenic origin, which can be interpreted as forest damages connected with seasonal grazing activity (Valde-Nowak, 1995b).

Both the palynological analysis and the artefact (yew bow) occurring in this part of the sequence, dated at ca 4.8 ka BP (3790–3500 and 3430–3380 cal BC) indicate, that at the beginning of the Subboreal Phase the area of the landslide, with flat areas and a lake, was penetrated by the Neolithic man. The (landslide) lake, as a watering place for wild animals, was a convenient area for hunting. The pollen analysis shows, that the colonisation, dated back to the beginning of the Subboreal Phase, was prolonged (being recorded during whole the early Subboreal) and was characterised by various intensities (Fig. 4). The intensification of the landslide flat usage is marked in the pollen diagram above the depth of ca 3.0 m (slightly above the artefact). The distinct, local drop of tree pollen is accompanied by the acute increase of pollen of plants preferring open habitats (Poaceae, Cyperaceae, Rubiaceae, Brassicaeace, *Taraxacum*, *Rumex* and *Juniperus*), as well as the appearance of *Urtica dioica* — typical synantropic species (Fig. 4). The high-energetic mineral sediment (silty sand with high participation of sand fraction), occurring slightly below this horizon contains charcoal particles. Its delivery to the basin was related both to climatic factors (strong climate moistening at the beginning of the Subboreal) and human activity, causing accelerated soil erosion, in connection with forest burnout, pasturing, possibly cultivation conducted probably in flattened landslide body area above peat bog (Fig. 1A). The beginning of this extremely intense period of the deforestation was in different logs dated at 3550–3000, 3650–3300 and 3250–3100 cal BC and was practically contemporaneous with the artefact (Table 1). Such a strongly marked episode of the deforestation of landslide flat areas was most probably connected with the colonisation of the Funnel Beaker Culture (4000–2800 BC), which represented an agricultural society commonly applying burnout deforestation for cultivation (e.g. in the areas of the loess uplands of the Małopolska region — *vide* Kruk and Milisauskas, 1999). Lack of ceramic artefacts does not enable unequivocal definition of the culture, nevertheless, the radiocarbon datings of the artefact and of deforestation horizons, indirectly indicate this culture.

Within the Kamiennik peat bog, the section referred to the early Subboreal Phase consists of two cycles, reflected on the loss of ignition curves and related to the delivery of the mineral material in the initial and final phases of the SB1 chronozone, separated by the less contaminated peat in the middle part (Fig. 3). The climate moistening, inducing the delivery of high-energetic allochtonous material to the basin, is confirmed by the appearance of aquatic plant pollen (*Nuphar*) (Fig. 4). It is symptomatic, that the beginning of the oldest period of human activity, identified on the pollen diagram coexisted with the climatic moistening at the beginning of the Subboreal Phase. It may confirm the common migration of human groups from valleys (fertile but often flooded during this climate moistening) to higher and drier mountain slopes as was also observed in other sites (Kozłowski and Kaczanowski, 1998).

Upper, drier section of the Subboreal Phase (SB2) commenced in the sequence (at the depth of 2.40 m) with the accumulation of less contaminated peat, indicating the stability of climate at this time (dated at 2500–1750 cal BC in log 3 and 2900–2200 cal BC in log 2 — Fig. 2). It is interesting, that this climate drying was accompanied with the decrease of indicators of human activity, which then appeared again at the beginning of the Subatlantic Phase, as a consequence of particularly intensive burnout deforestation in the area of the landslide (Fig. 3). The next, very intensive climate moistening occurring at the beginning of the Subatlantic (e.g. Starkel, 1998, 2002; Magny, 2004) is reflected in the sequence by significant delivery of the mineral material represented by the silty clayey sand horizon at the depth ca 1.20 m, dated at 240–540 cal AD and 420–650 cal AD. The occurrence of aquatic plants pollen (*Myriophyllum* and *Nuphar*) indicates the existence of a permanent lake in the basin during this period. The radiocarbon datings unequivocally indicate the connection of this mineral horizon with the early Subatlantic climate moistening, recorded e.g. in the upper Vistula River valley at AD 425–625, as extremely intensive floods (Starkel et al., 1996; Krąpiec, 1998). The intensive floods in the valleys of the Carpathian rivers forced the next phase of human migration (Przeworsk Culture, ca 200 BC–AD 450) and colonisation of the upper, drier parts of mountain slopes (Madyda-Legutko, 1996). The next disappearance of the indicators of human activity on the pollen diagram (above the dates: 240–540 cal AD and 420–650 cal AD) is contemporaneous with the Migration Period (AD 375–550), during which a significant depopulation took place (Godłowski and Kozłowski, 1979; Madyda-Legutko, 1996).

