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THE AGE OF THE SUBFOSSIL TRUNK HORIZON IN DEPOSITS OF THE WARTA RIVER VALLEY (CENTRAL POLAND) BASED ON ^{14}C DATING

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Abstract: The present study focuses on investigations carried out in the Late Vistulian succession of the Warta River deposits (central Poland) in which a horizon of subfossil trees was excavated. Preliminary conclusions on time record and past environmental conditions of a forest existence determined from radiocarbon dating, pollen analyses and geological evidence appear promising with view of tree-ring chronologies.

Keywords: subfossil forest, peat, pollen analysis, ^{14}C dating, Allerød, Younger Dryas, Warta River valley, central Poland.

1. INTRODUCTION

In the Warta River valley deposits an assemblage of subfossil trunks was found. A horizon with various fragments of trees is continuous in general. The stumps are found *in situ* but mostly as a series of collapsed trunks as well as individual branches and roots. The trees are presumably remnants of a riparian forest which existed on the Warta River valley bottom in the time of the Late Vistulian. The wood is relatively well preserved, with clearly visible annual tree-rings. At the current state of the investigation we can assume that the predominant species in the study area was pine. Pine is an important tree species suitable for constructing chronologies. As the findings, providing a unique annual record of such an age, are unknown so far from the territory of Poland and rare in Europe the site seems to be promising in the field of extending the tree-ring based ^{14}C calibration.

The current study presents preliminary information and tentative results of investigations carried out when the tree remnants were exhibited to direct observation. The aim of this paper is to point to a position of the subfossil trunk horizon in relation of a peat unit with which tree fragments are associated on the basis of ^{14}C dating, geological data and palaeobotanical signals.

2. GEOLOGY

The study site is located in the middle section of the Warta River valley in central Poland. The sediments deposited by the river were analysed in the area of the outcrop Koźmin of the Lignite Mine ADAMÓW JSC. On the east side of the Late Vistulian lower terrace (**Fig. 1**), which covers there a great part of the valley a horizon of subfossil trees was excavated.

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Fig. 1. *Geomorphological map (after Forysiak, 2005). 1 – morainic plain, 2 – hummocky morainic plain, 3 – fluvioglacial plain, 4 – end-morainic hillocks, 5 – kames, 6 – slopes, 7 – lower terrace of marginal valley, 8 – erosional terrace, 9 – alluvial high terrace, 10 – alluvial low terrace, 11 – valley floor, 12 – lacustrine plain, 13 – aeolian plain, 14 – dunes, 15 – peatlands, 16 – closed depressions, 17 – valleys of various origin, 18 – exploitation pits*

The investigated tree remnants are closely connected with a peat unit. They are situated at a depth of about 3 m below the present day surface. The peat deposit is spread over a wide area of this valley section, but is rather thin. It was deposited on the sandy surface accumulated by an Upper Plenivistulian sand-bed braided river (Petera-Zganiacz, 2007). The peat unit with fossil trunks is occasionally covered by gyttja but commonly by the overbank sandy-silty series of an anabranching river type 2 (Nanson and Knighton, 1996; Turkowska *et al*., 2004; Forysiak, 2005). Channels of the anabranching river may cut the trunk horizon and in such cases the peat deposit loses its continuity. The fluvial succession overlying the peat unit originated during the Younger Dryas cold period (Turkowska *et al*., 2004).

3. CHARACTERISTICS OF THE TRUNK HORIZON AND ^{14}C DATING

A continuous peat unit thickness ranges usually from 0.5 to 0.3 m or even less. The peat base is situated at varying altitude: in the middle part of the study area the base is about 93.5-94.5 m asl and rises eastwards and westwards up to 95 m asl (**Fig. 2**). The unit contains various tree fragments, but in some places it is devoid of them. The localities where subfossil trunks were found most often occur in the eastern part of the study area.

The length of the trunks reaches up to a few metres. Their diameters are locally significantly over 0.2 m. As their diameters equal or exceed the peat thickness, it is difficult to state the real position of the trunks in relation to the base or top of the peat. In some localities a significant assemblage of trunks was documented, where they were found lying one on the other even in three levels which causes the increasing of a peat and trunk horizon (**Fig. 3**). Additionally, the trunks are somewhat flattened, by pressure of an overlying material. The examples of *in situ* stumps have been found too (**Fig. 4**). They were rooted in the peat or in the underlying Upper Plenivistulian sandy deposits. Traces of the root system of the trees are visible as vertical organic veins, penetrating ground to at least 1 m (**Fig. 5**). The traces of branches evidently occur at the peat unit top.

