GEOCHRONOMETRIA Vol. 20, pp 57-60, 2001 – *Journal on Methods and Applications of Absolute Chronology*

EXTENSION OF MASTER FIR (*ABIES ALBA* MILL.) CHRONOLOGY FROM SOUTHERN POLAND

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Key words: DENDROCHRONOLOGY, MASTER FIR CHRONOLOGY, LOWER SILESIA STANDARD, *ABIES ALBA* MILL

Abstract: The paper presents results of the research on extension of the dendrochronological standard for fir (*Abies alba* Mill.) from the area of southern Poland. 893-year master chronology, constructed in 1999, covered the period 1106-1998 AD. Mediaeval timbers coming from archaeological excavations located in the area of the Old City of Wrocław and wood samples from architectural objects from the centre of Świdnica were used for construction of the LOWER SILESIA regional standard, spanning 250 years from 1054 to 1303 AD. High correlation and homogeneity of the elaborated standard with the southern Poland chronology, together with almost 200 years of overlapping of both, enabled 53-year extension back in time, to the year 1054. This way the southern Poland fir chronology became the fourth longest fir dendrochronological standard in Europe.

1. INTRODUCTION

The dendrochronological method is one of the most precise methods of absolute dating of objects from the last 10,000 years; the accuracy of dating being exactly one year. The dating is performed against a dendrochronological standard established for a given tree species from a determined area. The longer the standard, the larger are possibilities of dendrochronological dating. Actually the longest European standard is the German chronology for subfossil oaks (Becker, 1993). In Poland such a long standard has not yet been defined, but the research has been being continued on construction of the Holocene oak chronology for the area of southern Poland (Krąpiec, in print). Studies on construction of long absolute standards in Poland are focused not only on oak but on coniferous tree species as well. Almost thousand-years-long pine (*Pinus sylvestris*) chronology, spanning the period 1106-1991 AD, was constructed for northern Poland (Zielski, 1997). The second almost thousand-year-long standard produced in Poland for a coniferous tree species is the fir chronology covering years 1106-1998 AD, produced from 29 local chronologies which in turn were based on 410 samples of timbers coming from living trees and historical wood, representing architectural objects (churches, an orthodox church, old buildings etc.), archaeological findings and wooden shafts from the Wieliczka Salt Mine (Szychowska-Krąpiec, 2000). This standard enables dating of fir timbers from all over southern Poland. Apart from the first 80 years (fir timbers from that period were scarce) the chronology is multiple replicated (between 10 and 80 samples) and characterised by strong dendrochronological signal. The presented mediaeval Lower Silesia standard extends the southern Poland chronology to the middle of the eleventh century and broadens its replication in the twelfth century.

2. MATERIAL AND METHODS

The material for studies were fir timbers coming from archaeological excavations led in Wrocław and from architectural objects from Świdnica, sampled in the years 1996-2000.

In Wrocław huge amounts of timbers, mostly of oak and pine and only scarcely of fir (a few pieces each season of works), were explored within the area of the Old City, in the vicinity of the Kiełbaśnicza, Oławska, Nowy Targ, and Rynek streets. Somewhat higher number of fir timbers (11 samples) were encountered only in the last year of the excavations, season 1999/2000, during the archaeological works preceding the construction of heating, sewage and light installations along the street Nowy Targ.

In Świdnica timber samples were taken from architectural objects situated at Rynek and the adjacent streets (the area between the Bohaterów Getta, Teatralna, Mennicka, and Pułaskiego streets). These were mainly case planks, more rarely various beams.

Whole set of the collected samples was analysed in the Tree-Ring Laboratory of the Department of Stratigraphy and Regional Geology, University of Mining and

Metallurgy in Cracow. After preliminary standard procedure of preparation of samples for dendrochronological analysis they were measured with 0.01 mm accuracy with the measurement apparatus enabling computer registration and analysis of the results with the program TREE-RINGS (Krawczyk and Krąpiec, 1995). Based on the measured widths of the annual growth rings of a given sample individual ring patterns were established. Similarity and correlation of the produced patterns were evaluated with two statistical values: the modified value of the Student's *t* test (Baillie and Pilcher, 1973) and the Pearson's linear correlation coefficient *r*. The correctness of the standard construction and the degree of its homogeneity were checked with the program COFECHA (Holmes, 1994).

3. RESULTS

Lower Silesia standard

Visual comparison of synchronised growth patterns defined with respective statistical values resulted in construction of absolutely dated regional LOWER SILESIA standard, spanning 250 years from 1054 to 1303 AD. It consisted of 15 samples: 11 from Wrocław and 4 from Świdnica (**Fig. 1**). The samples contained various numbers of annual growth rings, between 171 (2SWD9) and 41 (2SWD8). The values expressing correlation of individual samples with the standard pattern are presented in **Table 1**. The value *t* is between $t = 12.92$ and $t = 6.26$, whereas the value of Pearson's linear correlation coefficient *r* is within the range 0.51-0.87. Taking into account that for a pair of correlated sequences *t* value is over 3.5 and the correlation coefficient is streaming to 1, the obtained values indicate high homogeneity of the produced standard. The other parameters: standard deviation, autocorrelation and the mean sensitivity also support this conclusion. The first order autocorrelation, i.e. the correlation of a standardised sequence of growth sequences with the same pattern shifted one year is within the limits of 0.579-0.910, whereas the average sensitivity defining the degree of diversification between two succeeding growth values in the time series is 2.47 on average.