The uppermost mineral and illuvial horizons in the sequence, dated at 350 ± 60 BP (1440–1650 cal AD), were probably connected with the climate variation during the Little Ice Age, whereas human activity (the third horizon of human activity on the pollen diagram) was correlated with the modern colonisation of the Carpathians (Godłowski and Kozłowski, 1979). Also currently the flats of the Kamiennik landslide are intensively exploited for farming (Fig. 1C).

7. Archaeological significance of the yew bow

7.1. Kamiennik site in a light of prehistoric settlements spread in the Carpathians

Landslide areas are considered to be undoubtedly inconvenient for the economic activity (e.g. Alexander, 1984; Kotarba, 1989; Brunsden, 1995; Borgatti and Soldati, 2005). However, the areas of stabilised landslides, abounding with flat surfaces, water and fertile soils, have been the appropriate places for human settlements since the prehistoric time (Margielewski, 2000, 2006a). Their occurrence in the higher parts of the mountains could have been profitable for the colonisation, regarding frequent, repeated floods in the valleys, intensified during the periods of climate moistening in the Holocene, as well as cold zones in the valleys, inconvenient for the agriculture (Godłowski and Kozłowski, 1979; Madyda-Legutko, 1996; Valde-Nowak, 2001). The intensification of the archaeological investigations in Polish Carpathians for the last thirty years apparently confirms frequent location of settlements of various cultures in the uppermost areas of the Carpathians. It concerns both the sites of various Neolithic cultures (Valde-Nowak, 2001) and colonisation of the later prehistoric periods, as e.g. Roman Period (Tunia, 1977; Madyda-Legutko, 1996).

The spreading of the Neolithic settlements in the Carpathians was connected with the significant social–economic changes, which took place about 3 ka BC in the area of Southern Poland. Significant intensification of agriculture, including burnout farming system, applied by the Funnel Beaker Culture and combined with advanced breeding, brought about specific ecological and economical crisis spread over the densely populated fertile loess uplands of Małopolska region (Kruk, 1993; Machnik, 1994; Kruk and Milisauskas, 1999, Kadrow, 2001). This phenomenon forced the migration of Neolithic settlements, which spread also in the Carpathians, that were earlier scarcely populated. The Raba and Skawa river valleys were the natural ways of the migration towards the central part of the Carpathians (*vide* map on Fig. 1) (Machnik, 1960). This is why the sites of the permanent settlement of the Funnel Beaker Culture (or slightly younger Baden Culture) are situated not more than 20 km far from the Kamiennik site, in the outlet of the Raba river valley of the Carpathians (e.g. Książnice and Jawczyce sites — *vide* map on Fig. 1) (Zoll-Adamikowa and Niżnik, 1963; Sochacki, 1971). But the area of the Kamiennik site and its vicinity are hardly recognised by archaeologists. On this area a relatively small number of archaeological artefacts were found, especially related to older settlement. This is connected with the difficulties of the archaeological prospection in the upper parts of mountains, above the cultivated fields, where the possibilities of discovering archaeological site are very restricted. Therefore the incidental findings of scattered artefacts are of basic importance for the progress of archaeological investigations. The artefacts are represented by findings of stone axes having features typical for the Neolithic cultures in Poznachowice, Szczyrzyc, Słupia and Kojszówka, which evidence the penetration of the Kamiennik surroundings by people of the Funnel Beaker Culture (*vide* map on Fig. 1) (Valde-Nowak, 1988). The stone axes referred to the Corded Ware Culture (the late Neolithic successor of the Funnel Beaker Culture), are found in a small number of sites located in the proximity of the Kamiennik site, as Lubień, Skomielna Czarna, Zawoja (Fig. 1) (Machnik, 1960). During the archaeological excavation at the prominent archaeological Mucharz site on Skawa river (*vide* map on Fig. 1) single artefacts made of Jurassic flint, indicative of the Funnel Beaker Culture or Baden Culture were found (Valde-Nowak and Tarasiński, 2007). But lack of the cultural layer connected with the artefacts at this site and lack of ceramics, indicates unstable settlements, significantly differing from the agricultural colonisation of the Funnel Beaker Culture in the areas of the Małopolska Upland (Kruk and Milisauskas, 1999). Remarkable up till now, the general lack of ceramic artefacts, commonly considered as explicit indicators of permanent settlement, theoretically suggests the occurrence of only movable settlement, connected with nomadic groups (*vide* Valde-Nowak, 1995b). So, it is difficult to state whether during the development of the Funnel Beaker Culture in the Carpathians the pasturing activity, as e.g. summer mountain grazing on the forested areas (being the element of so called forest management) took place, or the incidental findings indicate other forms of activity, for example hunting. In this aspect, the Kamiennik site is of significant importance for the archaeological research, not only regarding the unique artefact found there, but also regarding the paleoenvironmental impact of the colonisation, reconstructed on the basis of analysis of the depositional sequence of the landslide peat bog.

