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Factors of selection and quality of wood used for woodcraft in medieval Polish strongholds and early urban centres

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ABSTRACT. This paper discusses various aspects of the use of wood for crafts in the Middle Ages, based on xylological analyses of 4211 crafted items of everyday use discovered at 62 archaeological sites in Poland. Over 1500 items were identified in the authors' own analyses, and the remaining taxonomic data were taken from the literature. The research showed that the main types of wood used at the time were *Pinus sylvestris*, *Quercus* sp., *Fraxinus excelsior*, *Picea* sp. vel *Larix* sp., *Taxus baccata*, *Alnus* sp., *Abies alba* and *Euonymus* sp. Nineteen other taxa were used to make a much smaller pool of objects.

At most of the analysed sites a similar set of materials was used to produce the items, regardless of their age and location. The choice of wood was selective and was based on the characteristics of particular tree and shrub species. Large coopered vessels were primarily made of wood from *Quercus* sp., *Pinus sylvestris* and *Taxus baccata*. The manufacture of turned utensils usually involved *Fraxinus excelsior*, while stave bowls were made using only *Pinus sylvestris* and *Picea*/*Larix* (mainly *Picea abies*).

To verify the local availability of the source taxa, we used pollen sequences from natural and anthropogenic sites in the vicinity of the places where the examined artefacts were found. The choice of wood was limited by the availability of the trees and shrubs. In north-western Poland the most important taxa used for woodworking in the Middle Ages were *Pinus sylvestris*, *Quercus* sp., *Fraxinus excelsior* and *Fagus sylvatica*; in the south, *Picea*/*Larix* and *Abies alba* were used most frequently. Some items made of *Abies alba*, *Picea* and *Larix* were imported from other parts of the country.

We inferred two stages of the use of wood by medieval Polish craftsmen. In the first stage, from the mid-10th century to the late 12th century, they largely used deciduous taxa; the second stage, from the 13th to the 15th centuries, saw the increased use of conifers.

We found that the medieval craftsmen chose high-quality wood without defects. Radial wood with the best technical parameters was preferred. Its share increased in the late Middle Ages; this can be attributed to the craftsmen's increasing familiarity with carpentry techniques.

KEYWORDS: archaeobotany, xylology, medieval woodcraft, pollen data, Poland

INTRODUCTION

In the Middle Ages, large open areas were created on the Polish landscape as settlements grew and the economy developed, displacing woodlands. However, large-scale deforestation did not take place everywhere at the same time in Poland (e.g. Ralska-Jasiewiczowa & Latałowa 1996, Tyszkiewicz 2003, Makohonienko 2004, Noryśkiewicz 2013, Pelisiak et al. 2006, Wacnik et al. 2014). Gall Anonim (d. after 1116) described early medieval Poland as a country of "lush forests" (Dowiat 1985). It is estimated that woodlands and swamps occupied 70–80% of its area in the 10th century (Dembińska & Podwińska 1978). According to

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historical and archaeological data, the development of medieval settlements and agriculture – the main causes of deforestation – first occurred in Wielkopolska (Greater Poland) and in the southern part of the Małopolska (Lesser Poland) Uplands (Białobok 1970, Kornaś 1972, Makohonienko 2004, Buko 2011). In the early Middle Ages, the upper Carpathians and Sudetes were poorly exploited (Dembińska & Podwińska 1978, Parczewski et al. 2012, Wacnik et al. 2016). In Silesia and around Częstochowa, Olkusz, Nowy Sącz and the Świętokrzyskie Mts, the reduction of woodlands intensified in the 14th and 15th centuries, primarily in connection with industrial development (Białobok 1970). From the 11th/12th to the 16th centuries, woodlands were also cleared in north-eastern Poland (Kostrowicki 2009, Brown & Pluskowski 2011, Szal et al. 2014, Wacnik et al. 2012, Noryśkiewicz 2013).

Human-caused environmental changes associated with the formation of the cultural landscape were modified by natural factors such as climate change, for example during the so-called Dark Ages Cold Period (DACP), Medieval Warm Period (MWP) and Little Ice Age (LIA), as well as by hydrological phenomena and changes in soil cover (e.g. Lorenz 2000). The effects of human-environment interactions are particularly conspicuous in areas of highly varied landscape (Parczewski 2007). In the Carpathians and their foreland, for example, increased frequency of floods in the 10th–12th centuries was associated with the expansion of settlements and deforestation of alluvial plains (e.g. Starkel 1981, Starkel et al. 2006, Łanczont et al. 2006, Klimek et al. 2006, Gębica 2013, Gębica et al. 2013), while the Late Middle Ages were marked by increased colonization of the upper Vistula River catchment (Maruszczak 1988, Kukulak 2004). Cold climate was common in the Northern Hemisphere between 400 and 765 AD (Helama et al. 2014). Summing up the latest data on climate variability in Poland over the last millennium, Przybylak (2016) showed that the mean air temperature during the Medieval Warm Period, which probably persisted to the early 14th or early 15th century, was 0.5–1.0°C higher than nowadays. The so-called Little Ice Age began around the middle of the 16th century and ended probably in the second half of the 19th century. During this period, winters were cooler (by 1.5–3.0°C versus 1901–1960), but summers were warmer (by ca 0.5°C on average). Some authors (e.g. Dugmore et al. 2007, Büntgen et al 2006, 2013) point to a relationship between favourable climate during the MWP and economic, demographic, cultural and political development in Europe. On the other hand, worsening of the climate from the onset of the LIA contributed to economic crisis, widespread famine and plague pandemic (e.g. Iyigun et al. 2017, Lima 2014, Waldinger 2014).

Elements of the medieval economy such as agriculture, construction, metallurgy and potash-making played key roles in large-area deforestation (Tyszkiewicz 2003, Kostrowicki 2009). Wood-based manufacture, widespread during that time, also contributed to the exploitation of woodland communities. Wood was one of the main materials used to make items of everyday use, due to its wide availability, ease of processing, and useful physical properties (e.g. Rulewicz 1958, Dembińska & Podwińska 1978, Miśkiewicz 2010, Sydor 2011, Bobik 2012), especially its low weight and high strength (Tubielewicz 1994). The abundance and diversity of household items made of wood is shown in inventories of property left by the deceased. Records of the Sandomierz city council from the 16th century include information about townspeople possessing wooden chests, beds, benches, ladders, tables (and table legs), plates of various sizes, bowls, barrels, baskets, spoons, salt mortars, weaving combs, flax hackles and wooden plugs (Gloger 1903). Other historical data, according to which Prince Henry the Bearded (d. 1238) conveyed to the Trzebnica monastery three turners, of which "each shall [make] for Christmas 15 cups and 100 bowls, the same for Easter and St. Bartholomew's" (Dowiat 1985), also picture the scale and intensity of production of turned wooden vessels at that time.

Selective harvesting of economically valuable species of trees and shrubs for specialized craft manufacture may have affected the taxonomic composition and age structure of the woods, and to some extent may have contributed to the fragmentation of woodlands. In this context, the main purpose of this study was to identify the genera of the wood used for crafts, and to analyse the factors that influenced the choice of wood in the Middle Ages: namely, its availability in the vicinity of settlements as well as the technical and practical qualities of various kinds of wood.

We posited (1) that in the Middle Ages, the choice of wood for particular uses was selective and depended on its properties; (2) that the taxonomic spectrum of trees and shrubs serving as sources of the wood recovered from archaeological sites was strongly associated with the composition of woodland communities, reflected in the palynological record; and (3) that selective and large-scale exploitation of taxa for woodcraft could eliminate certain species from the woodlands of the nearby surroundings.

Our study relies on the results of published analyses (Cywa 2018a) and new xylological studies (by K. Cywa) of five archaeological sites: Czerchów 1, Szczecin Wzgórze Zamkowe 44, Szczecin-Podzamcze V/VI, Toruń Kopernika 11–13, and Tum (200 wooden artefacts in total). Previously unpublished data are also presented, showing the sorts, grades and quality of the wood used for crafts in medieval Poland. Particular emphasis is placed on analysis of the environmental aspects of wood selection at particular sites, relying on local palynological data as a source of information on the availability of various tree and shrub species.

OUTLINE OF THE MIDDLE AGES IN POLAND, BASED ON ARCHAEOLOGICAL AND HISTORICAL SOURCES

In Poland the medieval period lasted from the 5th/6th to late 15th centuries, and was a time of diverse transformations related to the organization of the Polish state (e.g. Wyrozumski 1982, Nowak 2010, Buko 2011). During the reign of the early Piasts, Europe had a variety of political structures, and the state borders and centres of power were not stable (Dowiat 1985). The most important trade routes running through Polish lands changed several times during the Middle Ages as a result of shifting spheres of influence and mutual relations among Europe's most economically developed regions (Samsonowicz 1973). Archaeological sources distinguish several stages of the early Middle Ages in Poland: the Early Slavic period, tribal period, and state (Piast) period (Fig. 1), which differed in their levels of social development and in the organization of manufacture (Buko 2011, Iwaszczuk 2014). From the 7th to 9th centuries, early urban centres developed in Poland as tribal communities matured, transforming from embryonic settlements in the tribal period to developed centres in the Piast State period (Buko 1999, 2011). In the early Middle Ages, the basis of Poland's territorial organization was a network of strongholds, which over time spawned suburban settlements as places for trade and crafts (e.g. Szulc 1995, Buko 1999, Marciniak-Kajzer 2011). These suburbs became the seeds of future towns (Szulc 1995). During the Piast period (late 10th to early 13th centuries) there were various types of early urban centres in Poland: those already established during the tribal period and then reorganized in the Piast period, such as Wolin, Szczecin, Wawel and Łęczyca, as well as those founded under the rule of the first Piasts, where previously open tribal settlements once stood, such as Płock, Kruszwica, Gdańsk, Opole and Wrocław (Buko 1999). During the formation of the Polish state (8th to early 10th centuries) there also were craft and trade centres in Western Pomerania, such as Wolin, Szczecin and Kołobrzeg, where, due to their different conditions of socio-economic development, the role of crafts and long-distance trade was far greater than in other centres; their infrastructure was like that of early cities (Piskorski 2005, Buko 2011). An important breakthrough in the development of towns in Poland was their chartering under German law in the 13th and 14th centuries (Dembińska & Podwińska 1978, Tyszkiewicz 2003, Marciniak-Kajzer 2011, Samsonowicz 2014). In the 15th century, each town had its own council and, unlike villages, had brick-and-mortar houses (Wyrozumski 1982). Hence, in medieval Poland, manufacture developed in the following types of early urban centres: pre-settlement centres; those chartered under Western European law (13th–14th centuries); and late medieval and early Renaissance towns from the 14th/15th–16th centuries, having a developed urban plan and administrative structure (Tyszkiewicz 2003). Chartering of cities under German law also involved the establishment of guild organizations of craftsmen in certain professions, which dealt with control of the production process (Barnycz-Gupieniec 1961, Jelicz 1965, Jezierski & Leszczyńska 2001, Samsonowicz 2014). The literature also draws attention to standardization of craft manufacture, involving simplification of technological processes, mass production, and acceleration of the production cycle (Barnycz-Gupieniec 1961, Wysocka 1999, Łosiński 2008, Bobik 2012). It is estimated that in 15th-century cities of Central Europe, craftsmen accounted for 33% to 69%

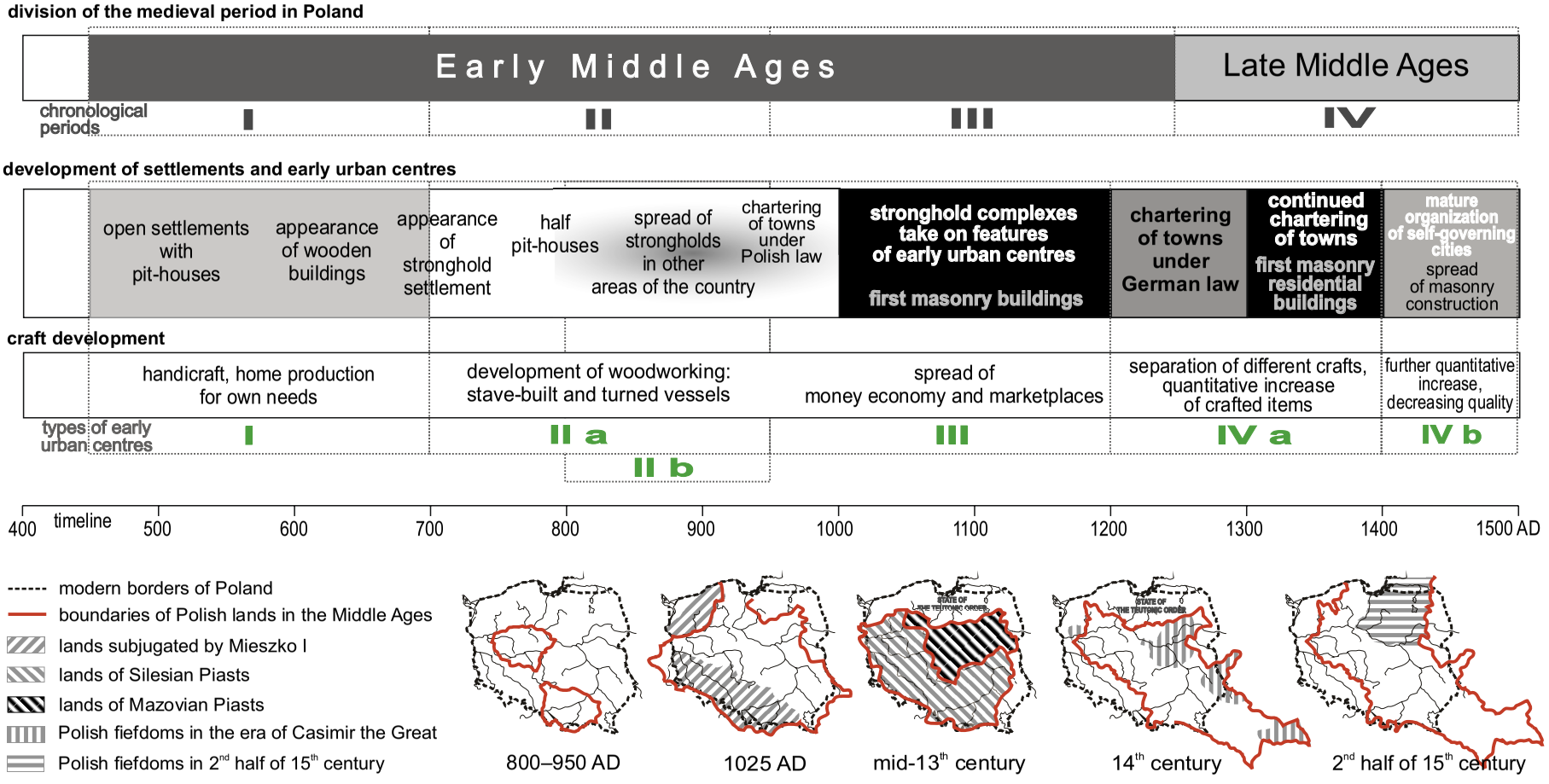


Fig. 1. Chronological division of the Middle Ages (period **I** – early Slavonic; period **II** – tribal/forming of the Piast State; period **III** – Piast State; period **IV** – late Middle Ages) and types of early urban centres in medieval Poland (type **I** – early Slavic open settlements; type **IIa** – tribal open settlements and castles; type **IIb** – craft/trading centres in Pomerania; type **III** – pre-charter city centres; type **IVa** – early urban centres chartered under German law; type **IVb** – late medieval town) (after Wyrozumski 1982, Tyszkiewicz 2003, Miśkiewicz 2010, Piskorski 2005, Nowak 2010, Buko 2011)

of the urban population (Samsonowicz 2014). Many of the occupations involved woodcraft: for example, carpenter, joiner, cooper, turner, wheelwright, boatbuilder, saddler and shield maker (Ostrowska 1962, Wysocka 2001, Tyszkiewicz 2003). On the other hand, historical data indicate that guild-based crafts were not the predominant form of organizing production in medieval Poland. They only predominated in Gdańsk, Toruń and Wrocław. In Kraków at the turn of the 15th/16th centuries there were still dozens of craft professions performed outside guilds (Jelicz 1965, Samsonowicz 2014). Some wooden items were made by householders themselves for their own needs. According to archaeologists, the items they made as part of their household chores included carved utensils, vessels, wickerwork, net floats and dugout canoes (Dembińska & Podwińska 1978, Wrzesiński 1994, Łosiński et al. 2003). Ethnographic data show that as late as the mid-19th century almost all the inhabitants of Polish villages in forested areas were engaged in woodworking (Skuza 2012). For example, making needles for tying and repairing fishing nets was traditionally one of the chores of children in Kashubia, an ethnic area in north-western Poland (Kucharska 1978). Some archaeological studies suggest that wood-turning was also done at home (Baran 2003, Kowalska & Dworaczyk 2011).

MATERIAL AND METHODS

XYLOLOGICAL ANALYSIS

We studied the use of wood for crafts in medieval Poland by examining various household items made of wood, discovered by archaeologists at sites of Polish strongholds and early urban centres: 1523 medieval artefacts from 19 archaeological sites housed in Polish museum and institute collections (Tab. 1, Fig. 2, Cywa 2018b (unpubl.): Annex 1). Some of the collections were large and diverse, such as those from Szczecin-Podzamcze V/VI and Toruń Bankowa 14/16, and others were single items, such as the finds from Drohiczyn, Czermno 70 and Kraków Sławkowska 14/6. The analysed artefacts are of very diverse functions (Fig. 3a). Among them are scoops, turned bowls, small stave bowls, parts of buckets and barrels, spoons, various dowels and plugs, tools and small construction elements (Pl. 1). Archaeologists consider such things to be typical of homes or homesteads, associated with daily household activities (e.g. Dziekoński & Kóčka 1939, Barnycz-Gupieniec 1959, 1961, Wysocka 1999, Grupa 2000, Kowalska & Dworaczyk 2011).

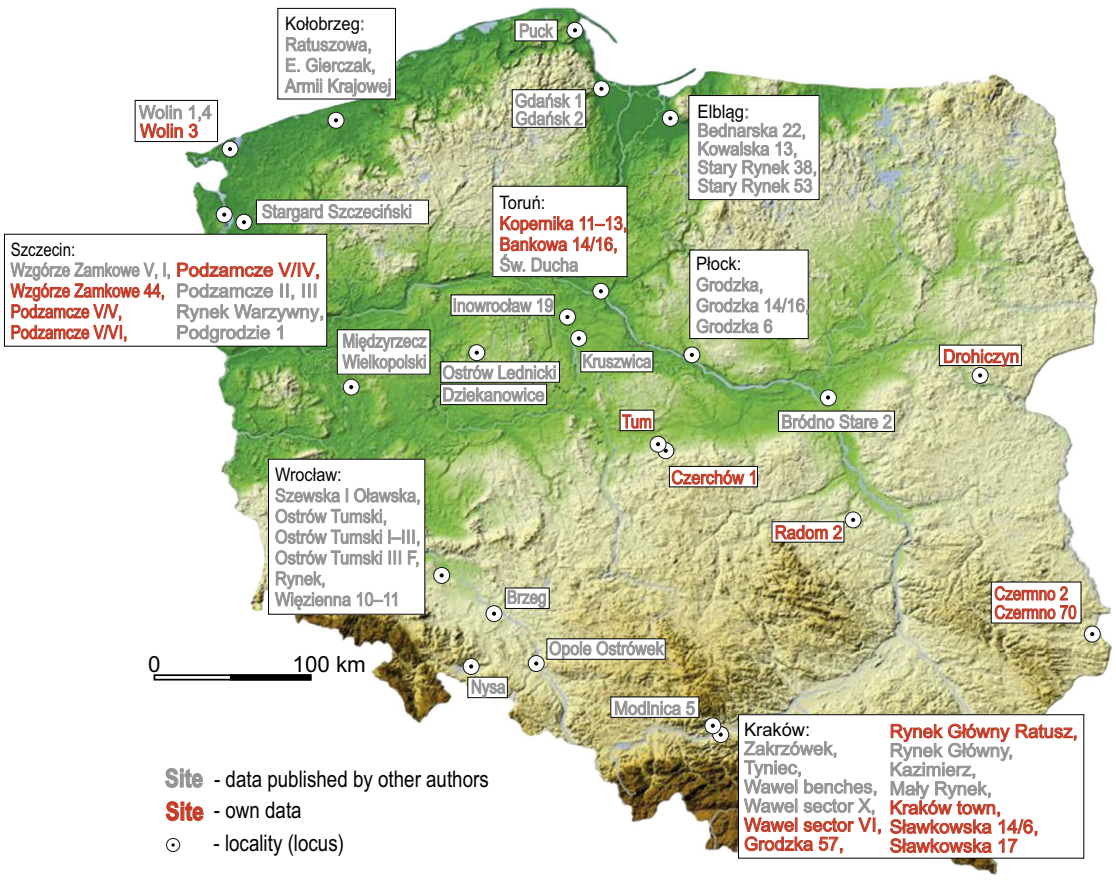


Fig. 2. Location of studied sites

Table 1. Summary of site-related data examined by the authors

Site	References	Chronology	Geographical coordinates	Main types of items	Owner institution	Number of items
Czerchów 1	Cywa 2018b (unpubl.)	10th–11th cent.	51°59′08.43″N, 19°18′21.10″E	architectural elements of wattle wall	Museum of Archaeology and Ethnography in Łódź	21
Czermno 2	Cywa 2016b, Cywa 2018a	10/11th–13th cent.	50°39′33.54″N, 23°42′32.90″E	scoop handle, board, slat, vessel turned on two sides	Centre for Archaeology of Hills and Uplands (Institute of Archaeology and Ethnology, Polish Academy of Sciences in Kraków)	8
Czermno 70	Cywa 2018a	10/11th–13th cent.	50°39′35.46″N, 23°42′29.86″E	sickle handle	Centre for Archaeology of Hills and Uplands (Institute of Archaeology and Ethnology, Polish Academy of Sciences in Kraków)	1
Drohiczyn	Cywa 2016a, Cywa 2018a	14th–15th cent.	52°23′38.48″N, 22°39′31.50″E	spindle	Institute of Archaeology University of Łódź	1
Kraków Grodzka 57	Cywa 2018a	late Middle Ages	50°03′25.38″N, 19°56′16.75″E	peg, dowel pin for making rope	Archaeological Museum in Kraków	2
Kraków Rynek Główny Ratusz	Cywa 2018a	early Middle Ages	50°03′41.33″N, 19°56′11.11″E	stave-built vessel	Archaeological Museum in Kraków	2
Kraków Sławkowska 14/6	Cywa 2018a	late Middle Ages	50°03′49.42″N, 19°56′14.81″E	baton-shaped object of unknown function	Archaeological Museum in Kraków	1
Kraków Sławkowska 17	Cywa 2018a	late Middle Ages – modern period	50°3′52.23″N, 19°56′19.40″E	stave-built and turned vessel, peg	Archaeological Museum in Kraków	10
Kraków town	Cywa 2018a	late Middle Ages	50°03′41.88″N, 19°56′23.19″E	stave-built vessel, float	Archaeological Museum in Kraków	2
Kraków Wawel VI, V, X,VII, XI	Cywa 2018a	Middle Ages	50°03′13.47″N, 19°56′06.15″E	objects of various functions	Royal Castle on Wawel Hill	129
Radom 2	Cywa 2018a	mid 9th cent. – mid 13th cent.	51°24′04.67″N, 21°07′51.95″E	objects of various functions	Jacek Malczewski Museum in Radom	161
Szczecin Wzgórze Zamkowe 44	Cywa 2018b (unpubl.)	late 10th cent. – early 12th cent.	53°25′34.72″N, 14°33′38.48″E	objects of various functions	Centre for Medieval Archaeology of the Baltic Region (Institute of Archaeology and Ethnology, Polish Academy of Sciences in Szczecin)	23
Szczecin-Podzamcze quarter V, excavation IV	Cywa 2018a (some objects were determined by D. Baran (2003) for the first time)	2nd quarter 13th cent. – late 14th cent.	53°25′31.96″N, 14°33′42.03″E	objects of various functions	National Museum in Szczecin	100
Szczecin-Podzamcze quarter V, excavation V	Cywa 2016a, Cywa 2018a	period before chartering of city – 15th cent.	53°25′31.96″N, 14°33′42.03″E	objects of various functions	National Museum in Szczecin	42
Szczecin-Podzamcze quarter V, excavation VI*	Cywa 2016a, Cywa 2018a, (some objects were first determined by D. Baran (2003) for the first time)	Middle Ages	53°25′31.96″N, 14°33′42.03″E	objects of various functions	National Museum in Szczecin	591
Toruń Bankowa 14/16	Cywa 2018a	1st half 13th cent. – 15th cent.	53°00′30.26″N, 18°36′14.99″E	objects of various functions	District Museum in Toruń	213
Toruń Kopernika 11–13	Cywa 2018b (unpubl.)	1st half 13th cent. – 15th cent.	53°00′33.33″N, 18°36′13.78″E	objects of various functions, mainly stave-built and turned vessels	District Museum in Toruń	145
Tum	Cywa 2018b (unpubl.)	late 10th cent. – 1st half 14th cent.	52°03′12.15″N, 19°13′38.48″E	objects of various functions	Museum of Archaeology and Ethnography in Łódź	6

Table 1. Continued

Site	References	Chronology	Geographical coordinates	Main types of items	Owner institution	Number of items
Wolin 3	Janowski et al. 2015, Cywa 2018a	Middle Ages	53°50′31.42″N, 14°36′59.24″E	objects of various functions	Centre for Medieval Archaeology of the Baltic Region (Institute of Archaeology and Ethnology, Polish Academy of Sciences in Szczecin)	65
Number of objects (total)						1523

* – new determination from this site included, grey shading – new sites

We individually examined the artefacts and all their wooden elements separately, including, for example, inserted dowels. To describe the anatomical structure of the wood of each item, LM observations of three sections (transversal, longitudinal tangential, longitudinal radial) were made at 25–400× using a Carl Zeiss Amplival microscope. Due to the historical value of the examined items, thin slices of wood were taken directly from the surface of the objects. In some cases the outer layers were very deteriorated, so larger pieces were cut in order to reach less damaged wood. Taxonomic identification was done by comparing diagnostic features (Pl. 2, 3) observed in particular sections (Gale & Cutler 2000, Lityńska-Zając & Wasylikowa 2005, Gärtner & Schweingruber 2013). Table 2 summarizes the most important anatomical features of the taxa identified and verified against comparative material from the collections of the W. Szafer Institute of Botany, Polish Academy of Sciences, and against descriptions in atlases of wood and bark anatomy (Greguss 1945, Freund 1951, Schweingruber 1978, Benkova & Schweingruber 2004, Schweingruber et al. 2011).

Anatomical characters can be used to identify the wood of most Polish trees and shrubs only to genus level (*Acer* sp., *Alnus* sp., *Betula* sp., *Populus* sp., *Quercus* sp., *Salix* sp., *Tilia* sp., etc.). For spruce and larch the determination is usually not precise and is limited to *Picea*/*Larix*. We distinguished spruce from larch using a method based on the mutual proportions of different types of bordered pits in transverse ray tracheids (Bartholin 1979, Anagnost et al. 1994). Our methodology for working on medieval material and our results in differentiating wood types are described in detail in a separate paper (Cywa, Lityńska-Zając, Wacnik, in preparation).

