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DENDROCHRONOLOGICAL STUDIES ON CONSTRUCTION OF PINE (*PINUS SYLVESTRIS* L.) STANDARD FOR SW POLAND

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Abstract: **Archaeological excavations led in Wrocław and Lubsko in the last few summer seasons yielded large amounts of pine (*Pinus sylvestris* L.) timbers. This rich material was used in tree-ring studies aimed at construction of a pine standard for south-western Poland. The research resulted in four absolutely dated local chronologies. For Lubsko two chronologies covering two different time intervals were established; 2LUBSZ for the years 1254-1376 AD, and the younger 2LUBSA for the years 1721-1848 AD. Timbers from Wrocław also allowed for construction of two local chronologies: the mediaeval 2WX1A spanning 254 years (1080-1333 AD), and the younger 2WRZ1 covering the period 1665-1831 AD. The produced chronologies were used for dating samples taken from mediaeval and modern wooden constructions from Lubsko and from the Old City of Wrocław.**

1. INTRODUCTION

Dendrochronological analysis, of which the main aim is absolute dating of timbers, is also applied in such branches of science like e.g. history of art and architecture or archaeology. Accurate and reliable dating of construction timbers allows for conclusions on the chronology of wooden objects; phases of repairing, reconstruction, development or renovations. Dating of archaeological artefacts and palaphites yields data on development of settlement cultures in a given site, enables determination of phases of prosperity and stagnation of the community studied, and facilitates archaeological stratigraphy (Baillie, 1982; Schweingruber, 1983; Billamboz, 1992). Dating possibilities principally depend on time extent of absolute tree-ring chronologies established for a given tree species growing in a given area, strength of the dendrochronological signal, and the state of development of the research. First steps of construction of a standard consist in producing object and site chronologies. At this stage of the research dating possibilities are limited to timbers coming from the very neighbourhood. Correlation of overlapping object and site chronologies leads to establishing of local chronologies for a given area, of significantly higher dating potential due to elimination of individual reactions of trees and simultaneous amplification of common reactions (Delorme, 1973). Depending on individual variability within a given tree species for which the standard is being constructed, correlation of synchronous object and site chronologies is higher or lower (Zielski, 1997).

In European dendrochronology the most researched species is undoubtedly *Quercus sp*., because of considerable length of life of individual trees, undisturbed, regular growth sequences, as well as common occurrence from early historic to present times. Due to these values of oak the biggest number of tree-ring chronologies, including the longest standards in Europe (Leuschner and Delorme, 1988; Spurk *et al*., 1998), were produced for this species.

Among conifers the most suitable species for dendrochronology, which does not present considerable difficulties at the research, is fir (*Abies alba*), characterised by strong dendrochronological signal of large geographical extent (Becker and Giertz-Siebenlist, 1970). Pine (*Pinus sylvestris* L.) is a taxon considered to be rather difficult for dendrochronological studies. Especially in the area of the East-European Lowland, including Poland, pine displays large variability of individual trees, brought about by diversity of environments it occurs in, which favours development of numerous forms and varieties within the species (Tomanek, 1987; Mejnartowicz, 1993). Additional difficulty in dendrochronological studies on pine is presented by quite frequently observed missing rings or presence of double rings caused by unfavourable biotic and/or abiotic conditions during the vegetation season. Missing rings as well as presence of one or even more apparent growth rings may result in miscellaneous sequences of annual growths. Moreover, high ecological tolerance of pine leading to its common occurrence in diversified environments is reflected in quite often observed irregular width of growth rings, e.g. narrow inner

rings or diversified width in various zones along the measured circumference. As a consequence the identification of synchronous sequences is more difficult. Weakly legible dendrochronological signal in the early stage of compiling the chronology brings about growing difficulties during further research.

Because of the above presented and some other reasons only one thousand-year pine standard of regional extent for the area of northern Poland, covering the years 1106-1991 AD (Zielski, 1997), has been so far produced in Poland. In 1996 in the Tree-Ring Laboratory of the University of Mining and Metallurgy in Cracow construction of a pine chronology for the area of Małopolska was attempted. Two years of research resulted in producing 375-year standard, covering the period 1622-1996 AD (Szychowska-Krąpiec, 1997). This standard was based on timbers sampled from architectural objects from Jędrzejów and Cracow as well as from shaft timbering from the Bochnia salt mine. The starting point of the chronology were pines growing in the Niepołomice Forest and in the vicinity of Nowy Targ. Cross-dating of successively older site chronologies extended it back in time to 1622 AD. As well-preserved pine timbers in seventeenth-century and older constructions or in archaeological sites in Małopolska are very rare, further attempts to extend the standard were so far unsuccessful.

