ABSOLUTE DATING OF THE BRONZE AGE DEFENSIVE SETTLEMENT IN HORODNIANKA (NE POLAND)

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ABSTRACT. In 2008–2009, during construction of the ring road around the town of Sztabin in NE Poland, archaeological rescue excavations were carried out at site no. 12 in Horodnianka. The excavations revealed the remains of a defensive settlement from the Bronze Age, with a total surface of 3 ha. Concentric wooden palisades reinforcing the settlement were situated on sandy, elevated embankments of the Biebrza River. Altogether, 189 samples of archaeological wood, mainly oak (*Quercus* sp.), were collected. Dendrochronological analysis demonstrated that the trees were cut down within a relatively short period of only 22 yr. On the basis of 22 contemporaneous dendrochronological sequences, the average curve HOR_AA1 (89 yr long) was constructed. However, attempts at dating the average curve against the chronologies from adjacent areas were unsuccessful. Therefore, determination of the time interval represented by the palisade oaks was attempted with the wiggle-matching method. Radiocarbon dating using liquid scintillation counting (LSC) was conducted for 6 suitable samples selected from the average curve. The ^{14}C results, after calibration, suggest the dates of cutting the oaks outlining the Horodnianka chronology most probably fall in the time interval 870–795 cal BC. This means that Horodnianka could be the furthest northeastern defensive fortification of the Lusatian culture.

INTRODUCTION

In 2008–2009, during construction of the ring road around the town of Sztabin in NE Poland, rescue excavations were carried out at site no. 12 in Horodnianka. From a cultural point of view, this site turned out to be remarkably diversified. The excavations unveiled remains of a defensive settlement from the Bronze Age, which stretched over a surface of 3 ha. Archaeological investigations, however, were restricted to an area only slightly over half a hectare. The excavations carried out resulted in an inventory of over 50,000 historical and/or prehistoric objects (Bednarz and Brzozowski 2009). Timbers from the palisades strengthening the settlement were subjected to dendrochronological and radiocarbon dating. Thus far, there is no evidence of Lusatian culture settlement in the region.

ARCHAEOLOGICAL INVESTIGATIONS

The site Horodnianka was discovered during a survey as a part of the program “Archaeological Pattern of Poland.” The rescue excavation investigations were preceded by surveys located on the area of the planned ring road around the town of Sztabin (Brzozowski et al. 2008). The investigated area is relatively flat, with peat layers 20 to 270 cm thick, lying on river-type and/or fluvioglacial sands. The site is located on the left bank of the Biebrza River, in an area of periodically flooded meadows. The excavation was carried out manually, removing 10-cm layers at a time, and allowed to distinguish 2 rather extensive settlements with economic and defensive functions. The settlements consisted of internal buildings surrounded with multiple palisade walls enclosing an area ~30–40 m in diameter, and an external palisade, which enclosed an area ~150 m in diameter. The excavations conducted examined both vast internal structures. The findings included ubiquitous flints, pieces of ceramics, bones, timbers, as well as stones, slag, and pugging (Bednarz and Brzozowski 2009).

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MATERIALS

This study deals with the archaeological timbers discovered during rescue excavations at site no. 12 in Horodnianka (Figure 1). The wood samples were taken from concentric palisades reinforcing and protecting the settlements, situated on sandy heights of the Biebrza River. Fragments of the uncovered palisade are presented in Figure 2. The excavation area is characterized by high groundwater level due to its proximity to the Biebrza River. Therefore, the wood has been relatively well preserved (with undisturbed tree ring structure), enabling dendrochronological analysis. The material was collected in 2008–2009 by the staff of the Regional Museum in Suwałki, directed by J Brzozowski. Altogether, 189 samples of archaeological timbers were subjected to dendrochronological and ^{14}C analyses. The choice for sampling material for the analyses largely depended on the kind and state of preservation of the structure. In many cases, cross-sections (entire circles, up to ~5 cm thick) were cut out with a motor-driven saw. Timbers with traces of processing and small twigs were collected as well. Unfortunately, in most cases the timbers represented trunks and boughs of relatively young trees (143 samples), exhibiting only a dozen or so annual growth rings.