The fragment of bow, found in the Kamiennik peat bog undoubtedly confirms the hunting activity of the Neolithic man in this area. However, the palynological and lithological analyses of the sediments unequivocally indicate that the hunting was not only one form of human activity in this time on this area. The pollen diagram confirms continuous, prolonged stay of the Neolithic man on this area, as well as human migrations in the subsequent prehistoric periods (Fig. 4). The burnout deforestation, marked in the pollen associations and sediments, indicates the intensive economic activity of man, although the lack of pollen of cultivated plants can arise doubts concerning the intensification of plant farming activity. However, it is difficult to postulate that work-consuming burnout deforestation could have produced only the pastureland. Similar growing activity of man in this phase of the settlement is unequivocally confirmed on the colluvial flats of the Mirkowo landslide, only 7 km west of the Kamiennik site (Fig. 1 — site 6 on the map) (Margielewski, 2006a). Apart from many human indicators (similar to the Kamiennik site), in the depositional sequence of this peat bog, the cereals' pollen (*Cerealia*) occurs in the horizon older than 3550 cal BC, thus contemporary with the colonisation of the Funnel Beaker Culture.

The results of study of the Kamiennik site indicate, that the flat areas of old, stabilised landslides, convenient for settlement for various reasons, offer great perspectives for archaeological prospections. The interdisciplinary palaeoenvironmental analyses are very helpful in these studies and contribute to the progress of the knowledge on the distribution of the older prehistoric cultures in the Carpathians.

7.2. Artefact from the Kamiennik site and its archaeological context in the European area

The artefact found at the Kamiennik landslide peat bog is distinctly sharpened. Its sharp endpoint is asymmetric in relation to the centre of its transversal cross-section (Fig. 5A–B). Similarly, the core of the wooden stick, forming the object, is situated out of its centre. These features confirm the anthropogenic nature of the object, while the material used (yew wood), the oval transversal cross-section and the typical shape of the endpoint can be unequivocally associated with a bow. The other interpretative possibility could be to regard the object as the head part of a fishing spear. This idea could be confirmed by the shape and oval transversal cross-section, referred to the Mesolithic findings in the peat bog site Vis I near Arkhangelsk (Russia — site 10 on Fig. 6) (Burov, 1990, 1998). But this interpretation is excluded by the use of yew wood, that is characterised by high flexibility, which is unprofitable as a thrown weapon. It is also characteristic, that all Neolithic bows found in Europe till now, were made of yew wood, whereas the Mesolithic bows were made of different kinds of wood, usually of elm (e.g. Andersen, 1985) but pine is also confirmed (e.g. Burov, 1998) (Fig. 6). The Neolithic yew bow was found with the so-called "Man from Similaun" (famous Ötzi), recovered in the upper part of the Ötzal valley in the Ötzal Alps near the boundary between Austria and Italy (Fig. 6 — site 2). It was dated by radiocarbon (Egg and Spindler, 1993) similarly to the artefact from the Kamiennik site. The other evidence of the preference of yew wood as the material for bow production were bows found in Bad Buchau in the Upper Swabia in Germany (Heumüller et al., 1998), in Schnidejoch in the Bernese Alps in Switzerland (Grosjean et al., 2007), and in Meare Heath in the Great Britain (Clark, 1963) (Fig. 6). Also one of the two bows found in Thayngen "Weier" in Schaffhausen Canton (near the Switzerland–Germany boundary) in the younger Neolithe layer, accounted to the Pfyn Culture was made of yew wood (Guyan, 1990) (Fig. 6). The important feature is that both the bows from Thayngen are similar in shape to the artefact found in Kamiennik: their transversal cross-sections are oval and the end parts are characterised by a typical narrowing. Also other features, like the diameter of both the bows corresponds to the bow fragment from Kamiennik site.