The two above mentioned pine chronologies are inappropriate for dating of pine wood from other areas of Poland, e.g. from south-western regions. Therefore, construction of such a standard for SW Poland has been attempted. The task was favoured by large amounts of pine wood explored during archaeological excavations led in towns of SW Poland, among others in Wrocław and Lubsko. The presented results are only an initial phase of compiling a tree-ring standard of regional extent. The produced local chronologies have been absolutely dated by teleconnection with absolute standards for Germany (Heußner, 1996) and northern Poland (Zielski, 1992).

2. MATERIALS AND METHODS

Timber samples for analyses were taken during archaeological excavations led in the area of mediaeval Wrocław in the years 1996-2000 as well as in Lubsko (voivodeship Lubuskie).

Archaeological studies led in the last few summer seasons within the Old City of Wrocław were directed by A. Limisiewicz from the company AKME. During the excavations huge amounts of timbers of various species were explored, quite a number of them, around 300 samples, representing pine (*Pinus sylvestris* L.). The timbers were in various states, but generally quite well preserved, with visible limits between annual growth rings. These were fragments of beams, radial planks, and stakes of various dimensions, from a few to several tens of centimetres.

Timbers from Lubsko originated from archaeological excavations directed by Alina Jaszewska MSc from the Archaeological and Conservatory Laboratory in Żary and led in several trenches within the area of the town in 1998 and 1999. Over 100 samples taken (mostly slices, a few centimetre thick) of the explored timbers represented various tree species. Most of them were conifers; 82 samples represented pine (*Pinus sylvestris*) and one sample spruce (*Picea abies*). Oak *(Quercus sp*.) prevailed among deciduous trees, a few samples were of alder (*Alnus sp*.), ash (*Fraxinus sp.*), and willow (*Salix sp*.).

The research was performed at the Tree-Ring Laboratory of the Department of Stratigraphy and Regional Geology, University of Mining and Metallurgy in Cracow. After the initial procedure of cutting several centimetres thick slices from samples containing over 25 growth rings and cleaning their surfaces of transversal cross-sections with a sharp knife the samples were measured with 0.01 mm accuracy on a special measurement device linked with PC. At measurements of samples containing zones with very narrow growth rings the colorant *Phloroglucin-Salzsäure* was used. Due to its different absorption by vessels of earlywood and latewood the ring borders were more distinct which facilitated their identification. The measurements, averaging, and correlation of annual growth patterns were carried out with a set of computer programs TREE-RINGS (Krawczyk and Krąpiec, 1995).

Based on the measured growth rings, individual patterns were established for each sample, which in turn were mutually synchronised with the computer program PROT_1A. Similarity of the produced patterns was evaluated with two statistical values: modified value of the Student's test *t* (Baillie and Pilcher, 1973) and the Pearson's coefficient of linear correlation r. When their values were high enough and shapes of synchronous individual patterns consistent, site chronologies could be produced. The correctness of this procedure was checked with the program COFECHA (Holmes, 1994). Absolute dating of floating chronologies was attempted against absolute regional standards for neighbouring areas: central Germany and northern Poland.

3. RESULTS

Abundant materials turned out yet during the measurements to be too diversified as for the usefulness in dendrochronological analysis. Around 30% of all inspected samples contained relatively small number of annual growth rings; between 25 and a little over thirty. Such an amount of growth rings is seldom sufficient for absolute dating and compiling a chronology, especially in the case of such variable species as common pine. Moreover, it turned out that at numerous samples annual growths were very irregularly developed, i.e. innermost or outermost parts of the examined sections consisted of a number of extremely narrow rings. In addition, at some of the analysed samples the phenomenon of missing rings was recognised and they had to be excluded from further analysis. Quite often the sections of the analysed samples displayed zones with irregularly, deconcentrically developed rings with a reaction wood. Such samples were also excluded from further analysis.

After selection of undisturbed growth sequences, separately for each town, they were visually matched and com-

puter correlated in order to distinguish synchronous samples. As a result four chronologies were compiled for two areas: Lubsko and Wrocław.

