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SHORT ARTICLE

Medieval oak chronology from the Vilnius Lower Castle

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Abstract

The paper describes the results of a dendrochronological investigation on historical oak (*Quercus robur* L.) timbers from the Vilnius Lower Castle excavations. In Lithuania, oak was used only in specific cases during the Middle Ages. Therefore, historical material for tree ring chronology building is lacking. However, the construction of a local oak chronology is of great importance as it can help to determine the provenance of many imported timbers that are part of wooden cultural heritage in Western Europe. Oak samples make 9.2% of the analysed timbers excavated in the Vilnius Lower Castle territory – the largest present-day collection of historical timbers in Lithuania. The main material for Vilnius oak chronology was obtained from the 'bridge foundation (BF)' construction found close to the Royal Palace gate at a depth of 4–5 m. Ring-width series of the oak beams of the 'BF', together with other excavated oak logs were cross-dated and a mean chronology of 217-year length was constructed. The chronology was dated to AD 1202–1418 against the Baltic reference chronologies BALTIC1 ($t = 7.57$), BALTIC2 ($t = 4.52$) and WINCHCOL ($t = 5.74$) (authors J. Hilliam, I. Tyers, D. Mills). The average date of the hardwood – sapwood boundary on the 'bridge' samples that have partially preserved sapwood is between 1406 and 1407. As the average number of oak sapwood rings is considered to be 16, the most probable felling date of trees used for the 'BF' is situated around 1423.

Keywords: Dendrochronology; Dendroarchaeology; *Quercus robur* L.; Historical timber trade; Lithuania

Introduction

Fluctuations in tree ring width depend on changing environmental conditions that are specific to the region. This means that dendrochronologists dating wooden objects have to use reference chronologies from the region off-origin of the wood. As opposed to the living trees, localisation of historical wood provenance is not so easy. Owing to trade relations wood was transported not only locally, but all over Europe (Eckstein et al., 1986; Baillie, 1995).

It is well known that in medieval times a lot of wood was exported to Western Europe from less densely populated and therefore not so deforested East and North European countries (Wazny and Eckstein, 1987; Bonde, 1992). In the 15–16th century, one of those important wood-exporting countries was the Great Duchy of Lithuania. One of the earliest written sources of wood export from Lithuania is a 1405 letter from the Great Master of the German Order to the Grand Duke of Lithuania Vytautas the Great, mentioning that Lithuanian wood is of great importance in the Danzig

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port (Ivinskis, 1934). The number of citations on Lithuanian wood export increases in documents after the defeat of the German order in the Grünwald battle in 1410. These notes show that wood has been regularly floated down the Nemunas (Memel) river to Prussia since the beginning of the 15th century (Ivinskis, 1934). Already in the first half of the 15th century the main assortments exported from Lithuania have been "Wagenschoss" (wainscots) made of oak (Ivinskis, 1934). Wainscots were an important part of the timbers exported from Gdansk/Danzig (Wazny, 1992), and were also traded in Riga (Zunde, 1998–1999). The 1472–1473 Normedia waterage register of timbers exported from Lithuania (stored in the Königsberg archive before the WWII and lost during the war), besides to oak timbers named "Wagenschoss" and "Klappholz", list such assortments as "Knarrholz", "Koggenbort", "Eibenholz", "Fassholz", "Stabholz" and "Maste" (Ivinskis, 1934). The exploitation of Lithuanian forests intensified when an office of Hanseatic League was set up in Kaunas in 1445. In the middle of the 16th century Lithuanian forests were heavily exploited, what made the Vilnius Seimas (the parliament) decide in 1547 to take wood export under a state monopoly (Ivinskis, 1933).

Historical written sources show that the main rout of the 15–16th centuries Lithuanian timber trade passed via Königsberg, the port with the right of timber resorting, to Danzig, the centre "par excellence" of timber trade around the Baltic sea (Ivinskis, 1934). The lack of documents prevents to estimate the volume of exported timbers. However, it is certain that some part of timbers shipped from Danzig to western European countries originates from the basin of Nemunas river and other parts of the Great Duchy of Lithuania.

