



DENDROCHRONOLOGICAL AND RADIOCARBON DATING OF THE MEDIÉVAL STRONGHOLD IN UJŚCIE (POLAND)

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Abstract: In 2008, the archaeological museum in Piła carried out excavations in the site No. 5 in Ujście upon the river Noteć (Poland), at the Rybacka Street and in the Old Market Square. In 12 archaeological excavations and 4 surveys abundant wooden structures were discovered, from which about 800 samples were taken, mainly of pine (*Pinus sylvestris* L.) and oakwood (*Quercus* sp.). The studies were aimed at absolute dating of wood with the dendrochronological method, the wiggle matching fitting curves method, as well as anatomical determination of wood. Absolute dating of the oakwood from the Rybacka Street allowed to distinguish the oldest fortifications of the stronghold from the ninth century, and also intensive introduction of wood in the years 980-1080 AD, whereas analysis of wood from the Old Market (survey IV) allowed to distinguish eight structural levels, from the 1530s until the 970s. On the basis of the pine wood 227-year-long local chronology 2U_02A was produced, dated with the wiggle-matching method for the period 860-1080 (± 10) cal. AD. Most of the pine samples proved to represent wood introduced in the 990s and 1040s (± 10) cal. AD, and also some repairs in the years 1000-1030 and 1050-1070 (± 10) cal. AD.

Keywords: archaeological wood, dendrological analysis, dendrochronology, radiocarbon dating, *Pinus sylvestris* L., *Quercus* sp., Ujście, Poland.

1. INTRODUCTION

In 2008, in the site No. 5 in Ujście archaeological excavation studies were carried out that preceded the reconstruction and revitalization of the Old Market Square and the adjacent streets. The excavations resulted in discovering rich wood material, mostly pine (*Pinus sylvestris* L.) and oakwood (*Quercus* sp.), representing structural elements of the mediaeval stronghold. This site, dated for the early Middle Ages, had already been excavated before. The first excavation works in Ujście were carried out by L. Leciejewicz and E. Dąbrowski at 9 Rybacka

street in 1953. The site was identified as remains of an ancient castellan's fortified castle. There were discovered well-preserved structures of the wall, the underlying pier, as well as the settlement buildings (Leciejewicz, 1961). The dendrochronological analysis of three preserved wood samples, made relatively recently, enabled to date the defensive structures for the 970s (time of Prince Mieszko I). Apart from timber structures, other valuable objects were encountered, among others ceramics and spurs dated to the turn of the seventh and eighth and the eighth century (Leciejewicz, 2008).

At establishing the chronology of the archaeological excavation site in Ujście it was decided that, except the commonly applied radiocarbon method, the dendro-

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chronological method should be used as well, successfully practiced in Central Europe for over 20 years (Zielski and Krąpiec, 2004; Danek *et al.*, 2007; Gurskaya, 2007; Rybniček *et al.*, 2010).

Dating oakwood samples from Wielkopolska should not present any substantial problem, since long standard chronology for this area, covering the period 449-1998 AD, has been already constructed (Krąpiec, 1998) and comparative materials from numerous early-mediaeval sites are also accessible (Kara and Krąpiec, 2005). The possibility of dating pine wood looks, however, quite differently. The longest Polish standards produced for the neighbouring areas embrace 1091-2004 AD for Małopolska (Szychowska-Krąpiec, 2010) and the period 1106-1994 AD for Kujawy and Gdańsk Pomerania (Zielski, 1997). The German standard worked out by Heussner (1996) reaches back from recent to 924 AD. Preliminary estimations, based on archaeological finds, indicated that wood samples from the Ujście pine structures could allow to extend the pine standards hitherto constructed.

2. STUDY AREA AND MATERIALS

Ujście is a town situated upon the river Noteć in the north-western part of Poland (Wielkopolska) (Fig. 1). Since 1996 the town of Ujście belongs to the Chapter of the Oldest Towns in Poland. The excavation work carried there in 2008 had rescue character and focused above all on recognizing the settlement zone outside the town walls (Rybacka Street) and the clobber of the stronghold (The Old Market Square). The excavation works were carried out by the District Museum in Piła under the management direction of J. Rola.

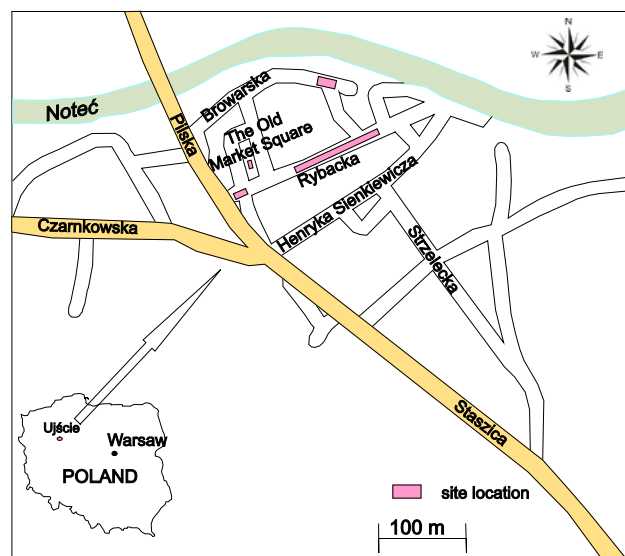


Fig. 1. Location of the archaeological rescue excavations in the Old Town of Ujście.