In the modern wood industry, the quality of the raw material is assessed in the standing trees and later in the cut wood (Kocięcki 1991). Logs of roundwood are sorted by size and quality (Szczuka & Żurowski 1994), based on the use of dendrometric methods and on standards for permitted wood defects (Kimbar 2011). In our examination we also paid attention to characteristics indicating the quality of the wood. We described and/or measured macroscopic features such as the number of annual growth rings visible in transverse section, their minimum and maximum width, the orientation of annual growth rings relative to the broadest surface of the object, the type of anatomical plane visible on the broadest surface, as well as the size and number of knots (Cywa 2018b (unpubl.): Annex 1). In this study,

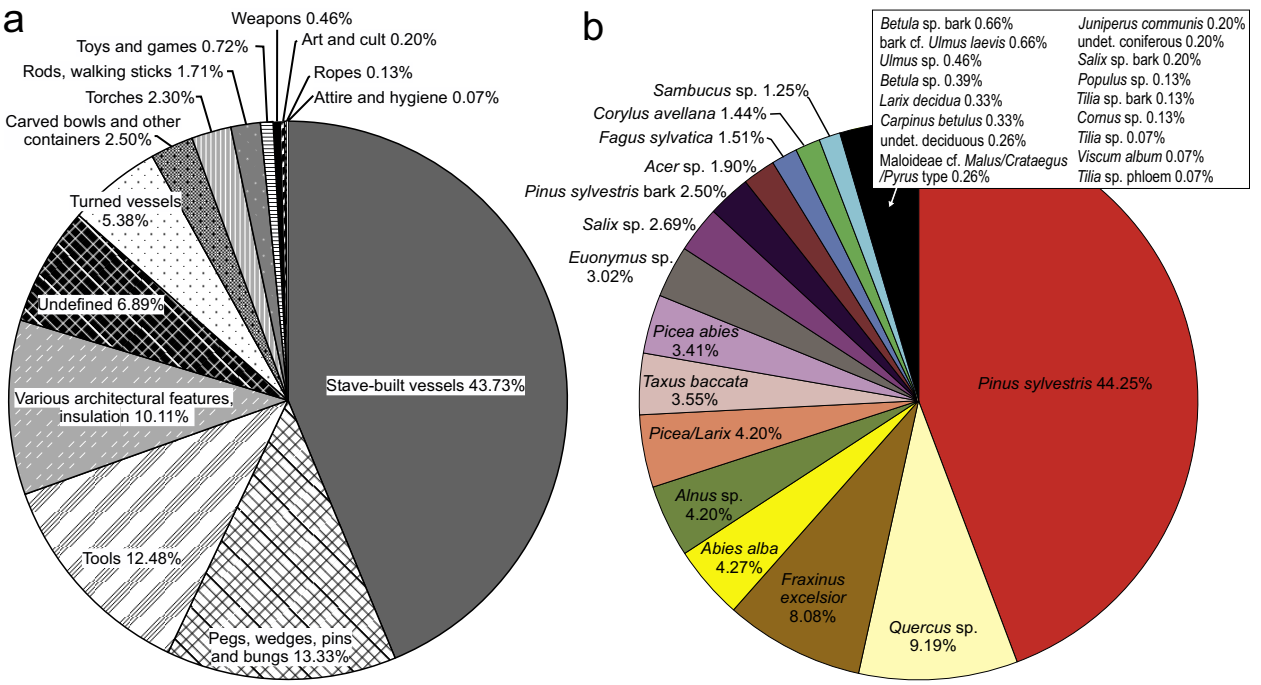


Fig. 3. Summary of functional (a) and taxonomic (b) composition of medieval wooden artefacts from Polish archaeological sites (N = 1523 objects determined by authors)

knots more than 2 cm in diameter are termed very large, knots 0.5–2 cm in diameter are large, and knots less than 0.5 cm in diameter are small. The presence of fungi and/or insect tunnels was also reported, as well as the state of wood preservation.

One of the most important parameters for assessing the technical quality of wood is annual growth ring width, with 3 mm width being the boundary between narrow-grain and wide-grain wood (Krzysik 1957, Kocięcki 1991). We did not use modern methods of determining average ring width (e.g. Krzysik 1957), since the original size of the logs from which the objects were formed (and hence the length of the rays) was unknown. We recorded the item as being made of narrow-grained wood when the measured annual grain width was less than 3 mm, and as being made of wide-grain wood when annual grain width was 3 mm or more. For artefacts of varying annual grain widths we applied a similar rule: it was noted as narrow-grain if the upper limit of annual grain width was less than 3 mm, and as wide-grain if the lower or upper limit was 3 mm or more.

Table 2. Summary of the most important diagnostic features of microscopic wood structure (after Schweingruber 1978, Wheeler et al. 1989, Richter et al. 2004, Surmiński 2000, Kokociński 2005), and list of species of trees and shrubs in Poland (after Mirek et al. 2002)

NATIVE SPECIES/GENERA IN POLAND	WOOD TAXA	POROSITY			VESSEL ARRANGEMENT						VESSEL SIZE				HELICAL THICKENINGS	PERFORATION PLATES		INTERVESSEL PIT ARRANGEMENT, SHAPE & SIZE					VESSEL-RAY PITTING				TYLOSES	STORIED VESSEL ELEMENTS	RAYS												RAY TRACHEIDS	TRANSITION FROM EARLYWOOD TO LATEWOOD		LATEWOOD		CROSS-FIELD PITTING				GROWTH RING BOUNDARIES						SOFTWOOD INTERCELLULAR CANALS					
		ring-porous	diffuse-porous	semi-ring-porous	solitary	diagonal and/or radial pattern	radial multiples	tangential bands	clusters	double in latewood	very large 0.161 mm	large 0.121–160 mm	small 0.041–0.080 mm	very small 0.040 mm		simple	scalariform	alternate	medium to large	minute < 4 um	shape of alternate pits is polygonal	circular to oval	vessel-ray pits with distinct borders; similar to intervessel pits in size and shape	vessel-ray pits restricted to marginal rows	large	vessel-ray pits with much reduced borders to apparently simple, pits outline rounded			very large 0.201 mm	large 0.151–0.200 mm	narrow 0.051–0.100 mm	very narrow 0.050 mm	aggregate rays	multiseriate	biseriate	large rays commonly 3–6 seriate	uniseriate	heterogenous	sheath cells	homogenous		abrupt	gradual	strong developed	weakly developed	fenestriform	picoid	cupressoid	taxodioid	distinct	indistinct	regular	wavy	width	narrow	many	few	absent	large	tiny	single
Acer pseudoplatanus L., *Acer campestre* L., *Acer platanoides* L.	*Acer* sp.		+		+		+			+			+		+ (Pl. 2.3)	+		+	+				+ (Pl. 2.3)							+						+ (Pl. 2.4)														+		+									
Alnus glutinosa (L.) Gaertn.*, *Alnus incana* (L.) Moensch*, *Alnus viridis* (Chaix) DC. In Lam. & DC.	*Alnus* sp.		+	+			+						+				+ (Pl. 2.5)	+ (Pl. 2.5)					+									+	+*				+ (Pl. 2.6)			+											+	+									
Betula humilis Schrank, *Betula nana* L., *Betula oycoviensis* Besser, *Betula pubescens* Ehrh., *Betula pubescens* Ehrh. subsp. *carpatica* (Willd.) Asch. & Graebn., *Betula pubescens* Ehrh. subsp. *pubescens*, *Betula szaferi* Jentys-Szaferowa ex Staszk.	*Betula* sp.		+	+			+						+				+	+		+			+								+			+			+	+		+											+	+									
Carpinus betulus L.	*Carpinus betulus*		+	+			+				+		+		+	+ (Pl. 2.7)																+	+ (Pl. 2.8)	+			+	+		+																					
Cornus sanguinea L., *Cornus sanguinea* L. *subsp. australis* (C.A. MEY.) Jav., *Cornus sanguinea* L. subsp. *hungarica* (Kárpáti) Soó, *Cornus sanguinea* L. subsp. *sanguinea*, *Cornus suecica* L. (taxon extinct in Poland)	*Cornus* sp.	+			+												+ (Pl. 2.10)																	+			+	+ (Pl. 2.11)	+																							
Corylus avellana L.	*Corylus avellana*		+	+			+								+		+ (Pl. 2.12)																+				+	+															+								
Euonymus europaea L., *Euonymus verrucosa* Scop.	*Evonymus* sp.		+	+	+								+		+ (Pl. 2.13)	+																					+ (Pl. 2.13)	+		+																					
Fagus sylvatica L., *Fagus sylvatica* L. subsp. *sylvatica*	*Fagus sylvatica*		+	+ (Pl. 2.14)	+ (Pl. 2.14)				+ (Pl. 2.14)				+			+ (Pl. 2.15)	+ (Pl. 2.15)						+						+ (Pl. 2.16)		+			+ (Pl. 2.16)			+ (Pl. 2.16)														+		+	+								
Fraxinus excelsior L.	*Fraxinus excelsior*	+ (Pl. 3.18)							+	+	+			+		+															+			+	+					+										+		+									
Pyrus pyraster (L.) Burgsd., *Malus sylvestris* Mill.	Maloideae cf. *Malus*/*Crataegus*/*Pyrus* type		+ (Pl. 3.1)	+	+ (Pl. 3.1)										+	+											+							+	+ (Pl. 3.2)			+		+																					
Populus tremula L*., *Populus alba* L.**, *Populus ×canescens* (Aiton) Sm., *Populus nigra* L.**	*Populus* sp.		+		+		+			+			+			+		+						+	+	+ (Pl. 3.8)	+**					+					+			+										+*	+**	+									
Quercus petraea (Matt.) Liebl., *Quercus robur* L.	*Quercus* sp.	+				+					+			+								+					+		+		+			+			+			+										+		+									
Salix alba L., *Salix alpina* Scop., *Salix aurita* L., *Salix bicolor* L., *Salix caprea* L., *Salix cinerea* L., *Salix daphnoides* Vill., *Salix eleagnos* Scop., *Salix fragilis* L., *Salix hastata* L., *Salix helvetica* Vill., *Salix lapponum* L., *Salix myrsinifolia* Salisb., *Salix myrtilloides* L., *Salix pentandra* L., *Salix purpurea* L., *Salix repens* L., *Salix repens* ssp. *rosmarinifolia* (L.) Hartm., *Salix starkeana* Willd., *Salix reticulata* L., *Salix retusa* L., *Salix xrubens* Schrank, *Salix silesiaca* Willd., *Salix triandra* L., *Salix viminalis* L., *Salix ×dasyclados* Wimm.	*Salix* sp.		+ (Pl. 3.9)	+	+ (Pl. 3.9)		+			+			+			+		+			+			+	+	+ (Pl. 3.10)						+					+	+ (Pl. 3.10)													+	+									
Sambucus nigra L., *Sambucus racemosa* L., *Sambucus ebulus* L.	*Sambucus* sp.		+ (Pl. 3.11)	+	+ (Pl. 3.11)			+	+							+ (Pl. 3.12)		+ (Pl. 3.12)			+ (Pl. 3.12)				+	+ (Pl. 3.13)	+							+		+ (Pl. 3.13)		+ (Pl. 3.13)	+																						
Tilia cordata Mill., *Tilia platyphyllos* Scop.	*Tilia* sp.		+	+					+						+	+												+						+				+		+																					
Ulmus laevis Pall., *Ulmus glabra* Huds., *Ulmus minor* Mill. emend. Richens	*Ulmus* sp.	+						+	+			+		+	+	+											+			+						+		+		+										+		+									
Viscum album L., *Viscum album* ssp. *abietis* (Wiesb.) *Vollm.*, *Viscum album* ssp. *album*, *Viscum album* ssp. *austriacum* (Wiesb.) Vollm.	*Viscum album*		+													+												+ (Pl. 3.17)								+ (Pl. 3.17)	+														+ (Pl. 3.16)										
Abies alba Mill.	*Abies alba*																																				+					+	+		+				+ (Pl. 2.1)			+		+	+			+			
Juniperus communis L., *Juniperus communis* subsp. *communis*, *Juniperus communis* subsp. *alpina* (Sm.) Celak., *Juniperus sabina* L. (very rare, relict)	*Juniperus communis*																																				+						+					+ (Pl. 2.17)	+									+			
Larix decidua Mill., *Larix decidua* ssp. *decidua*, *Larix decidua* ssp. *polonica* (Racib.) Domin	*Larix* sp.																																								+	+		+			+	+				+	+		+		+ (Pl. 3.5)			+	+
Picea abies (L.) H. Karst.	*Picea abies*																																								+ (Pl. 3.3)		+		+		+ (Pl. 3.3)	+				+	+	+			+ (Pl. 3.5)			+	+
Pinus sylvestris L.	*Pinus sylvestris*																																								+	+		+		+ (Pl.2.6)						+	+	+	+	+	+		+		+
Taxus baccata L.	*Taxus baccata*														+ (Pl. 3.15)																				×		+						+					+										+			

Archeological site descriptions and potential vegetation

Wolin

The oldest Wolin settlement was established at the end of the 8th century or somewhat later. It is thought that from the second half of the 9th century Wolin was already a fully developed early medieval town. As a centre of craft manufacture and as a transport and trade node it was one of the most important urban centres in the Baltic zone (Łosiński 2008, Stanisławski 2013). The Wolin settlement consisted of a fortified town with a port on the Dziwna Strait, a stronghold on Srebrne Wzgórze (Silver Hill), and suburban settlements; its densely built houses stretched 3–4 km along the western bank of the Dziwna Strait (Łosiński 2008, Malinowska-Sypek et al. 2010). The fortified suburban settlements were craft and trade districts. The town also had four ports. The town landscape was completed by a bridge over the Dziwna and a ferry crossing (Łosiński 2008). Wolin's glory days lasted from the second half of the 10th century through the first half of the 11th century. Following a series of Danish raids, its role declined toward the end of the 12th century (Łosiński 2008, Miśkiewicz 2010). Hydrological changes also contributed to the town's decline, causing silting of the port on the Dziwna. After the stronghold fell, a Slav village functioned on the site until the middle of the 12th century, and later it was granted a town charter under Lübeck law by the Pomeranian Duke Barnim I in 1278 (Miśkiewicz 2010).

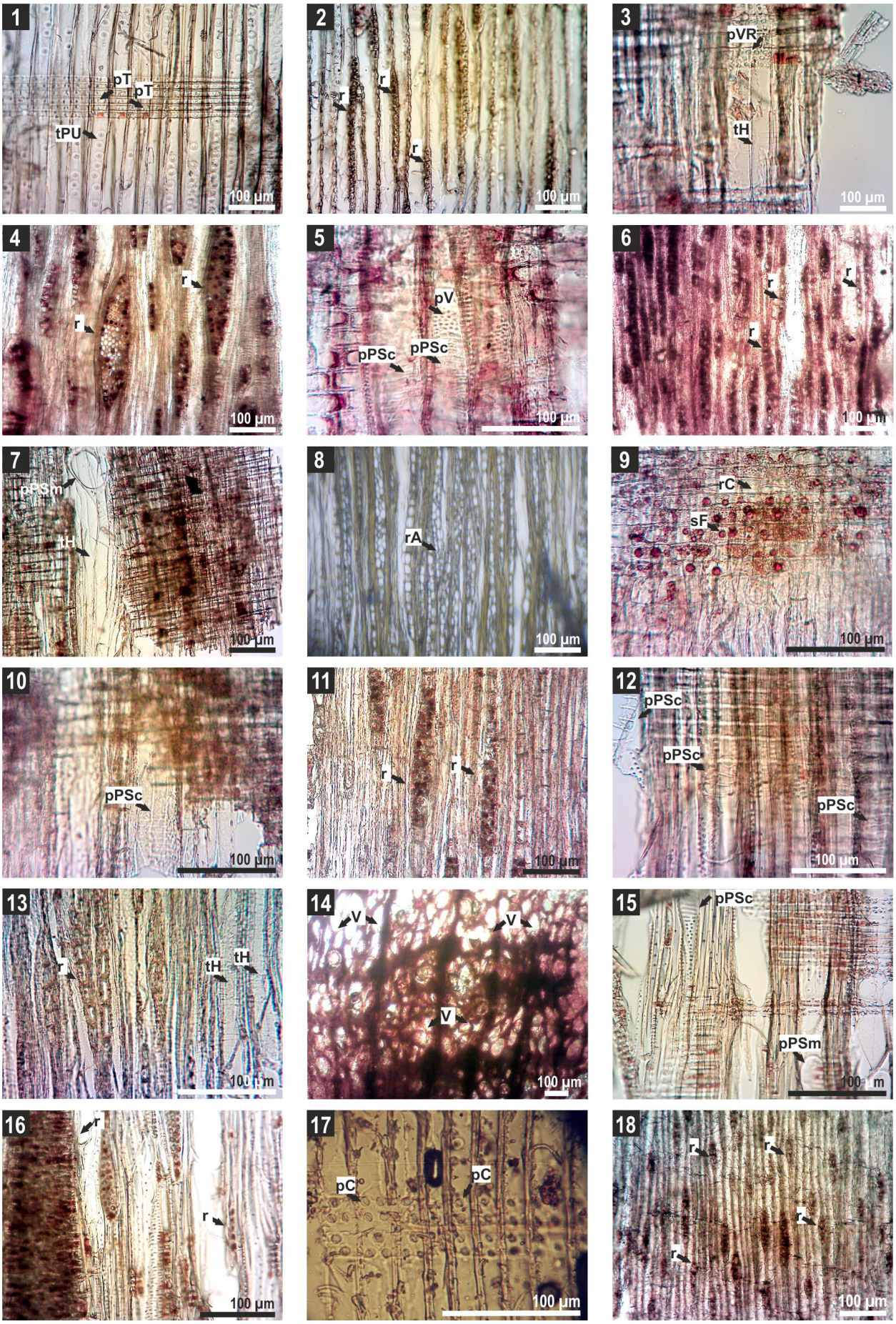
The artefacts from Wolin were discovered in 2011–2013 during excavation work done by the Institute of Archaeology and Ethnology, Polish Academy of Sciences in Szczecin, in the area between the Old Town (site 1) and the so-called Fishing Suburb (site 2); that research was supervised by A. Janowski. At that time the remains of early medieval port structures were uncovered, constructed possibly at the turn of the first and second decades of the 10th century (Janowski et al. 2015).

The potential natural vegetation of the Wolin area includes mostly subcontinental mixed coniferous forest (*Querco-Pinetum*) and lowland beech forest (*Melico-Fagetum*). Communities of alder forest (*Carici elongatae-Alnetum*) and oak-hornbeam forest (*Stellario-Carpinetum*) may have grown on the bank of the Dziwna close to the Wolin 3 site. Further inland, north of that site, communities of oak-birch forest (*Betulo-Quercetum*) and beech-oak forest (*Fago-Quercetum*) may also have been present (Matuszkiewicz 2008a).

Szczecin

The oldest farming settlement was established in the 8th century on Wzgórze Zamkowe (Castle Hill) (Cnotliwy et al. 1983, Piskorski 2005, Łosiński 2008, Kowalska & Dworaczyk 2011). In the 9th century, Wzgórze Zamkowe became increasingly densely settled and covered about 1.2 ha (Piskorski 2005). In the third quarter of that century at the latest, the settlement was surrounded by a horseshoe-shaped fortification (Cnotliwy et al. 1983, Leciejewicz & Wieczorowski 1983, Cnotliwy 1987). At the beginning of the 10th century, a craft and trade *suburbium* developed on the Oder River side at the foot of the hillside settlement (Leciejewicz & Wieczorowski 1983, Rulewicz 1984, Piskorski 2005, Łosiński 2008, Kowalska & Dworaczyk 2011). During the 11th century this lower town was also surrounded by fortifications (Piskorski 2005, Łosiński 2008). In the 11th century, Szczecin became a fully developed early urban centre (Łosiński 2008) consisting of two parts: a stronghold on Wzgórze Zamkowe and a sprawling craft, trade and fishing suburb on the Oder floodplain terrace (e.g.: Cnotliwy et al. 1983, Cnotliwy 1987, Łosiński et al. 2003, Kowalska & Dworaczyk 2011). At that time the Szczecin centre became a major town of Western Pomerania; this was associated with the breakdown of long-distance trade, which affected coastal centres (Cnotliwy 1996, Piskorski 2005, Kowalska & Dworaczyk 2011). Up to the beginning of the 12th century, Szczecin was an urban republic governed by the local aristocracy (Leciejewicz

Plate 1. Selected objects from the analysed sites (photo K. Cywa). **1**. Float, *Betula* sp. bark, inv. no. 526, Szczecin Wzgórze Zamkowe 44, Centre for Medieval Archaeology of the Baltic Region, Institute of Archaeology and Ethnology, Polish Academy of Sciences in Szczecin; **2**. Element of weaving workshop, *Quercus* sp., inv. no. 160/66, Radom 2 site, Jacek Malczewski Museum in Radom; **3**. Object of undetermined function, *Quercus* sp., inv. no. unknown, Czerchów 1 site, Museum of Archaeology and Ethnography in Łódź; **4**. Pedal of a foot-mortar?, *Betula* sp., inv. no. 228/64, Radom 2 site, Jacek Malczewski Museum in Radom; **5**. Carpentry mallet, undetermined deciduous, inv. no. 218/65, Radom 2 site, Jacek Malczewski Museum in Rado; **6**. Pestle?, *Acer* sp. inv. no. MAK/S/82/2, Kraków Sławkowska 14/6 site, Archaeological Museum in Kraków; **7**. Barrel stave, *Quercus* sp., inv. no. 480, Toruń Kopernika 11–13 site, District Museum in Toruń; **8**. Turned/carved vessel, *Acer* sp., inv. no. D76-77-19-12-D1, Radom 2 site, Jacek Malczewski Museum in Radom; **9**. Furniture fragment, *Quercus* sp., inv. no. unknown, Tum k/Łęczycy site, Museum of Archaeology and Ethnography in Łódź; **10**. Spade, *Quercus* sp., inv. no. 1160, Szczecin Podzamcze V/VI site, National Museum in Szczecin; **11**. Turning waste, *Acer* sp., inv. no. 7311, Szczecin Podzamcze V/VI site, National Museum in Szczecin; **12**. Part of musical instrument – mouthpiece, *Salix* sp., inv. no. 929, Wolin 3 site, Centre for Medieval Archaeology of the Baltic Region, Institute of Archaeology and Ethnology, Polish Academy of Sciences in Szczecin; **13**. Peg/rake tooth?, *Pinus sylvestris*, inv. no. 179/64, Radom 2 site, Jacek Malczewski Museum in Radom; **14**. Peg/plug?, *Taxus baccata*, inv. no. 7745, Szczecin Podzamcze V/VI site, National Museum in Szczecin; **15**. Needle/pricker, *Taxus baccata*, inv. no. 381, Szczecin Wzgórze Zamkowe 44 site, Centre for Medieval Archaeology of the Baltic Region, Institute of Archaeology and Ethnology, Polish Academy of Sciences in Szczecin; **16**. Oar, *Fraxinus excelsior*, inv. no. 531a, Toruń Kopernika 11–13 site, District Museum in Toruń; **17**. Scoop/mortar (semifinished?), *Alnus* sp., inv. no. 200/65, Radom 2 site, Jacek Malczewski Museum in Radom; **18**. Scoop, *Fraxinus excelsior*, inv. no. unknown, Tum k/Łęczycy site, Museum of Archaeology and Ethnography in Łódź; **19**. Bowl turned on one side (exterior view), *Fraxinus excelsior*, inv. no. 426, Toruń Kopernika 11–13 site, District Museum in Toruń; **20**. Corrugated object of undetermined function, *Taxus baccata*, inv. no. 185/66, Radom 2 site, Jacek Malczewski Museum in Radom; **21**. Dowel pin, *Alnus* sp., inv. no. 8392, Szczecin Podzamcze V/VI site, National Museum in Szczecin; **22**. Fragment of sharpened stick, *Corylus avellana*, inv. no. 8936, Szczecin Podzamcze V/VI site, National Museum in Szczecin. Scale bars = 5 cm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& Wieczorowski 1983, Cnotliwy 1996, Piskorski 2005). In the middle of the 12th century, West Pomeranian Duke Warcisław made it one of the main ducal seats (Cnotliwy et al. 1983). The town's decline coincided with repeated Danish raids, followed by the Brandenburg intervention (Kowalska & Dworaczyk 2011). Around the middle of the 13th century, the town was granted a charter under Magdeburg law (Cnotliwy 1987, Piskorski 2005, Łosiński 2008). In the 13th century the ducal castle was erected on the hill (Cnotliwy et al. 1983).

Material for xylological analyses came from both parts of the early medieval Szczecin settlement complex: the upper region, the so-called stronghold (Szczecin Wzgórze Zamkowe 44, trench No. XV); and the lower part, where the suburb and the port district were in the Middle Ages (Szczecin Podzamcze, quarter V, trenches IV–V). Quarter V is bordered by Panieńska Street, Rybaki Street, Środowa Street and Rynek Warzywny Street (Słowiński 2004, Janowski 2007, Łosiński 2008). The archaeological excavations at Szczecin Wzgórze Zamkowe 44 were supervised by M. Dworaczyk from the Centre for Medieval Archaeology of the Baltic Region, Institute of Archaeology and Ethnology, Polish Academy of Sciences in Szczecin, in 2012. The objects belonging to the medieval collection of wood from Szczecin Podzamcze, quarter V, were explored during long-term excavation work (1986–2001) by a team of archaeologists from the Archaeology and Conservation Laboratory, PP PKZ Szczecin, and then by researchers from the Archaeological Laboratory of the Pomeranian Ducal Castle in Szczecin (Wilgocki 1998, Wilgocki 1995, Janowski & Słowiński 2006, Janowski 2007, Łosiński 2008, Kowalska & Dworaczyk 2011).

According to the map of potential natural vegetation in the Szczecin area, the plant communities would be mostly oak-hornbeam forest (*Stellario-Carpinetum*) and alluvial poplar forest (*Salici-Populetum*). Associations of ash-alder woodland (*Fraxino-Alnetum*) may be found in the Oder valley, and lowland beech forest (*Melico-Fagetum*) in the area within a 10-km radius of the valley. Slightly further to the north, associations belonging to *Querco-Pinetum* and *Betulo-Qurcetum* could be present, and further to the south *Potentillo albae-Quercetum typicum* and *Fago-Quercetum*. On the other side of the Szczecin Lagoon, conditions seem to have been good for the development of continental marshy coniferous forest communities (*Vaccinio uliginosi-Pinetum*, *Leucobryo-Pinetum*) (Matuszkiewicz 2008a).