At present day in Lithuania the largest collection of historical timbers is collected at the Vilnius Castle excavations. This administrative centre of the Great Duchy of Lithuania was destroyed during the wars with Russia in the middle of the 17th century and demolished at the turn to the 19th century (Tautavičius, 1995). The current reconstruction activities and archaeological investigation of the Lower Castle territory allowed collecting a big amount of medieval and post-medieval timbers. The main tree species used in wooden constructions of the Lower Castle territory was Scots pine (Pukienė, 2004). Oak elements are rarely found. In order to build an oak chronology, a special effort was made to collect and analyse every oak sample suitable for dendrochronological analysis. In this paper, by studying the growth patterns of the selected oak specimens from the Vilnius Castle we assess the possibility to establish the first medieval local oak chronology for Lithuania and explore its relations with the existing Baltic oak reference chronologies.

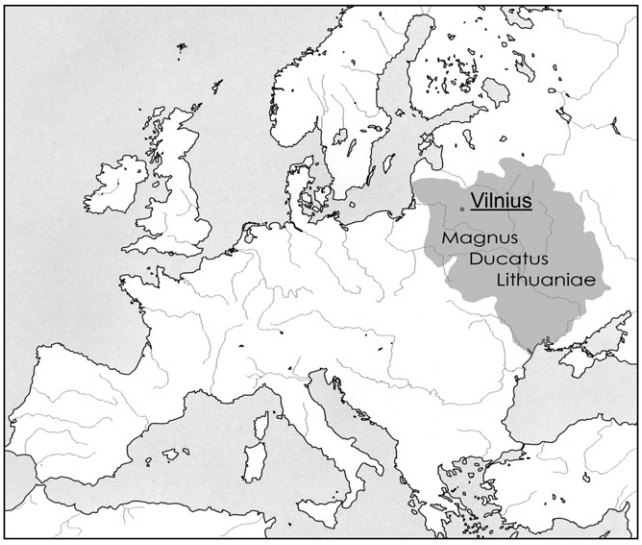

Fig. 1. The Great Duchy of Lithuania in the 15th century.

Site, material and methods

In the middle of the last millennium the Great Duchy of Lithuania spread over a vast territory in the central east Europe from the Baltic to the Black sea (Fig. 1). Vilnius is known as an administrative centre of Lithuania at least since 1323. The Lower Castle of Vilnius castle complex has been rebuilt several times and changed its use from the fortification system in the 14th century to the rulers' residence complex in later centuries (Kitkauskas, 1989).

During the long history up to 8 m thick cultural layer has been accumulated in the Castle territory. The upper layers represent a period of brick and stone constructions mainly of the 15–17th and later centuries. In the depth of approximately 4 m the layers rich with remnants of timber constructions (pavements, houses, piles, etc.) of previous centuries start. In some places the thickness of successive timber constructions is up to 4 m. Because of wet and peaty ground some stone basements of the Royal palace (Fig. 2) were built on wooden raft constructions too (Ožalas, 2001).

Dendrochronological material was collected by taking cross-sections of elements of excavated wooden constructions suitable for dendrochronological analysis. Depending on the availability at least 5 elements were sampled of each construction or a phase. Cross-sections were wrapped into plastic bags in order to avoid desiccation. Oak samples were selected from the wood collection for this study.

The largest assemblage of oak samples for oak chronology building came from a massive wooden construction excavated by the Castle Research Centre "Lietuvos pilys" in 1996–1999 and in 2002–2005 (Figs. 2 and 3).