The first part of timbers (434 samples) was taken from 12 archaeological excavations embracing successive sections of the Rybacka Street (72.4 m), one of the main streets in Ujście. The next, smaller part of wood (252 samples) was taken from three survey excavations, about 1.5×3 m in size each, located within the same street. The next investigated site was the Old Market Square, where the fourth survey was established. In this survey, about 2×3 m in size, well preserved wooden structures from older phases of the early Middle Ages were encountered, up to the depth of over 7 m below the surface of the terrain. 110 samples of wood were collected in the survey IV.

Altogether, from all excavations about 800 samples of wood were gathered, which represented a broad spectrum of the tree species. These were both structural elements and pales and also trunks of trees, posts, radial planks, boards and branches with traces of processing (Fig. 2). The way of sampling the material for the investigations largely depended on the kind and state of preservation of the building structures and their sizes. In many cases slices (entire circles), up to about 5 cm in thickness, were taken from trunks with a motor-driven saw. Wood with traces of processing or small twigs were handed over for examinations in the whole or in fragments.

Out of all the wood samples handed over for the dendrochronological analysis, the requirements of the method, i.e. the right number of growth rings and sufficiently good state of preservation of the structure of wood, were fulfilled by 300 samples. Altogether dendrochronological measurements were made for 109 samples of deciduous species (mainly oak) and 191 coniferous samples (predominantly pine).

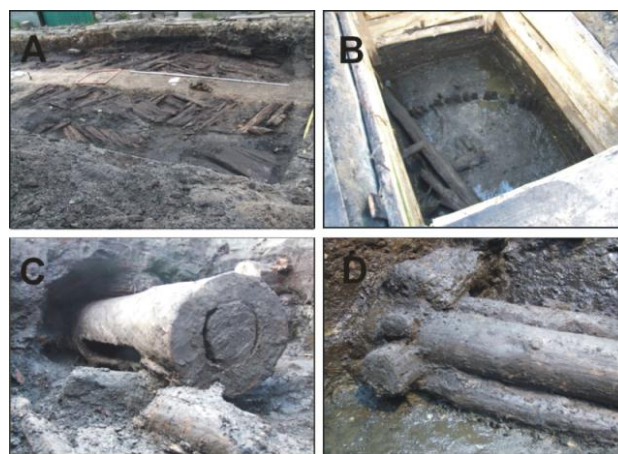


Fig. 2. Samples of wood from building structures and roads: A – Road structures preserved, Rybacka Street; B – Oak fence dated to after 1250 AD, IV construction level, survey IV, Old Market Square; C – Beehive dated to 15th c., II construction level, survey IV, Old Market Square; D – Fragment of a building dated to after 1250 AD, IV construction level, survey IV, Old Market Square.

3. METHODS

Dendrological analysis

All samples of wood, bigger than a few millimetres and exhibiting at least one annual growth fully developed, were subjected to the anatomical identification. Every sample was subjected to the standard preparation, consisting in cutting the surface layer of wood with a preparation knife. In the case of charred wood samples, legible image of the structure of wood could be obtained through breaking along the perpendicular cross-section plain. Another way of preparation consisted in cutting, with a preparation knife, a relatively thin scrap of wood, allowing for free transmission of light. Such a slice was oriented with respect to the plains and anatomical directions. Determination of wood was made with the stereoscopic microscope, with fluent regulation of magnification from 7 to 90x and with help of atlases and anatomical keys (Phillips, 1948; Schweingruber, 1990).

Dendrochronological analysis

Samples of wood complying with the requirements of the dendrochronological method were subjected to standard preparation, consisting in cutting the wood topcoat along the cross section with the preparation knife (OLFA). Measurements of the annual growth widths, with an accuracy of 0.01 mm, were made with help of the DENDROLAB 1.0 apparatus in the Dendrochronological Laboratory AGH-UST in Cracow. The measurement results were recorded with the QUERCUS program (Walanus, 2005). In order to receive representative measurement results, every sample was measured twice, along two different radii. The dendrochronological sequences measured were correlated and averaged which allowed to obtain individual patterns. That was made with the package of programs TREE-RINGS (Krawczyk and Krąpiec, 1995). Absolute dating of oaks was made against the Wielkopolska standard (Krąpiec, 1998).