Figure 1 Location of the rescue excavations in Horodnianka, NE Poland

METHODS

Measurements of annual growth width, with 0.01-mm accuracy, were made using the DENDROLAB 1.0 apparatus in the Dendrochronological Laboratory of the AGH, University of Science and Technology in Kraków (Poland). The measurements were registered and the annual growth sequences were graphically presented using the Quercus program (Walanus 2005). Pearson's coefficient of the linear correlation *r* and the value *t* (Baillie and Pilcher 1973) were calculated with the software TREE-RINGS (Krawczyk and Krąpiec 1995) and COFECHA (Holmes 1999). When identifying the best fitting positions of the individual sequences, high values of *r* and *t* were considered, as well as visual resemblance to the dendrochronological curves.

^{14}C dating using liquid scintillation counting (LSC) was performed in the Laboratory of Absolute Dating in Skała (Poland). The wood was chemically pretreated with the acid-alkali-acid (AAA) method. The procedure includes the standard synthesis of benzene from carbonized wood samples

Figure 2 Remains of the Bronze Age defensive settlement in Horodnianka

(Skripkin and Kovalyukh 1994). ^{14}C measurements were carried out with a 3-photomultiplier spectrometer, the HIDEX 300SL (see Krąpiec and Walanus 2011 for details).

Since the age of wood relatively dated with the dendrochronological method had to be determined independently, the wiggle-matching method was applied. The wiggle-matching technique, together with its mathematical assumptions, is described well by Bronk Ramsey et al. (2001). The method of fitting curves allows for age determination of the chronology with a precision considerably higher than individual ^{14}C dates (Pearson 1986). In this work, wiggle-matching analysis was performed with the program OxCal v 4.1.3 (Bronk Ramsey et al. 2001; Bronk Ramsey 2009) and the calibration curve IntCal09 (Reimer et al. 2009). Seven samples from selected fragments of the tree-ring sequences were relatively dated dendrochronologically. The D_Sequence model of OxCal with defined gaps was employed to account for almost the final tree rings of the oak chronology. The gap was a precisely known interval between the center of the relatively dated tree-ring series submitted for ^{14}C dating. The best match between the calibration curve and tree-ring data was calculated using the agreement index A, which indicates the extent to which the posterior distribution overlaps with the individual ^{14}C distributions in a similar way to a χ^2 test (Bronk Ramsey et al. 2001). Additionally, a series of dating tests was made for several wood samples, which were not included in the chronology, in order to check whether they represent the same time interval. Their conventional ^{14}C ages were then calibrated to calendar ages using OxCal.

RESULTS

This study was aimed at establishing the absolute chronology of the Horodnianka site, through dendrochronological and ^{14}C dating of the wooden palisades that defended and reinforced the settlement. Results of the wood anatomical analysis, together with the percentage of individual tree species gathered during the archaeological investigations in Horodnianka, are presented in Figure 3. Among the examined wood samples, oak (*Quercus* sp.), pine (*Pinus sylvestris*), and alder (*Alnus* sp.) predominated. Less frequent were ash (*Fraxinus excelsior*), maple (*Acer* sp.), spruce (*Picea abies Mill.*), elm (*Ulmus* sp.), and willow (*Salix* sp.).

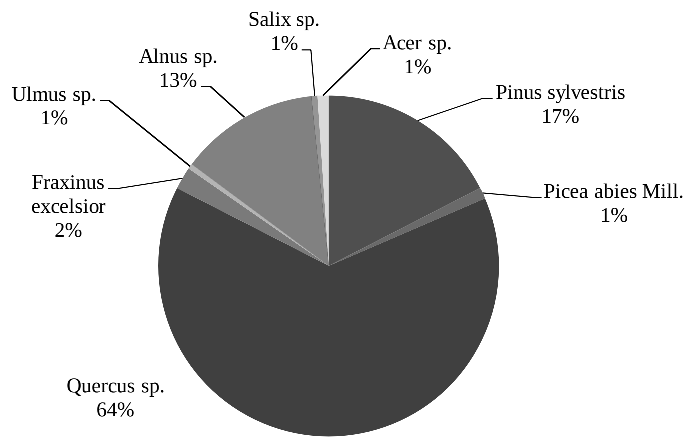

Figure 3 Anatomical analysis of wood from Horodnianka site

Of the 189 wood fragments collected, only 46 samples complied with the dendrochronological requirements. The samples chosen were well preserved enough to allow clear identification of the ring structure. They also contained an adequate number of readable tree rings, with no less than 24 annual increments. Measurements of annual growth width were made for 39 oak elements, 3 of pine, 3 of ash, and 1 of elm. In 36 samples, the last bark ring was preserved, which allowed to identify the season in which the trees were felled. Most of the oakwood (34 samples) retained the sapwood.