The objects made of organic materials have a specific meaning among the archaeological artefacts, reconstructed usually on the basis of the ceramics and stone tools, thus artefacts made of the materials resistant for the destruction. Among the wooden artefacts found in the accurately conserved relicts of the Stone Age, the bows are the most valuable. Although the relatively small number of specimens of this weapon that have been found, the common use of them in the late Paleolithic, Mesolithic and late Neolithic Ages, as well as at the beginning of the Bronze Age is evidenced by commonly found flint arrowheads, and even the rock (cave) paintings dated at the Neolithic Age, found e.g. in Cueva de la Arana cave (Heumüller et al., 1998) and Abrigo I del Barranco de las Letras (Rast, 1990) on the Iberian Peninsula.

The number of the findings illustrating the early archery production has increased; apart from the Mesolithic and Neolithic bows, the whole arrows and even quivers have been found. The mentioned Neolithic sites in Thayngen and Schnidejoch, which are very valuable due to the findings of arrows with lithic arrowheads, are the examples illustrating this progress of knowledge (Guyan, 1990; Grosjean et al., 2007). It should be emphasised that these arrows are made of the viburnum branch (*Viburnum* sp.), so the shrub used for arrows' production by Indians of the Huron Tribe (Guyan, 1990), and which occurrence in the Kamiennik landslide was confirmed by the palynological analysis (Fig. 4). This analysis did not show the occurrence of the yew tree in the proximity of the Kamiennik landslide, suggesting that the bow was made of the tree growing away from the study