Correctness of the construction of the LOWER SILESIA standard was checked by its teleconnection with other fir chronologies for neighbouring areas: eastern Austria – 977-1997 AD (Liebert *et al*., 1998), central Germany (Sachsen and Thuringen) – 994-1921 AD (Heußner, 1996), southern Germany – 820-1985 AD (Becker and Giertz-Siebenlist, 1970, with unpublished extensions), Czech – 1131-1997 AD (Kyncl and Kyncl, 1996). The similarity of the produced standard with other chronologies, expressed by *t* values, is high; from $t=5.57$ to $t=10.14$ (**Fig. 2**). The highest values of *t* were observed at comparison of the produced standard with two German chronologies (from 9.55 to 10.14) and the Czech one ($t = 8.50$). This should be explained by similar climatic conditions (similar influence of Atlantic air masses). In the case of teleconnection with the Austrian chronology the similarity is lower, $t=5.57$. It is due to various absolute heights above sea level of the areas where the analysed firs grew. The area of Wrocław and Świdnica are situated within the Silesian Lowland and Świdnica Plain, where the altitudes are not higher than 300 m a.s.l. (Mileska, 1998). The eastern Austria is a mountain area with heights between 800 and 2000 m a.s.l.

High similarity of the produced standard with four European chronologies proves correctness of the construction and points out a strong dendrochronological signal (high correlation values) and its broad geographical extent (high distances between individual areas of occurrence of fir populations: Czech – 200 km, Germany – 700 km).

***Fig. 1**. Dendrochronological dating of sequences constituting the regional LOWER SILESIA standard.*

Table 1.*Sequences forming chronology LOWER SILESIA*

No.	Series	Dating of sequences	No. of years	Correlation with master [t*], [r]	Mean width ring [mm]	Standard deviation	Autocorrelation	Mean sensitivity
1	**3WR1**	1181- 1260	80	8.861 0.718	2.54	0.962	0.838	0.199
2	**3WR14**	1109 -1248	140	7.566 0.547	0.56	0.289	0.766	0.292
3	**3WR22**	1128 -1227	100	6.274 0.543	1.00	0.590	0.910	0.213
4	**3WR23**	1075 -1213	139	6.929 0.515	0.56	0.391	0.814	0.291
5	**3WR24**	1125 -1226	102	6.890 0.575	0.93	0.617	0.904	0.224
6	**3WR26**	1075 -1212	138	8.424 0.591	0.46	0.354	0.842	0.324
7	**3WR27**	1124 -1226	103	6.919 0.575	0.97	0.556	0.886	0.210
8	**3WR28**	1054 -1129	76	6.599 0.741	0.47	0.302	0.863	0.279
9	**3WR33**	1088 -1153	66	8.536 0.741	0.47	0.213	0.613	0.181
10	**3WR7**	1193 -1242	50	7.268 0.739	1.50	0.742	0.809	0.228
11	**3WR8**	1188 -1253	66	8.025 0.719	1.08	0.569	0.885	0.204
12	**2SWD8**	1263 -1303	41	10.526 0.872	3.00	1.029	0.579	0.229
13	**2SWD9**	1106 -1276	171	12.922 0.709	0.92	0.472	0.834	0.237
14	**3SWD13**	1186 -1272	87	10.503 0.759	1.57	0.891	0.793	0.259
15	**3SWD14**	1247 -1297	51	6.267 0.683	1.87	0.551	0.597	0.200