The tree-ring measurements resulted in annual growth sequences from 25 to 147 yr in length. The measured samples usually contained between 25 and 50 annual increments (Figure 4). Computer correlations and visual comparisons of the curves allowed identification of trees that grew contemporaneously. On the basis of 22 cross-dated dendrochronological sequences of oak, the HOR_AA1 chronology was outlined, spanning 89 yr (Figure 5). Values of the coefficients *t* and *r*, reflecting the similarity between the chronology and the individual samples included in its composition, are presented in Table 1. Cross-correlation of the remaining sequences against the HOR_AA1 chronology allowed for relative dating of 10 further samples. This way, 32 total contemporaneous dendrochronological series were dated.

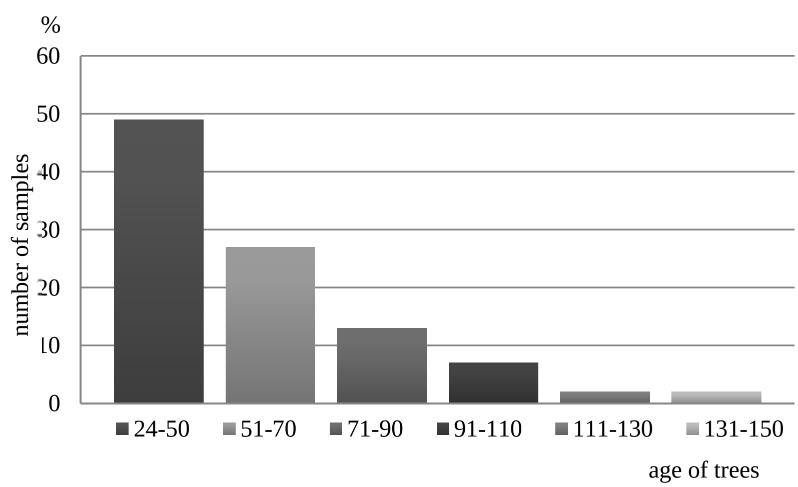

Figure 4 Percentage of 20-yr age ranges of trees used in dendrochronological analysis

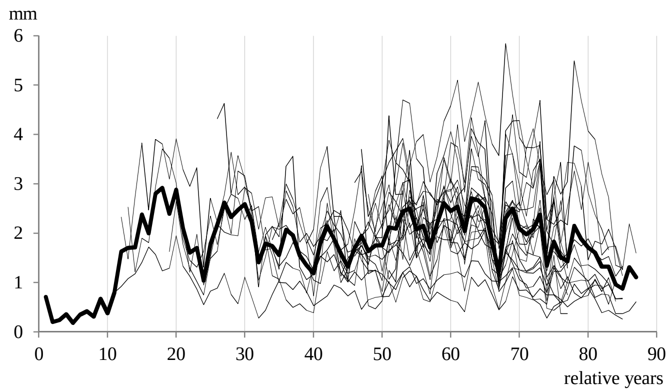

Figure 5 The chronology HOR_AA1 with individual sequences included

Table 1 Selected statistic parameters of each sequences against the site chronology.