Lubsko

As a result of visual matching of synchronised growth sequences and calculating of statistical parameters two chronologies were constructed: 2LUBSZ and 2LUBSA.

The chronology 2LUBSZ is based on 13 samples, containing from 37 to 88 growth rings (**Fig. 1**). They represent timbers explored during archaeological excavations led in the area of the town:

- old road – (ditches Ic and Id, stratigraphical unit 8 – 2LUBS5, 11, 44, 48, 36, 73, 35)
- vestiges of wooden structures – ditch VII (2LUBS39 and 18), object 24 – higher layers (2LUBS47), and object 27 – mechanical layer Z3 (2LUBS54 and 71).

Five samples contained completely developed sequences of annual growths (2LUBS5, 47, 54, 48, and 73). Similarity of individual patterns with the established chronology is between $t = 4.90$ and $t = 10.70$. The chronology was absolutely dated against the German standard spanning the years 924-1921 AD. Consistent shapes of the curves and high values of the statistical parameters ($t = 6.25$, $r = 0.50$) enabled to fix the beginning of the chronology 2LUBSZ to 1254 AD and its end to 1376 AD.

The second chronology 2LUBSA was based on five samples representing timbers explored from the layer VIIIe, object 36, from the eastern and western parts. These samples contained relatively long growth patterns, between 113 and 128 rings, and all of them retained the outermost sapwood rings. Correlation of individual patterns with the established chronology is from $r = 0.53$ to $r = 0.80$, whereas t value is between 6.64 and 14.54.

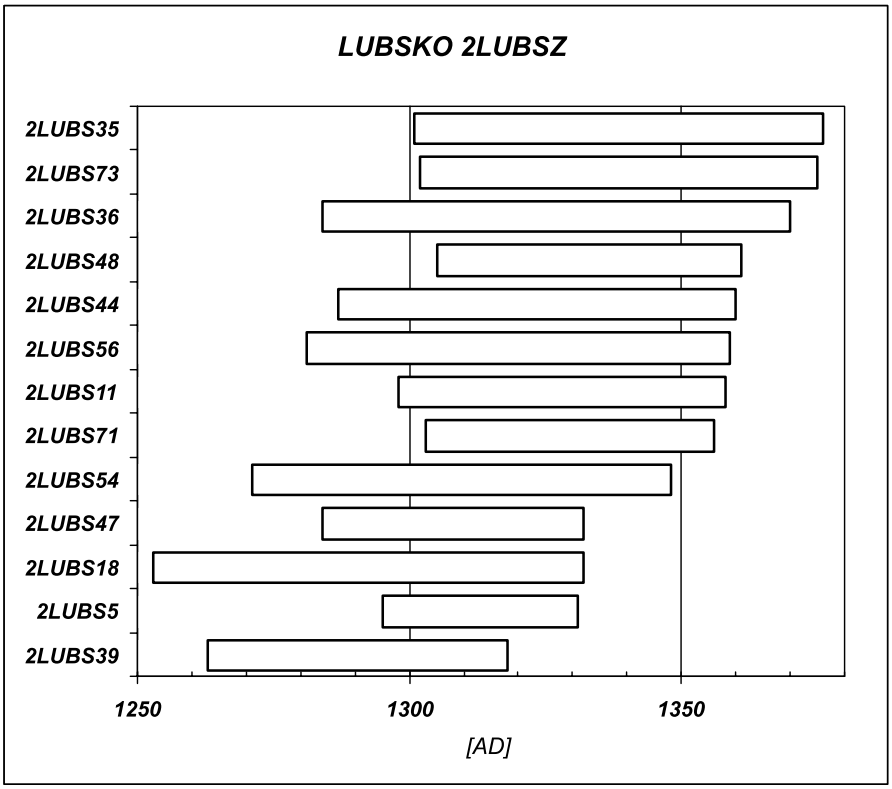

Fig. 1. *Dendrochronological dating of sequences building the local chronology 2LUBSZ.*