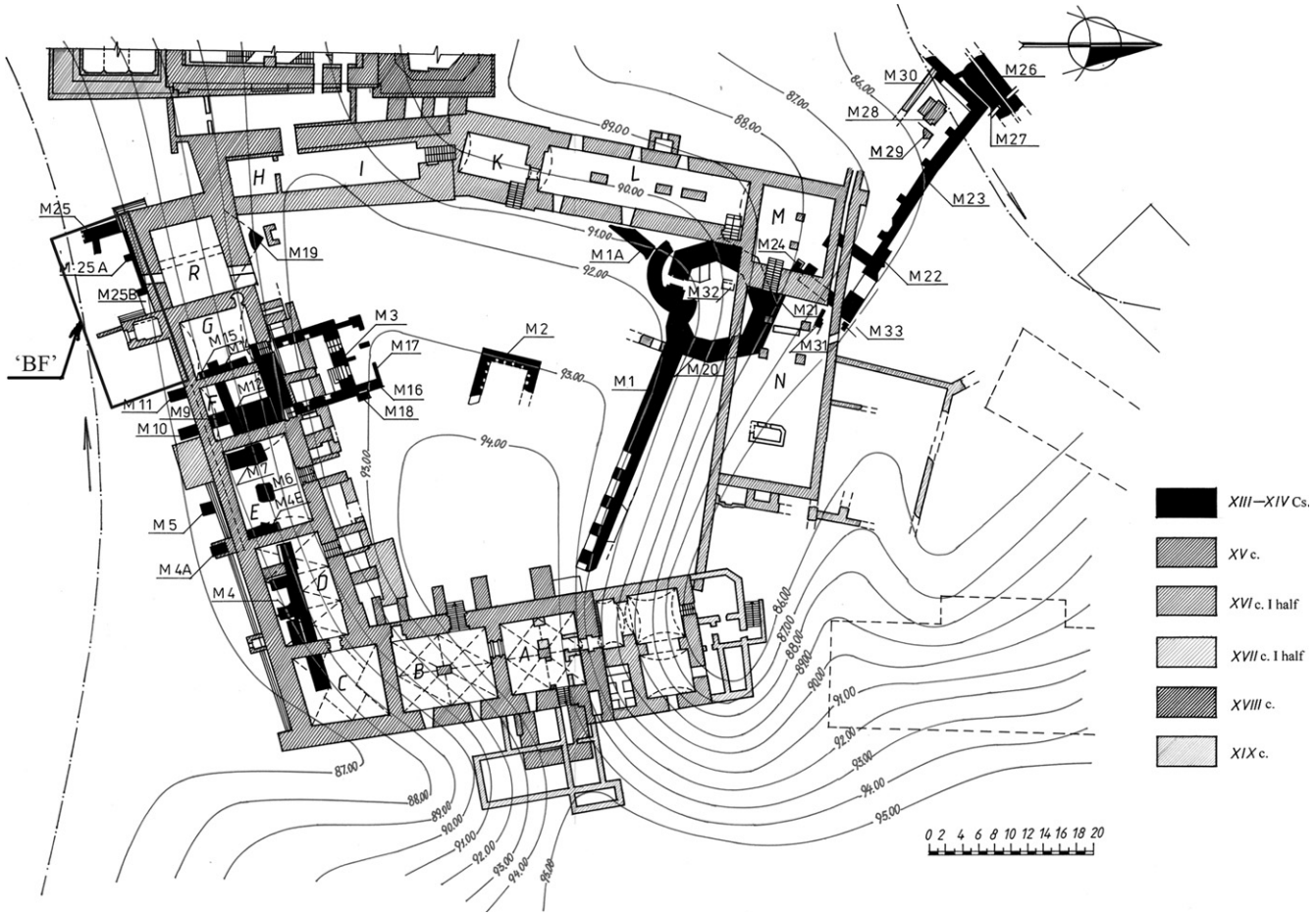

Fig. 2. Map of the stone basements of the Royal palace at the Vilnius Lower Castle. 'BF' marks the place of the wooden 'bridge foundation' construction.