Different procedure was applied at dating pine wood which was connected with the fact that the longest Polish standard reached back only to the beginning of the twelfth century. In the first step of the analysis contemporaneous individual sequences were identified, out of such ones which counted more than 50 annual growth rings. The identification of the contemporaneous individual sequences was based on some statistical parameters, i.e. Pearson's coefficient of linear correlation r and t -value (Baillie and Pilcher, 1973) and also on visual matching of the dendrograms. Based on the most convergent sequences the local chronology was produced. Correctness of its construction was tested with the COFECHA program (Holmes, 1999) and then it was compared with available pine standards worked out for Central Europe (Heussner, 1996; Zielski, 1997; Szychowska-Krąpiec, 2010).

Radiocarbon analysis and wiggle-matching method

Radiocarbon dating presented in this paper was carried out in the Laboratory of Absolute Dating in Skala near Cracow, Poland. The measurements of the ^{14}C concentration were carried out with the scintillation technique (Liquid Scintillation Counter). The measurements were made with the low-background scintillator of new generation, HIDEX 300 SL (Krąpiec and Walanus 2011). Calibration of the radiocarbon dates (expressed as cal. AD with probability of 68% and 95%) was carried out with help of the program OxCal (3.10 version) (Bronk Ramsey, 2001).

The age of the pine chronology was determined with the wiggle-matching method which allows for dating objects with considerably higher accuracy than in case of single radiocarbon measurements (Pearson, 1986). The analysis was made on six samples containing annual growth rings of the pine trees, relatively dated dendrochronologically (Fig. 3). The curve outlined on the basis of results of the radiocarbon measurements and the time interval between the middles of sections represented by the tree rings was used to determine a curve corresponding to a section of the calibration curve IntCal09 (Reimer *et al.*, 2009). Best fitting of the curve obtained to the calibration curve was determined with help of the OxCal program (3.10 version) (Bronk Ramsey, 2001).

4. RESULTS

The anatomical analyses of wood lifted at the archaeological works in Ujście allowed to determine the species changeability represented in the individual culture layers. This changeability, in turn, gives rise to the analysis of preferences at use of all sorts of the tree species in the early-mediaeval stronghold. Altogether 796 samples of wood were subjected to the anatomical investigations. Frequency figures of the individual tree species are presented in Fig. 4. The determination of the tree species demonstrated domination of the conifers (67%), mainly represented by the pine (*Pinus sylvestris* L.) – 527 samples. Larch (*Larix decidua* Mill.) and fir (*Abies alba* Mill.) were noted only occasionally. Deciduous tree species made up 33% of the material analysed, with predomination of oak (*Quercus* sp.) – 17%, and less frequent alder (*Alnus* sp.) – 7%, and birch (*Betula* sp.) – 4%. The ash tree (*Fraxinus excelsior*) and willow (*Salix* sp.) tim-

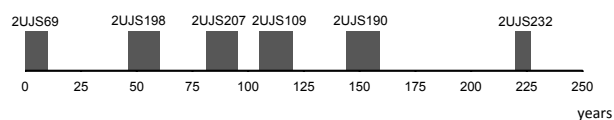


Fig. 3. Samples used for dating with the wiggle-matching method. Growth rings analysed are marked in gray.

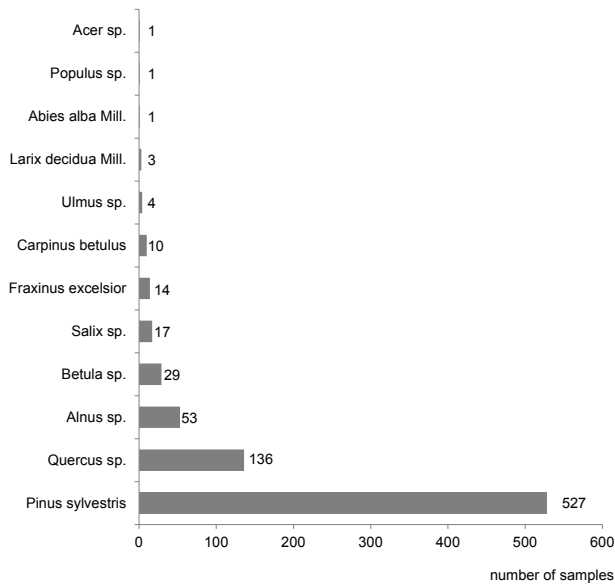


Fig. 4. Anatomical analysis of wood from Ujście.

bers were noted in considerably lower amounts (2% each), whereas the hornbeam (*Carpinus betulus*), elm tree (*Ulmus sp.*), maple (*Acer sp.*) and poplar (*Populus sp.*) – only occasionally. The frequency pattern of the individual tree species in the structural elements is also very interesting. Posts (97 samples) were made in majority from oakwood (40%) and pine (20%). They were also made of alder (12%), ash tree (10%), willow (7%) and birch (6%). The hornbeam, maple, and elm were used more rarely. Such choice of timber seems to be intentional, on account of higher durability of the pine, oak and alder in aqueous environment (Krzysik, 1953). Thanks to that, these structures were more resistant to decaying.