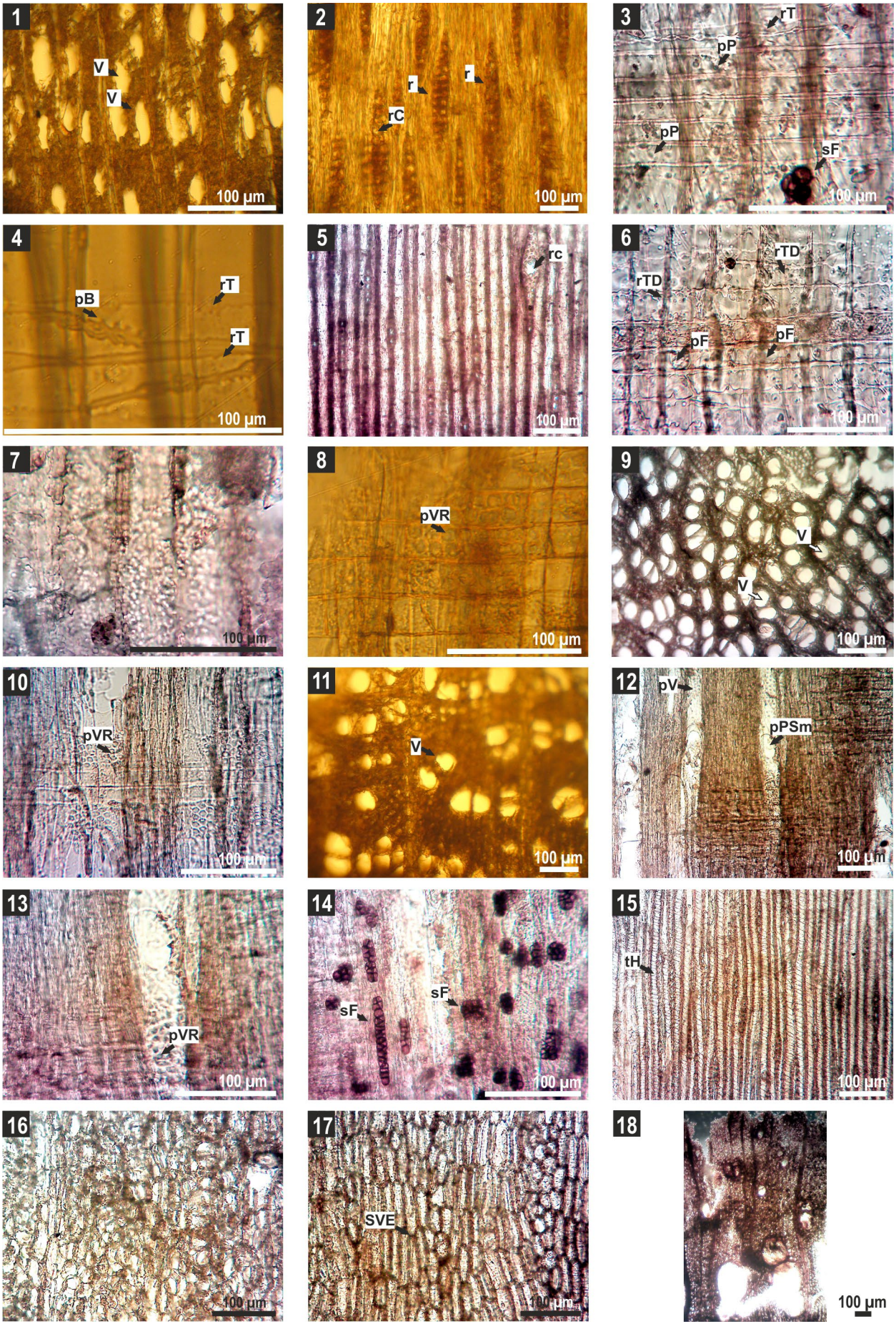
Toruń

The establishment and development of settlements near Toruń were associated with its location, where the Vistula River intersected a transport route leading from south-western lands of Poland to Prussia. A system of Vistula crossings was created in this region (Jasiński 1981). In 1228, Duke Konrad Mazowiecki leased the Chełmno and Michałów lands to the Teutonic Order, as part of a campaign to conquer and Christianize Prussia. Initially the Teutonic Knights settled on the south bank of the Vistula, opposite present-day Toruń, in a stronghold called Vogelsang. In 1231 they crossed the Vistula and erected a stronghold called Thorn on the north bank of the Vistula in the area of the present-day village of Stary Toruń; an urban settlement quickly developed there. In 1233 the settlement that had been growing near the stronghold became a town. Due to river overflows, three years later the town was relocated 10 km up the river, to the site of the present Old Town. After that relocation the initial settlement was named Stary Toruń (Old Toruń) (Jasiński 1981, Mikulski 1999, Biskup et al. 2008, Pluskowski 2013). Toruń was governed by the Teutonic Order until 1454. In the 13th century, Toruń maintained close relationships with Hanseatic towns, developing into an important centre of trade and crafts, particularly active in the trade network between Poland and Prussia (Gąsiorowski 2007, Tandecki 2008, Pluskowski 2013).

The artefacts were discovered at sites in the oldest part of the Old Town in Toruń. Archaeological excavations at Toruń Bankowa 14/16 were conducted in 1995 under the supervision of L. Grzeszkiewicz-Kotlewska, and rescue excavations were conducted at Toruń Kopernika 11–13 (S.E. Monument Conservation Labs, Toruń) in 1984–1987 (Uziembło 2003).

The potential natural vegetation in the Toruń area includes *Stellario-Carpinetum*, *Peucedano-Pinetum*

Plate 2. Selected anatomical features of examined wood, by taxon (photo K. Cywa). **1**. *Abies alba*, radial section, Kraków Sławkowska 17 site, inv. no. MAK/S/64/8:3a; tracheid pitting mostly uniseriate (**tPU**), taxodioid pits (**pT**) in cross-field pitting; **2**. *Abies alba*, tangential section, Kraków Sławkowska 17 site, inv. no. MAK/S/64/8:3a; no resin canals, average ray (**r**) height: 15–25 cells; **3**. *Acer* sp., radial section, Kraków Sławkowska 14/6 site, inv. no. MAK/S/82/2; helical thickenings (**tH**), vessel-ray pits (**pVR**) with distinct borders, similar to intervessel pits in size and shape; **4**. *Acer* sp., tangential section, Kraków Sławkowska 14/6 site, inv. no. MAK/S/82/2; larger rays (**r**) commonly 4–10-seriate; **5**. *Alnus* sp., radial section, Wolin 3 site, inv. no. 411 B; scalariform perforation plates (**pPSc**) with 10–20 bars, intervessel pits (**pV**) alternate; **6**. *Alnus* sp., tangential section, Wolin 3 site, inv. no. 411 B; uniseriate rays (**r**); **7**. *Carpinus betulus*, radial section, Toruń Bankowa 14/16 site, inv. no. 90/1/2001 B; simple perforation plate (**pPSm**), fine helical thickenings (**tH**); **8**. *Carpinus betulus*, tangential section; Szczecin Podzamcze V/VI site, inv. no. 7276, aggregate rays (**rA**); **9**. *Cornus* sp., radial section, Kraków Wawel VI site, inv. no. 11733/62/2; fungal spores (**sF**), ray cells (**rC**) procumbent with mostly 2–4 rows of upright or square marginal cells; **10**. *Cornus* sp., radial section, Kraków Wawel VI site, inv. no. 11733/62/2; scalariform perforation plates with more than 20 bars; **11**. *Cornus* sp., tangential section, Kraków Wawel VI site, inv. no. 11733/62/2; heterogeneous, predominantly 2–3-seriate rays (**r**); **12**. *Corylus avellana*, radial section, Szczecin Podzamcze V/VI site, inv. no. 8045; scalariform perforation plates (**pPSc**) with 5–10 bars; **13**. *Euonymus* sp., tangential section, Drohiczyn site, spindle; helical thickenings (**tH**), uniseriate rays (**r**); **14**. *Fagus sylvatica*, transversal section, Wolin 3 site, inv. no. 1586; wood diffuse-porous to semi-ring-porous, solitary or clustered vessel (**V**); **15**. *Fagus sylvatica*, radial section, Kraków Sławkowska 17 site, inv. no. MAK/S/64/8:5b; simple (**pPSm**) and scalariform (**pPSc**) perforation plate; **16**. *Fagus sylvatica*, tangential section, Kraków Sławkowska 17 site, inv. no. MAK/S/64/8:5b; uniseriate to very large multiseriate rays (**r**); **17**. *Juniperus communis*, radial section, Szczecin Podzamcze V/IV site, inv. no. 467; cupressoid pits (**pC**) in cross-field pitting; **18**. *Juniperus communis*, tangential section, Wolin 3 site, inv. no. 327; no resin canals, rays (**r**) very low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and *Querco-Pinetum* communities. *Salici-Populetum* communities would be mostly in the Vistula valley, and communities of medio-European oak-hornbeam forest (*Galio-Carpinetum*) within 10 km to 20 km south of the town (Matuszkiewicz 2008a).

Tum near Łęczyca and Czerchów

A stronghold was built at Tum on a floodplain in the Bzura River valley (Makohonienko 2014, Grygiel & Jurek 2014). Three phases of stronghold functioning have been identified: the tribal period (end of 8th century to 1060s), early Piast period (end of 10th century to beginning of 12th century) and castellany stronghold period (middle of 13th century to first half of 14th century). The end of stronghold functioning in the early Piast period was associated with a fire. It was followed by a period of stagnation lasting from the first half of the 12th century to the beginning of the second half of the 13th century, when the stronghold fortifications were modified, giving rise to the castellany seat (Grygiel & Jurek 2014). In the 13th century a new town was chartered under German law; it developed into the present-day Łęczyca (Malinowska-Sypek 2010).

The examined artefacts were discovered during archaeological excavations at the stronghold site in 1948–1954 under K. Jażdzewski and A. Nadolski, and in 2009–2011 under R. Grygiel (Grygiel & Jurek 2014). The majority of objects (carpentry mallet, fragment of furniture, scoop) were associated with the early Piast period. (Here we note that these medieval carpentry mallets generally resemble a cudgel rather than a modern-day wooden mallet composed of two separate wooden elements: handle and head). A wooden spade, dated to the period between the mid-13th and mid-14th centuries, was discovered during exploration of the moat fill in 2010.

The Czerchów stronghold is about 9 km south-east of the Tum stronghold (Trojan 2014), in Ozorki municipality on the right bank of the Bzura River between the villages of Czerchów and Opalanki (Kamińska 1953, Motylewska 2012). The Czerchów stronghold functioned from the last quarter of the 9th century to the middle of the 11th century (Kamińska 1953, Trojan 2014). It played a role in the defence system of the Łęczyca region and was a site of local government. In the 1140s, when the region of Łęczyca and Częstochowa was taken over by the Piasts, Łęczyca became the leading centre of government. The stronghold burned to the ground in the 10th century at the latest. After it was rebuilt, it existed until its final destruction in the middle of the 11th century (Motylewska 2012, Trojan 2014).

The wooden objects from the Czerchów 1 site were obtained during excavation work in 2015 by the Archaeological and Ethnographic Museum in Łódź, supervised by R. Grygiel.

The potential natural vegetation in this region includes medio-European oak-hornbeam forest (*Galio-Carpinetum*) and subcontinental mixed forest (*Querco-Pinetum*), and, along watercourses, alder swamp woodland (*Carici elongatae-Alnetum*) and ash-alder forest (*Fraxino-Alnetum*). To the north of Tum there are particular locations on the map of potential plant cover where *Thero-Salicornietea* communities may be found, associated with saline seepages. Thermophilous oak forest (*Potentillo albae-Quercetum* typicum) possibly grew south of Czerchów (Matuszkiewicz 2008a).

Drohiczyn

In the early Middle Ages, Drohiczyn was one of the centres of the Ruthenian dukedom of Olgovichi and later of Davidovichi (Andrzejewski & Sikora 2009) on the Polish-Ruthenian frontier, where water and land trade routes between Kievan Rus and Western Europe crossed (Malinowska-Sypek et al. 2010). It formed around a stronghold, probably founded in the first half of the 11th century by Yaroslav I the Wise, Prince of Kiev. It was built on the site of a previous early medieval "tribal" settlement (7th–10th centuries). An open settlement developed around the stronghold (Andrzejewski & Sikora 2009). The highpoint of this town was in the 12th and 13th centuries. In the first half of the 13th century, Drohiczyn temporarily became the property of Duke Konrad Mazowiecki. The development of the Drohiczyn centre was slowed in the second half of the 13th century and in the 14th century, when the dukes of Lithuania, Mazovia and Ruthenia strongly competed for the town. In 1498, Aleksander

Plate 3. Selected anatomical features of examined wood, by taxon (photo K. Cywa). **1**. Maloideae cf. Malus/Crataegus/Pyrus type, transversal section, Wolin 3 site, inv. no. 626; wood diffuse-porous, solitary vessel (**V**); **2**. Maloideae cf. Malus/Crataegus/Pyrus type, tangential section, Wolin 3 site, inv. no. 626; biseriate rays (**r**), ray cells (**rC**) round; **3**. *Picea abies*, radial section, Szczecin Podzamcze V/IV site, inv. no. 475; fungal spores (**sF**), piceoid pits (**pP**) in cross-field pitting, ray tracheids (**rT**) present; **4**. *Picea abies*, radial section, Kraków Wawel VI site, inv. no. 10056/61/3; pit borders (**pB**) of ray tracheids (**rT**) angular with dentate thickenings; **5**. *Picea*/*Larix*, tangential section, Szczecin Podzamcze V/IV site, inv. no. 475; radial intercellular resin canal (**rc**); **6**. *Pinus sylvestris*, radial section, inner layer of wood, Kraków Wawel VI site, inv. no. 8803/59/1; transversal tracheid walls dentate (**rTD**), large fenestriform pits (**pF**); **7**. *Pinus sylvestris*, radial section, outer layer of wood, Kraków Wawel VI site, inv. no. 8803/59/1; cell structure degraded; **8**. *Populus* sp., radial section, Tum site, large peg; large vessel-ray pits (**pVR**) with much-reduced borders, pit outline rounded; **9**. *Salix* sp., tangential section, Szczecin Podzamcze V/VI site, inv. no. 7106; wood diffuse-porous, solitary vessel (**V**); **10**. *Salix* sp., radial section, Toruń Kopernika 11–13 site, inv. no. 244 C; large vessel-ray pits (**pVR**) with much-reduced borders, pit outline rounded, heterogeneous rays; **11**. *Sambucus* sp., transversal section, Kraków Wawel VI site, inv. no. 4298/56; wood diffuse-porous, solitary vessel (**V**) outline angular; **12**. *Sambucus* sp., radial section, Szczecin Podzamcze V/VI site, inv. no. 9647; simple perforation plates (**pPSc**), intervessel pits (**pV**) alternate, polygonal; **13**. *Sambucus* sp., radial section, Szczecin Podzamcze V/VI site, inv. no. 9647; vessel-ray pits (**pVR**) rounded with much-reduced borders, heterogeneous rays; **14**. *Sambucus* sp., radial section, Szczecin Podzamcze V/VI site, inv. no. 9647; cell structure degraded, fungal spores (**sF**); **15**. *Taxus baccata*, tangential section, Kraków Wawel VI site, inv. no. 8803/59/2; helical thickenings (**tH**) in longitudinal tracheids; **16**. *Viscum album*, transversal section, Szczecin Podzamcze V/VI site, inv. no. 8069 B; difficult to distinguish vessels from parenchyma cells, indistinct limit of growth rings; **17**. *Viscum album*, tangential section, Szczecin Podzamcze V/VI site, inv. no. 8069 B; uniseriate to triseriate rays, storied vessel elements (**SVE**); **18**. *Fraxinus excelsior*, transversal section, Szczecin Wzgórze Zamkowe 44 site, inv. no. 513; wood ring-porous

Jagiellończyk, Duke of Lithuania, granted Drohiczyn a town charter under Magdeburg law (Andrzejewski & Sikora 2009, 2013).

Only a single wooden object comes from the Drohiczyn site – a spindle discovered during excavations in 2006, supervised by J. Sikora of the Institute of Archaeology, University of Lodz. The archaeological research there was done for the Podlaskie Province Heritage Conservator (Andrzejewski & Sikora 2009).

The potential natural vegetation of the Drohiczyn is composed predominantly of *Tilio-Carpinetum* communities and *Salici-Populetum* associations along the banks of the Bug River, as well as *Querco-Pinetum* and *Peucedano-Pinetum* communities within 10 km of it (Matuszkiewicz 2008a).

Radom

The Radom 2 site is in the western part of the present-day city of that name in the Mleczna River valley (Solarska & Trzeciecki 2012). The settlement discovered in that area covered around 5 hectares (Kalaga & Wajda 2012, Fuglewicz 2012, 2013a, Buko 2013) and stretched along both sides of the river (Solarska & Trzeciecki 2012). The settlement was an open one; settlement was scattered due to the presence of numerous swamps in the river valley (Fuglewicz 2010, 2012, 2013a,b, Trzeciecki 2013). At the turn of the 9th century the settlement was temporarily abandoned when the Mleczna River rose (Fuglewicz 2012, 2013b, Auch et al. 2013). In the middle of the 10th century, when its water level dropped again, settlers returned to the Radom 2 site and a stronghold was constructed near the settlement. Then the settlement along the Mleczna River became an ancillary settlement, changing in character from rural to early urban. In the 11th–13th centuries, crafts and trade started to predominate over other occupations of its inhabitants (Fuglewicz 2012, 2013a). The settlement at Radom 2 functioned until the end of the 12th century or the first half of the 13th century, when another rise of the water level caused the nearby trade settlement to take over the role of supply base for the stronghold (Fuglewicz 2012, 2013b, Trzeciecki 2013). The Radom settlement continued to function in that form until the middle of the 14th century, when the new town of Radom was chartered (Fuglewicz 2013b).

The Radom stronghold, founded by the Piasts and serving as a castellan seat, was of great strategic importance for the defence of the internal frontier of Małopolska and Masovia (Fuglewicz 2013b, Trzeciecki 2013). The Radom settlement was also on an important route between Wielkopolska and Ruthenia (Fuglewicz 2013a, Buko 2013).

The analysed objects from Radom 2 were obtained during excavation work in 1964–1966. At that time the archaeological work was supervised by E. Kierzkowska-Kalinowska of the Institute of the History of Material Culture, Polish Academy of Sciences in Warsaw (Kalaga & Wajda 2012, Fuglewicz 2013a, b). Several of the studied items were discovered in 1978–1980 during rescue excavations at that site done by E. Ćwiertak of the Heritage Conservation Laboratory in Łódź.

According to the map of the potential natural vegetation, *Tilio-Carpinetum* communities could be dominant in the Radom area. Apart from these communities, subcontinental mixed coniferous forest (*Querco-Pinetum*) may be found within 10 km of the site, and to the south, 20–40 km from the city, subcontinental thermophilous oak forest (*Potentillo albae-Quercetum* typicum) and upland mixed fir forest (*Abietetum polonicum*) (Matuszkiewicz 2008a).

Kraków

Slavs established their settlements on Wawel Hill in Kraków as early as the 7th century. From the 9th century it was a political and economic centre of the Vistulan state (Malinowska-Sypek et al. 2010), and in the middle of the 10th century the stronghold belonged to the state of Boleslaus I of Bohemia. The Kraków territory (Ziemia krakowska) was incorporated into the Piast State during the reign of Bolesław I the Brave in the last quarter of the 10th century (Kozieł 1977). Kraków proceeded to become one of the most important centres of state and church administration (Pianowski 1977, Firlet & Pianowski 2006). It was a seat of the bishopric subordinate to the Metropolis of Gniezno, and in the mid-11th century it became the capital city of Poland (Jelicz 1965, Kozieł 1977). From the 9th century onwards, defence fortifications of the stronghold ringed the summit of the hill (Pianowski 1977, Firlet & Pianowski 2006), and the main suburb, Okół, was directly at its foot on the north-east side (Żaki 1977a, Kozieł 1977, Dembińska & Podwińska 1978, Łukasik 2015). Initially the open settlement was concentrated around Saint Andrew's and Saint Martin's churches (Dembińska & Podwińska 1978). The town of Kraków was chartered under Magdeburg law in 1257 (Jelicz 1965, Łukasik 2015). Afterwards, all open suburban settlements were incorporated into the town (Dembińska & Podwińska 1978, Łukasik 2015). In the 13th century, the first Cloth Hall (Sukiennice) was erected in Kraków's market square (Jelicz 1965, Niemiec 2008). The number of Kraków inhabitants reached an estimated 10 000 at the end of the 14th century, and about 15 000 by the middle of the 15th century (Łukasik 2015).

Wooden objects for xylological analyses have been discovered in various parts of the Old Town and Wawel Hill. Items from sites within the suburban and urban settlements were found during research by A. Żaki and S. Kozieł in the 1950s (Kraków Main Market – Town Hall site) and during archaeological work supervised by Kraków branch of the State Studios for Conservation of Cultural Property in the 1970s. Wawel material was collected during archaeological work in sectors VI and V of Wawel Hill in the 1950s and 1960s, mainly from the 5th archaeological layer established for that site (Żaki 1977b, Kozieł 2006). At that time, archaeological research at Wawel was done by the National Art Collection at Wawel Castle and the Archaeology Laboratory of the Restoration Authority of Wawel Royal Castle, under the supervision of A. Żaki and later S. Kozieł (Kozieł 2006).

The potential natural vegetation of the Kraków area is composed predominantly of lowland lime-oak-hornbeam forests (*Tilio-Carpinetum*). *Salici-Populetum*, *Ficario-Ulmetum* typicum and *Fraxino-Alnetum* riparian forests could be found along the banks and tributaries of the Vistula, and 10–20 km to the north

Table 3. List of taxonomically determined collections of medieval wooden items from Poland (published and archived material)

Site	References	Identification	Chronology	Geographical coordinates	Main types of items	Number of items
Bródno Stare	Robak 2009, Ruszkowska et al. 2011	unknown author	10th cent. – early 11th cent.	52°17′48.59″N, 21°03′34.60″E	log and bark lining of box for cereals, wheel	3
Brzeg	Głosek & Kajzer 1977	unknown author	14th cent.	50°51′38.13″N, 17°28′12.37″E	bow	1
Dziekanowice	Stępnik 2013, Wrzesiński & Wrzesińska 2007	Stępnik T.	11th cent.	52°31′11.37″N, 17°23′16.11″E	axe handle	1
Elbląg Bednarska 22	Popławska 2004, Łyczywek 2013	unknown author	mid 15th cent.	54°09′34.32″N, 19°23′43.33″E	block from musical instrument mouthpiece, fife	2
Elbląg Kowalska 13	Popławska & Lachowicz 2017, Łyczywek 2013	unknown author	14th cent.	54°09′32.79″N, 19°23′49.20″E	vielle	1
Elbląg Stary Rynek 38	Łyczywek 2013, Popławska & Lachowicz 2014	unknown author	late 15th cent. or early 16th cent.	54°09′29.07″N, 19°23′44.78″E	recorder and block from mouthpiece	2
Elbląg Stary Rynek 53	Popławska & Lachowicz 2017, Łyczywek 2013	unknown author	mid 15th cent.	54°09′33.98″N, 19°23′44.54″E	gittern	3
Gdańsk 1	Barnycz-Gupieniec 1959	unknown author	late 10 cent. – 13th cent.	54°21′16.59″N, 18°39′31.03″E	objects of various functions	165
Gdańsk 2	Barnycz-Gupieniec 1961	unknown author	13th cent. and 14th – 15th cent.	54°21′13.45″N, 18°39′14.17″E	turned vessels	29
Inowrocław 19	Grabska 1979	unknown author	mid 13th cent. – 14th cent.	52°47′49.72″N, 18°15′36.04″E	objects of various functions	152
Kołobrzeg Armii Krajowej	Polak 1999	unknown author	2nd half 13th cent. – 14th cent.	54°10′36.36″N, 15°34′28.62″E	bow	1
Kołobrzeg E. Gierczak	Polak 1998a, b, Nyborg & Rębkowski 1998	Łotocka Z., Oktaba J., Ważny T.	3rd quarter 13th cent. – 4th quarter 14th cent.	54°10′25.85″N, 15°34′29.60″E	objects of various functions	31
Kołobrzeg Ratuszowa 9–13	Polak 1996	Łotocka Z., Oktaba J.	3rd quarter 13th cent. – 3rd quarter 14th cent.	54°10′37.64″N, 15°34′36.42″E	objects of various functions	30
Kraków Kazimierz	Wasylikowa 1958	Reymanówna M.	14th or 15th cent.	50°03′5.25″N, 19°56′4.94″E	barrel	1
Kraków Mały Rynek	Gluza 2009, Krąpiec 2009	Gluza I.	13th–15th cent.	50°03′40.39″N, 19°56′25.72″E	objects of various functions, pieces of worked wood of undetermined function	60
Kraków Rynek Główny	Gluza 2005 (unpubl.), Zaitz 2006	Gluza I.	late 13th cent. – mid 15th cent.	50°03′41.74″N, 19°56′12.76″E	objects of various functions	55
Kraków Sławkowska 17	Puziuk & Tyniec 2013	Lityńska-Zając M.	late Middle Ages – modern period	50°03′52.23″N, 19°56′19.40″E	maces	3
Kraków Tyniec	Reymanówna 1970 (unpubl.), Kozłowski 1971	Reymanówna M.	11th–12th cent.	50°01′8.77″N, 19°48′8.97″E	abbot's stick	1
Kraków Wawel benches	Gostwicka 1965	unknown	Middle Ages	50°03′17.50″N, 19°56′13.30″E	carved benches	2
Kraków Wawel X	Reymanówna (unpubl.), Wasylikowa 1978, Wasylikowa 1991	Reymanówna M.	Middle Ages	50°03′12.37″N, 19°56′7.42″E	objects of various functions, pieces of worked wood of undetermined function	79
Kraków Zakrzówek	Gluza 1977	Gluza I.	mid 11th – mid 13th cent.	50°02′24.25″N, 19°55′00.72″E	objects of various functions	28
Kruszwica 4	Dzieduszycki 1976	Surmiński J., Gądziński Z.	mid 11th cent. – early 16th cent.	52°40′22.36″N, 18°19′37.62″E	objects of various functions	30
Międzyrzecz Wielkopolski	Woźnicka 1961, Łaszkiewicz & Michalak 2007, Stępnik 2013	unknown author, Stępnik T.	13th cent. – 16th cent.	52°26′42.17″N, 15°34′18.69″E	stave-built and turned vessels, hatchet handles	353
Modlnica 5	Lityńska-Zając et al. 2015	Lityńska-Zając M.	2nd half 11th – 1st quarter 12th cent.	50°07′15.31″N, 19°52′0.39″E	parts of Slavic headband	2
Nysa flute	Popławska & Lachowicz 2014	unknown author	after 1350 and before 1420	50°28′17.89″N, 17°20′2.8″E	flute	1
Opole Ostrówek I–IV	Gediga 1969, Bukowska-Gedigowa & Gediga 1986, Robak 2009	Surmiński J.	10th cent. – 2nd half 12th cent.	50°40′02.89″N, 17°55′07.15″E	objects of various functions	544