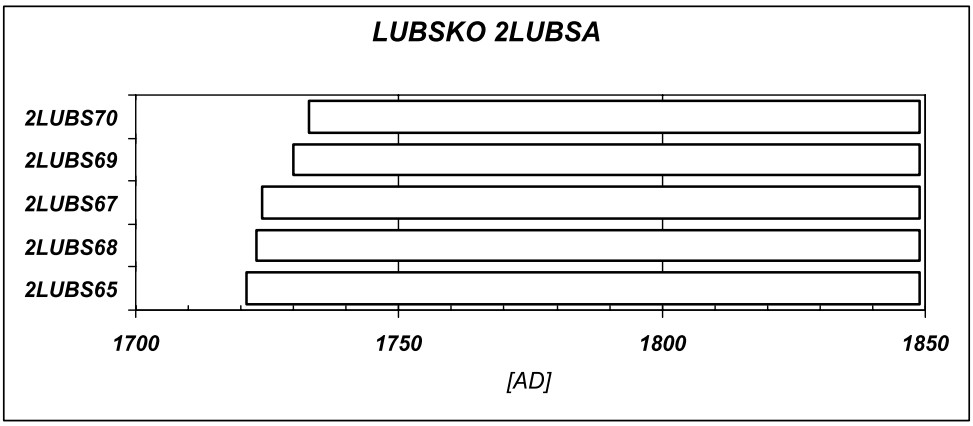

Fig. 2. *Dendrochronological dating of sequences building the local chronology 2LUBSA.*

The produced 128-year chronology was correlated with the standard pattern for Brandenburgia (Heßner, 1996). The similarity of both patterns amounts to t = 5.3, and for the indexed sequences, amplifying short-time changes which reflect climatic conditions, it is even higher (t = 7.1). The obtained values as well as consistent shapes of both curves enabled dating the chronology 2LUBSA to 1721-1848 AD (**Fig. 2**).

Wrocław

Two local chronologies (2WX1A and 2WRZ1A) were constructed for Wrocław. Comparison of them revealed that they are not synchronous.

The 254-year chronology 2WX1A was based on seven samples representing wood explored during excavations led at Rynek in different trenches. Two samples 2WR363 and 367 came from the trench no 6 from the same object (no 2), but its different levels (2WR363 from level 3 and 2WR367 from level 4), the sample 2WR357 represented wood from an old market stall, the sample 2WR649 was taken from the radial plank D1 from the trench XII, and the sample 2WR654 from the object no 7 (hotel). The youngest in the produced chronology is the sample 2WR366, taken at Rynek, from the beam B2, the object no 7. The analysed samples contained from 38 to 113 growth rings. The similarity of individual ring patterns with the produced chronology, expressed with the value t, is from t = 6.65 to t = 21.71, whereas the correlation expressed by the coefficient r is between 0.59 and 0,91. It should be noted that the first 100 years of the chronology 2WX1A is defined by only one sample (2WR386), the next 100 years is based on five samples, and the last 70 years is also entirely based on one sample 2WR366.

An attempt of absolute dating of this chronology by teleconnection with the standard chronologies for northern Poland and Germany showed certain similarity of the 2WX1A with the German standard (t = 3.41). Higher similarity was observed at its comparison with the local curve 2LUBSZ (t = 3.79, r = 0.4). These statistical indications were confirmed by visual comparison of both patterns, which allowed to assume that the local curve 2WX1A covers the years 1080-1333 AD (**Fig. 3**).

The second Wrocław chronology, 167-year 2WRZ1, is based on six samples containing from 87 to 136 growth rings. The samples represent timbers explored during archaeological excavations at Nowy Targ (sewage trench – 2WR887, 884, 886 and 911) and at the junction of the streets Piaskowa and Nankiera from the trench 3h (for light – sample 2WR898 and for waterworks – 2WR891). Four samples contained total sapwood (2WR891, 898, 886 and 884) and the sample 2WR891 retained bark as well. Similarity of individual ring patterns with the produced chronology is high, t value being between 6.82 and 16.13. The chronology 2WRZ1 was correlated with standards for neighbouring areas: northern Poland and Germany. Its similarity with the standard for N Poland is t = 6.67,