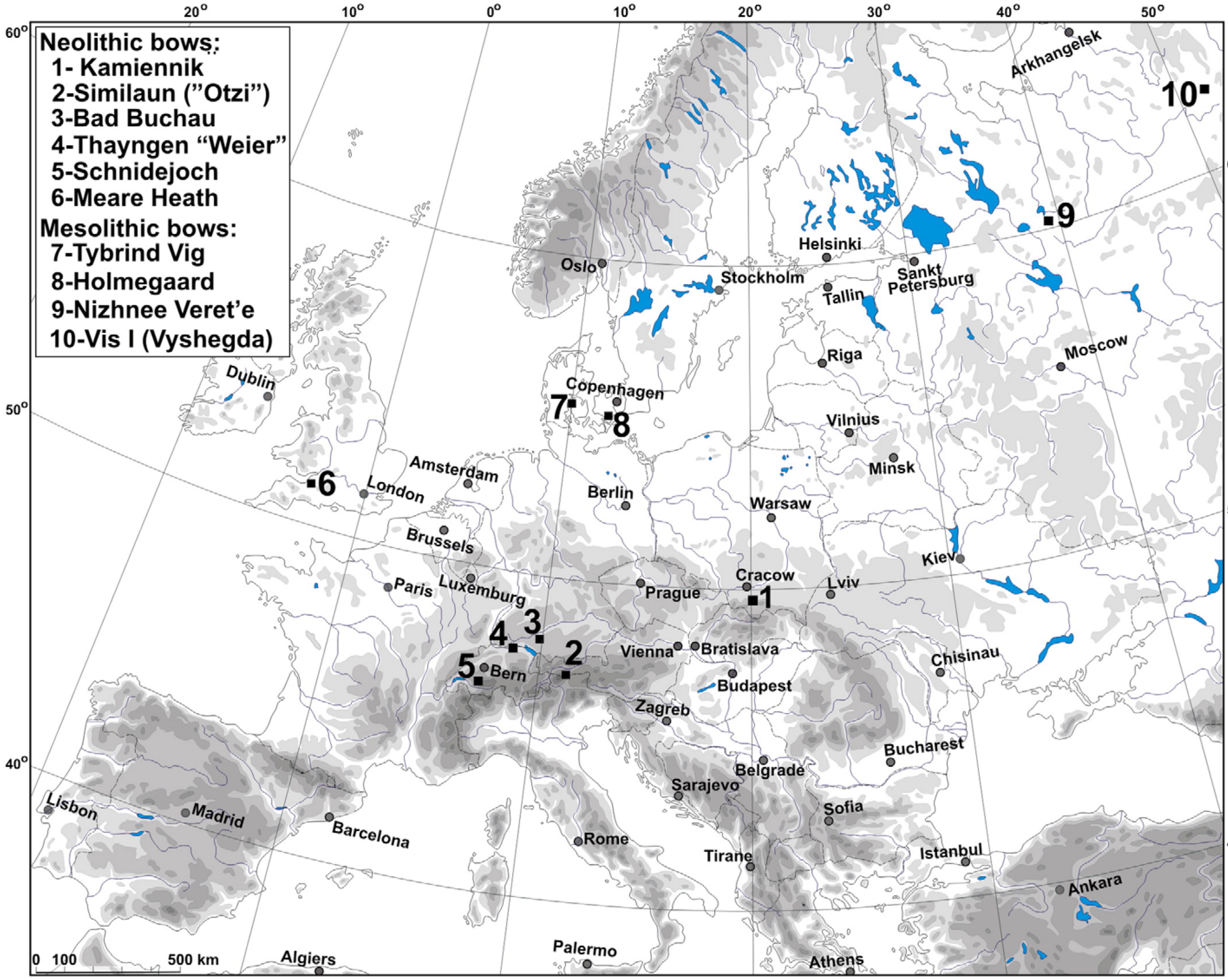

Fig. 6. Map of the distribution of the archaeological sites of yew bow findings in Europe (Mesolithic and Neolithic), mentioned in the text, including the Kamiennik site (site 1).

area. Thus the yew stick was brought to the site in the form of a finished tool.

8. Conclusions

The fragment of bow found within the sediments of the Kamiennik landslide peat bog is an unique artefact, one of the few found in Europe up till now, confirming the presence (and hunting activity) of the Neolithic man (ca 3790–3380 cal BC) in the Carpathians. From the archaeological viewpoint, it is an unusual evidence of the penetration of mountainous areas, not long ago considered to be inconvenient for the colonisation by the prehistoric man. The essential element of this study is the palaeoenvironmental context of the artefact. The detailed, interdisciplinary study of the peat depositional sequence, in which the artefact was found, not only enables the confirmation of an almost continuous occupation of man (most probably of the Funnel Beaker Culture) of this site, but indicates that the hunting was not the only form of his activity. In the deposits the intensive human activity — breeding and probably cultivation, conducted by the Neolithic man — was also recorded. The climate conditions were of significant importance for his economic activity. The study of the depositional sequence of the peat bog confirms the cyclic migrations of various cultures both in the Neolithic Period and, subsequently, in the Roman Period (Przeworsk Culture) to the upper, dry parts of the mountain slopes, caused by the periodical climate moistening during the Middle and Late Holocene, generating the intensification of floods in river valleys. These periodical climate fluctuations at the beginning of the Subboreal and Subatlantic Phases were apparently recorded in the depositional sequence of the peat bog as distinct lithological changes. The economic activity of the prehistoric man conducted on the flat areas of the Kamiennik landslide essentially influenced acceleration of the erosional–depositional processes recorded in the depositional sequence of the peat bog.

Results of the study conducted on the Kamiennik Landslide show the significance and perspectives of archaeological prospections in landslide areas, that are numerous in the European mountains, and — as it is apparent — convenient for human settlement since the prehistoric time. The crucial advantage of these studies, is the possibility to reconstruct the impact of prehistoric man on a mountainous environment on the basis of analysis of landslide peat bog deposits, which are very sensitive indicators of the palaeoenvironmental changes in the Late Glacial and the Holocene, both palaeoclimatic and anthropogenic.

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