Table 3. Continued

Site	References	Identification	Chronology	Geographical coordinates	Main types of items	Number of items
Ostrów Lednicki**	Zielski 1993, Stępnik 1996, Grupa 2000, Szulta 2000, Tokarski 2000, Stępnik 2013, Pastuszka 2015	Zielski A., Stępnik T., unknown author	Middle Ages	52°31′40.12″N, 17°22′45.51″E	objects of various functions	205
Płock Grodzka	Trzeciecki 2000, Polak 2000	Sokulska A.	late Middle Ages – modern period	52°32′36.67″N, 19°41′16.66″E	lining of well	1
Płock Grodzka 14/16	Trzeciecki 2000, Polak 2000	Sokulska A.	late Middle Ages – modern period	52°32′36.67″N, 19°41′16.66″E	spoon, stave-built and turned vessels	4
Płock Grodzka 6	Trzeciecki 2000, Polak 2000, Popławska & Lachowicz 2014	Sokulska A.	late Middle Ages – modern period	52°32′36.67″N, 19°41′16.66″E	staves of barrel, flute	3
Puck	Popławska & Lachowicz 2014	unknown author	late 14th cent. – mid 15th cent.	54°43′4″N, 18°24′31″E	recorder and block from mouthpiece	2
Stargard Szczeciński*	Bobik 2012, Kwiatkowski & Majewski 2012	Bobik I., Krąpiec M.	turn of 13th /14th cent. – mid 14th cent.	53°20′15.32″N, 15°02′42.64″E	stave-built and turned vessels	160
Szczecin Rynek Warzywny	Rulewicz 1958, Molski 1968, Gorczyński at al. 1969, Rulewicz 1986, Kowalska & Dworaczyk 2011	Molski B., Jasnowska J., Surmiński J.	late 8th cent. and 2nd decade 10th cent. – mid 13 cent.	53°25′31.07″N, 14°33′44.05″E	objects of various functions	66
Szczecin Wzgórze Zamkowe excavations V and I	Cnotliwy et al. 1983	Jasnowska J.	7/8th cent. –mid 13th cent.	53°25′34.29″N, 14°33′36.83″E	objects of various functions	17
Szczecin-Podgrodzie quarter 1	Głosek & Uciechowska-Gawron 2009/2010, Jagielska 2009/2010	Jagielska I.	1170 – 1197	53°25′34.74″N, 14°33′45.19″E	shield	1
Szczecin-Podzamcze excavations II and III	Łosiński et al. 2003, Robak 2009	Stępnik T.	turn of 1st/2nd decade 12th cent. – 5th decade 13th cent.	53°25′32.69″N, 14°33′45.01″E	objects of various functions	89
Szczecin-Podzamcze quarter V, excavation VI	Wilgocki 1995, Słowiński 2004	unknown author, Bobik I.	Middle Ages	53°25′31.96″N, 14°33′42.03″E	objects of various functions	19
Toruń Bankowa 14/16	Catalogue card of The District Museum in Toruń (unpubl.)	Stawska V.	1st half 13th cent. – 15th cent.	53°00′30.26″N, 18°36′14.99″E	spade	1
Toruń Św. Ducha	Civis Thorunensis 1931	unknown author	15th cent.	53°00′32.52″N, 18°36′12.31″E	parts of water pipe	3
Wolin 1, 4	Stępnik 2014	Stępnik T.	late 10th cent. and 1st half 11th cent.	53°50′33.96″N, 14°37′00.41″E	objects of various functions	133
Wrocław Ostrów Tumski	Ostrowska 1962	Jasnowska J., Gądziński Z.	11/12th cent. – early 13th cent.	51°06′56″N, 17°02′34″E	objects of various functions	46
Wrocław Ostrów Tumski III F	Rakoczy 2015a, Myśkow & Rakoczy 2015	Myśkow E.	early Middle Ages	51°6′53.59″N, 17°2′43.75″E	objects of various functions	20
Wrocław Ostrów Tumski I–III	Rakoczy & Myśkow 2014, Rakoczy 2015b	Myśkow E.	late 10th cent. – 13th cent.	51°6′54.28″N, 17°2′43.21″E	turned vessels	31
Wrocław Rynek	Wysocka 1999, Wysocka 2001, Pyszyński 2001	Pyszyński W.	mid 13th cent. – late 14th cent.	51°6′38.55″N, 17°01′50.32″E	objects of various functions	89
Wrocław Szewska i Oławska	Piekalski 2010	Pyszyński W.	Middle Ages	51°06′37.98″N, 17°02′05.53″E	stave-built and turned vessels	67
Wrocław Więzienna 10–11	Świętek 1999	unknown author	2nd half 13th cent. – mid 15th cent.	51°06′46.94″N, 17°01′57.90″E	objects of various functions	151
Number of objects (total)						2688

* – some determinations were not included in Cywa 2018a
grey shading – sites not included in Cywa 2018a

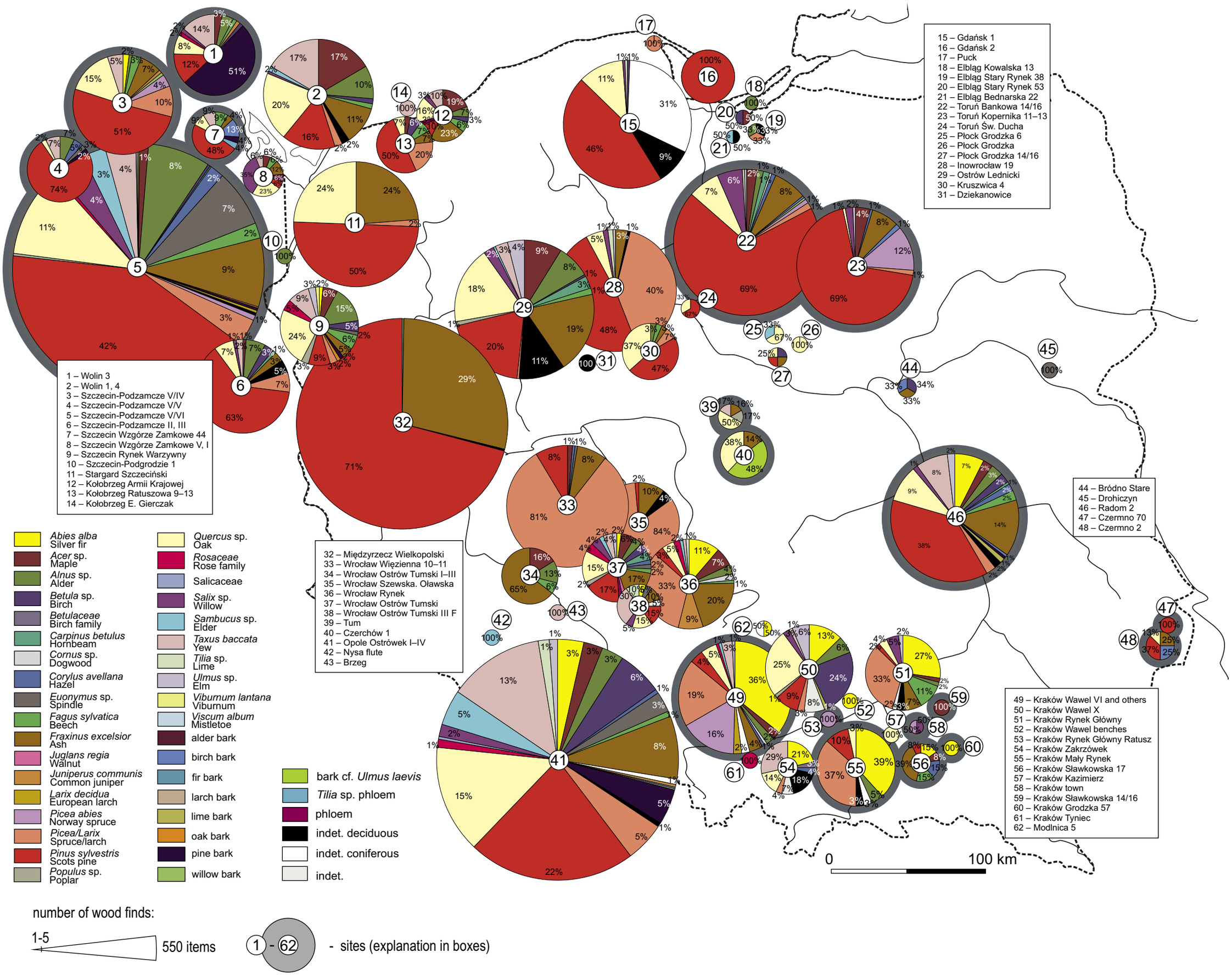

Fig. 4a. Xylological data from particular archaeological sites in Poland – taxonomic composition, grey shading of pie chart edges indicates sites examined by the authors

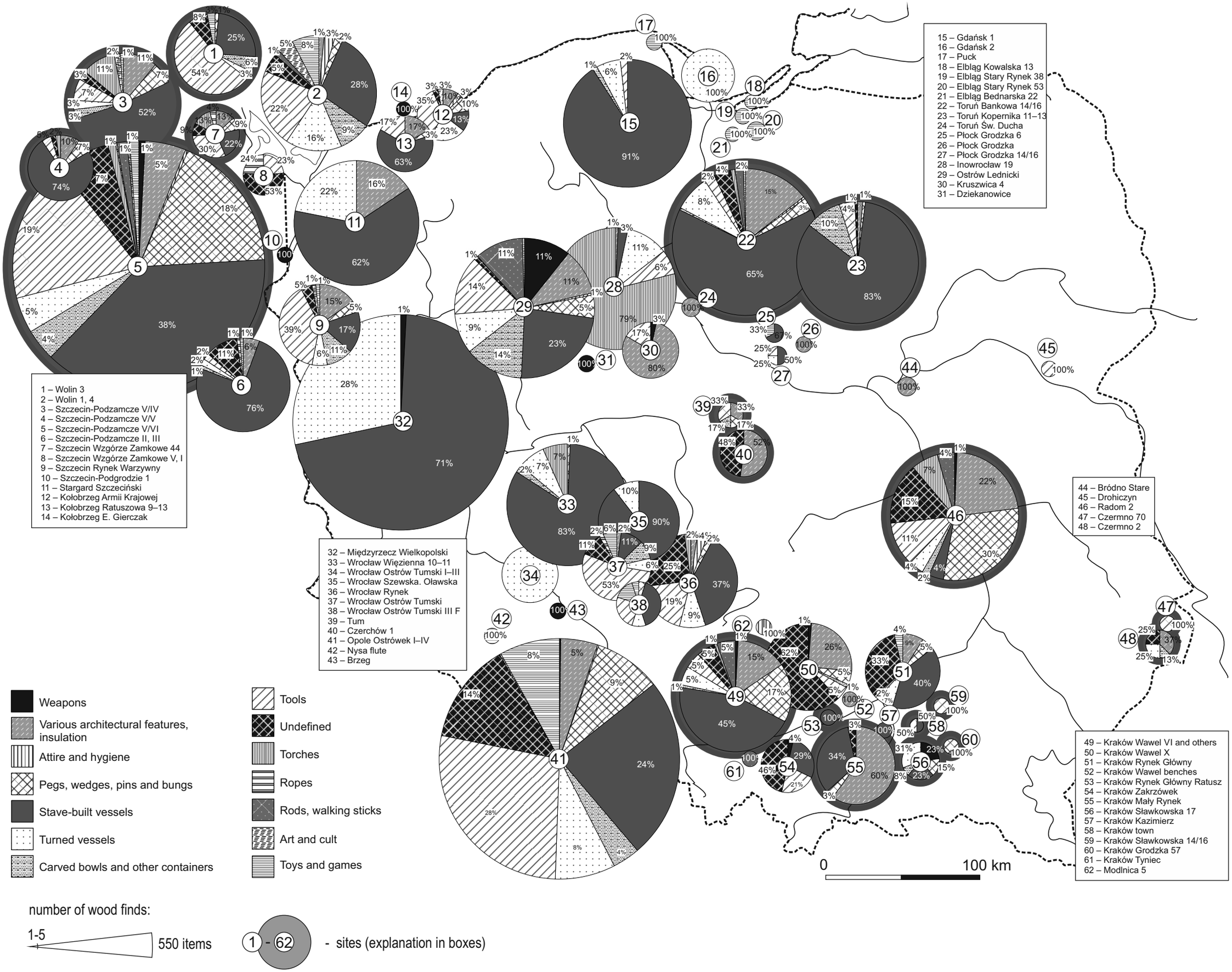

Fig. 4b. Xylological data from particular archaeological sites in Poland – functional composition, grey shading of pie chart edges indicates sites examined by the authors

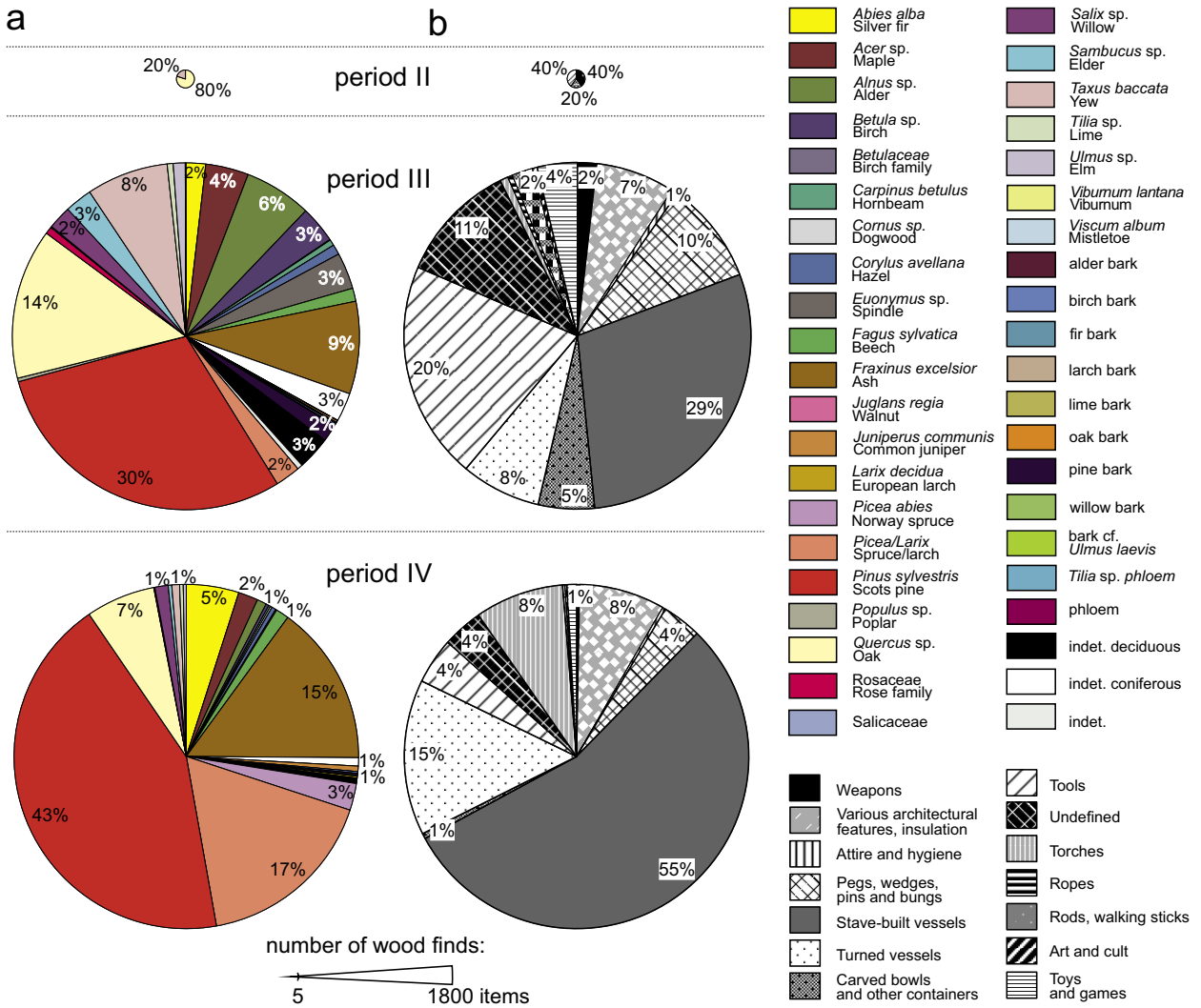

Fig. 5. Characteristics of medieval wood and bark objects from Polish archaeological sites (N = 4211), by chronological period: **a** – taxonomic composition; **b** – functional composition

and south there may have been sites of submontane acidophilous oak forest (*Luzulo luzuloidis-Quercetum*). *Leucobryo-Pinetum* and *Querco-Pinetum* communities may be found 20–40 km north-west of the city. To the south, the Carpathian foothills may be covered by upland fir forest (*Abietetum polonicum*). Even further to the north, communities of *Galio-Abietenion*, *Abieti-Piceetum montanum* and beech forest *Dentario glandulosae-Fagetum* may also develop (Matuszkiewicz 2008a).

Czermno

Czerwień, at the site of the present-day village of Czermno, was the capital city of the Cherven towns; a densely populated settlement on the middle Bug River, in the Middle Ages it was on the Polish-Ruthenian frontier and was a point of contention between the Kingdom of Poland and Kievan Rus in the 10th and 11th centuries (Kuśnierz 2003, Dobrowolski et al. 2015). The complex was established near where the Sieniocha River flows into the Huczwa River (Dobrowolski et al. 2015). In consequence of the increase in Poland's international position during the reign of Bolesław I the Brave, the Cherven towns were temporarily incorporated into the Piast State. Following the crisis of the Polish monarchy early in the 11th century, Poland lost the Cherven towns in 1031 (Wołoszyn 2013). In the 11th century, Ruthenia consolidated its power over Czerwień. The stronghold was destroyed probably around 1240, and its final decline was at the turn of the 13th/14th centuries. The stronghold, with fortified suburbs, open settlements, a port for boats, and three graveyards, formed an extensive settlement complex covering about 100 hectares. The settlements covered both sides of the Huczwa River and were connected by a wooden bridge (Poznański 2010 (2011), Wołoszyn et al. 2016). The Czermno 2 site, the so-called nearer suburb, is on the west side of the stronghold, separated from it by a marshy hollow. On the south side the complex is enclosed by an earth embankment nearly 2 km long (Wołoszyn 2013).

The majority of wooden objects from Czerwień came from excavations at the Czermno 2 site in 1976–1979 by J. Gurba of the Archaeology Department, Maria Curie-Skłodowska University in Lublin (Kuśnierz 2003). One object from the Czermno 70 site (iron sickle with wooden handle) was discovered in 2014 during rescue work on the bank of the Huczwa River by M. Wołoszyn and M. Piotrowski (Wołoszyn et al. 2016).

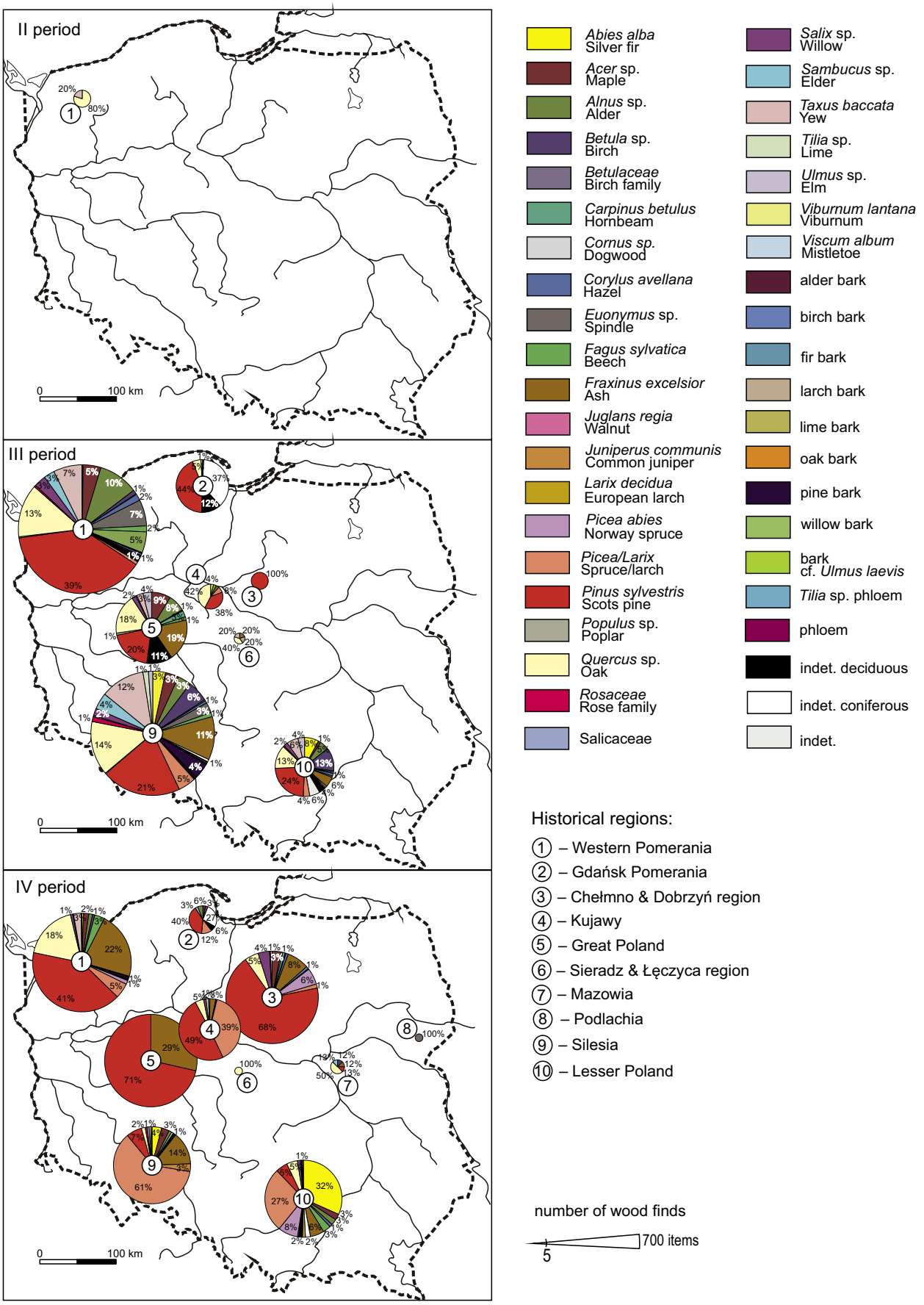

Fig. 6. Taxonomic composition of wood and bark in historical regions, by chronological period

According to the map of potential natural vegetation, communities of subcontinental mixed coniferous forest (*Querco-Pinetum*) and *Tilio-Carpintum* associations could be found in the nearest vicinity of the site. Thermophilous oak forest (*Potentillo albae-Quercetum*) may occur within 10 km. The river banks may be covered by communities of riparian woodland (*Ficario-Ulmetum* and *Fraxino-Alnetum*) (Matuszkiewicz 2008a).

TAXONOMY DATABASE OF WOODEN OBJECTS OF DAILY USE FROM POLAND

We supplemented the results of our own research with xylological determinations of medieval wooden objects described in the literature from 62 sites in Poland (Figs 2, 4a–b, Tab. 3). The database contains taxonomical data describing 4211 wood items dating from the 9th to 15th centuries. This database served as the basis for analysing the use of wood in medieval Poland in terms of its technical and practical properties of the wood as well as in geographic and chronological terms. These questions were discussed in an earlier publication (Cywa 2018a). In this paper we also include our own data from five new sites (Czerchów 1, Szczecin Wzgórze Zamkowe 44, Szczecin-Podzamcze V/VI, Toruń Kopernika 11–13, Tum) and additionally from 13 sites published by other authors (Dziekanowice, Elbląg Bednarska 22, Elbląg Kowalska 13, Elbląg Stary Rynek 53, Kraków Rynek Główny, Kraków Tyniec, Modlnica 5, Ostrów Lednicki, Płock Grodzka, Stargard Szczeciński, Toruń Św. Ducha, Wrocław Ostrów Tumski III F, Wrocław Ostrów Tumski I–III).

In some cases we raised the original taxonomical identification in publications (e.g. *Acer platanoides*, *Sambucus nigra*, *Euonymus europaea*) to higher taxa in order to standardize the collected determinations and adapt them to the generally accepted rules for differentiating fossil wood to species level (e.g. Schweingruber 1978). Due to the lack of information on the methods used to distinguish spruce from larch wood (except for rather dubious ecological criteria), all of those determinations were treated as *Picea*/*Larix*.

For papers whose authors did not specify the number of objects of a particular type made from a particular taxon, we assumed that at least one item of that type was crafted from wood of that taxon.

Based on the chronology of the artefacts (Supplementary Material 1[1]), we assigned them to successive periods of the Middle Ages in Poland (Fig. 1). The time frames of the periods are based on information from the archaeological and historical literature (Wyrozumski 1982, Tyszkiewicz 2003, Miśkiewicz 2010, Piskorski 2005, Nowak 2010, Buko 2011). Artefacts whose chronology did not fit our time intervals were not included in the chronologial analysis. In the final selection, the periods (Fig. 5, 6) covered 3586 objects: 5 items in period II (tribal), 1797 items in period III (Piast period) and 1784 items in period IV (late Middle Ages). Applying the same method as in earlier work (Cywa 2018a), we discuss the changes in the use of wood in relation to historical regions of Poland, not to particular sites (Fig. 6).

[1] Available on page http://www.botany.pl/images/ibwyd/acta_paleo/Acta_Palaeobot_58_2_Cywa_et_al_Suppl_1.pdf

RESULTS

ORIGINAL XYLOLOGICAL RESEARCH

Taxonomic composition of the wood studied

Among the examined wood finds we confirmed the use of 24 tree and shrub taxa: *Abies alba*, *Acer* sp., *Alnus* sp., *Betula* sp., *Carpinus betulus*, *Cornus* sp., *Corylus avellana*, *Euonymus* sp., *Fagus sylvatica*, *Fraxinus excelsior*, *Juniperus communis*, *Larix decidua*, *Picea abies*, *Picea*/*Larix*, *Pinus sylvestris*, *Populus* sp., *Quercus* sp., Maloideae cf. *Malus*/*Crataegus*/*Pyrus* type (Rosaceae), *Salix* sp., *Sambucus* sp., *Taxus baccata*, *Tilia* sp., *Ulmus* sp. and *Viscum album*. Our analysis (Fig. 3b) showed that pinewood was the most commonly used material (44% of artefacts), followed by *Quercus*, *Fraxinus excelsior*, *Abies alba*, *Alnus*, *Picea*/*Larix*, *Taxus baccata*, *Picea abies*, *Euonymus* and *Populus*. These ten taxa accounted for 87% of all artefacts. *Acer*, *Fagus sylvatica*, *Corylus avellana* and *Sambucus* sp. comprised slightly more than 6%. Other taxa were very rare, none reaching as much as 0.5% of the total. *Ulmus* wood was used to make only 7 items, including 2 planks, a bucket stave, a dowel, a ladle, a rod, and one plate turned on both sides; *Betula* sp. was used for only 6 items (beater, 2 pedals of a foot-mortar, 3 items of undefined function); *Carpinus betulus* was used for 5 (lath, wooden weight, 2 items of undefined function, pole); *Larix decidua* was used for 5 (4 discs, 1 stave of a small stave-built bowl); Maloideae cf. *Malus*/*Crataegus*/*Pyrus* type was used for 4 (2 spoons, hammer head, item of undefined function); *Juniperus communis* was used for only 3 (stick, peg, item of undefined function); *Populus* sp. wood was used to make a peg and a spar; *Viscum album* was used to make one peg; *Tilia* sp. was used to make one lath; and *Cornus* sp. was present as a fragment of a debarked branch with traces of processing used to make a hammer handle.