Finally, out of such rich material, only 37% of samples complied with the requirements of the dendrochronological method. The measurements of the annual growth widths were made for 106 samples of the deciduous tree species (96 oaks, five alder trees, three of the ash, and two elm ones). Amongst the coniferous trees, 189 samples of the pine and two samples of larch were measured. Unfortunately, most samples of the coniferous wood could not be dendrochronologically analysed because of too short individual sequences (less than 25 annual growth rings). The measurements of the coniferous timbers were often difficult because of very narrow incremental zones, weak visibility of the boundaries between the successive annual rings, due to young age of plants or provenance from the top part of the trunk, as well as because of missing rings. Short sequences of the annual growths, representing young trees, also predominated among the oak samples. The sequences measured contained from 24 to 187 annual growth rings; 48 samples

were absolutely dated against the regional oak standard for Wielkopolska (Krąpiec, 1998).

Results of dating of the oak samples taken from the excavations in the Rybacka Street are presented in Fig. 5, in form of the block-diagram. 26 wood samples were successfully dated with the dendrochronological method. Thanks to presence of the last ring produced by the tree before cutting it down, so-called ring in bark, five samples could be dated with one-year accuracy. For the remaining samples, deprived of the youngest rings, it was not possible to determine the time of cutting down the oak trees so precisely. However, taking into consideration the fact that majority of the analysed samples represented various beams, it may be assumed that the number of lacking growths should not be higher than several ones. The dates of cutting samples with fragmentary sapwood were evaluated with the formula determining the number of the sapwood rings at the oaks growing in the Wielkopolska region: $13 (-7/+8)$ (Krąpiec, 1998). In the case of dating the remaining samples the situation was more difficult on account of lacking of the total sapwood layer. In such cases only the earliest possible date of cutting the tree down may be established; obtained by adding to the date of the youngest heartwood ring preserved the equivalent for the years corresponding to the lacking sapwood rings. One should remember, however, about a number of missing heartwood rings, practically impossible to determine.

Distribution pattern of the results (Fig. 5) points out a considerable period of time from which the examined oakwood originates. Oak structural elements from the oldest fortifications of the stronghold appeared in the Rybacka Street in the excavations labelled with numbers

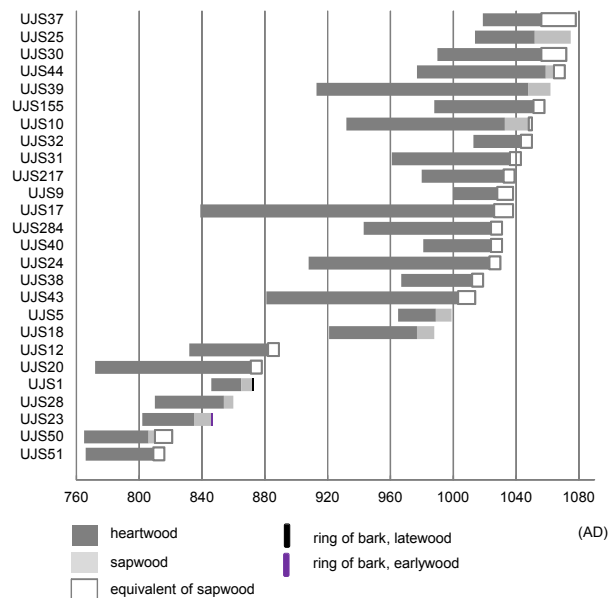


Fig. 5. Dendrochronological dating of growth sequences for oaks from Rybacka Street in Ujście.

from 171-165 to 110-105 and in the surveys I-III. They represented trees felled in the period from about 816 AD to about 889 AD; the analysed timbers could come from the first stronghold structures in Ujście. The samples with the total sapwood retained allowed for precise determination of their ages. The last ring with the latewood developed in the sample UJS23 pointed at cutting the tree down during the vegetation break, i.e. in the period between late autumn 847 and early spring 848 AD, whereas the ring in bark with the earlywood (sample UJS1) allowed to state that oak was cut down in the period from late spring till early summer 873 AD.

Apart from the oldest series of samples, numerous oak structural elements represented timbers introduced in the period from 989 AD to 1078 AD. The period of more intensive introduction of wood, represented by six samples (UJS24, UJS40, UJS284, UJS17, UJS9, UJS217), took place in the 1030s. The youngest oaks appearing in the excavations at the Rybacka Street came from the trees which ended their growth in the 1060s and 1070s; this may point at a next phase of development of the stronghold.