Lab code	Nr of years	Correlation with chronology HOR_AA1 [*t*]	Correlation with chronology HOR_AA1 [*r*]
HOR1	74	6.232	0.603
HOR4	29	6.144	0.809
HOR5	28	4.635	0.703
HOR6	37	4.559	0.634
HOR8	51	6.503	0.696
HOR9	38	6.146	0.736
HOR10	67	8.083	0.719
HOR13	32	5.557	0.737
HOR14	27	6.027	0.796
HOR15	87	8.898	0.703
HOR17	30	3.908	0.624
HOR18	59	6.115	0.643
HOR22	29	5.203	0.735
HOR28	43	6.420	0.777
HOR29	38	5.533	0.699
HOR30	55	7.086	0.711
HOR33	26	4.138	0.679
HOR35	37	9.950	0.873
HOR36	73	4.646	0.494
HOR38	64	5.726	0.608
HOR42	45	5.923	0.688
HOR43	39	5.833	0.713

Results of the relative dendrochronological dating of Horodnianka wood samples are presented in the block diagram (Figure 6). Dendrochronological analysis demonstrated that the trees had been felled within a relatively short time interval, only 22 yr. Moreover, distinct periods (time intervals) of introduction of the wood material into the palisades, marked with the ranges A–C in Figure 6, could be observed. The first period took place in the year 77, the second one in the years 83–85, and the third represented the period 87–89 (all ranges given in relative years). The chronology produced was compared against the available chronologies constructed for oak from Poland and neighboring countries (Krąpiec 2001; Zielski and Krąpiec 2004). Unfortunately, no synchronous position, enabling unequivocal dating, could be stated. The principal cause of the failure apparently consists in too few annual growth rings in the chronology.

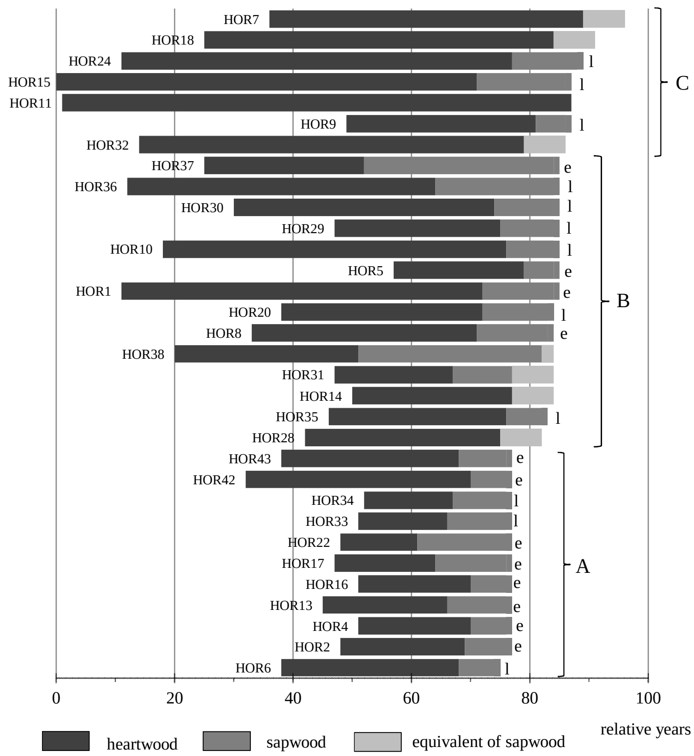

Figure 6 Correlation block diagram of dendrochronological sequences from Horodnianka forming the chronology HOR_AA1. The last growth ring with earlywood marked with *e* and the last growth ring with latewood marked with *l*. There are 3 distinct periods of introduction of wood material into the palisade, marked with A–C.

The age of the palisade samples was determined via wiggle-matching, which has been frequently applied for dating relative dendrochronological sequences (Kruse et al. 1980; Linick et al. 1985; Pearson 1986; Krąpiec 1992). The method has proven useful for wood from various epochs and regions (van der Plicht et al. 1995; Slusarenko et al. 2001; Vasiliev et al. 2001; Galimberti et al. 2004; Imamura et al. 2007).

From the HOR_AA1 chronology, 7 samples (HOR1, HOR9, HOR15, HOR30, HOR36, HOR37, HOR43) were selected for ^{14}C dating using LSC. The rings selected, together with their positions in the chronology, are presented in Figure 7 and Table 2. For HOR15, analysis was conducted on the inner trunk (*i* in Table 2), whereas for samples HOR1, HOR9, HOR36, HOR37, HOR43, rings were taken from the external trunks (*e* in Table 2). Only for sample HOR30 was dating conducted on rings from the center of the trunk (rings 14–28). In every case, 15–30 annual growth rings were ^{14}C dated.