The number of taxa differed between northwestern and south-eastern Poland (Fig. 7). In the historical regions of Western Pomerania and the Chełmno & Dobrzyń region (7 sites) a total of 24 taxa of trees and shrubs were recorded,

Historical regions			Western Pomerania					Chełmno&Dobrzyń region		Sieradz&Łęczyca region	Podlachia	Lesser Poland									
Locality			Szczecin					Toruń		Czerchów	Tum	Drohiczyn	Kraków							Radom	Czermno
Taxa \ Sites		Wolin	Wolin 3	Szczecin Wzgórze Zamkowe 44	Szczecin-Podzamcze V/IV	Szczecin-Podzamcze V/V	Szczecin-Podzamcze V/VI	Toruń Bankowa 14/16	Toruń Kopernika 11-13	Czerchów 1	Tum	Drohiczyn	Kraków Grodzka 57	Kraków Rynek Główny Ratusz	Kraków Sławkowska 14/6	Kraków Sławkowska 17	Kraków Wawel VI and others	Kraków town	Radom 2	Czermno 2	Czermno 70
Number of items		65	23	100	42	591	213	145	21	6	1	2	2	1	10	129	2	161	8	1
Deciduous taxa	*Acer* sp.	3.08%				1.18%	2.35%	4.14%						100.00%	10.00%	2.33%		2.48%		
	Alnus sp.	4.62%		1.00%	7.14%	7.78%	1.41%									2.33%		3.11%		
	Betula sp.					0.34%												2.48%		
	Carpinus betulus					0.17%	1.41%											0.62%		
	Cornus sp.						0.47%									0.78%				
	Corylus avellana				4.76%	1.86%	0.94%	0.69%							20.00%	0.78%		1.86%		
	Euonymus sp.				2.38%	7.45%						100.00%								
	Fagus sylvatica	1.54%	8.70%	3.00%		2.03%									10.00%			2.48%		
	Fraxinus excelsior		4.35%	7.00%		8.63%	7.51%	7.59%		14.29%	16.67%				30.00%	3.88%		4.29%	25.00%	
	Populus sp.					0.17%					16.67%									
	Quercus sp.	7.69%	8.70%	15.00%	2.38%	11.66%	6.57%	0.69%	38.10	50.00%						4.65%		9.32%	12.50%	
	Maloideae cf. *Malus/Crataegus/Pyrus* type	1.54%				0.34%										0.78%				
	Salix sp.	1.54%				3.89%	5.63%	2.07%										1.24%		
	Sambucus sp.					3.05%										0.78%				
	Tilia sp.						0.47%													
	Ulmus sp.					0.17%	0.47%	0.69%								0.78%		1.86%		
	Viscum album					0.17%														
	Betula sp. bark	1.54%	13.04%				0.47%	1.38%										0.62%	25.00%	
	cf. *Ulmus laevis* bark								47.62%											
	Salix sp. bark			1.00%			0.47%										50.00%			
	Tilia sp. bark																	1.24%		
	Tilia sp. phloem		4.35%																	
	indet. deciduous					0.17%												1.86%		
Coniferous taxa	*Abies alba*			2.00%		0.17%							100.00%		20.00%	35.66%		7.45%		
	Juniperus communis	1.54%		1.00%		0.17%														
	Larix decidua					0.34%										2.33%				
	Picea abies			4.00%		0.68%	0.94%	12.41%						100.00%		16.28%	50.00%			
	Picea/Larix			10.00%		3.38%	1.41%	1.38%								19.38%		2.48%		
	Pinus sylvestris	12.31%	47.83%	51.00%	73.81%	42.98%	69.45%	69.97%							10.00%	3.88%		37.89%	37.50%	100.00%
	Taxus baccata	13.85%	8.70%	5.00%	7.14%	2.88%					16.67%					3.10%		8.07%		
	Pinus sylvestris bark	50.77%	4.35%		2.38%	0.34%												0.62%		
	indet. coniferous															2.33%				
Number of taxa			22					11		4	1					19				

Fig. 7. Shares of trees and shrubs used to make the objects from particular sites (N = 1523)

	Taxa \ Locality	Wolin	Szczecin	Toruń	Drohiczyn	Tum	Czerchów	Kraków	Radom	Czermno
	Number of items	65	756	358	1	6	21	146	161	9
Deciduous taxa	*Acer* sp.	3.08%	0.93%	3.07%				3.42%	2.48%	
	Alnus sp.	4.62%	6.61%	0.84%				2.05%	3.11%	
	Betula sp.		0.26%						2.48%	
	Carpinus betulus		0.13%	0.84%					0.62%	
	Cornus sp.			0.28%				0.68%		
	Corylus avellana		1.72%	0.84%				2.05%	1.86%	
	Euonymus sp.		5.95%		100.00%					
	Fagus sylvatica	1.54%	2.25%					0.68%	2.48%	
	Fraxinus excelsior		7.80%	7.54%		16.67%	14.29%	5.48%	14.29%	22.22%
	Populus sp.		0.13%			16.67%				
	Quercus sp.	7.69%	11.51%	4.19%		50.00%	38.10%	4.11%	9.32%	11.11%
	Maloideae cf. *Malus/Crataegus/Pyrus* type	1.54%	0.26%					0.68%		
	Salix sp.	1.54%	3.04%	4.19%					1.24%	
	Sambucus sp.		2.38%					0.68%		
	Tilia sp.			0.28%						
	Ulmus sp.		0.13%	0.56%				0.68%	1.86%	
	Viscum album		0.13%							
	Betula sp. bark	1.54%	0.40%	0.84%					0.62%	22.22%
	cf. *Ulmus laevis* bark						47.62%			
	Salix sp. bark		0.13%	0.28%				0.68%		
	Tilia sp. bark								1.24%	
	Tilia sp. phloem		0.13%							
	indet. deciduous		0.13%						1.86%	
Coniferous taxa	*Abies alba*		0.40%					34.25%	7.45%	
	Juniperus communis	1.54%	0.26%							
	Larix decidua		0.26%					2.05%		
	Picea abies		1.06%	5.59%				16.44%		
	Picea/Larix		3.97%	1.40%				17.12%	2.48%	
	Pinus sylvestris	12.31%	45.90%	69.27%				4.11%	37.89%	44.44%
	Taxus baccata	13.85%	3.57%			16.67%		2.74%	8.07%	
	Pinus sylvestris bark	50.77%	0.53%						0.62%	
	indet. coniferous							2.05%		

Fig. 8. Total shares of taxa at main localities (N = 1523)

with 19 taxa in Lesser Poland (9 sites). The taxa found only among the items from northwestern sites are *Euonymus* sp. (although also from Drohiczyn in eastern Poland), *Populus* sp., *Tilia* sp., *Viscum album* and *Juniperus communis*. Only 4 taxa were identified from the Sieradz & Łęczyca region (central Poland) and only one from Podlachia (eastern Poland); few sites have been discovered in those places.

Results of xylological analysis in relation to particular sites

The xylological analysis results are summarized in Cywa 2018b (unpubl.): Annex 1 and shown in Figure 7. Since the sites in Szczecin, Toruń, Czermno and Kraków are close to each another (maximum straight-line distance between sites: 0.1 km in Szczecin and Toruń, 0.8 km in Czermno, 1.25 km in Kraków) and were associated with the functioning of the same town centre (Fig. 2), the taxonomic composition of these wood finds is discussed jointly for each of those towns (Fig. 8). This approach also made it easier to compare the results of the wood analyses with the palynological data.

Wolin

The use of 9 tree and shrub taxa was confirmed in the examination of 65 items from the Wolin 3 site: *Acer* sp., *Alnus* sp., *Fagus sylvatica*, *Quercus* sp., Maloideae cf. *Malus*/*Crataegus*/*Pyrus* type, *Salix* sp., *Juniperus communis*, *Pinus sylvestris* and *Taxus baccata*. Birch and pine bark was also identified. Objects made of pine bark were particularly abundant (50.8% of the total number of items from this site). Pine bark was used for fishing net floats, the category that contained the highest number of items from Wolin (Cywa 2018a: fig. 3.3, Cywa 2018b (unpubl.): Annex 1). Among the items made of wood, those made of yew (14%),

pine (12%) and oak (8%) predominated. These were the main materials for coopers. Pine was the raw material for the top plate of the soundboard of a stringed instrument (*nyckelharpa*; Janowski et al. 2015) and a peg of undefined function. Yew wood was used to make a tool handle, and oak was used to make 2 scoops. Alder (5%) and maple (3%) were used to make a scoop (alder) and all the turned plates found at the site (maple). Other taxa did not exceed 2%. An interesting object made of a fine debarked willow twig was a plug that had been part of a musical instrument's mouthpiece (Plate 1.12). The only spoon found on the site was made from hardwood of a fruit tree determined as Maloideae cf. *Malus*/*Crataegus*/*Pyrus* type. The use of wood from apple, hawthorn or pear trees is justified by their hardness, durability and aesthetic qualities (smoothness and reddish colour). Pear wood is particularly hard and resists shrinking in contact with moisture, which would make it good material to use for spoons. *Malus* sp. wood, in contrast, is most prone to cracking and warping (Krzysik 1957, Surmiński 1990).

Szczecin

Among the 756 wooden items found in deposits at Szczecin Wzgórze Zamkowe 44 (23 items), Szczecin-Podzamcze V/IV (100), Szczecin-Podzamcze V/IV (42) and Szczecin-Podzamcze V/VI (591), 22 tree and shrub taxa were determined: *Acer* sp., *Alnus* sp., *Betula* sp., *Carpinus betulus*, *Corylus avellana*, *Euonymus* sp., *Fagus sylvatica*, *Fraxinus excelsior*, *Populus* sp., *Quercus* sp., Maloideae cf. *Malus*/*Crataegus*/*Pyrus* type, *Salix* sp., *Sambucus* sp., *Ulmus* sp., *Viscum album*, *Abies alba*, *Juniperus communis*, *Larix decidua*, *Picea abies*, *Picea*/*Larix*, *Pinus sylvestris* and *Taxus baccata*. Some objects were made of pine, birch and willow bark and lime phloem. Pine (46%), oak (12%), ash (8%), alder (7%) and spindle (6%) were the woods most commonly used. Pine and oak were used for coopered items and for various types of pegs/nails and wedges (most often used to join the planks of clinker-built boats). Pine was also used for torches (Cywa 2018a: fig. 3.17), and oak for making large tools such as spades (Pl. 1.10, Cywa 2018a: fig. 3.25). Alder was used mainly for making scoops and beaters (Cywa 2018a: fig. 3.34). Ash was a common material for turned bowls and for pegs embedded in architectural elements. The latter use of ash wood was also recorded from other sites. The shares of medieval wooden objects from Szczecin were lower for spruce/larch (4%), yew (4%), willow (3%), elder (2%) and beech (2%). Spruce/larch was one of the most commonly used materials for making the end discs and staves of small stave-built bowls. When identified to species level, *Larix decidua* was noted as the material for 2 end discs, and *Picea abies* for 8 staves. The material used for the hoops that bound the staves of this type of bowl was willow wood. *Taxus baccata* was used to make 5 spoons, 4 tool handles, a needle (Pl. 1.15), a dowel/plug (Plate 1.14) and several staves for large coopered vessels. Elder was used to make several spindles and was the only material used for tubular objects with holes (Cywa 2018a: fig. 3.33) and/or without holes, which may be the remains of pipes. Examples of pipes without holes, with only a two-sided trimmed mouthpiece, known from Slavic lands, are the so-called *skuducze.* Ethnographic work indicates that pipes made from straight elder twigs were mainly children's toys (Moszyński 1939). *Fagus sylvatica* was used at the Szczecin sites to make architectural elements, spades and vessel lids, as well as dowels for joining architectural elements. The other taxa appeared occasionally. The use of hazel wood is interesting, as it was essentially very similar to its contemporary uses. Its debarked branches were used to make pegs, shafts and, after sharpening, several types of primitive prickers. Hazel usually has a high bush habit, with long, raised, straight branches that are easy to adapt as shafts, sticks or rods (Amann 2009, Krzyściak-Kosińska & Kosiński 2010, Kłosiewicz & Kłosiewicz 2011, Rodak-Śniecińska 2011, Adamczyk 2015). For this reason, hazel was considered a useful tree by Polish countryfolk: created by God for the poor, for "feeding, heating and support" (Ziółkowska 1988).

Pine, birch and willow bark was used to make fishing net floats (Pl. 1.1) and children's toy boats, and lime phloem was used for rope-making.

Toruń

At two Toruń sites – Toruń Bankowa 14/16 (213 items) and Toruń Kopernika 11–13 (145 artefacts) – 13 wood and shrub taxa were determined: *Acer* sp., *Alnus* sp., *Carpinus betulus*, *Cornus* sp., *Corylus avellana*, *Fraxinus*

excelsior, *Quercus* sp., *Salix* sp., *Tilia* sp., *Ulmus* sp., *Picea abies*, *Picea*/*Larix* and *Pinus sylvestris*. Items of birch bark and willow bark were found. Pine accounted for the highest percentage of objects (70%), followed by ash (8%), spruce (6%), oak (4%), willow (4%) and maple (3%). The shares of other taxa did not exceed 1%. Pine was used mostly to make staves and end discs of small stave-built bowls and architectural elements both large (part of a latrine seat cover) and small (laths with or without holes). Turned bowls (Pl. 1.19) and plates were made mainly of ash wood. Ash was also used to make an oar (Pl. 1.16) and a dowel (stub) in a latrine seat (Cywa 2018a: fig. 3.20), which was used to raise it (R. Uziembło, personal comm.). Oak was most often used for the manufacture of thick boards and beams, which probably are remains of construction elements or carpentry waste. Oak was also used in the only discovered barrel stave (Plate 1.7) and in several lids/end discs of vessels. Most of the plates turned on both sides found in Toruń were made of maple; willow was used to make hoops, a shoe patten (Cywa 2018a: fig. 3.28) and besom twigs. Alder branches were also used for the last item. Modern garden besom manufacturers usually make them from birch branches. At the Toruń Bankowa 14/16 site, a small fragment of a debarked branch with scant visible traces of processing was one of the few pieces determined as *Cornus* sp.

Drohiczyn

In Drohiczyn only one wooden object was discovered: a spindle decorated with round grooves and made of *Euonymus* sp. (inv. no. 741/06, Cywa 2016a: fig. 3.5).

Tum and Czerchów

At the site in Tum near Łęczyca, 6 objects were studied and 4 wood taxa were identified: *Quercus* sp. (50% of the total xylological spectrum from this site), *Fraxinus excelsior*, *Populus* sp. and *Taxus baccata*. About 10 km from Tum, at Czerchów 1, 21 wooden artefacts were found and only 3 taxa were determined: *Quercus* sp. (40% share), *Fraxinus excelsior*, and fragments of debrided bark, probably of *Ulmus laevis* (Freund 1951). At both of these sites in the Łódź region, oak wood was the most abundant; in the items from Czerchów 1 it was represented by architectural elements (including fragments of debarked branches, most likely remains of a wattle from building construction), one small pin, and 2 ear-shaped objects of undetermined function (Pl. 1.3). The last of these artefacts resemble an artefact discovered at Mikulčice in the Czech Republic (Poláček et al 2000: Pl. 40.2, cat. no. 155) and a somewhat bigger object from Radom 2 in Poland (Pl. 1.2), interpreted by archaeologists as from a weaving workshop (Fuglewicz 2013a). Xylological analyses also showed that the remnants of the vertical elements of the wattle structure were of oak and its horizontal elements were made from ash branches. At the Tum site, 2 large tools were made of oak: a spade (Grygiel et al. 2014: fig. 236.9) and a carpentry mallet (Grygiel et al. 2014: fig. 147.3); there was also a structural element, probably part of furniture (Pl. 1.9, Grygiel et al. 2014: fig. 147.4). Ash was used for a scoop (Plate 1.18, Grygiel et al. 2014: fig. 148). Yew was used for a long, massive peg, and poplar for a sharpened, wedge-shaped spar hewn directly from a debarked bough.

Kraków

Among the 146 objects discovered at the Kraków sites (Kraków Grodzka 57, 2 items; Kraków Main Market Square, 2 items; Kraków Sławkowska 14/6, 1 item; Kraków Slawkowska 17, 10 items; Kraków Wawel VI, 129 items; Kraków town, 2 items), 16 tree and shrub taxa in addition to willow bark were identified: *Acer* sp., *Alnus* sp., *Cornus* sp., *Corylus avellana*, *Fagus sylvatica*, *Fraxinus excelsior*, *Quercus* sp., Maloideae cf. *Malus*/*Crataegus*/*Pyrus* type, *Sambucus* sp., *Ulmus* sp., *Abies alba*, *Larix decidua*, *Picea abies*, *Picea*/*Larix*, *Pinus sylvestris* and *Taxus baccata*. Fir (34%), spruce/larch (17%) and spruce (16%) had the major shares in the overall taxonomic spectrum, followed by ash (6%), oak (4%), pine (4%) and maple (3%). The remaining taxa did not exceed 3% of the total. Fir, besides being used for construction elements such as boards, shingles and laths, was used primarily by coopers (inv. no. MAK/S/65/8/3a; Cywa 2018a: fig. 3.4). Most of the stave-built bowls discovered at the sites were made of fir, but also the end disc of a large stave-built vessel, a pricker, various types of pins such as a peg for braiding rope (inv. no. MAK/S/213a; Cywa 2018a: fig. 3.24), and vessel lids and an oar. Elements of small stave-built bowls were also made of spruce/larch wood (25 cases of the use of *Picea abies*,

Type of object / Wood sorts	Furniture, various architectural features	Land transport	Water transport	Wooden structures of various sort	Big stave-built vessels	Stave-built vessels	Big tools	Carpentry mallets	Mashers	Rods. walking sticks	Big handles	Arrow shafts	Bows	Small tools	Spoons	Big ladles	Heavy beaters	Beaters	Small ladles	Scoops	Carved bowls	Turned bowls
Number of items	137	8	2	7	206	1	19	5	7	26	1	4	2	84	20	1	3	3	2	19	8	82
board	83.21%	100.00%	100.00%	100.00%	99.51%	100.00%	84.21%			23.08%	100.00%	100.00%	50.00%	90.48%	100.00%	100.00%	100.00%	100.00%	100.00%	73.68%	62.50%	1.22%
log	0.73%																					
log half	0.73%																			10.53%	12.50%	
log quarter	2.19%																					
short log					0.49%															10.53%	25.00%	98.78%
bough	5.84%						5.26%	60.00%	28.57%													
bough quarter																				5.26%		
bough ramification																						
branch	6.57%						10.53%	40.00%	71.43%	61.54%			50.00%	9.52%								
branch quarter	0.73%									11.54%												
branch ramification										3.85%												
twig																						
undefined																						

Type of object / Wood sorts	Turning waste	Staves of small, shallow bowls	Discs of small, shallow stave-built bowls	Hoops of small, shallow stave-built vessels	Ambiguous function	Torches	Parts of musical instrument mouthpieces	Stringed musical instruments	Fifes	Tubular objects	Special pegs, wedges. connectors	Big pegs, pins & bungs	Small pegs, pins & bungs	Attire & hygiene	Art & cult	Toys & games	Ropes	Wreaths	Baskets	Floats	Waste	Undefined function & treated wood
Number of items	5	381	59	19	4	35	1	1	2	3	65	38	100	1	3	7	2	1	11	46	32	60
board		100.00%	100.00%	68.42%	75.00%	100.00%		100.00%			78.46%	81.58%	86.00%	100.00%	100.00%	71.43%			81.82%	100.00%	100.00%	80.00%
log																						1.67%
log half																						
log quarter																						
short log	20.00%																					1.67%
bough																						
bough quarter																						1.67%
bough ramification																						8.33%
branch							100.00%				20.00%	18.42%	14.00%			14.29%						1.67%
branch quarter																14.29%						1.67%
branch ramification					25.00%																	
twig				31.58%					100.00%	100.00%	1.54%						100.00%	100.00%	18.18%			3.33%
undefined	80.00%																					

continued

Fig. 9. Sorts of wood used to manufacture different functional types of objects

and in 3 cases *Larix decidua*). Ash was used to make turned as well as hollowed and carved vessels, oak was used only for construction elements, and pine mainly for staves of large stave vessels and torches. Maple was employed for objects most likely used as household/kitchen utensils, for example a small wooden pestle (inv. no. MAK/S/82/2, Pl. 1.6) and a bowl. In Kraków a mallet consisting of a separately made head and shaft was also found, made of heavy, mechanically resistant Maloideae (head) and *Cornus* sp. (shaft). Dogwood is particularly hard (Serwa 1986, Seneta 1987, Amann 2009). For this reason it was used in former Poland to make various mechanical parts, knife handles, and rods for loading a firearm (Jundziłł 1799, Gerald-Wyżycki 1845).

Radom

At the only site in Radom (161 items), the use of 14 taxa of trees and shrubs was confirmed: *Acer* sp., *Alnus* sp., *Betula* sp., *Carpinus betulus*, *Corylus avellana*, *Fagus sylvat*ica, *Fraxinus excelsior*, *Quercus* sp., *Salix* sp., *Ulmus* sp., *Abies alb*a, *Picea*/*Larix* and *Taxus baccata*, and 3 tree taxa represented by bark remains: pine, lime and birch. The most numerous objects were made of pine (39%), followed by ash (14%), oak (9%), fir (8%), yew (8%) and alder (3%). Pine was used to make various types of small structural elements identified as fragments of boards and beams, as well as pegs and most of the torches. Pine was also used at this site for making small tools such as a sharpened pricker and a wooden tooth that was probably from a rake (inv. no. 179/64, Pl. 1.13). Ash was used for a single scoop, all the turned plates, a dowel inside an oak construction element, and a piece of furniture (inv. no. 235/64; Cywa 2018a: fig. 3.14). *Quercus* sp. was used for boards, laths, and wooden items of various sorts such as fragments of a weaving workshop (inv. no. 160/66, Pl. 1.2; Fuglewicz 2013a: tabl. 53.1) and a piece (rocker) from a cheesemaking workshop (inv. no. 130/66; Cywa 2018a: fig. 3.18, Fuglewicz 2013a: tabl. 44.3). Laths and boards were made of fir, which was also used for a torch and a spoon (inv. no. D76-77/26/12; Cywa 2018a: fig. 3.23), a stick, a thin, curved, claw-shaped pin (inv. no. 183/66) and 2 awls/prickers (inv. no. 155/66; Cywa 2018a: fig. 3.27, Fuglewicz 2013a: tabl. 38.11). Yew was primarily used by coopers; all of the large vessels and a disc discovered at Radom 2 were made of it (inv. no. R2/30/79; Skubicha & Kwiatkowska-Rzodeczko 2013: pp. 105). It was also used to make a carefully crafted corrugated object of undefined function (inv. no. 185/66, Pl. 1.20) and a spindle. Alder was used for a semifinished scoop/mortar (inv. no. 200/65, Pl. 1.17). Birch was used for an object described by archaeologists as "probably a pedal of a foot-mortar" (inv. no. 228/64, Pl. 1.4).

Czermno

A total of 9 artefacts were discovered at the Czermno sites (Czermno 2, Czermno 70). Three tree and shrub taxa were found: *Pinus sylvestris* (44%), *Fraxinus excelsior* (22%) and *Quercus* sp. (11%), as well as many irregular fragments of birch bark (Cywa 2016b). Ash was used for a bowl turned on both sides (inv. no. 775; Cywa 2016b: fig. 1.1), oak for a spoon/scoop handle (inv. no. 780; Cywa 2016b: fig. 1.2), and pine for a sickle handle and undetermined lath-like and plank-like construction elements (inv. no. 779, 779a, 779b; Cywa 2016b: fig. 1.3–4).

Technical aspects of wood materials used

Use of certain wood types

Analyses of the descriptive data related to the curvature of annual growth rings as seen on transverse sections of the objects (straight, curved, concentric with respect to centrally located pith) and their orientation relative to the surfaces of the object allowed us to determine which sorts of wood grades were preferred in the Middle Ages. Sorts are types of wood of certain dimensions and quality, having a specific purpose (e.g. Szczuka & Żurowski 1994). Some of the medieval artefacts were made of minimally processed roundwood, usually only debarked and stripped, so that the shape of the trunk, bough or branch was preserved; other objects were made from boards obtained by splitting roundwood longitudinally (all surfaces worked) (Fig. 9). We distinguished several categories of roundwood: large logs and large parts of logs (Pl. 4.16); short logs; boughs and parts of boughs; small branches and parts of branches (Pl. 4.12); and small twigs.

The descriptive data show that the objects were most commonly made using the split sorts, that is, boards. Of the 1523 items analysed, 1294 were made of boards, which represents 85% of the materials. Only 223 objects (15%)


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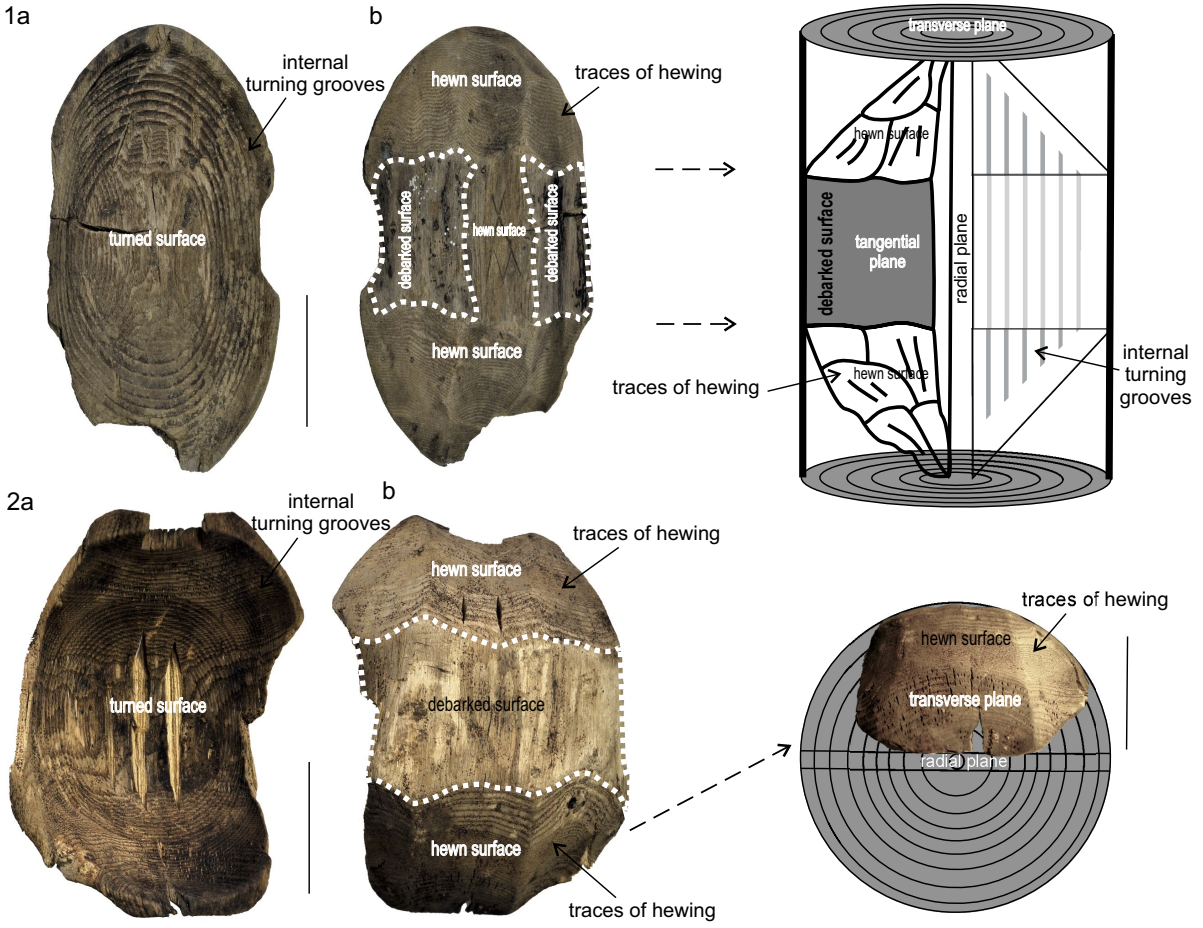


Fig. 10. Diagram showing how bowls turned on one side (on the inside) were made from logs of *Fraxinus excelsior*: **1** – inv. no. 1335, Szczecin Podzamcze V/VI site, National Museum in Szczecin (**a** – interior view; **b** – exterior view); **2** – inv. no. 1861, Szczecin Podzamcze V/VI site, National Museum in Szczecin (**a** – interior view; **b** – exterior view). Scale bars = 5 cm

were cut from boughs and branches. Boards were the main material for most of the featured functional categories of objects. The manufacture of beaters (Pl. 4.13), carpentry mallets (Pl. 4.11), the majority of rods and sticks, pipes and parts of musical instrument mouthpieces used only roundwood sorts. Unsplit boughs or branches of trees were also often used as parts of furniture and construction elements, tools (e.g. knife handles), dowels, pins and plugs. Logs split in half were used to make hollowed and carved vessels and scoops. Nearly all turned vessels (99%) were made of short logs, which were then split in two (Fig. 10). Small