Results of absolute dating of the oak samples explored from the survey IV in the Old Market Square are presented in **Table 1** and **Fig. 6**. Only 22 of 55 oakwood samples handed over for the analysis could be successfully dated, mainly because of low numbers of the tree rings in them. Except for dendrochronological dating, nine radiocarbon dates were produced for samples from different archaeological mechanical layers. Results of the radiocarbon da-

ting, presented in **Fig. 6** and **Table 2** – part A, allowed to distinguish eight structural levels. The first one was outlined by the sample UJS287, dated dendrochronologically to after 1531 AD. The second structural level embraced the archaeological mechanical layers V-VII, dated to the fifteenth century. The third level (mechanical layers IX-XIII) was distinguished on the basis of dendrochronological dating of four oak samples (UJS254, UJS252, UJS274, UJS279), dated to the 1340s and 1350s. The fourth level was formed by the mechanical layers XV-XIX, with the highest number of dendrochronologically dated oaks, cut down in the years 1254-1258 AD. Out of that population twelve samples with the ring in bark retained came from the trees cut down in the year 1258 AD. Additional radiocarbon analysis was made for one pine sample labelled 2UJS288 (MKL133: 810±30 BP). The fifth structural level (mechanical layers XXI-XXIII) was dated to the first half of the thirteenth century (sample 2UJS295 – MKL380: 920±30 BP). The sixth level (mechanical layers XXV-XLV) was dated with the radiocarbon method, on the basis of two samples of oak and one of pine (UJS245, UJS246, 2UJS260 – MKL446: 1330±40 BP, MKL443: 1000±40 BP, MKL381: 980±30 BP) and also dendrochronologically (sample UJS275, ca. 1078 AD). The seventh structural level (mechanical layers XLVII-XLIX) corresponds to the period ca. 1040 AD which is indicated by the ¹⁴C dating of the pine labelled 2UJS276 (MKL442: 990±30 BP). The oldest level, reaching 7 m below the terrain surface, was dated on the basis of the radiocarbon analysis of pine samples for the years ca. 970 AD.

Table 1. Results of dendrochronological analysis of the oakwood samples, archaeological survey IV.

No	Laboratory code	Mechanical layer	Sequence length	Sapwood	Ring of bark (+/-)		Sequence dating	Date of cutting down tree	Structural level
					Latewood (l)	Earlywood (e)			
1	UJS287	I	137	-	-	-	1385-1521	after 1531	I
2	UJS252	XII-XIII	47	33-47	+, l	-	1311-1357	1357	III
3	UJS254	XIV-XV	46+2	31-46	-	-	1311-1357	1357	III
4	UJS274	X-XI	44	35-44	+, l	-	1309-1352	1352	III
5	UJS279	X-XI	33	26-33	+, l	-	1313-1345	1345	III
6	UJS239	XVIII-XIX	50	41-50	+, l	-	1209-1258	1258	IV
7	UJS240	XVIII-XIX	39	29-39	+, e	-	1220-1258	1258	IV
8	UJS241	XVIII-XIX	60	50-60	+, l	-	1199-1258	1258	IV
9	UJS261	XVIII-XIX	43+1	38-43	-	-	1211-1257	1257	IV
10	UJS262	XVIII-XIX	52	46-52	-	-	1206-1257	1257	IV
11	UJS263	XVIII-XIX	58	49-58	-	-	1200-1257	1257	IV
12	UJS264	XVIII-XIX	52	43-52	+, l	-	1207-1258	1258	IV
13	UJS265	XVIII-XIX	59	49-59	+, l	-	1200-1258	1258	IV
14	UJS266	XVIII-XIX	56	46-56	+, l	-	1203-1258	1258	IV
15	UJS267	XVIII-XIX	58	48-58	+, l	-	1201-1258	1258	IV
16	UJS268	XVIII-XIX	60	49-60	+, l	-	1199-1258	1258	IV
17	UJS269	XVIII-XIX	52	41-52	+, l	-	1207-1258	1258	IV
18	UJS270	XVIII-XIX	58	50-58	+, l	-	1201-1258	1258	IV
19	UJS271	XVIII-XIX	60	50-60	+, l	-	1199-1258	1258	IV
20	UJS272	XVIII-XIX	66	55-66	+, l	-	1193-1258	1258	IV
21	UJS286	XVI-XVII	41	32-41	+, l	-	1214-1254	1254	IV
22	UJS275	XXXI	171	157-171	-	-	908-1078	1078 (-0/+7)	VI

Most of the pine (*Pinus sylvestris* L.) samples measured represented narrow-ringed trees, and a considerable part of them exhibited complete incremental sequences, with the ring of bark. Correlations of the dendrochronological sequences and visual comparisons of dendrograms allowed to construct the floating chronology 2U_02A, spanning 227 years. It was outlined on the basis of 49 curves characterized with the highest mutual similarity (Fig. 7). The majority of samples from the chronology cover the time interval from 80 to 200 relative year. Only the beginning of the sequence (first 50 years) is poorly defined because it is based on only two sequences; 2UJS69 and 2UJS80. On account of the fact that the pine wood appeared in the excavation together with the oakwood, it may be supposed that it also represented the early-mediaeval period. Unfortunately, hitherto there are no appropriately long dendrochronological curves, reaching so far backwards for the Wielkopolska region. Com-

parison of the chronology 2U_02A with the existing pine standards for the neighbouring areas, i.e. the regional chronology for northern Poland, covering the period 1106-1991 AD (Zielski, 1997) and the chronology for northern Germany, 924-1995 AD (Heussner, 1996), did not allow for identification of synchronous positions, most probably because they were too short. In such a situation the wiggle-matching method turned out to be the best one. From the floating chronology 2U_02A six samples were selected, with rings, of which relative dating is presented in Fig. 3 and Table 2 (part B). Fig. 8 presents results of fitting six radiocarbon age determinations of the pine samples with the calibration curve (Reimer *et al.*, 2009). Taking into account position of the first ring dated with the radiocarbon method, from the sample 2UJS61, it is possible to determine the period represented by the curve 2U_02 for the years 860-1080 (± 10) cal. AD.