The *in situ* stumps suggest an existence of the forest synchronically with the peatbog formation. For some collapsed trunks there is no evidence that they were relo-

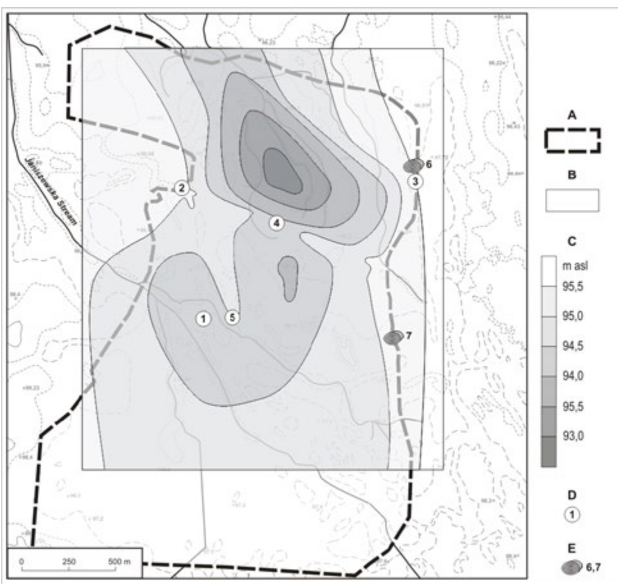

Fig. 2. *Position of the bottom of the peat unit and location of the dated peat and tree trunks. A – extent of the Koźmin outcrop, B – study area, C – altitude of the peat unit bottom, D – location of the peat base age determinations (results of dating in Table 1), E – tree trunks dating location (results of datings in Table 1)*

Fig. 3. *Assemblage of the tree trunks in the peat unit*

Fig. 4. *Stump found* in situ

Fig. 5. *Involutions of the peat base and traces of the root system*

cated over the floodplain. They occur in part of the peat unit which is devoid of any mineral interlayers pointing to fluvial interruptions. On the other hand, the trees may have been washed away and buried in the sediment by overbank flow, on the boundary of the peat and the overlying deposits or even within the floodplain series (**Fig. 6**). Some of those trunks which were eroded by the anabranching river became deposited in the channels (Turkowska *et al*., 2000, 2004).

20 samples from two profiles of the peat unit were submitted for pollen analysis (**Figs. 7**, **8**). Pollen analysis indicates an open forest with a slight admixture of *Betula.* Vegetation was dominated by herbaceous plants, mainly Cyperaceae and Gramineae. Later on, pine forest was replaced by open birch forest with patches of heliophilous plants (*Artemisia,* Cruciferae, Chenopodiaceae, Ericaceae). Finally, pollen spectrum contains single grains of rush plants and aquatic species, thus the top of the profile reflects stand waters or a pool with very limited discharge. The obtained results indicate that the peatbog was formed under cold climatic conditions, progressively more severe towards the top of the unit. The palynological investigations set the time of the peatbog existence to the second, *Pinus*-phase of Allerød and the beginning of Younger Dryas. Detailed interpretation of the results of the pollen analysis at Koźmin with comments by a palynologist have been presented earlier (Petera, 2002; Turkowska *et al*., 2000, 2004; Forysiak 2005; Petera-Zganiacz and Dzieduszyńska, 2007).

A characteristic feature of the peat unit are deformations observed in its lower part such as flat-bottomed involutions and drop structures of small size (**Fig. 5**). These deformations may be of cryogenic origin (Vandenberghe, 1988; Kasse, 1999; Swanson *et al*., 1999) and are in accordance with the sharp climatic conditions described especially for the first half of the Younger Dryas (e.g. Isarin *et al*., 1998; Renssen *et al*., 2001) when at least local permafrost reactivation was possible (e.g.

Fig. 6. *Tree trunks in overlying alluvial deposits*

Bohncke *et al*., 1993; Goździk, 1995; Klatkowa, 1996).