Plate 4. Selected macroscopic features of artefact surfaces (photo K. Cywa). Scale bars = 5 cm. **1**. Radial bucket stave with transverse knot, *Pinus sylvestris*, Szczecin-Podzamcze V/VI site, inv. no. 8000; **2**. Radial stave of single-hoop stave-built bowl with transverse knot, *Picea abies*, Szczecin-Podzamcze V/IV site, inv. no. 631; **3**. Object of undetermined function with worked hole at knot, *Pinus sylvestris*, Szczecin-Podzamcze V/VI site, inv. no. 5217; **4**. Object of undetermined function with visible signs of insect infestation, *Alnus* sp., Szczecin-Podzamcze V/VI site, inv. no. 6014; **5**. End disc/cover with clogged hole at knot (from tangential wood), *Pinus sylvestris*, Toruń Kopernika 11–13 site, inv. no. 509; **6**. Spade with visible insect tunnels, *Quercus* sp., Szczecin-Podzamcze V/VI site, inv. no. 7555; **7**. Ball carved from circular fork of branch, *Pinus sylvestris*, Radom 2 site, inv. no. 70/80; **8**. End disc/cover covered with thallus, *Quercus* sp., Szczecin-Podzamcze V/VI site, inv. no. 2266; **9**. Bucket stave, *Pinus sylvestris*, oblique alignment of annual growth rings (from semitangential wood), Szczecin-Podzamcze V/VI site, inv. no. 7733; **10**. Bucket stave (semifinished?), parallel alignment of annual growth rings (from tangential wood), *Pinus sylvestris*, Szczecin-Podzamcze V/VI site, inv. no. 7217; **11**. Carpentry mallet carved from branch, concentric alignment of annual growth rings (from unsplit roundwood) *Quercus* sp., Szczecin-Podzamcze V/VI site, inv. no. 7610; **12**. Object of undetermined function carved from forked branch (from unsplit roundwood), *Quercus* sp., Szczecin-Podzamcze V/VI site, inv. no. 7411; **13**. Beater carved from branch, concentric alignment of annual growth rings (from unsplit roundwood), *Acer* sp., Radom 2 site, inv. no. 195/65; **14**. Bottom surface of bucket stave, *Pinus sylvestris*, perpendicular alignment of annual growth rings (from radial wood), Szczecin-Podzamcze V/VI site, inv. no. 9719; **15**. Top surface of bucket stave, somewhat oblique alignment of annual growth rings (from radial wood), *Pinus sylvestris*, Szczecin-Podzamcze V/V site, inv. no. 57_E; **16**. Fragment of undebarked beam (semifinished/waste?), concentric alignment of annual growth rings (half-split roundwood), *Pinus sylvestris*, Radom 2 site, inv. no. 181/65; **17**. Bucket stave, parallel alignment of annual growth rings (from tangential wood), *Taxus baccata*, Szczecin-Podzamcze V/VI site, inv. no. 7816

	Taxa \ Wood sorts	Board	Log	Log half	Log quarter	Short log	Bough	Bough quarter	Bough ramification	Branch	Branch quarter	Branch ramification	Twig	Undefined
	Number of items	1294	2	4	3	87	15	1	1	84	6	3	17	6
Deciduous taxa	*Acer* sp.	0.77%				17.24%				1.19%				50.00%
	Alnus sp.	3.55%		75.00%		6.90%	20.00%	100.00%		4.76%	16.67%			
	Betula sp.	0.39%	50.00%											
	Carpinus betulus	0.31%									16.67%			
	Cornus sp.						6.67%				16.67%			
	Corylus avellana	0.85%								11.90%	16.67%			
	Euonymus sp.	3.48%									16.67%			
	Fagus sylvatica	1.39%				1.15%				4.76%				
	Fraxinus excelsior	3.71%				72.41%				14.29%				
	Populus sp.	0.08%					6.67%							
	Quercus sp.	9.66%					60.00%		100.00%	4.76%	16.67%			
	Maloideae cf. *Malus/Crataegus/Pyrus* type	0.23%								1.19%				
	Salix sp.	1.70%				1.15%				11.90%			47.06%	
	Sambucus sp.	1.00%								1.19%			29.41%	
	Tilia sp.	0.08%												
	Ulmus sp.	0.46%				1.15%								
	Viscum album									1.19%				
	Betula sp. bark	0.62%												33.33%
	cf. *Ulmus laevis* bark	0.77%												
	Salix sp. bark	0.23%												
	Tilia sp. bark	0.15%												
	Tilia sp. phloem												5.88%	
	indet. deciduous	0.15%								1.19%				16.67%
Coniferous taxa	*Abies alba*	4.25%	50.00%							9.52%			5.88%	
	Juniperus communis	0.08%								2.38%				
	Larix decidua	0.39%												
	Picea abies	4.02%												
	Picea/Larix	4.87%								1.19%				
	Pinus sylvestris	50.70%		25.00%	100.00%					11.90%		66.67%	11.76%	
	Taxus baccata	2.94%					6.67%			16.67%		33.33%		
	Pinus sylvestris bark	2.94%												
	indet. coniferous	0.23%												

Fig. 11. Distribution of wood sorts used for making the studied artefacts

2nd-order branches were used for ropes and basket wattle (mainly *Pinus sylvestris*), small hoops (*Salix* sp.) (Cywa 2018a: fig. 11.1a–b), pipes, and tubular objects which probably were semifinished (only *Sambucus* sp.).

Our analysis of the relationship between the type of tree or shrub and the wood sort (Fig. 11) showed that the items carved or hewn from boards were dominated by pine, oak, spruce/larch and fir, species characterized by good cleavage (Krzysik 1957, Szczuka & Żurowski 1994, Talarkiewicz 2007). The round sorts used were various types of wood such as alder, ash, hazel, yew, pine and oak, taxa that vary in how well they split. Only dogwood and mistletoe were not identified in items made from boards.

Ways of splitting round wood

According to the different orientations of annual growth rings in lumber, modern sawn lumber can be divided into the following types: radial, where the annual rings are perpendicular to the widest surface (Fig. 12); semitangential/semiradial, with intermediate alignment of the rings; and tangential, where the rings are parallel to the widest surface (Świderski 1966, Szczuka & Żurowski 1994). Since large saws were not in use in the 10th to 12th centuries (Hołubowicz 1955, Wysocka 2001), these sorts of lumber were most likely obtained by splitting roundwood along the fibers with carpentry mallets and wedges (Ostrowska 1962, Gerlach 2011). We distinguished each of the three annual growth ring orientations in the medieval objects (Fig. 13, Pl. 4.9–10, 14–15, 17). Of 1294 items, as many as 70% (905 items) were made from radial sorts, followed by tangential (24%, 316 items) and semitangential (6%, 73 items). Of the radial ones (Fig. 14), pine (54%) and oak (11%) had the highest shares; the most frequent woods split tangentially were pine (37%), oak (7%) and ash (7%). The wood of such trees and shrubs such as birch, hazel,

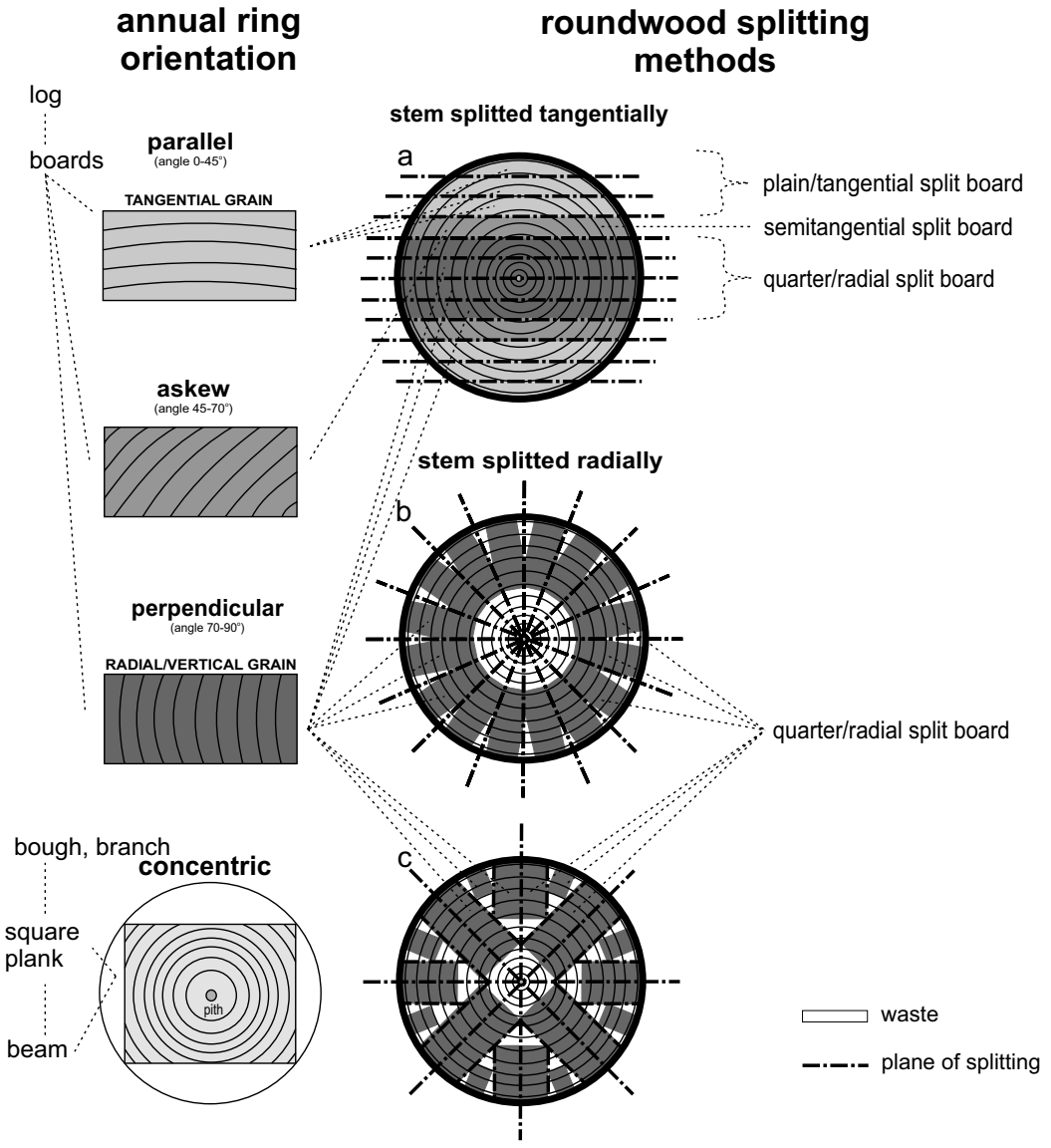


Fig. 12. Division of split sorts by orientation of annual growth rings (after Szczuka & Żurowski 1994), and their relation to various methods of splitting round wood manually (after Coles 2006, Świderski 1966)

Rosaceae and elm were split tangentially more frequently than radially.

Evaluation of wood quality based on annual ring width

In the majority (61%) of the items the surface of the object was so damaged and soiled that it was impossible to identify and measure the narrowest and widest annual growth rings (Cywa 2018b (unpubl.): Annex 1). This was most often the case for objects made of the wood of diffuse-porous deciduous trees and shrubs; even in modern wood their growth ring boundaries are not particularly pronounced. Among the items examined for annual growth ring width (601), the largest percentage (66%) was narrow-grain wood. In the coniferous group, taxa such as *Pinus sylvestris*, *Taxus baccata* and *Juniperus communis* were represented mainly by narrow-grain wood, and *Abies alba*, *Picea abies* and *Picea*/*Larix* by wide-grain wood (Fig. 15). Among the deciduous taxa, wide-grain wood appeared more often than narrow-grain in items made from maple, alder, willow and elder. Items of other deciduous taxa were predominantly of narrow-grain wood.

Wood defects

In order to assess the condition of the wood used in the items from the archaeological sites, we noted the presence of macroscopic and anatomical anomalies such as knots and signs of damage caused by fungi and insects (Cywa 2018b (unpubl.): Annex 1). Of the 1523 items studied, knots were found in only 99 (7%), over

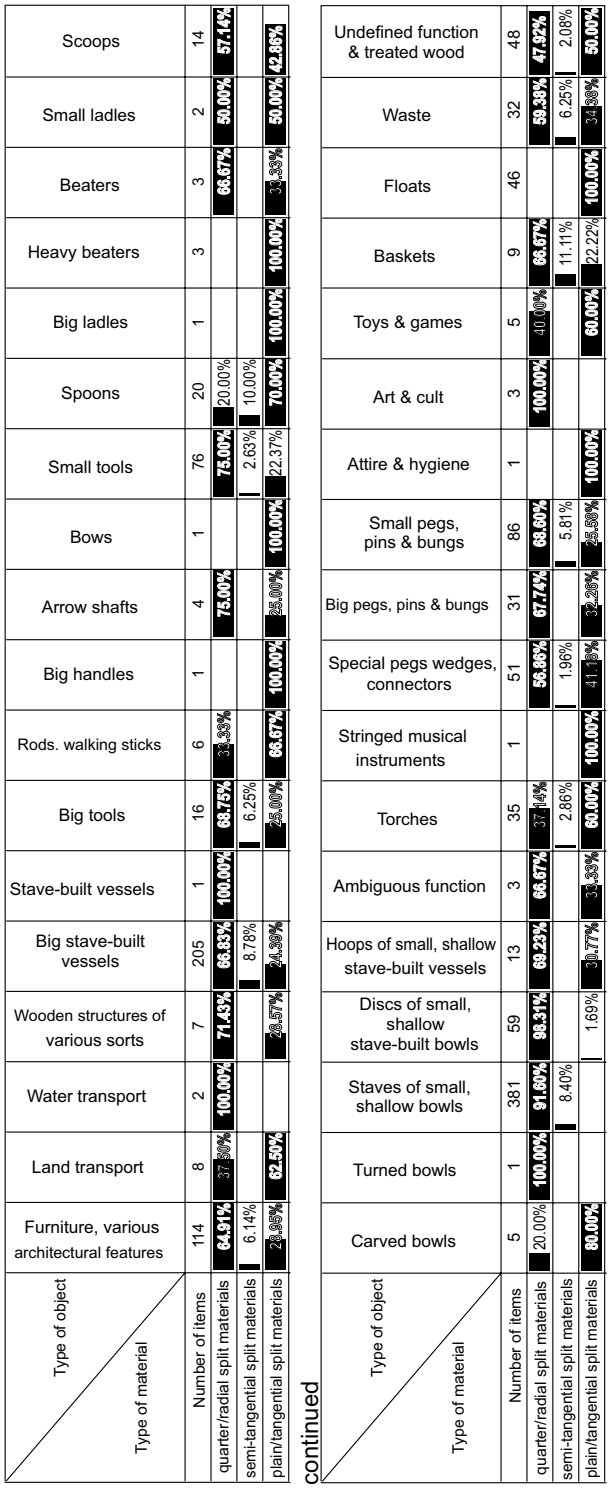


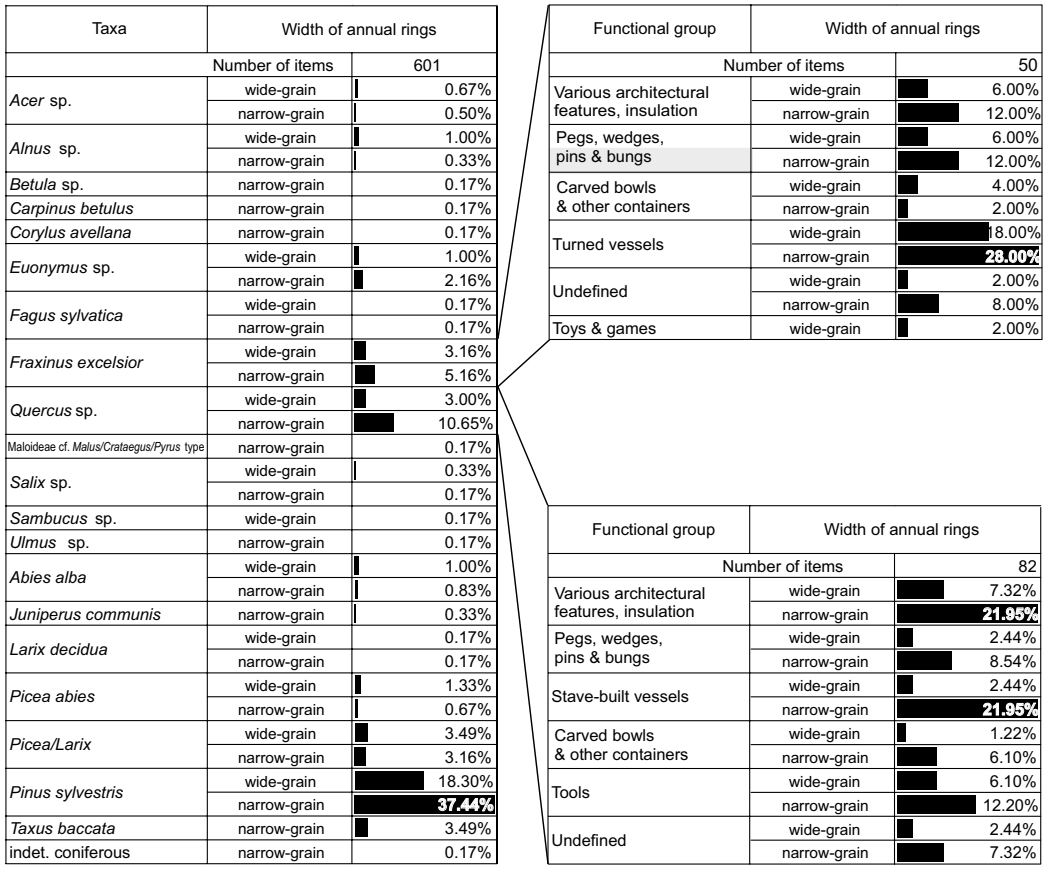
Fig. 13. The use of different wood sorts (according to annual ring orientation) for the production of different types of items

Taxa \ Type of material	quarter/radial split wood	semitangential split wood	plain/tangential split wood
Number of items	905	73	316
Deciduous taxa: *Acer* sp.	0.55%		1.58%
Alnus sp.	2.87%	1.37%	6.01%
Betula sp.	0.22%		0.95%
Carpinus betulus	0.44%		
Corylus avellana	0.22%	1.37%	2.53%
Euonymus sp.	4.31%		1.90%
Fagus sylvatica	1.22%		2.22%
Fraxinus excelsior	2.65%	4.11%	6.65%
Populus sp.	0.11%		
Quercus sp.	11.38%		6.96%
Maloideae cf. *Malus/Crataegus/Pyrus* type			0.95%
Salix sp.	1.66%		2.22%
Sambucus sp.	1.10%		0.95%
Tilia sp.	0.11%		
Ulmus sp.	0.22%		1.27%
Betula sp. bark			2.53%
cf. *Ulmus laevis* bark			3.16%
Salix sp. bark			0.95%
Tilia sp. bark			0.63%
indet. deciduous	0.22%		
Coniferous taxa: *Abies alba*	4.31%	5.48%	3.80%
Juniperus communis	0.11%		
Larix decidua	0.55%		
Picea abies	5.19%	6.85%	
Picea/Larix	6.30%	6.85%	0.32%
Pinus sylvestris	53.70%	71.23%	37.34%
Taxus baccata	2.21%	2.74%	5.06%
Pinus sylvestris bark			12.03%
indet. coniferous	0.33%		

Fig. 14. Distribution of wood sorts used, by taxon

half of which (55 items) had only single knots. Very large knots were found in only 2 objects, large ones in 42, small ones in 43, and whorls in 12. Among the items from the most technically demanding functional group, coopered products, knots were found on only 10 of the 522 studied staves and only one of the 104 discs studied (Pl. 4.5). The knots found in the staves of coopered containers went across the width of these items in most cases (Pl. 4.1–2), that is, in a manner that did not compromise the seal (Papierowski 1952, Świderski 1966).

Nowadays the presence of knots in wood is sometimes considered a virtue. An example might be wood that has a complicated fibre system due to the occurrence of signs of twigs and resting buds. Such aesthetically pleasing material is most often used for decorative purposes in the production of furniture and veneers (Krzysik 1957, Kimbar 2011). This type of wood was not found in the material we studied. In a few cases the hole left after removing a knot was used as an opening, avoiding the need to drill one. One example is a wooden artefact of undetermined function found at Szczecin-Podzamcze V/VI (Pl. 4.3). Numerous knots are also visible on the surface of an artefact from Radom, a wooden ball (Pl. 4.7) probably used as a fishing net weight or as a toy ball (Dziekoński & Kóčka 1939, Ostrowska 1962, Świętek 1999). It was carved from wood of the whorl at the ramification of a 2nd-order pine branch. Perhaps this particular piece of wood was selected to take advantage of the increased density, weight and hardness of wood found in knots (Krzysik 1957), which would have been



Taxa	Width of annual rings	
	Number of items	601
Acer sp.	wide-grain	0.67%
	narrow-grain	0.50%
Alnus sp.	wide-grain	1.00%
	narrow-grain	0.33%
Betula sp.	narrow-grain	0.17%
Carpinus betulus	narrow-grain	0.17%
Corylus avellana	narrow-grain	0.17%
Euonymus sp.	wide-grain	1.00%
	narrow-grain	2.16%
Fagus sylvatica	wide-grain	0.17%
	narrow-grain	0.17%
Fraxinus excelsior	wide-grain	3.16%
	narrow-grain	5.16%
Quercus sp.	wide-grain	3.00%
	narrow-grain	10.65%
Maloideae cf. *Malus/Crataegus/Pyrus* type	narrow-grain	0.17%
Salix sp.	wide-grain	0.33%
	narrow-grain	0.17%
Sambucus sp.	wide-grain	0.17%
Ulmus sp.	narrow-grain	0.17%
Abies alba	wide-grain	1.00%
	narrow-grain	0.83%
Juniperus communis	narrow-grain	0.33%
Larix decidua	wide-grain	0.17%
	narrow-grain	0.17%
Picea abies	wide-grain	1.33%
	narrow-grain	0.67%
Picea/Larix	wide-grain	3.49%
	narrow-grain	3.16%
Pinus sylvestris	wide-grain	18.30%
	narrow-grain	37.44%
Taxus baccata	narrow-grain	3.49%
indet. coniferous	narrow-grain	0.17%

Functional group	Width of annual rings	
	Number of items	50
Various architectural features, insulation	wide-grain	6.00%
	narrow-grain	12.00%
Pegs, wedges, pins & bungs	wide-grain	6.00%
	narrow-grain	12.00%
Carved bowls & other containers	wide-grain	4.00%
	narrow-grain	2.00%
Turned vessels	wide-grain	18.00%
	narrow-grain	28.00%
Undefined	wide-grain	2.00%
	narrow-grain	8.00%
Toys & games	wide-grain	2.00%

Functional group	Width of annual rings	
	Number of items	82
Various architectural features, insulation	wide-grain	7.32%
	narrow-grain	21.95%
Pegs, wedges, pins & bungs	wide-grain	2.44%
	narrow-grain	8.54%
Stave-built vessels	wide-grain	2.44%
	narrow-grain	21.95%
Carved bowls & other containers	wide-grain	1.22%
	narrow-grain	6.10%
Tools	wide-grain	6.10%
	narrow-grain	12.20%
Undefined	wide-grain	2.44%
	narrow-grain	7.32%

Fig. 15. Width of annual growth of rings in the wood used to make the studied artefacts in medieval Poland

	Taxa \ State of preservation	Very good	Good	Fairly good	Poor	Very poor
	Number of items	426	979	8	91	19
Deciduous taxa	*Acer* sp.	0.47%	1.53%	25.00%	6.59%	21.05%
	Alnus sp.	2.11%	4.29%	37.50%	10.99%	
	Betula sp.	0.47%			4.40%	
	Carpinus betulus	0.23%	0.20%	12.50%	1.10%	
	Cornus sp.		0.20%			
	Corylus avellana	0.23%	2.04%		1.10%	
	Euonymus sp.	2.58%	3.06%		5.49%	
	Fagus sylvatica	1.41%	1.23%		5.49%	
	Fraxinus excelsior	3.52%	0.93%		1.10%	
	Populus sp.		0.10%			5.26%
	Quercus sp.	9.86%	9.60%		4.40%	
	Maloideae cf. *Malus/Crataegus/Pyrus* type		0.10%		3.30%	
	Salix sp.	0.23%	2.96%		9.89%	10.53%
	Sambucus sp.	0.70%	1.53%		1.10%	
	Tilia sp.	0.23%				
	Ulmus sp.	0.47%	0.41%			5.26%
	Viscum album		0.10%			
	Betula sp. bark	0.47%	0.82%			
	cf.*Ulmus laevis* bark	2.35%				
	Salix sp. bark		0.31%			
	Tilia sp. bark		0.20%			
	Tilia sp. phloem				1.10%	
	indet. deciduous				1.10%	15.79%
Coniferous taxa	*Abies alba*	0.70%	5.52%		7.69%	5.26%
	Juniperus communis	0.23%	0.10%	12.50%		
	Larix decidua	0.23%	0.41%			
	Picea abies	4.93%	3.17%			
	Picea/Larix	2.35%	3.88%	12.50%	15.38%	5.26%
	Pinus sylvestris	61.50%	40.86%		10.99%	10.53%
	Taxus baccata	4.69%	2.55%		7.69%	10.53%
	Pinus sylvestris bark		3.88%			
	indet. coniferous				1.10%	10.53%

Fig. 16. Preservation of medieval wood, by taxon

a useful characteristic if the ball was used to weight a net.

Wood defects include damage caused by insects (Krzysik 1957, Kimbar 2011) and various types of rot caused by fungi (Kimbar 2011). Insect tunnels inside wood can cause barrels to leak (Świderski 1966). Evidence of insect and/or fungal attack was found in only 114 of the 1523 items studied (Cywa 2018b (unpubl.): Annex 1). Insect tunnels appeared in 21 items (Pl. 4.4.6), superficial mycelium on 51 items (Pl. 4.8), and fungal spores and hyphae inside the vessels and/or tracheids of 42 items (Pl. 2.9, Pl. 3.3.14). Insect tunnels were found most commonly in pinewood, ash, birch, alder and beech; fungi were found on the surface of *Fraxinus excelsio*r, *Quercus* sp. and *Alnus* sp., and inside vessels and tracheids in tissue of ash, alder, pine, spindle and elder.

Preservation of archaeological wood

To assess the artefacts' state of preservation, we used microscopy to look for degradation of wood tissue and anatomical structures. Preservation was poor or very poor (Pl. 3.7, 14) in 7% of the artefacts, fairly good in 0.5%, good in 64%, and very good in 28% (Cywa 2018b

(unpubl.): Annex 1). The deciduous trees and shrubs whose wood was most prone to deterioration (Fig. 16) were *Acer* sp., *Salix* sp., Maloideae cf. *Malus*/*Crataegus*/*Pyrus* type, *Carpinus betulus*, *Fagus sylvatica* and *Alnus* sp., and among the conifers, *Picea*/*Larix* and *Taxus baccata*.

ORIGINAL RESEARCH RESULTS AND ARCHIVAL XYLOLOGICAL DATA

Our research results, combined with other taxonomic data, reveal some geographical, chronological and technological regularities in the use of wood for crafts in medieval Poland.

Geo-chronological perspective

The map in Figure 4a portrays the composition of the wood used for medieval items from all xylologically studied archaeological sites in Poland, and shows clear differences in the use of trees and shrubs between the northern and southern parts of Poland.

Oak was a significant component of the taxonomic spectra of most of the studied sites. Pine had a very high share, often exceeding 50%, in the northern part of the country (Western Pomerania and Gdańsk Pomerania, Toruń, Inowrocław, Międzyrzecz Wielkopolski). In Wrocław, Opole, Kraków and Radom the share of pine was distinctively smaller and was comparable to the shares of other taxa. In the south the use of spruce/larch wood was higher, especially in Wrocław and Kraków. In those towns the most commonly used wood was fir, which often had a 20–30% share. Among the objects discovered in Western Pomerania, only 4 items (spoon, portable altars) were made of *Abies alba* (Cywa 2018b (unpubl.): Annex 1). Ash had the lowest share in the material from the Kraków sites.

In the Piast State period of the early Middle Ages (period III; Fig. 5) the wood used in crafts was dominated by pine, oak, ash and yew. A great variety of material was used, with a relatively high proportion of deciduous wood. In the late Middle Ages (period IV; Fig. 5) the number of deciduous taxa decreased, and the use of pine, spruce/larch and fir increased. Changes in the use of wood over time in the different historical regions of Poland are shown in Figure 6, where it can been seen that the use of fir wood increased only in southern parts of Poland; the use of pine was more common in the north.