t - calculated according to the algorithm of Baillie and Pilcher (1973)*

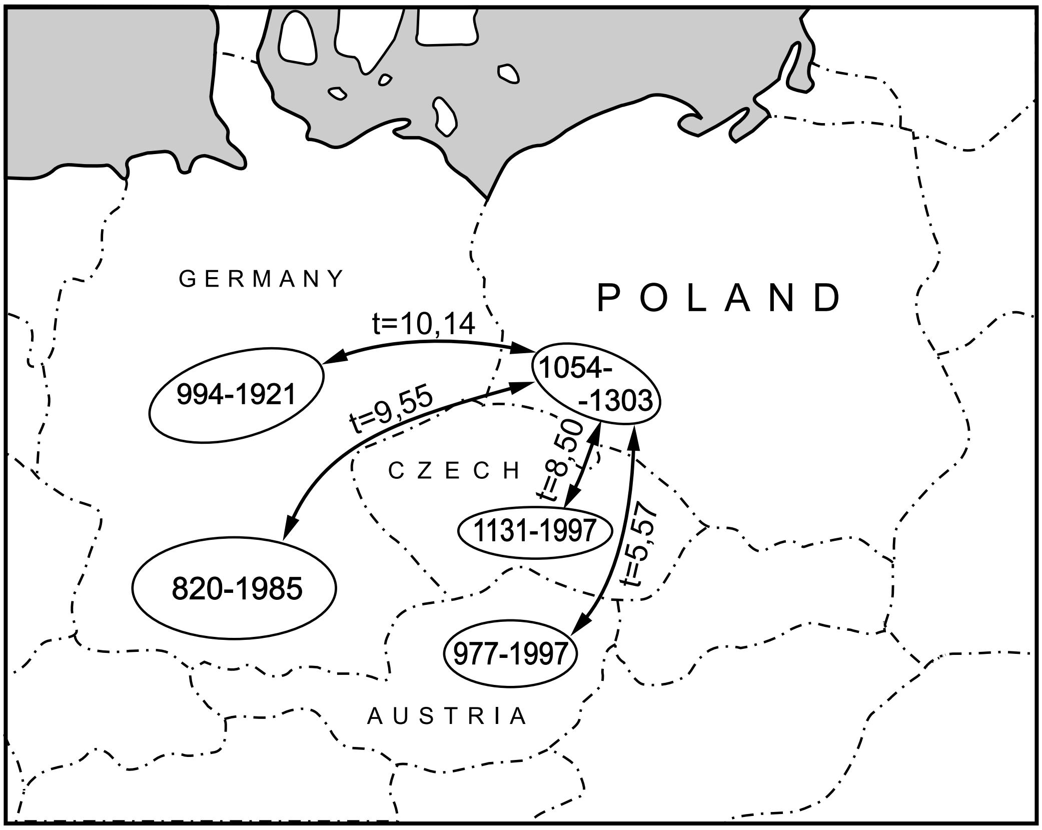

Fig. 2. *Teleconnection of the LOWER SILESIA standard with other European standards.*

The Lower Silesia standard was correlated with the fir chronology for southern Poland, beginning in 1106 AD. Visual matching of the two curves indicated high similarity which was confirmed by statistical values $t = 12.2$ and $r = 0.66$. Both standards share a time interval of 198 years. The first growth ring of the southern Poland chronology, dated to 1106 AD, corresponds to the 53rd growth ring of the Lower Silesia standard. This enabled to extend the southern Poland chronology 53 years back in time and to fix its beginning in 1054 AD.

Specific character of this taxon, according to Larsen (1986) conditioned with low genetic variability and low capability of adaptation, caused strong dendrochronological signal of the constructed standards and their high dating potential, which manifests themselves in successful dating of timber samples from distant localities e.g. Wrocław, Bytom or Cracow.

Dating of historical timbers

The samples from Wrocław and Świdnica forming the Lower Silesia standards were absolutely dated. The samples from Świdnica were dated to the years between 1272 and 1303 AD. Based on the obtained results, one can conclude that the case planks and beams coming from the buildings at Market Square (Rynek) of the town and the neighbouring streets were most probably made in the same time. As none of the samples contained its last growth ring, it should be assumed that the trees of which the analysed elements were made had been cut down in the first or second decade of the thirteenth century.

In the case of the samples from Wrocław the time interval of the obtained results was much broader: from 1129 to 1260 AD. The dates of timbers sampled from ditches for heating and sewage installations at the street Nowy Targ, display 15-year dispersion: 1212-1227 AD, except two samples: 3WR33 (1153 AD) and 3WR28 (1129 AD). The youngest value (1227 AD) should be assumed as dating the wood that might come from fir trees felled in 1230s. The sample 3WR33, dated as 60-70 years older than the remainder, may represent an internal part of a trunk or a reused timber. One timber from the street Nowy Targ, coming from the sewage ditch, proved to be the parent for the oldest sample (3WR28) of the Lower Silesia chronology. Wooden structures (planks and supporting beams) from Rynek and the Old City of Wrocław may be assumed as almost contemporaneous, as their dates display high similarity: from 1242 AD (Oławska Street) to 1260 AD (Rynek). It can be undoubtedly stated that the wood from the object No 12 at 28, Kiełbaśnicza Street is five years younger than the wood from the object at the same street No 25a, as in both cases the last sapwood rings were preserved.

3. CONCLUSIONS

1. Dendrochronological analysis of historical wood from Wrocław and Świdnica enabled construction of the mediaeval 250-year Lower Silesia standard, covering the period 1054-1303 AD.
2. Due to strong dendrochronological signal and its broad geographical extent, the Lower Silesia standard enabled 53-year extension of the southern Poland fir chronology, up to now covering the period 1106-1998 AD. This way the latter became the longest Polish chronology for coniferous trees, being 945 years long, from 1054 to 1998 AD.
3. The Lower Silesia chronology enabled dating of timbers explored from archaeological excavations led in the Market Square (Rynek) of Świdnica for the turn of the thirteenth and fourteenth centuries. Wooden constructions from Rynek and the Old City of Wrocław were dated by this chronology back to the twelfth and thirteenth centuries.

ACKNOWLEDGEMENTS

Financial support for this study was provided by the AGH grant, BW No. 10.10.140.274.

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