Time frame for the peat unit formation and the subfossil forest existence has been determined using the conventional radiometric method. The results cover a wide range between 11 850 and 10 200 ^{14}C BP. The values of ^{14}C ages are listed in **Table 1**. They represent conventional age determination and its calibration using OxCal v. 4.1, program (Bronk Ramsey, 1995; OxCal) with both 95.4% and 68.2% cal age probability on the base of the IntCal09 calibration curve (Reimer *et al*., 2009).

Samples from the peat material were taken as much as possible from the base of the unit (**Fig. 2**). Two oldest dates from the peat – 10 870±170 BP (Lod-699)/ 13 149-12 524 cal BP and 12 469-12 432 cal BP (95.4%) and 10 830±170 BP (Lod-767)/ 13 122-12 416 cal BP (95.4%) are for samples from lower altitudes: 94.5 and 94.3 m asl. Another date, situated also at lower localities (93.9 m asl), is clearly younger: 10 200±430 BP (Gd-9740)/ 12 941-10 660 cal BP (95.4%). Dates for higher situated localities are: 10 680±100 BP (Lod-1396)/

Table 1. *Results of ^{14}C dating*

No.	Altitude (m asl)	^{14}C age (yr BP)	Cal. age range 95.4% conf. Intervals (yr BP)	Cal. age range 68.2% conf. Intervals (yr BP)	Laboratory code
PEAT UNIT					
1	93.9	10 200±430	12 941 – 10 660 (95.4%)	12 517 – 12 488 (1.5%) 12 425 – 11 274 (66.7%)	Gd-9740
2	95.1	10 350±90	12 542 – 11 954 (92.1%) 11 895 – 11 827 (3.3%)	12 390 – 12 056 (68.2%)	Lod-1389
3	95.5	10 680±100	12 844 – 12 395 (95.4%)	12 696 – 12 531 (66.6%) 12 453 – 12 445 (1.6%)	Lod-1396
4	94.3	10 830±170	13 122 – 12 416 (95.4%)	12 912 – 12 581 (68.2%)	Lod-767
5	94.5	10 870±170	13 149 – 12 524 (94.4%) 12 469 – 12 432 (1.0%)	12 935 – 12 601 (68.2%)	Lod-699
TREE TRUNK					
6	-	10 310±90	12 518 – 12 481 (1.6%) 12 426 – 11 765 (93.8%)	12 381 – 12 260 (20.4%) 12 224 – 11 983 (47.8%)	Lod-1402
7	-	11 850±80	13 874 – 13 454 (95.4%)	13 815 – 13 598 (68.2%)	MKL-256