The construction (a view from above see Fig. 4) was found close to the southern gate of the Royal Palace at a depth of 4–5 m at the altitudes of H abs. 90.15–90.49 (Ožalas, 2003). It is made of longitudinal and transversal horizontal beams of rectangular cross-section and planks laid in several layers and joined by short vertical posts. The sides of beam cross-sections are 30–45 cm. The width of the construction is 6–7 m, the length is about 20 m.

The construction was built along a before-palace stone/brick wall, most probably a defence wall of the castle (Fig. 3, No. 2). A part of timbers was dismantled during the building of the later palace tower. All this massive construction capable to support heavy weight could be the basement of some kind of a bridge at the entrance to the castle bailey. Having no more information about the use of the construction, it was provisory named as a 'bridge foundation' (BF). Two basal timber layers of it were made of oak beams; planking and upper timbers were mostly of pine.

Some oak specimens were found in other constructions at the Castle territory: revetments, rafts under foundations, posts and remnants of unknown constructions.

All the collected oak samples were analysed using standard dendrochronological technique. Tree ring width was measured along two radii prepared by a razor blade. The measurement was carried out at the dendrochronological laboratory of the Castle Research centre by using Sheffield tree-ring measurement stage, to the nearest 0.01 mm. Measured ring width series were processed with the programme Dendro software package (author I. Tyers). *T*-Values according to Baillie and Pilcher (1973) were used as statistical test for cross-matching tree ring series. Cross-dating was carried out based on statistical tests and visual cross-matching. The chronology was constructed by averaging the cross-dated unstandardised ring width series.

Results

Scots pine (*Pinus sylvestris* L.) was predominating species in the excavated wooden constructions in the Lower Castle territory. Among the overall 294 analysed wooden specimens 86.8% were pine elements. Oak