Relationships between the woodworking method, the function and type of object, and the properties of the various wood species

Splitting is employed to divide lumber into smaller parts to make a range of objects, from bucket staves and spoons to thin boards or slats (Skuza 2012). The processing methods used for particular tree and shrub taxa are shown in Figure 17. The split lumber used for making things such as boards, torches and staves was obtained from pine, oak, spruce/larch and yew. Turning technique was used mainly to make bowls and plates, rarely cups and lids (Wysocka 1999, 2001), but also toy spinning-tops (Rulewicz 1958) and some undetermined items (e.g. knobs of different kinds) (Wysocka 1999, 2001). The wood most commonly used for turning was ash (mainly for bowls and plates) and pine (spindles, bowls), as well as other deciduous trees and shrubs such as alder and maple (mainly bowls and plates) or spindle

Taxa \ Woodworking method	Split	Split & hewn	Carved	Turned	Hollow & carved	Bent	Wattle & basketwork
Number of items	994	1304	1095	544	213	41	20
Abies alba bark			0.09%				
Alnus sp. bark			0.09%				
Betula sp. bark	0.40%		0.55%				5.00%
Larix decidua bark			0.09%				
Pinus sylvestris bark			6.21%				
Quercus sp. bark			0.09%				
Salix sp. bark			0.27%				
Tilia sp. bark	0.10%	0.15%					
cf. *Ulmus laevis* bark	1.01%						
Tilia sp. phloem							5.00%
phloem							10.00%
Populus sp.		0.15%	0.55%		0.47%		
Tilia sp.		0.15%	0.37%	1.29%	1.88%		
Salicaceae			0.18%				
Salix sp.			3.74%	0.18%	1.88%	43.90%	60.00%
Picea abies	5.23%						
Picea/Larix	29.78%	8.36%	2.28%		0.47%	2.44%	
Pinus sylvestris	56.94%	52.07%	17.90%	9.56%	1.41%	7.32%	15.00%
Abies alba	1.61%	5.44%	5.75%		1.41%	2.44%	
Larix decidua	0.50%						
Alnus sp.	0.20%	1.92%	6.67%	4.04%	13.62%		
Corylus avellana		0.08%	2.28%		0.47%	2.44%	
Betula sp.	1.81%	0.15%	3.01%	2.02%	5.16%	2.44%	
Betulaceae			0.09%				
Acer sp.	0.10%	0.23%	3.01%	6.25%	19.72%	2.44%	
Ulmus sp.	0.20%	0.69%	1.10%	1.29%	0.47%		
Fraxinus excelsior		1.76%	8.58%	54.96%	19.25%	12.20%	
Quercus sp.	0.91%	4.80%	18.72%	1.29%	10.80%	7.32%	5.00%
Juglans regia			0.09%				
Juniperus communis			0.37%	0.18%	3.76%		
Sambucus sp.	0.10%		3.38%	2.21%	1.41%		
Rosaceae	0.10%		0.73%	0.37%	3.76%		
Carpinus betulus		0.23%	1.00%				
Cornus sp.			0.37%				
Euonymus sp.			0.64%	9.38%	3.76%		
Fagus sylvatica		0.69%	2.83%	0.92%	3.76%		
Taxus baccata	0.30%	8.05%	5.30%	2.21%	4.23%	9.76%	
Viburnum sp.				0.18%			
Viscum album			0.09%				
indet. deciduous		0.77%	2.92%	3.31%	2.35%	7.32%	
indet. coniferous	0.30%	4.22%	0.18%	0.37%			
indet.	0.40%	0.08%	0.46%				

HARDNESS

Fig. 17. Relationship between processing method and type of wood (N = 4211, taxa given in order of increasing hardness)

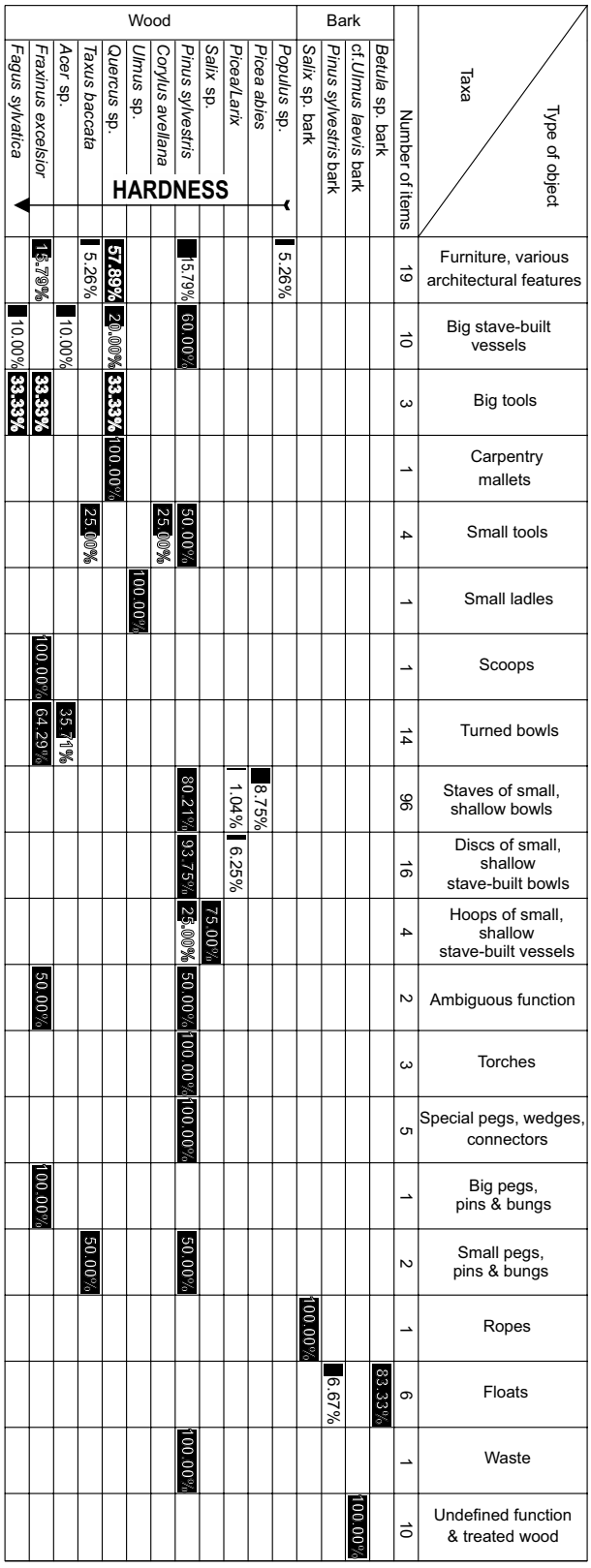


Fig. 18. Taxonomic composition of wood and bark used for making the studied artefacts (not included in Cywa 2018a), by type and function of the object

(spindles). Carved as well as carved and hollowed objects showed the greatest variety of materials used in their production. For carved items the most commonly used types of wood were oak, pine and ash, and for carved and hollowed items *Acer* sp., *Fraxinus excelsior*, *Alnus* sp. and *Quercus* sp. Woven items (e.g. baskets, ropes) and bent items (e.g. hoops of coopered vessels) were usually made of *Salix* sp., *Pinus sylvestris* and *Fraxinus excelsior*.

In analyzing how the medieval craftsmen selected wood for making certain products, we considered the technical and working characteristics of the wood of particular tree and shrub species. Among the artefacts from the Czerchów 1, Szczecin Wzgórze Zamkowe 44, Szczecin-Podzamcze V/VI, Toruń Kopernika 11–13 and Tum sites (Fig. 18), we found that large items such as pieces of furniture, construction elements, large tools, tub staves and bucket staves were made mainly of oak and pine, less often of ash and yew. Small tools and their handles were made of pine, yew and hazel. Ash was selected mostly for making turned vessels and scoops. Small stave bowls were made exclusively of pine and spruce/larch, and their hoops were made mainly from willow twigs. Pine was most commonly used for torches. Fishing net floats were made from pine or birch bark.

DISCUSSION

ASSESSMENT OF THE TECHNICAL QUALITY OF THE WOOD SORTS USED

Wood sorts and their processing methods

In the Middle Ages, items of everyday use were, as today, made primarily from split wood. Whole boughs or branches were used less frequently. It is easier to use roundwood; it involves simply cutting a log or branch to a certain length, stripping and debarking it. Making boards is a more complex woodworking process by which roundwood is divided into smaller elements. It is difficult to say whether all the inhabitants of medieval towns had the necessary skills, or whether those were the proprietary skills of guilds. Possibly the wood that was used widely, such as oak and pine, was already traded in semifinished form. Finished sorts may have been the material used for non-specialized home crafts. A historically documented example of this is a mid-14th-century agreement between a merchant and a craftsman in the French city of Salon, according to which the craftsman was supposed to collect and split the wood purchased

by the merchant. These sorts were to be resold and the profits split between the two signatories to the agreement (Rutkowska-Płachcińska 1969). Ethnographic data from Poland also tell of split semifinished staves or shingles being made for other producers (Skuza 2012).

Carpentry mallets and pestles were made only from roundwood. This is surprising, because the compressive strength of wood is lower when force is applied to it across its fibres (Lis & Lis 2013).

Plates and bowls turned on one side were made exclusively of halved short logs of ash (Fig. 10.1,2). All the turned vessels we examined were turned only on the inside; the outside was only roughhewn. According to archaeological data, this method of turning does not appear until the 13th century, a time associated with standardization and mass production of crafts (e.g. Barnycz-Gupieniec 1959, Bobik 2012, Rakoczy & Myśkow 2014). Based on that characteristic, we can suggest the approximate width of the logs used for making turned vessels. The width of bowls and plates turned on one side corresponds approximately to the diameter of the log from which they were made (Fig. 10.2). The width of this type of object ranged from 6.2 to 28 cm, usually 11–16 cm; radial cracking and flattening no doubt introduced some error in these measurements. The middle part of the outer surface of most of these utensils (Fig. 10.1a,b) was only debarked, exposing the outer layer of the trunk or bough. In view of such a design, their height should indicate the approximate radius of the log. Only 27 of the 40 vessels turned on one side were preserved whole, allowing their height to be measured (Cywa 2018b (unpubl.): Annex 1). Their height ranged from 1.8 to 5 cm, most often 3–4.5 cm (59%). The breadth and height measurements of vessels turned on one side indicate that they were made mainly from medium-sized boughs (or trunks) of ash, mostly 6–16 cm in diameter.

According to Rakoczy & Myśkow (2014), the 13th-century standardization of the production of turned bowls and plates led to uniformity of the wood used, which for vessels turned on one side was ash. Our results confirm this only in part. All the taxonomically determined vessels turned on one side were indeed made of ash wood, but a wider spectrum of wood was used in the production of vessels and lids turned on both sides. For the objects from the Kraków sites we documented selective acquisition of ash wood for the production of turned vessels,

Chronological period	Type of object	Taxa	Locality			
			Kraków	Radom	Szczecin	Toruń
		Number of items	10	2	33	31
IV	Covers turned on both sides	*Salix* sp.				3.23%
	Supports turned on both sides	*Acer* sp.	10.00%			
	Turned vessels	*Acer* sp.	10.00%			3.23%
		Alnus sp.				3.23%
		Fraxinus excelsior	**50.00%**			3.23%
	Vessels turned on both sides	*Fraxinus excelsior*	**20.00%**			
	Plates turned on both sides	*Acer* sp.				**29.03%**
		Fraxinus excelsior				6.45%
		Ulmus sp.				3.23%
	Bowls turned on both sides	*Alnus* sp.				3.23%
		Fagus sylvatica	10.00%			
		Fraxinus excelsior			3.03%	6.45%
	Bowls turned on one side	*Fraxinus excelsior*			**69.70%**	22.58%
	Plates turned on one side	*Fraxinus excelsior*				13%
III	Waste cores	*Acer* sp.			9.09%	
		indet. deciduous			3.03%	
		Fraxinus excelsior			3.03%	
	Turned covers	*Alnus* sp.			3.03%	
	Turned vessels	*Fraxinus excelsior*		**50.00%**		
	Vessels turned on both sides	*Fraxinus excelsior*		**50.00%**		
		Alnus sp.			3.03%	
	Plates turned on both sides	*Acer* sp.			3.03%	
	Bowls turned on one side	*Fraxinus excelsior*			3.03%	

Fig. 19. Types of wood used in the production of turned utensils (and covers) in periods III and IV

despite low local availability (see p. 272). In Kraków all the studied vessels were turned on both sides. The wood used for making the artefacts from the different periods of the Middle Ages is described in Figure 19. Ash was used for making items turned on one side and on two sides in both the early and late Middle Ages. Other researchers have found that in the late Middle Ages the number of bowls turned on one side increased versus those turned on two sides (Barnycz-Gupieniec 1961, Rakoczy & Myśkow 2014).

The orientation of annual growth rings relative to the wide surface of the object indicates the manner in which round sorts of wood were cut to make smaller pieces, and in turn how this affected the quality of the boards produced and the resulting wood waste. The simplest method of manually splitting roundwood is tangential splitting (Fig. 12a), which, although it does not generate waste, produces boards with different annual growth ring orientations and thus of unequal quality. With this method of splitting roundwood, only the central boards have a perpendicular ring arrangement, most advantageous in terms of technical characteristics. This type of board, a radial plank, is the least susceptible to deformation (Świderski 1966). Radial splitting of roundwood, on the other hand, consists in splitting the trunk in half, then in quarters and then in eighths (Coles 2006, Fig. 12b), and/or splitting the trunk into quarters and then splitting each of them radially into quarter-split wood (Świderski 1966, Fig. 12c). With radial split wood, all the splitting planes pass through the centre of the trunk, yielding material of uniform quality but at the same time a relatively large amount of waste (Świderski 1966). Our examination of the annual growth rings of the split wood showed that radial splits were most preferred. The preference of these craftsmen for the best-quality split wood testifies to their knowledge of its macroscopic structure. Medieval manufacturers preferred radial sorts even though their production was more labour-intensive and was associated with increased waste. Modern-day estimates indicate that up to 40% waste is generated in manual production of radial staves (Wierzbicki 1950, Michalak 1963). There is an evident advantage of using radial instead of tangential planks for making construction elements, parts of equipment, dowels and coopered vessels (Fig. 13). To serve their purposes, items that belong to these functional groups should possess high strength and resistance to deformation, both of which are characteristics of radial boards. The superiority of this type of material for making parts of stave-built vessels relates to the way coopered products are made. The perpendicular arrangement of the wood's growth rings with respect to the surface of the staves significantly contributes to the seal-tightness of stave-built vessels (Papierowski 1952, Świderski 1966). It is thought that radial staves are best because any possible wood defects such as knots, cracks and transverse resin canals (in conifers) run parallel to the wide plane of the stave (Pl. 4.1–2). It is easier to keep the dimensions of radial staves uniform, ensuring uniformity of the vessels' shape. Radial boards are also preferred for making end discs of stave-built vessels; they are much less likely to bend during drying, which might make the edge of the disc fall out of the croze (Świderski 1966).

Radial splitting is considered by some authors to be best for manual splitting of oak roundwood, and tangential splitting as best for ash (Coles 2006). The reason for this is the absence of wide radial rays in ash, which would hinder longitudinal splitting. Interestingly, our analyses showed that oak and pine were the most common woods used for the items made from radial wood (Fig. 14); among the ones made from tangential sorts, many were made of ash, along with pine and oak.

Among the items from the Piast State period (early Middle Ages, period III), the share of tangential sorts relative to radial ones is much higher than in the late Middle Ages (Fig. 20). Their higher share indicates that

Chronological period	Type of material	
	Number of items	1154
IV	roundwood	7.02%
	quarter/radial split wood	40.21%
	semitangential split wood	2.60%
	plain/tangential split wood	5.89%
III	roundwood	7.45%
	quarter/radial split wood	22.96%
	semitangential split wood	1.91%
	plain/tangential split wood	11.70%
II	quarter/radial split wood	0.17%
	plain/tangential split wood	0.09%

Fig. 20. Uses of selected types of wood, by chronological period

the more straightforward technique of tangential splitting roundwood was a more common practice at the time. In the late Middle Ages, associated with the emergence and specialization of craft guilds, the share of radial boards increased, reflecting the increasing knowledge of carpentry techniques.

Width of annual growth rings

In wood of conifers, narrow grain is considered an indicator of high strength and hardness; in wood of deciduous trees, wide-grain is taken as an indicator of those mechanical properties (Pieriełygin 1956, Krzysik 1957, Michalak 1963, Szczuka & Żurowski 1994, Kimbar 2011). For coniferous wood, we found that narrow-grain wood was more readily selected than wide-grain wood only in the case of pine, yew and juniper. Historical data confirm that Polish boatmakers especially valued "Polish, Lithuanian and Russian narrow-grain pine [...] with a ring width of only 2 mm" (Gerlach 2011). Spruce and/or larch were mostly represented by wide-grain wood. *Picea*/*Larix*, *Larix decidua* and *Picea abies* were used primarily for making small stave-built bowls, not particularly strong but suitable for serving food (Polak 1996, Wysocka 2001). Wood with lower strength and poorer technical characteristics was used, also in the case of deciduous ring-porous trees. Especially striking is the use of narrow-grain oak and ash logs. Oak and ash were among the most important and most often used sources of wood in medieval Poland. Perhaps the lower strength of narrow-grain oak and ash was compensated by ease of processing: narrow-grain oak and ash wood is softer and easier to work (Krzysik 1957, Szczuka & Żukowski 1994). In the Middle Ages, mainly simple tools such as axes, chisels, drills, spokeshaves, adzes (Barnycz-Gupieniec 1959, Dembińska & Podwińska 1978, Marciniak-Kajzer 2011) and pedal-driven lathes (Woźnicka 1961, Wysocka 2001, Sydor 2011) were used for woodworking; hence the choice of soft material. It should be noted that oak and ash are much harder than, for example, pine (e.g. Warywoda 1957, Michalak 1963, Szczuka & Żurowski 1994, Kokociński 2004). It is possible that wide-grain oak was used mainly for construction. Our detailed study of the ring size of *Quercus* sp. and *Fraxinus excelsior* in particular functional groups of objects showed that wide-grain ash was used mainly for making hollowed vessels. For turned vessels both narrow-grain and wide-grain were used, albeit with the former predominant. Among the items made of oak, one of Poland's harder deciduous ring-porous species, each functional group of objects was dominated by narrow-grain wood.

As the width of annual rings depends largely on climate, habitat and tree growth conditions (Krzysik 1957, Schweingruber 1993, Ważny 2001, Zielski & Krąpiec 2009), one may wonder whether the general prevalence of narrow-grain wood among the studied items was due to the prevailing climatic conditions or to deliberate selection. The palaeoclimatic data (e.g. Büntgen et al. 2013, Przybylak 2016) indicate that chronological periods II and III (Fig. 1) were associated with climate warming, and period IV with climate cooling. We found that narrow-grain wood was dominant in periods II, III and IV, suggesting that the selection was deliberate. We note that for oak, ash and pine the quantitative ratio of wide-grain to narrow-grain wood (Fig. 21) was higher during warmer climate.

Chronological period	Taxa	Width of annual rings	
IV	Number of items		144
	Fraxinus excelsior	wide-grain	6.25%
		narrow-grain	11.11%
	Quercus sp.	wide-grain	0.69%
		narrow-grain	15.28%
	Pinus sylvestris	wide-grain	6.94%
		narrow-grain	**38.89%**
II, III	Number of wooden items		312
	Fraxinus excelsior	wide-grain	2.88%
		narrow-grain	3.53%
	Quercus sp.	wide-grain	5.13%
		narrow-grain	12.18%
	Pinus sylvestris	wide-grain	**29.17%**
		narrow-grain	**40.06%**

Fig. 21. Width of annual growth rings of selected tree and shrub taxa in the studied artefacts, by chronological period

Wood defects and state of preservation

Knots are one of the major defects of wood. They make it difficult to work (Kocięcki 1991, Kimbar 2011) by, for example, increasing the wood's resistance to splitting (Krzysik 1957). Knots can also shorten the life of an item by reducing its bending strength, tensile strength and compression strength (Lis & Lis 2013,

Elevation a.s.l [m]	State of preservation / Site	Very good	Good	Fairly good	Poor	Very poor
	Number of items	426	979	8	91	19
3	Wolin 3	0.47%	5.11%	12.50%	8.79%	21.05%
9	Szczecin-Podzamcze V/IV	11.27%	4.70%	25.00%	4.40%	
9	Szczecin-Podzamcze V/V	0.23%	4.19%			
9	Szczecin-Podzamcze V/VI	23.24%	46.88%	25.00%	32.97%	5.26%
19	Szczecin Wzgórze Zamkowe 44	1.64%	0.92%		5.49%	10.53%
50	Toruń Bankowa 14/16	28.64%	8.58%	37.50%	1.10%	15.79%
53	Toruń Kopernika 11–13	25.12%	3.78%		1.10%	
101	Tum	1.17%				5.26%
117	Czerchów 1	4.46%	0.10%		1.10%	
123	Drohiczyn		0.10%			
149	Radom 2		4.61%		17.58%	10.53%
191	Czermno 2		0.61%		2.20%	
191	Czermno 70		0.10%			
216	Kraków Grodzka 57		0.20%			
219	Kraków Rynek Główny Ratusz		0.20%			
219	Kraków town		0.20%			
220	Kraków Sławkowska 14/6		0.10%			
220	Kraków Sławkowska 17	0.94%	0.61%			
226	Kraków Wawel VI and others	2.82%	8.99%		25.27%	31.58%

Fig. 22. State of preservation of artefactual wood from medieval Poland, by elevation of site above sea level

Kimbar 2011). Nowadays, very knotty wood (measured as number of knots per length/surface unit) is considered unusable for construction. In the artefacts we examined there were no knots, suggesting that their makers avoided wood containing even the smallest defects. Since the butts of logs usually have fewer knots than the tops (Krzysik 1957), we can suggest that in the Middle Ages the lower part of the trunk was the main source.

We found traces of insect feeding and/or the presence of fungi in only 8% of the items. Most of the fungal spores and hyphae that penetrated the interior of wood cells were only in the superficial wood layers, indicating that they invaded the items not during medieval times but rather recently, as the humidity level changed after their removal from the medieval layers.

Research has shown that the trees and shrubs whose wood is most prone to deterioration are *Acer* sp., *Salix* sp., Maloideae cf. *Malus*/*Crataegus*/*Pyrus* type, *Carpinus betulus*, *Fagus sylvatica* and *Alnus* sp., and among the conifers, *Picea*/*Larix* and *Taxus baccata*. For maple, willow, hornbeam, beech and alder, this is consistent with their potentially low durability outdoors or under changing humidity (e.g. Warywoda 1957, Michalak 1963, Szczuka & Żurowski 1994). Surprisingly, although yew is considered to be very durable, we found that the anatomical structure of the yew items was degraded. This observation is difficult to explain, and it also contradicts findings on the state of cellulose preservation in secondary cell walls of medieval wooden vessels from Wrocław (Pyszyński 2001). The preservation of wood items from archaeological sites depends largely on the humidity of the layers in which they were deposited. The state of preservation was worst for material from Czerchów 1, Czermno 2, Kraków Wawel VI, Radom 2 and Szczecin Wzgórze Zamkowe 44 (Fig. 22). Wood preserves well under anaerobic conditions below the water table or in waterbodies (Lityńska-Zając & Wasylikowa 2005, Krajewski & Witomski 2012). In theory, items discovered on elevations above groundwater and/or off river floodplains should show the worst preservation. We compared the degree of wood deterioration (Fig. 22) between objects from sites close to each other but differing in elevation above mean sea level (sites in Kraków and Szczecin), and found that the artefacts from Szczecin Wzgórze Zamkowe 44 and Kraków Wawel VI were in much worse condition than those from lower-elevation sites.

CONDITIONS OF WOOD SELECTION FOR CRAFTS IN THE MIDDLE AGES

Technical and working properties of the wood

In analysing the types of wood used to make items in particular functional groups (Fig. 18) from Czerchów 1, Szczecin Wzgórze Zamkowe

44, Szczecin-Podzamcze V/VI, Toruń Kopernika 11–13 and Tum, we found correlations similar to those found in work on items from other sites in Poland (Cywa 2018a). Oak and pine, and more rarely ash and yew, which are hard (oak, yew) and strong (oak, ash, yew, pine) (Krzysik 1957), were used mainly to make large items requiring high mechanical resistance, such as furniture, fragments of construction elements, large tools and bucket staves. Small tools and/or their handles were made of *Pinus sylvestris*, *Taxus baccata* and *Corylus avellana*. In this case as well, the hardness and strength of the wood counted (Amann 2009). *Fraxinus excelsior* and *Acer* sp., whose wood is relatively uniform and easy to work, were most commonly chosen for the manufacture of turned vessels and scoops. For daily use of turned vessels, an important feature of that wood is low shrinkage; it does not deform during drying (Skuza 2012). Only small stave bowls were made exclusively from pine wood and spruce/larch. These are high-cleavage woods, easier to split into thin staves (Talarkiewicz 2007). The stave bowl hoops were made mainly of thin 2nd-order willow twigs. Pine was most commonly used for torches, and fishing net floats were made from pine or birch bark.

These results support the scheme previously described for selecting the wood used for crafting items: the selection depended on their purpose and was justified by the technical and working properties of particular species (Cywa 2018a). This seems to be the universal scheme for all studied sites in Poland.

The woodworking method also influenced the selection of taxa (Fig. 17). Data from all Polish sites suggest that the split items (e.g. boards and torches) as well as the split and hewn ones (e.g. staves) were made mostly from pine, oak, spruce/larch and yew, woods of high cleavage. The wood most commonly used for turning was ash (mainly for bowls and plates) and pine (spindles, bowls), as well as wood of diffuse-porous deciduous trees and shrubs such as alder and maple (mainly vessels) or spindle (spindles). The density of that wood does not differ much between late and early wood, making it amenable to machining. Pine does not show such a characteristic. This is probably why it was rarely used for turning large objects like bowls and plates. Many pine utensils were identified at Gdańsk 2 and Inowrocław 19, and some at Opole Ostrówek I–IV, Szczecin-Podzamcze II and III. A turned lid made of *Pinus sylvestris* is also described among the wooden artefacts from Novogrod (Brisbane & Hather 2007). The variety of wood was greatest for carved as well as hollowed and carved items: for carved objects the most commonly used types of wood were oak, pine and ash, and for hollowed and carved objects *Acer* sp., *Fraxinus excelsior*, *Alnus* sp. and *Quercus* sp. In mortars and scoops, hollowing was narrowest across the wood fibres. Woven or braided products such as baskets and ropes, and bent ones such as coopers' hoops, were usually made of *Salix* sp., *Pinus sylvestris* and *Fraxinus excelsior*.

Taxonomic composition of woodland communities in the Middle Ages and local availability of wood raw material

Information about whether or not the wood or bark of certain species used by medieval craftsmen could be obtained from nearby forests does not tell us everything about the use of local raw material. It does indicate the natural potential of the local woodland communities, and it signals the possible directions and purposes of exploiting the woodlands surrounding the archaeological sites. It also may indicate whether there was a need to import certain desired species or to import ready-made items. Information on the composition of the medieval woodland communities obtained from palynological, historical and cartographic sources helps to assess the local availability of woody taxa. In this study we used data from palynological research, mainly from natural sites in the vicinity of Kraków, Radom, Łęczyca, Toruń, Wolin and Szczecin, which are centres of the richest finds of wooden items used in the Middle Ages.