For the Horodnianka wiggle-matching, the agreement index for the complete D_Sequence was 102.8%, with An = 26.7% (n = 7), suggesting that the overall fit is acceptable. The ^{14}C dating results of the 7 samples from the HOR_AA1 chronology, after the dependent calibration (Figures 8 and 9), indicate that the oak trees outlining the chronology were felled in 870–795 cal BC. Also, cross-dating was obtained for sequences containing fewer tree rings (from 25 to 86). Some of the curves with longer sequences do not display any similarity with each other. They perhaps grew in unfavorable conditions, e.g. under canopy cover. Such trees often are characterized by zones of narrow tree rings

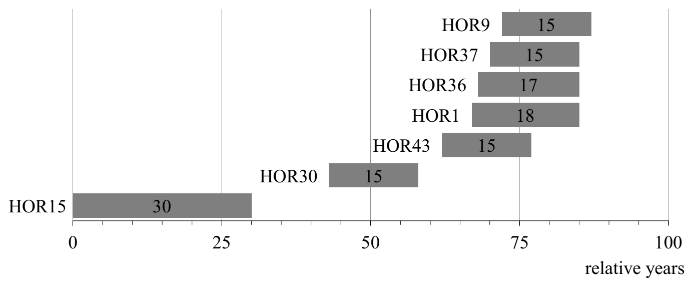

Figure 7 Selected tree-ring series used in the wiggle-matching

Table 2 Sample descriptions with conventional and calibrated ages of samples from Horodnianka. Age ranges determined with confidence levels of 68% and 95% using OxCal (Bronk Ramsey 2009).

Sample description[a]	Code[b] (MKL-)	^{14}C age (BP)	Cal age range (68.2%)	Cal age range (95.4%)	Nr of width series	Nr of rings[c]/ their position
HOR15, *Quercus*, w–m	678	2820 ± 60	1060–890 BC (68.2%)	1130–820 BC (95.4%)	87	30i/1–30
HOR43, *Quercus*, w–m	677	2760 ± 50	980–950 BC (7.3%) 940–830 BC (60.9%)	1020–800 BC (95.4%)	39	15e/63–77
2HOR2, *Pinus*	674	2740 ± 50	930–820 BC (68.2%)	1000–800 BC (95.4%)	30	—
HOR25, *Quercus*	683	2740 ± 50	930–820 BC (68.2%)	1000–800 BC (95.4%)	96	15e/—
HOR30, *Quercus*, w–m	880	2690 ± 40	895–865 BC (21.5%) 860–805 BC (46.7%)	920–790 BC (95.4%)	55	14–28/45–59
HOR1, *Quercus*, w–m	675	2690 ± 50	895–865 BC (21.9%) 860–805 BC (46.3%)	970–950 BC (1.2%) 940–790 BC (94.2%)	74	18e/68–85
HOR12, *Quercus*	679	2690 ± 50	895–865 BC (21.9%) 860–805 BC (46.3%)	970–950 BC (1.2%) 940–790 BC (94.2%)	72	18i/—
HOR36, *Quercus*, w–m	681	2660 ± 50	895–875 BC (11.0%) 850–790 BC (57.2%)	920–760 BC (95.4%)	73	17e/69–85
HOR9, *Quercus*, w–m	676	2640 ± 50	890–880 BC (3.5%) 850–770 BC (64.7%)	920–750 BC (93.5%) 690–660 BC (1.9%)	38	15e/73–87
HOR37, *Quercus*, w–m	682	2620 ± 50	840–760 BC (68.2%)	910–740 BC (84.0%) 690–660 BC (5.0%) 650–590 BC (5.4%) 580–560 BC (1.0%)	60	15e/71–85
HOR19, *Quercus*	685	2610 ± 50	840–760 BC (64.1%) 690–670 BC (4.1%)	900–740 BC (76.3%) 690–660 BC (7.0%) 650–550 BC (12.1%)	93	17i/—
HOR2, *Quercus*	680	2590 ± 50	820–750 BC (52.7%) 690–660 BC (8.8%) 640–590 BC (6.6%)	850–720 BC (60.5%) 700–530 BC (34.9%)	68	15i/—