Basing on the chronology dated out, it was possible to establish the age for 102 pine samples (Fig. 9). Among them the elements dated for the first half of the eleventh century predominated. Analysis of the distribution pattern of the age of the pine wood samples used in objects of the stronghold in Ujście permits for distinguishing two phases of intensive introduction of wood. The first structural

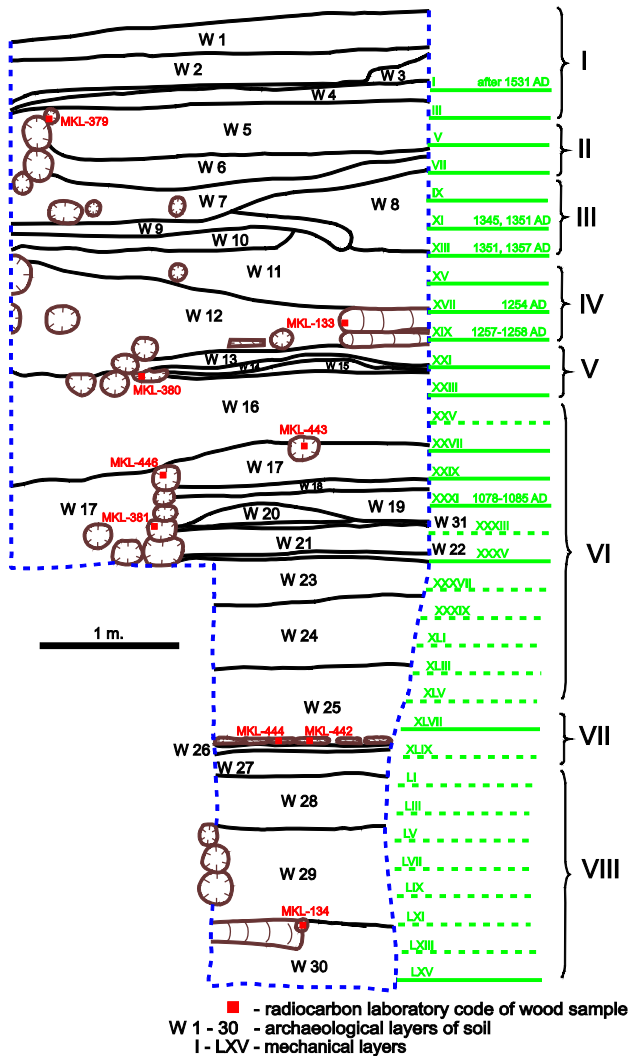


Fig. 6. The Old Market Square in Ujście, archaeological survey IV, profile W.

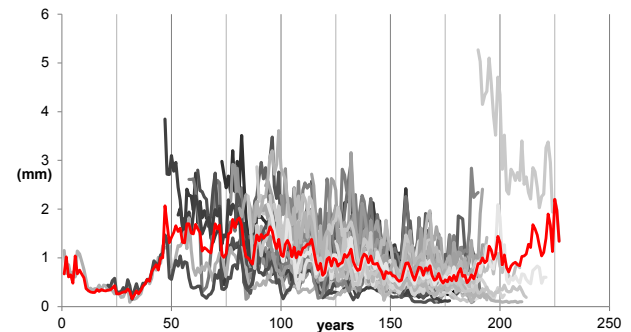


Fig. 7. Dendrochronological dating of growth sequences, forming the local chronology 2U_02A.

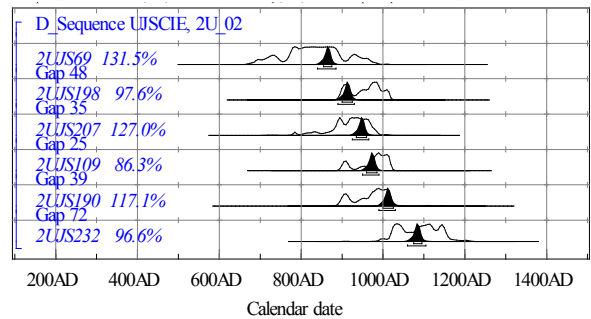


Fig. 8. Wiggle-matching method for the samples forming the chronology 2U_02A.