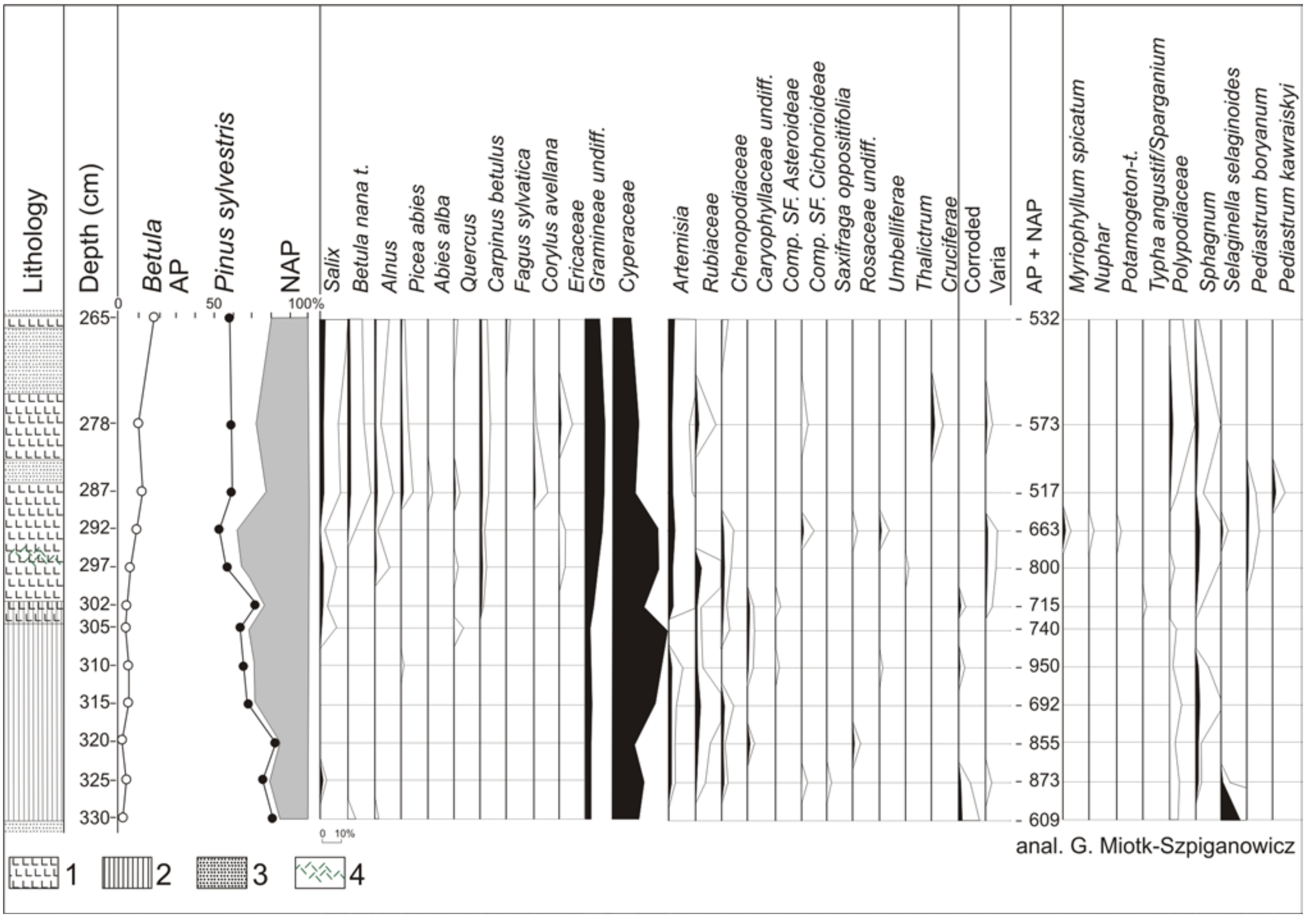

Fig. 7. *Pollen diagram 1 (after Turkowska et al., 2000). 1 – silty gyttja, 2 – peat, 3 – sand, 4 – plant remains*

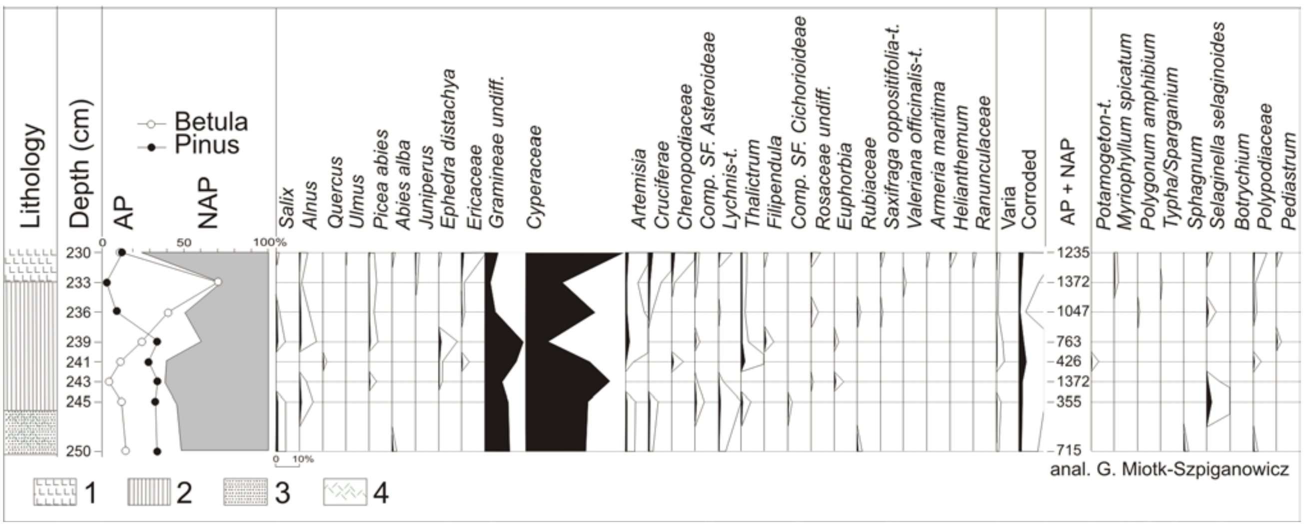

Fig. 8. *Pollen diagram 2 (after Forysiak et al., 1999). 1 – silt, 2 – peat, 3 – sand, 4 – plant remains*

12 844-12 395 cal BP (95.4%) and 10 350±90 BP (Lod-1389)/ 12 542-11 954 cal BP and 11 895-11 827 cal BP (95.4%); the latter is from a locally disturbed fragment of the peat unit.