[a]Sample name, species (w–m = sample used for wiggle-matching).
[b]Laboratory code of the Laboratory of Absolute Dating in Skała, Poland.
[c]Number of tree rings used in wiggle-matching analysis and their position in the chronology: *i* = internal annual growth (oldest ring), *e* = external annual growth (the youngest ring).

and they record the climatic signal in annual growth sequences insufficiently. Dendrochronological dating of such trees is thus often not possible. Therefore, 5 samples were subjected to ^{14}C dating: MKL-674; MKL-679; MKL-680; MKL-683; MKL-685 (Table 2). The results indicate that these samples most probably originated from the same time period as the palisade elements analyzed. For the ash, elm, and pine wood, hetero-connection with the newly constructed oak chronology was applied, but, unfortunately, dendrochronological dating was unsuccessful.

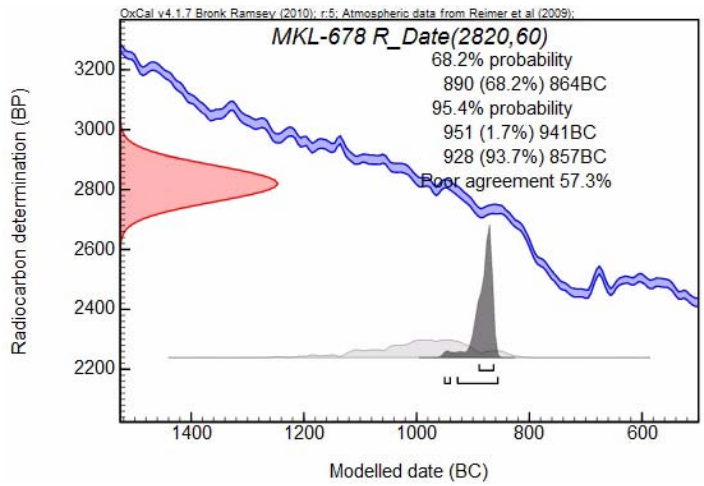

Figure 8 Calibrated position of the first ring of the oak chronology HOR_AA1

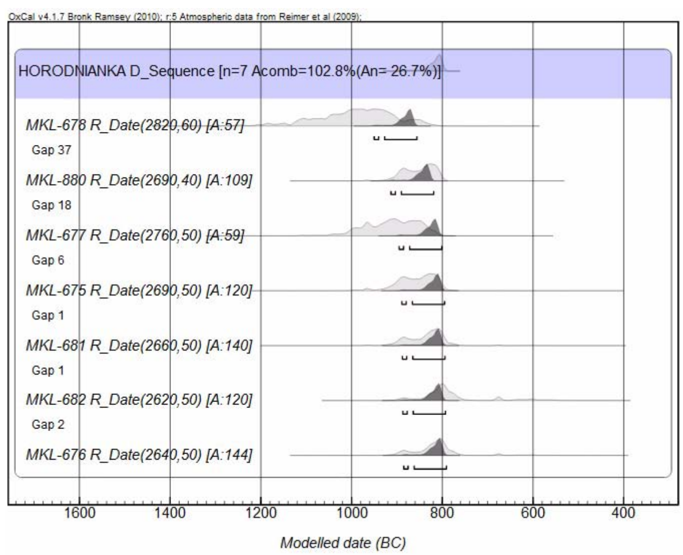

Figure 9 ^{14}C wiggle-matching of the floating oak chronology HOR_AA1

CONCLUSION

Combining the dendrochronological and ^{14}C analyses allowed for absolute dating of the timber structures fortifying the Horodnianka settlement. These structures were constructed from trees felled at the turn of the 10th and 9th centuries BC. The Horodnianka settlement is likely the northernmost defensive settlement of the Lusatian culture. More than 1300 pieces of pottery and over 3500 flinty archaeological finds were found that have been attributed to the Lusatian (Brzozowski et al. 2008; Bednarz and Brzozowski 2009). Therefore, Horodnianka proves to be a key site in the ancient history of northeastern Poland. Further archaeological data and absolute dating combined with Bayesian analysis should allow in the future for stratigraphy of this site and delineation of its settlement phases. This is especially true since only a small percentage of the entire 3-ha settlement has been excavated.

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