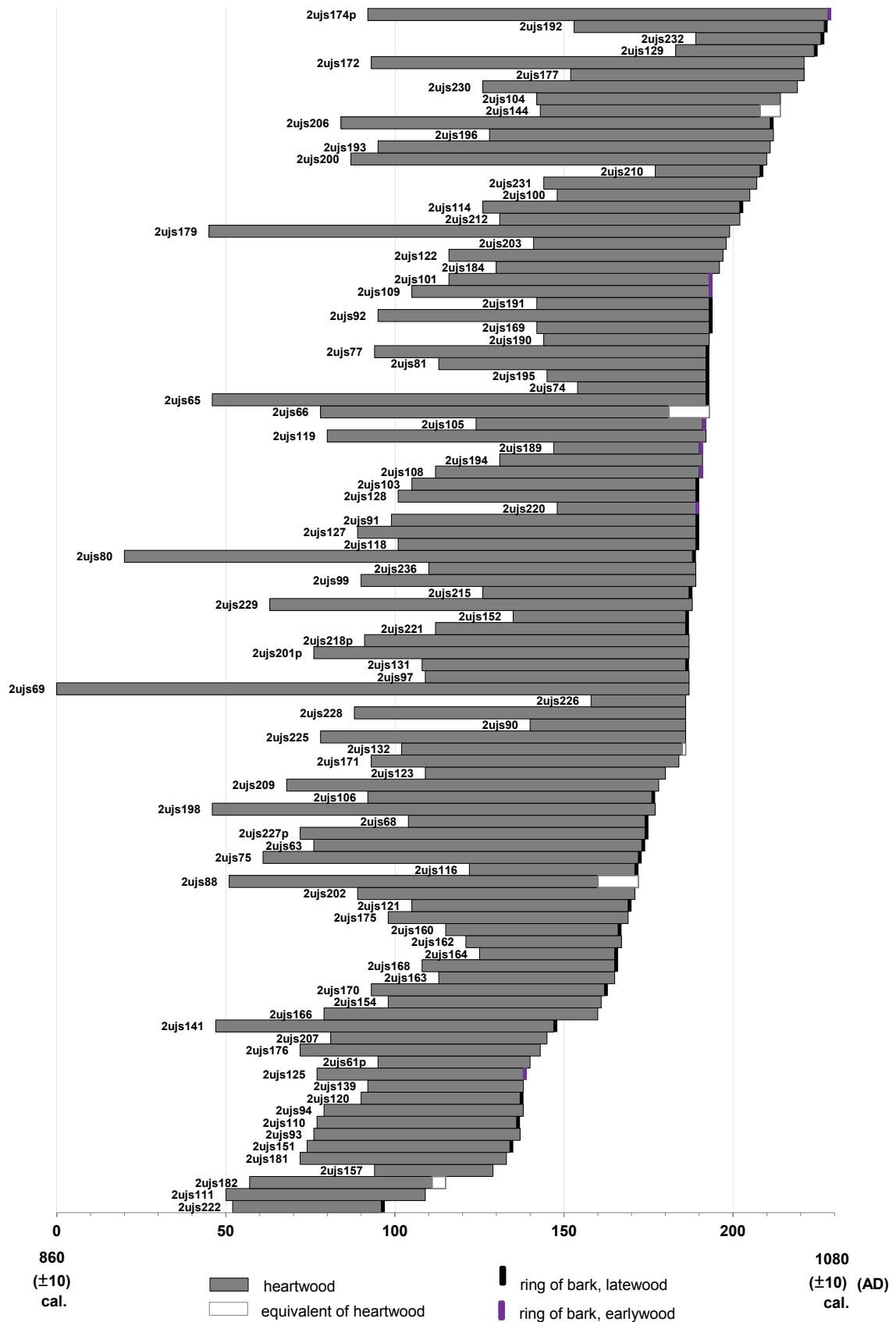


Fig. 9. Correlation diagram of growth sequences sampled in Ujście, forming the pine local chronology 2U_02A.

Table 2. Sample description with conventional and calibrated ages of wood samples taken from the mediaeval stronghold in Ujście (A – dates of wood connected with an investigation of The Old Market Square in Ujście, B – dates used in order to anchor the floating pine chronology 2U_02A).