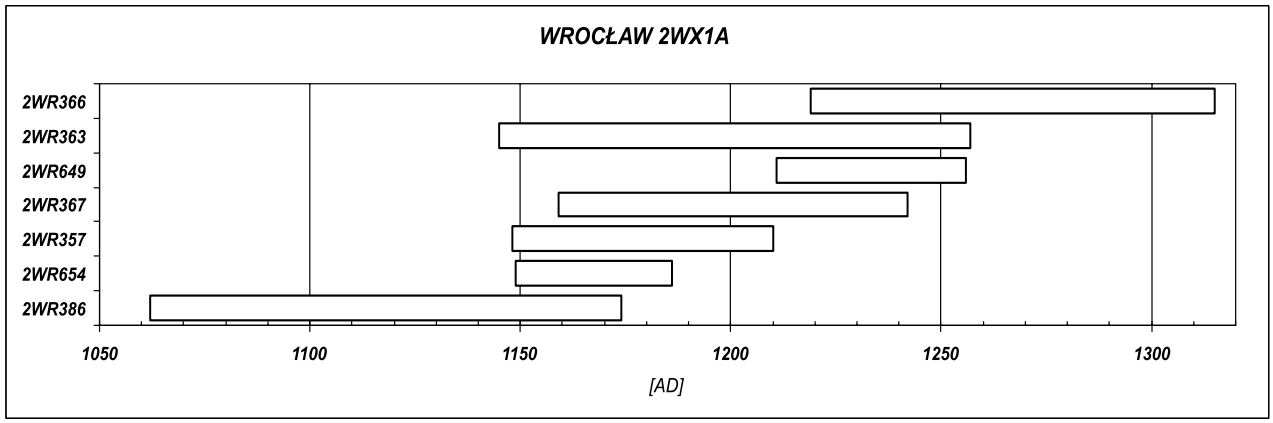

Fig. 3. *Dendrochronological dating of sequences building the local chronology 2WX1A.*

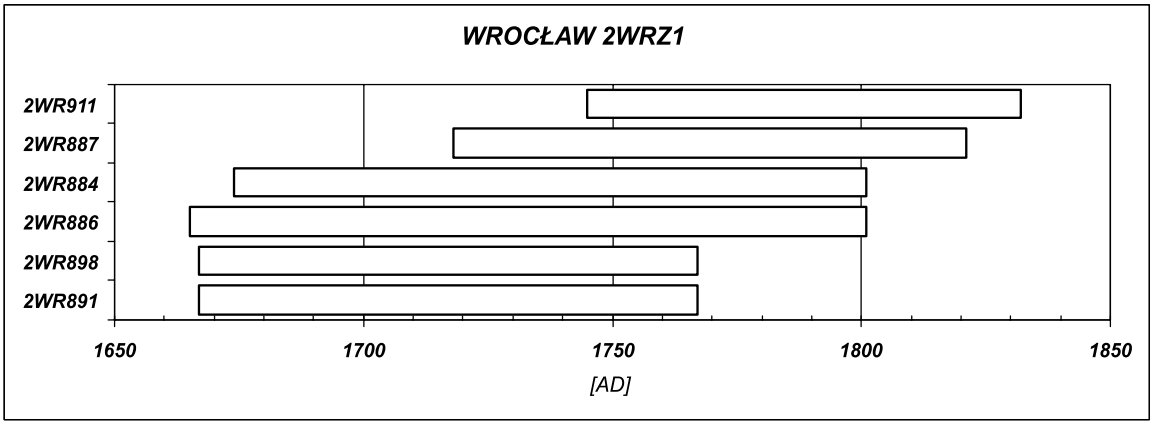

Fig. 4. *Dendrochronological dating of sequences building the local chronology 2WRZ1.*

correlation coefficient amounts to r = 0.46, teleconnection with the German standard provided similar values (t = 5.05, r = 0.37). Visual matching of the analysed curves confirmed their consistence and allowed for absolute dating of the chronology 2WRZ1 to the years 1665-1831 AD (**Fig. 4**).

4. CONCLUSIONS

1. Dendrochronological studies of archaeological samples of pine timbers from Wrocław and Lubsko resulted in construction of four local chronologies, absolutely dated against absolute regional standards from neighbouring areas. These first pine master patterns for south-western Poland make the beginning of construction of a pine regional standard.
2. The constructed chronologies define the following time intervals: 2LUBSZ 1254-1376 AD, 2LUBSA 1721-1848 AD, 2WX1A 1080-1333 AD and 2WRZ1 1665- 1831 AD.
3. The produced chronologies enabled absolute dating of archaeological samples from Lubsko and Wrocław. 32 samples representing pine timbers from, among others, mediaeval wooden structures from Lubsko were dated against the chronologies 2LUBSA and 2LUBSZ. The Wrocław chronologies enabled dating of timbers explored from the Old City (Polish Square ASP, Dominikański Square, 32 Purkyniego St. and 5 Garncarska St.) to the second half of the 13th century.

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