Samples from the preserved wood were taken from internal rings. One of the dated fossil trunks, of a diameter of about 20 cm, was taken from their assemblage (**Fig. 3**) near to the site with peat date of 10 680±100 BP (**Fig. 2**). Sampled wood came from a pine tree (*pers. comm.* M. Klos). Its age was determined at 10 310±90 BP (Lod-1402)/ 12 426-11 765 cal BP and 12 518-12 481 cal BP (95.4%). The second sampled pinewood, from the trunk of a diameter of over 30 cm was situated close to the peat base (**Fig. 2**). It has given result of 11 850±80 BP (MKL-256)/ 13 874-13 454 cal BP (95.4%).

4. CONCLUSIONS

The peat unit formation took place non-synchronus. It is supported by a wide range of ^{14}C dates and by the presence of the layer of gyttja in these localities where the base of the peat is lowered. In the light of the existing palynological data it may be possible to coincide in time the peat unit formation with the end of Allerød and the beginning of Younger Dryas. As the peat formation is assumed non-synchronic, only two pollen profiles seem to be insufficient to estimate environmental conditions of the peatbog functioning. In general such palaeobotanical signal (**Figs. 7**, **8**) is in agreement with the radiocarbon ages. The obtained ages point to the Younger Dryas chronozone, placed between 10 000 and 11 000 BP by Mangerud *et al.* (1974). The dates also suggest the Younger Dryas interval if the calibrated range is taken into account, was 12 650-11 550 cal BP – Greenland Stadial 1 in Greenland event stratigraphy by Björck *et al.* (1998) and 12 650-11 500 cal BP after stratigraphy based on large set of radiocarbon dates for Poland by Michczyńska *et al.* (2007, 2008), though the bottom limits of age ranges point to the Allerød as well (**Table 1**).

The tree stand, according to preliminary assessment, was dominated by a pine forest. It may be assumed that the oldest trees started to grow even before the peat formation, already on the sandy Plenivistulian surface. Taking into account the older dating for the trunk 11 850±80 BP (**Table 1**) and the documented vertical traces of the root system (**Fig. 5**), the forest may have existed in the milder climatic conditions of the Bølling-Allerød complex (GI – 1 Greenland Interstadial 1 in Greenland event stratigraphy by Björck *et al.*, 1998). The younger dating of the trunk (10 310±90 BP) points to the forest existence being continued throughout the Younger Dryas.

The outlined above time frame is in accordance with geological arguments. The presence of the upper gyttja as well as involuted structures, which warped the peat testify to raising groundwater table. The uplift was possible due to permafrost reactivation in the favourable conditions under the peatbog, as a response to the Younger Dryas cooling. Increasing wetness may have led to the destruction of the forest (Petera-Zganiacz and Dzieduszyńska, 2007). The good condition of the observed trunks results probably from their quick burial by the sediments of a high energy anabranching river type 2 during the second part of the Younger Dryas (Nanson and Knighton, 1996; Turkowska *et al.*, 2004; Forysiak, 2005).

Good preservation of the wood offers a possibility to obtain a detailed climate proxies providing information of environmental conditions of the Late Vistulian in central Poland. The authors are planning to submit the material from the Koźmin site to further investigations such as stable isotopes stored in the cellulose of tree-rings, more complex palaeobiological studies and radiocarbon analyses from tree-rings.

Similar finding of a subfossil pine and birch forest of a Younger Dryas age is known from the lignite area of Cottbus in eastern Germany (Spurk *et al*. 1999). Trees from that site enabled to extend the pine chronology and the tree-ring based ^{14}C calibration up to the middle Younger Dryas (Friedrich *et al*., 1999, 2004).

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