Sample description ^a	Radiocarbon laboratory code ^b	¹⁴ C age (BP)	Age range (68%) (cal. AD)	Age range (95%) (cal. AD)	No. of tree-ring width series	No. of rings ^c / their cross dated position in tree-ring chronology	Site description/ symbol of mechanical layer
A							
2UJS293, <i>Pinus sylvestris</i>	MKL-444	1070 ± 40 BP	890 AD–920 AD (16.0%) 960 AD–1020 AD (52.5%)	890 AD–1030 AD (95.4%)	30	25e	survey IV / XLVII
2UJS297, <i>Pinus sylvestris</i>	MKL-134	1030 ± 40 BP	970 AD–1040 AD (68.2%)	890 AD–1050 AD (87.5%) 1080 AD–1150 AD (7.9%)	106	20i	survey IV / LX
2UJS276, <i>Pinus sylvestris</i>	MKL-442	990 ± 30 BP	990 AD–1050 AD (44.1%) 1090 AD–1120 AD (19.3%) 1140 AD–1150 AD (4.8%)	980 AD–1060 AD (56.8%) 1070 AD–1160 AD (38.6%)	48	15i	survey IV / XLVII
2UJS260, <i>Pinus sylvestris</i>	MKL-381	980 ± 30 BP	1010 AD–1050 AD (36.1%) 1090 AD–1120 AD (25.4%) 1130 AD–1150 AD (6.7%)	990 AD–1160 AD (95.4%)	35	15i	survey IV / XXXV
2UJS246, <i>Pinus sylvestris</i>	MKL-443	1000 ± 40 BP	980 AD–1050 AD (50.5%) 1090 AD–1120 AD (14.5%) 1140 AD–1150 AD (3.2%)	970 AD–1160 AD (95.4%)	65	15i	survey IV / XXVI-XXVII
UJS245, <i>Quercus</i>	MKL-446	1330 ± 40 BP	650 AD–710 AD (53.7%) 740 AD–770 AD (14.5%)	640 AD–780 AD (95.4%)	26	26	survey IV / XXVIII-XXIX
2UJS295, <i>Pinus sylvestris</i>	MKL-380	920 ± 30 BP	1040 AD–1100 AD (42.5%) 1110 AD–1160 AD (25.7%)	1020 AD–1100 AD (95.4%)	90	15i	survey IV / XX-XXI
2UJS288, <i>Pinus sylvestris</i>	MKL-133	810 ± 30 BP	1215 AD–1260 AD (68.2%)	1170 AD–1275 AD (95.4%)	43	12i	survey IV / XVI-XVII
2UJS259, <i>Pinus sylvestris</i> ,	MKL-379	440 ± 30 BP	1430 AD–1465 AD (68.2%)	1410 AD–1500 AD (94.0%) 1600 AD–1610 AD (1.4%)	106	15e	survey IV / II-III

^a name of dated sample, species, w-m – sample used for wiggle-matching^b Laboratory code of the Laboratory of Absolute Dating in Skala, Poland^c number of tree-rings taken for wiggle-matching analysis, i – internal annual growth (the oldest one), e – external annual growth (the youngest one)

Table 2. Continuation.

Sample description ^a	Radiocarbon laboratory code ^b	¹⁴ C age (BP)	Age range (68%) (cal. AD)	Age range (95%) (cal. AD)	No. of tree-ring width series	No. of rings ^c / their cross dated position in tree-ring chronology	Site description/ symbol of mechanical layer
B							
2UJS69, <i>Pinus sylvestris</i> , w-m	MKL-119	1190 ± 50 BP	770 AD–900 AD (64.8%) 920 AD–940 AD (3.4%)	680 AD–970 AD (95.4%)	187	10i/1–10	Rybacka street, survey I / III
2UJS198, <i>Pinus sylvestris</i> , w-m	MKL-123	1080 ± 30 BP	890 AD–920 AD (19.9%) 940 AD–1020 AD (48.3%)	890 AD–1020 AD (95.4%)	133	13i/47–60	Rybacka street, 140-135
2UJS207, <i>Pinus sylvestris</i> , w-m	MKL-124	1130 ± 30 BP	885 AD–905 AD (14.6%) 910 AD–970 AD (53.6%)	780 AD–790 AD (1.0%) 810 AD–990 AD (94.4%)	74	14i/82–95	Rybacka street, 140-135
2UJS109, <i>Pinus sylvestris</i> , w-m	MKL-447	1060 ± 30 BP	900 AD–920 AD (5.4%) 970 AD–1020 AD (62.8%)	890 AD–1030 AD (95.4%)	89	15i/106–120	Rybacka street, survey II / IV
2UJS190, <i>Pinus sylvestris</i> , w-m	MKL-448	1060 ± 40 BP	900 AD–920 AD (12.1%) 960 AD–1020 AD (56.1%)	890 AD–1030 AD (95.4%)	49	15i/145–159	Rybacka street, 135-130
2UJS232, <i>Pinus sylvestris</i> , w-m	MKL-121	960 ± 40 BP	1020 AD–1060 AD (22.2%) 1080 AD–1160 AD (46.0%)	990 AD–1170 AD (95.4%)	38	7e/221–227	Rybacka street, 145-140

^a name of dated sample, 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 taken for wiggle-matching analysis, i – internal annual growth (the oldest one), e – external annual growth (the youngest one)

phase took place in the years 990s, whereas the second one in the years 1040s. In the years 1000-1030 and 1050-1070 (±10) cal. AD the wood was introduced successively, probably at necessary repairs and/or small constructions.

5. CONCLUSIONS

- 1) Dendrochronological analyses enabled to determine the species variability in wood applied in the stronghold in Ujście on the basis of ca. 800 fragments originating from the period from the ninth to the eleventh century in the area of Rybacka Street and from the tenth to the sixteenth century in the survey IV.
- 2) Oak wooden structures present the oldest phases of the stronghold development, from the beginning of the ninth century to the 1080s. As least two phases of intensive introduction of the pine wood are marked in the 990s and in the 1040s.
- 3) The chronology 2U_02A worked out can serve for dating pine samples from that period from other sites in Wielkopolska.

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