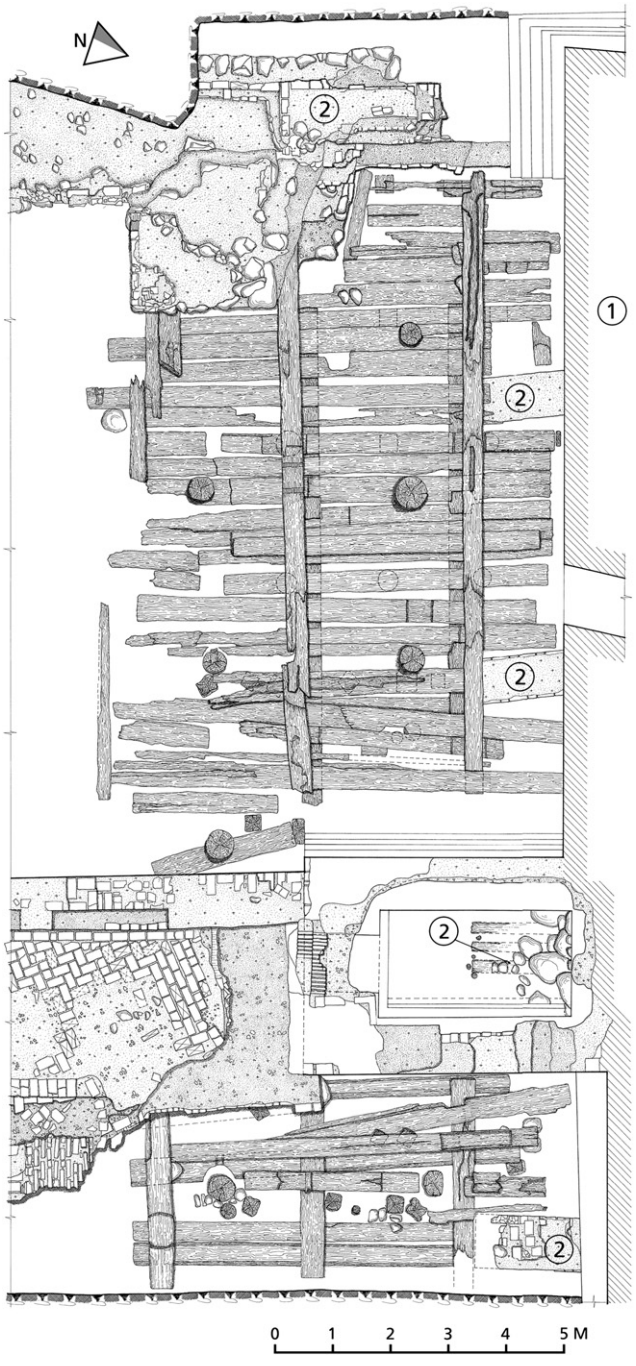

Fig. 3. Plan of the wooden construction 'BF' close to the southern gate of the Royal Palace. Number 1 marks the wall of the Renaissance Palace, 2 indicates remaining parts and counterforts of the earlier pre-palace wall. Drawing by R. Ašmėnaitė.

makes only 9.2% of the excavated timbers. Rest of the wooden samples, i.e. 4.0%, was alder (*Alnus* sp.) timbers. Larger quantity of oak was used in certain constructions. In the 'BF' construction oak timbers make 61% of the construction elements.

Collected oak samples had 30–300 annual rings. Samples containing 150–200 rings predominated. Number of remaining sapwood rings ranged from 0 to 16. Only two samples of younger than 50-year-old oaks had bark edge preserved.

Fig. 4. Wooden 'bridge foundation' construction along the southern wall of the palace: a view from above. Only the western part of the construction can be seen (photo by V. Abramauskas).

Thirteen oak timbers from the 'BF' construction and two oak logs of unknown use from the third wood layer east of the palace were successfully cross-dated. The cross-dated tree ring series were 133–211-year length. Shorter series and some long series from very slow-growing oaks failed to cross-match. Six samples of BF contained up to nine sapwood rings. One of the two logs from the third wood layer had 15 sapwood rings, another had only hardwood preserved.

Mean *t*-value between all the series pairs is 6.91 (see Table 1). Some high *t*-values suggest the beams may be made of the same tree. However, more investigations on the homogeneity of individual tree growth fluctuations are needed for final solution.

A mean oak chronology ZP04QRC1 of 217-year length was constructed from the cross-dated individual series. Fig. 5 shows the distribution of time spans covered by the series that found the chronology. In order to establish an absolute date for the chronology it was compared against the reference chronologies from the Poland and English chronologies of Baltic origin. The best agreement ($t = 7.57$) was found with an English oak chronology of Baltic origin BALTIC1 (authors J. Hilliam, I. Tyers) at the position dating the Vilnius chronology to 1202–1418 (see Fig. 6). Vilnius oak chronology also shows good agreement with other English chronologies WINCHCOL (D. Mills, $t = 5.74$) and BALTIC2 (J. Hilliam and I. Tyers, $t = 4.52$). The resemblance with Polish oak chronologies from regions

Table 1. Statistical *t*-values of the correlation between cross-dated oak series from the Vilnius Lower castle