Wolin and Szczecin

The results of palynological studies of the sites at Kołczewo, Racze Lake and Wolin II (Latałowa 1992a, b, 1999) and the profiles taken from the Szczecin Lagoon, core 42/99 (Latałowa & Borówka 2003, Witkowski et al. 2004), provided information about the woodland communities in these areas. Between the 8th and 11th centuries the shares of *Fagus*, *Carpinus*, *Pinus* and *Alnus* declined, and the frequency of pollen indicating the presence of humans increased near the Kołczewo site. In the Lake Racze area, *Fagus*, *Alnus* and other

tree taxa decreased sharply from around the 8th century. Then *Quercus* and *Alnus* increased again, together with cereals and other indicators of human activity. From the 11th century onwards the environs of both sites were strongly deforested. The diagram from the Szczecin Lagoon also shows significant deforestation, though on a smaller scale than shown in other diagrams from the region. Sediments associated with the Middle Ages show signs of a reduction of deciduous woodland components such as alder, beech and ash, accompanied by an increase of pine, willow, oak, juniper and indicators of agriculture (e.g. Latałowa & Borówka 2003, Witkowski et al. 2004).

The pollen sequence from Wolin II confirms that the wood that craftsmen used for making household items was mostly available in the immediate area, and that only *Acer* sp. and *Taxus baccata* may have come from farther away. A 10th-century spoon was made of Maloideae cf. *Malus*/*Crategus*/*Pyrus* type but the palynological data do not support the presence of these taxa in the region, except for a single *Malus* type pollen grain identified at Wolin II (the chronology of this part of the sediment is not accurate; Latałowa 1992b). *Malus sylvestris* seeds were found at Wolin 4 and 5, and also in Szczecin, Białogard, and Kołobrzeg, while in Szczecin and Kołobrzeg there were seeds of *Pyrus communis* (Klichowska 1990, Badura 1998, 1999). Moreover, sources written in the 11th and 13th centuries often mention town and monastery orchards and gardens where fruit trees were grown, mainly plum and apple (Hensel 1951, Dolatowski 1990). In the woodlands throughout Poland there were three native species of wild hawthorn shrub: *Crataegus monogyna*, *C. laevigata* (especially in western Poland) and *C. rhipidophylla* (mainly in the mountains) (Białobok & Hellwig 1955, Mirek et al. 2002). Despite the presence of beech in the regional woodland, only one item made from its wood was discovered. There were no items made of hornbeam, though it was an important tree in morainic areas and was subject to extensive clearing in the Middle Ages. Yew was not a common component of the stands but was nevertheless used to make 9 objects.

The information about the availability of wood species in the medieval environs of Szczecin is less precise because it is based on pollen profiles from at least 20–30 km away. Of the 22 taxa we identified in the artefacts from this area, nine were not present in the pollen sequence from the Szczecin Lagoon: *Taxus baccata*, *Abies alba*, *Euonymus*, *Acer*, *Larix*, *Populus*, Maloideae, *Sambucus* and *Viscum album*. The continuous pollen curve for *Picea abies* showed values below 1%. Even such a low share of pollen may represent the local occurrence of spruce trees (e.g. Latałowa & van der Knapp 2006), but as the sites are located outside the natural range of those trees, these pollen grains might be a component of the regional pollen rain (Obidowicz et al. 2004, Lisitsyna et al. 2011, Nosowa et al. 2015). Some of the nine taxa (e.g. *Populus*, *Sambucus nigra*) grew about 40 km NNE of Wolin II, while *Taxus baccata*, *Euonymus* and *Viscum album* grew on the northern part of Wolin Island (Latałowa 1992b). The lack of palynological data indicating the local occurrence of *Abies alba*, *Picea abies* and *Larix* is not surprising, as today the area is also outside the natural range of these trees. The presence of 3 items made of fir and as many as 40 spruce and/or larch items in Szczecin-Podzamcze, quarters V, IV and VI, probably indicates transport of the wood or trade of products.

Toruń

The nearest pollen sequences with a well-recognized medieval section are from the Chełmno region, about 10 km from Toruń. These are profiles from the peat bog at Gronowo V, from Lake Kamionkowskie (Noryśkiewicz 2013) and from Lake Grodzieńskie (Filbrandt-Czaja 2009). A little farther, 35 km away, there are profiles from Lake Wieczno, Lake Czyste and the Linje peat bog (Noryśkiewicz 2005, 2013). For ca 650–1230 AD the pollen diagrams show the progress of the settlement phase and associated gradual deforestation of the area. In the early Middle Ages, oak and hornbeam woodland declined more strongly. In the Gronowo V and Lake Kamionkowskie area, in the 9th century the regeneration of hornbeam woods was accompanied by the expansion of birch. The most intensive clearing of mixed forests occurred from the 11th century to the early 12th century in connection with the construction of a stronghold. The decline of the settlement in the 12th century was marked by the expansion of pine, birch and alder, and also beech and hornbeam, while the shares of elm, lime and ash decreased. During the late Middle Ages, deforestation continued after the invasion of

the Teutonic Knights. Human pressure was significantly weaker in the Linje and Kamionki areas, where woodland persisted over extensive sandy areas with less fertile soil. Most of the taxa that supplied wood for crafts, except for *Picea*, *Larix*, *Cornus* and *Taxus*, were found in the regional woodland communities. The archaeological sites in Toruń held many items made of pine, which was a common component of the local woodlands, increasing especially in the late Middle Ages (Noryśkiewicz 2013). The increase of pine is also observed in the composition of the items found at the sites. In the Piast State period (early Middle Ages, period III) only 11 pine objects were identified, but in the late Middle Ages (period IV) as many as 237 items made of pine were found. Interestingly, spruce was used to make at least 20 items even though the study area is outside the natural range of that tree. In the palynological record, *Picea abies* pollen sometimes has a fairly stable share of up to 1% (e.g. Linje peat bog, Gronowo V, Mełno), which Noryśkiewicz (2013) interpreted as a sign of the proximity of the spruce boundary to the Chełmno region and even the possibility of its dispersed occurrence in woods. However, we have no confirmation of the local presence of larch. In the genus *Cornus*, *C. sanguinea* pollen was found at Lake Wieczno Południowe. *Taxus baccata* grew in the Chełmno region, as indicated by the presence of its pollen in the Lake Mełno sediments.

Tum and Czerchów

The history of vegetation in the vicinity of the medieval settlement complex at Tum was the subject of a detailed palynological study (Makohonienko 2014) as part of a comprehensive environmental archeology research project addressing the medieval origins of Łęczyca (Grygiel & Jurek 2014). Data on the history of the environment of central Poland, including the vegetation, were summarized in a publication by Forysiak (2012, and references therein). Pollen analyses of the archaeological sites, mainly the moats in Tum, showed that there were oak-hornbeam forests near the castle in the Middle Ages, which probably formed enclaves in human-altered open landscape. Wet habitats hosted riparian forest types such as ash-alder and willow-poplar (Makohonienko 2014). Local craftsmen probably obtained ash, poplar and elm from those places. The presence of poplar in the subfossil record is weakly marked, but according to Makohonienko (2014) this may be due to poor preservation of its pollen in sediments. Only one item found in Tum, a fragment of a sharpened pole, was made of poplar. The use of *Populus* sp. to make a pole that possibly was a structural element is difficult to justify. In Central European climatic conditions, poplar wood has very low durability, ranging from 3 to 30 years (Warywoda 1957, Surmiński 1973). It also has the lowest hardness among the domestic species of trees and shrubs (Warywoda 1957, Michalak 1963, Szczuka & Żurowski 1994, Kokociński 2004). Poplar is currently used as construction material only in areas where the continental climate restricts the activity of microorganisms and insects that degrade wood, such as in Siberia (Surmiński 1973).

The stronghold's surroundings provided access to most of the species needed to make the wooden objects discovered at the sites. The area is within the modern range of *Taxus*, but among the taxa identified in the artefacts it was the only one that did not appear in the local palynological profile. Isopollen maps of *Taxus* (Krupiński et al. 2004) indicate that the nearest yew sites dated to ca 1000 AD were in Kujawy (Lake Gopło; Jankowska 1980) and in the Gostynin Lake District (Lake Gościąż; Ralska-Jasiewiczowa et al. 1998).

Kraków

Most of the information about the medieval vegetation of Kraków comes from cultural layers and objects revealed during archaeological excavations. The use of these data is problematic, since the plant remains in such sediments are deteriorated and their species composition has been altered by both the intentional and the collateral effects of human activity (Wasylikowa et al. 2009). The taxonomic composition of the collected plant remains varies significantly, depending on the location, historical function of the site, and sedimentation time (e.g. Bieniek et al. 2006, Mueller-Bieniek 2012). The pollen sequence from 7 Krupnicza Street, originating from outside the medieval centre of Kraków, is already largely anthropogenic in the medieval section (Sokołowski et al. 2008). For the purposes of this study, paleobotanical data were used from Kraków Rynek Profile CW (Wasylikowa et al. 2009, Wacnik unpubl.), covering sediments from the early and late Middle

Ages; and from Wawel Sector X, dating from the 9th to 12th/13th centuries (Wasylikowa 1978). A few peat bog profiles from sites near Kraków have been studied palynologically, the closest of which is from Cholerzyn near Kryspinów (Madeyska & Obidowicz 2001) and from Podłęże (Dzięgielewski et al. 2013) and Stanisławice (Nalepka 2003, 2015) in the Niepołomice Forest. Slightly further south are profiles from sites in the Beskid Makowski Mts, such as Pcim-Sucha (Margielewski et al. 2010). Pollen analyses document strong deforestation of the area of the medieval town and its surroundings. They also show significant differences between the Holocene histories of the woodlands of the Cholerzyn Depression and those of the Niepołomice Forest, especially with respect to the woodland-forming role of pine, spruce and fir. In the Middle Ages, in the Cholerzyn area, about 10 km from the town centre, a large area remained wooded and the main trees found there were pine, spruce, fir, oak and hornbeam, and in wetlands alder and birch (Madeyska & Obidowicz 2001). In the same period, pine and pine-oak woods expanded, with a few other trees and shrubs, especially *Alnus*, *Corylus avellana*, *Carpinus betulus* and *Fagus sylvatica*. Forest exploitation was limited, though it increased in the Middle Ages (Nalepka 2003). A comparison of the composition of medieval woodland communities and the taxonomical composition of the wood used by craftsmen shows that most of the trees and shrubs they used were available in the immediate vicinity of Kraków, except for *Larix*, *Cornus* and *Taxus baccata*. The absence of pollen of these three taxa, whose wood was identified in the examined material, does not rule out their scattered presence in the regional woodlands. They may be underrepresented in pollen profiles as a result of factors such as limited spread of their pollen. For *Larix*, Gunin et al. (1999) showed that its pollen disperses a distance of only 200–350 m. Similarly, *Taxus*, which is usually a component of the undergrowth, is less likely to disperse pollen. Data from modern pollen traps suggest that pollen dispersal can be quite limited even in dense yew populations, with a majority of pollen grains falling on nearby male trees (Noryśkiewicz 2006). Also, *Taxus* pollen can be overlooked, especially in poorly preserved, deteriorated subfossil sediment. Pollen of *Cornus sanguinea* and *Cornus* sp. was found in medieval layers of Kraków's Main Market Square (Koperowa unpubl.), as were their fruits (Mueller-Bieniek 2012). These findings are only additional confirmation of the use of these taxa rather than their presence in the area. The Maloideae wood that was used to make a single object could have originated from *Malus/Pyrus/Crategus* trees or shrubs. They were not found as pollen, but seeds of *Pyrus communis* and *Malus sylvestris/domestica* have appeared repeatedly in archaeobotanical studies. They may have originated from the wild or from gardens; apple trees, both wild and cultivated, were widespread in the Middle Ages (Mueller-Bieniek 2012, Woch 2012). *Sambucus nigra* was found as pollen and diaspores both at 17 Kanonicza Street and at the Main Market Square (Bieniek et al. 2006, Wacnik unpubl., Koperowa unpubl.), and at peat bog sites in the vicinity of Kraków. Considering its occurrence in developed, fertile habitats, rich in nitrogen and phosphorus, elder is likely to occur not only on the edges of woods but also in town. It should be noted that not all locally grown trees, including those that are quite numerous, were desirable crafts material. For example, there is no evidence of the use of *Carpinus*, *Tilia* and *Betula* wood, although hornbeam could have been used primarily for heating as the raw material for making charcoal (Kluk 1805, Makohonienko 2000, Cywa 2018a), and lime as raw material for wickerwork (Cywa 2018a). A lime grove was found in a medieval layer dating to the 11th–12th centuries at Wawel Hill (Wasylikowa 1978, Lityńska-Zając 2010). *Pinus sylvestris* was used to make only 6 items, very few as compared to its availability. The most numerous items were made of fir (50 items) and *Picea* and *Picea / Larix* (48 items), trees which were frequent (except for *Larix*) in the woodland communities. Significant values of *Abies alba* pollen were recorded between 500 and 1500 AD in the Carpathians (Obidowicz & Nalepka 2013). In the vicinity of Pcim-Sucha, Cholerzyn and Podłęże (Nalepka D., pers. comm.), the pollen frequency of fir did not exceed 10%. In light of data from modern pollen monitoring, pollen threshold values greater than 6% mean the presence of local fir woods (Pidek et al. 2013). To the south of Kraków and in the Cholerzyn area, the observed pollen values of 5–10% indicate the significant role of spruce in forests. In a study of the relationship between the frequency of *Picea* in pollen spectra and the abundance of its trees in the vegetation of central European Russia (Nosowa et al. 2015), values of 5–10% were noted at sites from

southern parts of the taiga or coniferous-broadleaved forest vegetation zones when the samples were taken from spruce-dominated forests and from mixed forests with spruce and pine. Although it was a rare element of the woodland, *Fraxinus* was used rather often (8 items). Ash pollen was not found in the Niepołomice Forest. In Cholerzyn its value was below 1%, and ca 0.5% in the Western Carpathians. Current data from the Roztocze region show that scattered trees of *Fraxinus excelsior* produce 0.5–0.9% pollen values in material from Tauber traps (Pidek 2013). This low share of pollen suggests acquisition of this species under low local availability.

Radom

Detailed information on the local woodland community in the Middle Ages was given by Kupryjanowicz et al. (2013). The Radom 100/8 pollen profile collected in the surroundings of the medieval fortification at Piotrówka (Szwarczewski et al. 2010) gives only a general picture of the vegetation, and it is dated from palynological data only. The Radom 2017 profile from Pacyna near Radom has radiocarbon dates confirming the medieval age of the sediments. The palynological record shows that the most important and commonly available trees in the valleys of the Pacynka and Mleczna rivers were pine and alder. In the case of pine, this matches its position in the xylological spectrum from the Radom 2 site, where it was a major source of wood. Oak, lime, hornbeam and birch may have been minor woodland-forming elements. Like spruce, elm, maple, ash, beech and willow, fir may have occurred occasionally in the stands, although probably at some distance from the site (Kupryjanowicz et al. 2013, Szwarczewski et al. 2010). In spite of this, items made of ash, oak and fir were much more frequent than those made of easily accessible alder. There are two other palynological profiles, from Suchedniów and Pakosław about 30 km SSW of Radom, studied in the 1960s and dated only palynologically. These reflect the Holocene history of vegetation in the Świętokrzyskie Mts, also in the younger section of the Subatlantic phase (Szczepanek 1961). Those profiles show that almost all the taxa sourced for wood grew no more than 30 km from Radom. Basically the only exception was *Taxus baccata*. Although the region is within the present-day range of this species, near its eastern border (Szafer & Zarzycki 1977), isopollen maps indicate that yew probably was not present in the regional woodlands in 500–1500 AD (Krupiński et al. 2004).

* * *

Our xylological study documented geographical differences in the selection of taxa used for woodcraft.

In the south of Poland, spruce/larch and fir were used, especially in the Wrocław and Kraków areas. Common fir was used almost exclusively in areas where it occurred naturally (Supplementary Material 2.1[2]) (Białobok & Hellwig 1955, Danielewicz 2012). Its wood was of great importance for the production of coopered items and construction elements. This was confirmed by a dendrochronological study of construction wood from the Main Market Square in Kraków, where more than half of the samples tested were determined to be *Abies alba* (Krąpiec et al. 2006). In contrast, only 4 items made of *Abies alba* wood (spoon and 3 fragments of a putative altar) were among those discovered in Western Pomerania (NW Poland) (Cywa 2018b (unpubl.): Annex 1). They were most likely objects of early medieval trade in luxury goods (Cywa 2018a).

European larch is primarily a mountain species which occurs naturally in Poland in the upper montane forest belt of the Tatras (Białobok & Hellwig 1955, Boratyński 1986). The centre of occurrence of *Larix decidua* subsp. *polonica* is in the Świętokrzyskie Mts and central Poland (Boratyński 1986, Jagielska 2010). Three items made of *Larix decidua* were found in southern Poland, and 2 items in north-western lowlands. This is not enough to draw conclusions about its import to northern regions of the country, although European larch wood was certainly traded at the time, as confirmed by historical data from the first half of the 15th century showing overstocking of larch and yew wood at the port in Gdańsk (Kromer 1741). Isopollen maps from ca 500–1000 AD show that pollen of *Larix* was present at sites in the Carpathian Mts, Świętokrzyskie Mts and Roztocze, but also in northern Poland, outside the present range (Wacnik et al. 2004). Toponymy data also suggest that European larch may have spread considerably wider than

[2] Available on page http://www.botany.pl/images/ibwyd/acta_paleo/Acta_Palaeobot_58_2_Cywa_et_al_Suppl_2.1.pdf

its natural range (Boratyński 1986; Supplementary Material 2.1). On the other hand, the low share of European larch wood in comparison to spruce indicates that its use for crafts was low in the Middle Ages. Our work suggests that the use of good-quality larch wood (e.g. Krzysik 1957, Kocięcki 1991, Szczuka & Żurowski 1994) for crafts was restricted by its limited availability in medieval woodlands.

Picea abies was used for crafts at Szczecin-Podzamcze V/IV, Szczecin-Podzamcze V/VI, Toruń Bankowa 14/16, Toruń Kopernika 11–13, Kraków Wawel VI and Kraków town. In Poland there are two centres of the frequent occurrence of spruce: north-east (Masurian Lakeland and Podlasie) and south (belt of central uplands, Silesian Lowland, Sandomierz Valley, mountains from the Sudetes to Bieszczady Mts). The share of this species in Polish woodland stands is highest in the Sudetes (70%), Carpathians (17.5%) and Mazury-Podlasie region (10.5%) (Danielewicz 2012). The absence of spruce at the Szczecin and Toruń sites in the Middle Ages is confirmed by palynological data (see p. 269). Its abundant presence in items from Szczecin and Toruń probably indicates import (Supplementary Material 2.1 and 2.2[3]).

Oak was a significant component of the taxonomic spectra of medieval wood at most studied sites (Fig. 4a). At present, *Quercus robur* grows throughout Poland (in the mountains up to 600–700 m a.s.l.) and *Q. petraea* has no stations only in north-eastern Poland (Bugała 1991, Adamczyk 2015).

In northern Poland, pine trees had a very high share among the wood used. In the south its use was noticeably less even though it was locally available (e.g. near Kraków). On an interregional scale, the isopollen maps for AD 500–1000 indicate a lower share of pine pollen, and hence a lower number of pine communities in southern and south-eastern Poland (Latałowa et al. 2004). Historical data also confirm that the share of pine in the forests and woodlands of the Carpathians and Sudetes was low in the Middle Ages. Pine usually occurred as single trees, rarely forming small groups in the least fertile habitats, where it competed with spruce (Białobok 1970). The southern border of pine runs through Poland along the Carpathians, where it is found in lower montane forest belts (Białobok & Hellwig 1955, Bugała 1991).

Sites with a high proportion of beech are concentrated mainly in the north-west and south of the country, following the natural range of this sub-Atlantic species (Matuszkiewicz & Kowalska 2017) (Supplementary Material 2.1). Nowadays the beech forests in southern and central Poland are restricted mainly by decreasing precipitation toward the east, and by increasing summer temperature (Matuszkiewicz 2008b).

The pattern of use is similar for *Taxus baccata* (Supplementary Material 2.2), whose occurrence is also related to the influence of oceanic climate (Barański 1981, Noryśkiewicz 2006). The largest shares of medieval yew wood were recorded at the Wolin 1 and 4, Wolin 3 and Opole Ostrówek sites. The presence of yew wood among artefacts from Wolin (Fig. 4a) is not reflected in the local palynological diagrams, although it potentially grew in this part of Poland (Supplementary Material 2.2) (EUFORGEN 2017). At present it is a component of old beech forest (*Galio odorati-Fagetum*), occurring in Poland mainly in the Pomeranian Lakeland (Matuszkiewicz et al. 2012). There are no palynological data on the presence of this species in the Radom region, although the share of this taxon in the total spectrum was high (8.07%). The north-eastern border of yew in Poland runs along the Vistula River, at the interface of oceanic and continental climates (Środoń 1975, Barański 1981, Noryśkiewicz 2006, Bodziarczyk & Chachuła 2008, Marszałek & Scelina 2015), and Radom is on its border (Supplementary Material 2.2). In view of the very frequent use of yew wood in the early Middle Ages in many places in different parts of Poland, and the absence of pollen in palynological profiles of the Kraków, Tum, Szczecin, Wolin and Toruń areas, it can be assumed that the pollen of this tree is generally underrepresented in sediments.

The palynological data do not confirm the occurrence of *Cornus* sp. in the vicinity of the Kraków Wawel VI and Toruń Bankowa 14/16 sites, where objects of this type of wood were identified. In both cases these items were made from very thin branches, so they may have been made from the only dogwood species growing wild in Poland, *Cornus sanguinea* (Bugała 1991, Amann 2009). *C. mas*, which has a thicker trunk and branches, may have

[3] Available on page http://www.botany.pl/images/ibwyd/acta_paleo/Acta_Palaeobot_58_2_Cywa_et_al_Suppl_2.2.pdf

grown around the historical borders of Poland in Podolia, Volhynia and Ukraine (Jundziłł 1799, Gerald-Wyżycki 1845). This species was also cultivated in Poland outside its natural habitat for a long time (Jundziłł 1799, Gerald-Wyżycki 1845, Seneta 1987, Mowszowicz 1979, Bugała 1991).

Hornbeam often appeared in local palynological profiles as an important component of the surrounding woodland communities but rarely appeared among the crafts. The only explanation for this seems to be that in medieval Poland the wood was used exclusively for fuel (Cywa 2018a). Lime was also rarely identified in the artefacts, but in this case its low presence at the sites can be attributed to its low durability, around 20 years both in the open air and under constant immersion (Surmiński 1991).

CHANGES IN THE USE OF TREES AND SHRUBS DURING THE MIDDLE AGES IN POLAND

Our analysis of the material revealed differences in the management of wood resources in successive chronological periods, related to the different types of early urban centres. The data (Fig. 6) show that from the Piast State period (period III) to the late Middle Ages (period IV) the taxonomic diversity of deciduous tree and shrub species used for crafts decreased in all regions of Poland. Ash was the exception; its share remained stable in the Piast period and the late Middle Ages. In Western Pomerania the use of oak did not diminish dramatically. In the Piast State period, pine was most commonly used throughout Poland. In the late Middle Ages the use of coniferous wood increased considerably at all sites; in West and Gdańsk Pomerania, Greater Poland (Wielkopolska) and the Chełmno & Dobrzyń region this involved pine and to a lesser extent spruce/larch, while in Silesia and Lesser Poland (Małopolska) it involved spruce/larch and fir. The medieval palynological sequences from Toruń indicate that pine increased there in the late Middle Ages (Noryśkiewicz 2013). *Taxus baccata* was very poorly represented among the coniferous taxa throughout Poland; this is consistent with historical and palynological information about its extirpation (e.g. Czartoryski 1975, Cedro 2004, Pawelec 2010, Iszkuło et al. 2016, Cywa 2018a).

The results for common yew clearly suggest that medieval craft manufacture may have contributed to the extirpation of some tree and shrub species in woodland communities. Yew, with its excellent physical and mechanical properties (Krzysik 1957, Szczuka & Żurowski 1994), was the fourth most common wood used by craftsmen in the Piast period, while in the late Middle Ages it was only twelfth on the list of trees and shrubs used. The reduction of the share of yew at that time was also partly due to a ban imposed in 1423, primarily to protect this valuable tree from theft (Grzywacz & Grzywacz 2008).

We infer two stages in the use of wood by medieval Polish craftsmen: (1) from the mid-10th century to the end of the 12th century, when a very diverse pool of wood was used, especially deciduous taxa, including shrubs; and (2) from the 13th to the 15th centuries, when the use of coniferous trees and shrubs increased. In most regions the use of pine declined in favour of spruce/larch.

These changes in the selection of wood took place when the first cities were chartered under German law in Poland, craft guilds were established, and the end of the climatic optimum occurred. The decline in the species diversity of the wood used may be related to specialization of crafts, especially since historical sources say that guild statutes could specify the kind of material from which items were to be made (Jezierski & Leszczyńska 2001). The decline in the use of wood from deciduous trees may also be the result of deforestation of the habitats most suitable for agriculture and settlement.

CONCLUSIONS

Our study revealed that a great variety of wood was used in medieval Poland for the production of articles of everyday use, but only some of the identified taxa were used on a mass scale. Most of the items were made of pine, oak, ash, spruce/larch, yew, alder, fir and spindle.

The material culture of the times was dominated by *Pinus sylvestris* wood, which was easily accessible as a common component of the Polish flora, has good strength and mechanical properties, and is lightweight and easy to process. In the Middle Ages it was used mainly to make stave-built vessels and torches.

The taxonomical determinations of the 4211 wooden items from 62 archaeological sites

in Poland indicate that the properties of the wood of particular species were well-known to medieval woodworkers, and that the choice of material for production was selective, was consistent with the intended purpose of the items, and was based on the properties of the given type of wood. The methods of processing also affected the selection.

Similar ranges of wood types were used for certain types of objects from all sites analysed. Large coopered vessels were made of oak, pine and yew. The wood most commonly used for turned vessels was ash. Stave-built bowls were made exclusively of easily split pine and spruce/larch.

The medieval craftsmen chose wood of high quality, without defects, avoiding wood containing even the smallest knots. Roundwood processing mainly employed radial splitting, producing radial boards with good technical characteristics. The share of radial material increased especially in the late Middle Ages; this is related to the development and specialization of craft guilds, along with improving knowledge of carpentry techniques.

Unlike today, wood product manufacture relied primarily on narrow-grain wood, which has worse mechanical and working properties but is soft and would have been easier to work with using simple hand tools.

The breadth and height measurements of the vessels turned on one side indicate that their production mainly involved medium-sized *Fraxinus excelsior* boughs with average diameter of 6–16 cm.

In north-western Poland the most important craft materials in the Middle Ages were pine, oak, ash and beech; in the south, spruce/larch and fir were used the most. These choices reflect the natural ranges of these trees in Poland.

The choice of wood depended on the technical requirements of the finished product but was limited by the local availability of tree and shrub species. In most cases, wood with the desired properties grew in the vicinity of the sites. Only some objects made of fir, spruce or larch were imported from distant places.

We distinguished two stages in the use of wood by medieval craftsmen in Poland. In first stage, lasting from the mid-10th century to the late 12th century, they used a very diverse pool of raw materials, with a large share of deciduous taxa. In the second stage (13th–15th centuries) they used more coniferous taxa. Probably this change is related to encroachment of the most fertile land, formerly occupied by deciduous woodland, by agriculture and settlements. Our analysis showed that the use of pine in Poland was greatest during the Piast State period of the early Middle Ages. In the late Middle Ages its use decreased significantly in southern regions, while the use of spruce/larch and fir increased.

This research confirmed historical information about the intensive use of yew in the early Middle Ages, which led to a significant decrease in the presence of this tree in the woodland communities of the late Middle Ages.

The available pollen sequences from the immediate vicinity of the archaeological sites provided information about the composition of the medieval woodland communities growing in their neighbourhood, and verified the local availability of wood-bearing taxa.

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