File names	—	—	Zp02-176	ZP02-177	Zp02-180	Zp02-194	ZP02-195	Zp02-196	ZP02-266	ZP03-17	ZP02-265	ZP99-11	ZP98-34	ZP98-35A	ZP99-09	ZP99-10
—	Start dates	Dates end	1232	1218	1202	1239	1271	1243	1226	1228	1206	1227	1215	1238	1226	1208
—			1418	1396	1412	1401	1418	1408	1388	1406	1362	1400	1395	1408	1405	1399
Zp02-197	1253	1414	7.89	5.19	6.60	5.86	7.96	7.26	3.39	5.69	2.17	6.53	5.48	7.39	6.51	4.04
Zp02-176	1232	1418	*	8.18	10.14	10.62	11.09	10.37	7.33	8.57	3.44	9.62	11.29	10.76	5.40	6.06
ZP02-177	1218	1396	*	*	10.81	8.79	5.99	7.23	5.88	18.44	5.86	7.68	10.84	5.75	3.51	2.33
Zp02-180	1202	1412	*	*	*	13.61	8.20	9.31	6.34	10.76	4.61	10.23	17.52	9.69	4.44	2.33
Zp02-194	1239	1401	*	*	*	*	7.25	9.42	4.51	8.95	3.14	9.52	17.84	9.40	5.21	4.00
ZP02-195	1271	1418	*	*	*	*	*	6.99	5.11	5.57	3.03	9.98	5.83	9.67	5.54	5.27
Zp02-196	1243	1408	*	*	*	*	*	*	4.85	6.33	2.45	9.44	7.95	9.73	4.20	5.04
ZP02-266	1226	1388	*	*	*	*	*	*	*	5.66	7.52	6.62	5.59	5.61	3.66	6.62
ZP03-17	1228	1406	*	*	*	*	*	*	*	*	3.45	7.45	11.21	6.48	2.92	3.67
ZP02-265	1206	1362	*	*	*	*	*	*	*	*	*	3.04	5.44	2.67	4.09	2.11
ZP99-11	1227	1400	*	*	*	*	*	*	*	*	*	*	9.88	16.17	2.44	3.21
ZP98-34	1215	1395	*	*	*	*	*	*	*	*	*	*	*	8.35	3.84	2.27
ZP98-35A	1238	1408	*	*	*	*	*	*	*	*	*	*	*	*	3.61	3.78
ZP99-09	1226	1405	*	*	*	*	*	*	*	*	*	*	*	*	*	7.11

not far from Lithuania (author T. Wazny) is lower (see Table 2 for *t*-values between the series).

Discussion and conclusions

Tree ring series of about a half of collected oak samples were successfully synchronized and used to build a chronology. The cross-dated trees are quite homogeneous in age and tree ring pattern. This homogeneity suggests the trees were growing under similar site conditions in a close area. It is difficult to say how close this site was to Vilnius, i.e. how "local" is the constructed chronology. Construction expense accounts from the middle of the 16th c. mention sites of pine logging in ducal forests at a distance of 20–30 km from Vilnius (Vitkauskienė, 2006). However, considering the well-developed waterway system of the former Great Duchy of Lithuania it is possible that the location of logging activities were scattered and distant. Unfortunately, historical studies on local economical relations in medieval–post-medieval times are lacking and the subject is complicated due to destroyed archives. Explanation of the failure to cross-date the rest of oak samples could be the scattering of the series in time or remote and differing sites of the tree provenance.

In the set of the cross-dated oak timbers there was no one with the bark edge present. The latest ring of the samples from the 'BF' is dated to 1418. Seven cross-dated samples had only hardwood present, rest six samples contained up to nine sapwood rings. The latest hardwood ring is dated to 1411. The average date of hardwood–sapwood boundary on the samples that have partially preserved sapwood is between 1406 and 1407. It is known that the number of oak sapwood rings differs depending on the geographical region of oak growth (Bartholin et al., 1992). In Lithuania this value is not studied. The minimal number of oak sapwood rings found in Europe is 7 (Hillam et al., 1987). Following this evaluation the earliest possible date of tree felling for the 'BF' construction is 1418. The closest region to Lithuania where the number of oak sapwood rings is studied is Poland (Wazny, 1990). Within the 90% confidence level the sapwood width is 9–24 rings in different regions of Poland. The median is 16 rings. Assuming 16 as the average number of sapwood rings in Lithuanian oak trees too, the most probable felling date of the trees used for the 'BF' is around 1423.

The series of one of the two cross-dated logs from the third wood layer has 15 sapwood rings. It is dated to 1226–1388 with the last hardwood ring dated to 1373. The construction in which these logs were used most probably was built around 1389.

Vilnius oak chronology shows higher correlation with English imported timber chronologies than with vicinal

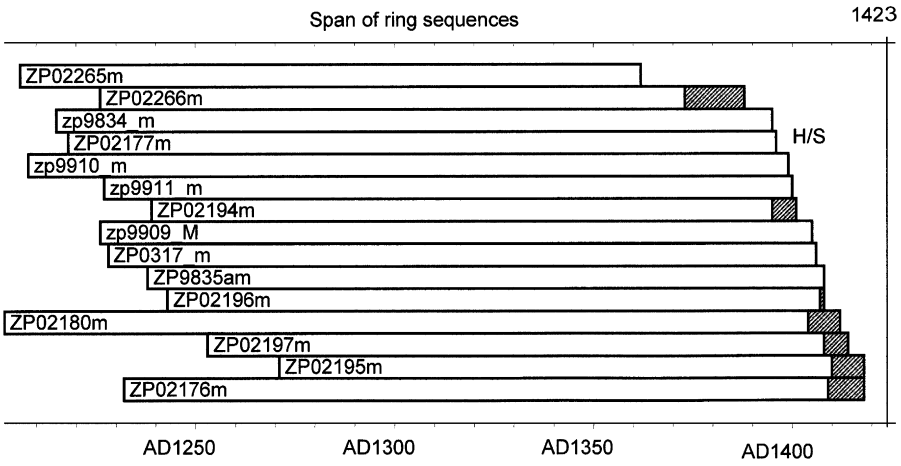

Fig. 5. Bar diagram of cross-dated tree ring sequences used to construct Vilnius oak chronology ZP04QRC1. Sapwood zone is shaded. A line at 1423 shows the most probable tree felling date.

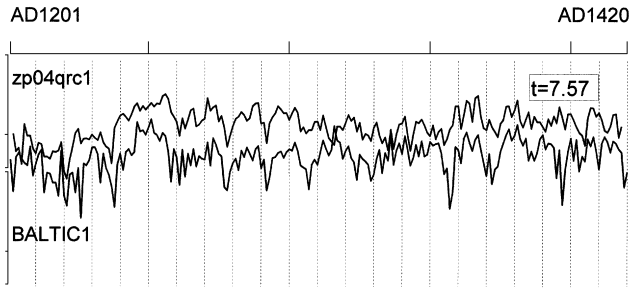

Fig. 6. Comparison of Vilnius oak chronology ZP04QRC1 and English chronology of imported oak of Baltic origin BALTIC1 (J. Hilliam, I. Tyers).

Table 2. Statistical agreement (t(BP) value) between Vilnius oak chronology ZP04QRC1 and some regional oak chronologies

Filenames	—	—	ZP04QRC1
—	Start dates	Dates end	AD1202
—			AD1418
Baltic1	AD1156	AD1597	7.57
Wnchcol1	AD1207	AD1495	5.74
Baltic2	AD1257	AD1615	4.52
Bransk	AD1247	AD1427	4.07
NPoland	AD996	AD1985	3.16
Bielsk	AD1262	AD1503	2.76
Dabrowno	AD1079	AD1344	—

Polish chronologies. This leads to two conclusions. Low similarity between Lithuanian and Polish oak chronologies indicates the regional differences in climatic signal. Dissimilarity in tree growth fluctuations diminishes the chance to cross-date oak series from different regions but on the other hand implicates the possibility to make a finer separation of provenances of timbers exported from the Baltic region. High similarity of the constructed Vilnius oak chronology with English BALTIC1 chronology indicates the presence of data of oaks exported from Lithuania in BALTIC1 and is an evidence for historic timber trade relations.

Considering the low percentage of oak timbers in historical buildings and constructions special attention should be paid to identifying oak specimens in archaeological collections and every oak timber usable for dendrochronological investigation should be sampled. Creation of a network of local and regional oak chronologies in the region east of the Baltic Sea is also essential for better understanding historical timber trade routs, refining provenances of timbers imported to Western Europe countries and homogenizing chronologies created using man-worked wood.

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References

Baillie, M.G.L., 1995. A slice through time. B.T. Batsford Ltd., London, (176pp.).

Baillie, M.G.L., Pilcher, J.R., 1973. A simple crossdating programme for tree-ring research. Tree-ring Bulletin 33, 7–15.

Bartholin, T., Bonde, N., Christensen, K., Daly, A., Eriksen, O.H., 1992. Dendrochronological dating at the National Museum of Denmark. Arkaeologiske Udgravninger i Denmark, 305–321.

Bonde, N., 1992. Dendrochronology and timber trade in northern Europe from the 15th to 17th century. Lundqua Report, vol. 34, pp. 53–55.

Eckstein, D., Wazny, T., Bauch, J., Klein, P., 1986. New evidence for the dendrochronological dating of Netherlandish paintings. Nature 320, 465–466.

Hillam, J., Morgan, R.A., Tyers, I., 1987. Sapwood estimates and the dating of short ring sequences. In: Ward, R.G. (Ed.), Application of Tree-ring studies,. BAR International Series, vol. 333. Oxford, pp. 165–185.

Ivinskis, Z., 1933. Lietuvių ir prūsų prekybiniai santykiai pirmoje 16 a. pusėje (Trade relations between Lithuanians and Prussians in the 1st half of the 16c.). Kaunas (in Lithuanian).

Ivinskis, Z., 1934. Lietuvos prekyba su Prūsais, I d. (Trade of Lithuania with Prussia, I p.). Kaunas (in Lithuanian).

Kitkauskas, N., 1989. Vilniaus pilys. Mokslas, Vilnius, 231pp. (in Lithuanian, with Russian and English summary).

Ožalas, E., 2001. Vilniaus Žemutines pilies medinės konstrukcijos (Holzkonstruktionen beim Bau des Herrscherpalas in der Wilnaer Niederburg). In: Lietuvos pilių archeologija. Klaipėda University, Lithuania Minor history museum, Centre for the cultural heritage, Klaipėda, pp. 173–183 (in Lithuanian with German summary).

Ožalas, E., 2003. Tyrimai Valdovų rūmų pietinio korpuso išorėje (Archaeological investigations in an outer southern wing of the Palace). In: Urbanavičius, V. (Ed.), Vilniaus Žemutinės pilies rūmai, 5. Lietuvos pilys, Vilnius, pp. 41–52, 283–284, 310–311 (in Lithuanian with English and Russian summary).

Pukienė, R., 2004. Historical wood from the Vilnius Lower Castle excavation. In: Bonde, N., Eckstein, D. (Eds.), Eurodendro-2004: Conference of the European Working Group for Dendrochronology. Hamburg, p. 39.

Tautavičius, A., 1995. Valdovų rūmų tyrimus įpusėjus? (Is it a halfway of the Rulers' Palace investigation?). Science and Arts of Lithuania III (7), 4–30 (in Lithuanian).

Vitkauskienė, R.B., 2006. XVI–XVIII a. Lietuvos Didžiosios Kunigaikštystės valdovų rūmai istoriniuose šaltiniuose (Historical evidence on the Palace of GDL Rulers in the 16–18th centuries). In: Vilniaus Žemutinė pilis XIV a.–XIX a. pradžioje. Lietuvos pilys, Vilnius, pp. 72–128 (in Lithuanian with English summary).

Wazny, T., 1990. Aufbau und Anwendung der Dendrochronologie fur Eichenholz in Polen. Dissertation, Hamburg University.

Wazny, T., 1992. Historical timber trade and its implications on dendrochronological dating. Lundqua Report, vol. 34, pp. 331–333.

Wazny, T., Eckstein, D., 1987. Der Holzhandel von Danzig/Gdansk – Geschichte, Umfang und ReichWeite. Holz als Roh- und Werkstoff 45, 509–513.

Zunde, M., 1998–1999. Timber export from old Riga and its impact on dendrochronological dating in Europe. Dendrochronologia 16–17, 119–130.