

Dendrochronology vs. dating of complex stratigraphic sequences

The example of medieval Wrocław

Dendrochronologie a datování komplikovaných souvrství
Příklad ze středověké Vratislavi

Marek Krąpiec – Jerzy Piekalski

The aim of the paper is to evaluate the usefulness of dendrochronological analyses in studying complex stratigraphic sequences. The problem is discussed basing on the example of Wrocław, the main town of historic Silesia, where the thickness of medieval layers containing wood ranges between 3 and 5 m. The first attempts to date them using dendrochronology were made at the end of the 1980s. Some dates, or their short series, were then used as a basis for far-reaching conclusions regarding the chronology of the beginnings of settlement or breakthrough events. The preliminary stage of dendrochronological analyses and uncritical acceptance of interpretations ended in Wrocław with the excavations carried out in 2000. Longer series of dendrochronological dates have become one of the basic tools for dating complex sequences. The results of stratigraphic research and the outcomes of dendrochronological analyses were correlated being aware of limitations set by both categories of sources and methods of their analysis. It was stated that giving up on an in-depth critique of dendrological samples as a category of sources can result in a considerable distortion of the acquired results.

dendrochronology – method value – stratigraphy – Middle Ages – town

*Cílem článku je hodnocení využitelnosti dendrochronologie při studiu složitých stratigrafických situací, a to na příkladu slezské Vratislavi, kde středověké terény obsahující dřevo dosahují mocnosti 3–5 m. První pokusy o datování archeologických vrstev pomocí dendrochronologie proběhly na konci 80. let 20. století. Některá data nebo jejich krátké série byly využity pro dalekosáhlé závěry o chronologii počátků osídlení či přelomových událostí. Tato etapa poznamenaná nekritickou interpretací získaných dat skončila ve Vratislavi v souvislosti s archeologickými odkryvy v r. 2000. Základním nástrojem pro datování složitých situací se staly početnější řady dendrochronologických dat. Stratigrafická pozorování byla korelována s dendrochronologickými daty s vědomím limitů obou pramenných kategorií a příslušných metod. Opo-
menutí důkladné kritiky dendrologických vzorků coby samostatné kategorie poznávacích pramenů může vyústit v závažné pokřivení výpovědi dendrochronologické analýzy.*

dendrochronologie – zhodnocení metody – stratigrafie – středověk – město

Introduction

It is hard to overestimate the importance of dendrochronological studies for the correctness of analysis and dating of sites with preserved timber. Making use of dates of cutting a tree that was going to be used as building material contributed to radical changes of chronology and interpretations of important historical events. Motte-and-bailey castles, dated initially in North-Western Europe to the 9th century and associated with the reaction to Viking raids, can be an example (*Herrnbrodt 1958; Hinz 1981*). Dendrochronological dates moved the chronology of the first wood-and-earth castles to the end of the 10th century, or even to the

11th century, placing them in different historical conditions and indicating their social, rather than military role (Biller 1993, 112–117; De Meulemeester – O’Conor 2007, 323–331). Similarly, the chronology of the oldest strongholds of the Western Slavs was changed from the 7th–8th century to the 9th–10th century, provoking a lively discussion on their origins (Hensel 1987, 393–525; Henning 1998; Urbanczyk ed. 2004; Brather 2008, 119–140). Particular value has this dating method when researching sites with rich and complex systems of organic stratigraphic sequences. Medieval towns north of the Alps belong to that group to a large extent. However, achieving the right value of dendrochronological analyses depends on meeting numerous requirements. They usually include the need to obtain a large series of dates, taking into account stratigraphic position of the samples and, what is the most difficult, determining if the timber for construction was used for the first time or re-used (Kulesa 2001; Boschetti-Maradi – Kontic 2012; Schultze 2014; Krauskopf – Wiese 2014; Harder 2014). A separate problem is the relationship of dating with cultural and dendrochronological determinants. This issue is presented in detail on the example of one of the wells in the town of Most (Klápště – Kyncl – Kyncl 2000). As we already know, giving up on an in-depth critique of dendrological samples as a category of sources can result in a considerable distortion of the acquired results. The aim of the paper is to evaluate the usefulness of dendrochronological analyses in studies on complex stratigraphic sequences. We also hope that the case study of Wrocław will prove useful for analyses of other centres of similar specific nature.

Application of dendrochronological method in Wrocław: Discussion

In Wrocław, the main town of historic Silesia, the thickness of medieval layers containing wood ranges between 3 and 5 m. The first attempts to date them using dendrochronology were made at the end of the 1980s. The construction of the rampart in the oldest part of the settlement complex, on Ostrów Tumski, was dated to the 940s, basing on one date (fig. 1a). However, we should add that this dating was regarded as a confirmation of a wide-ranging research based on an analysis of stratigraphy and artefacts (Kaźmierczyk 1991, 17–45). At the same time, the first datings from the area of the town on the left bank of the Odra river appeared. The first decades of the 13th century were determined as the chronology of a well complex from Dominikański square (fig. 1b; Berduła et al. 1993, 106–108). The time of acquiring material for the construction of the oldest timber framed buildings on plots at 8–9 Igielna Street was estimated to be 1236 and 1241 (fig. 1c; Piekalski 1995, 76). Some yet rather scarce dates were obtained for timber that was used for the construction of street surface, loose elements present in the layers and more numerous ones from wells or cesspits (Krapiec 1993).

Their interpretation was usually rather clear-cut, which means the date of cutting a tree was accepted as the approximate time of placing the timber in the discovered construction, or becoming a deposit in the layer (e.g. Buško – Piekalski 1993a, 148; 1993b, 170–171; Bresch – Buško – Lasota 2001, 57, 66–68). It was noted then that it is possible to draw conclusions regarding reparations or re-using of timber for constructing wells and cesspits, when having enough samples (Krapiec 1993). At the same time, the results were used as a basis for far-reaching interpretations considering transformations and development of

the town, including the incorporation period (e.g. *Mruczek 2000*, 268; *Chorowska 2010*, 74–75). The preliminary stage of dendrochronological analyses and rather uncritical interpretations ended in Wrocław with the excavations carried out by Cezary Buško and Jerzy Niegoda at Piaskowa Street and Nowy Targ square in 1999–2000 (*fig. 1d*; *Buško ed. 2005*). The obtained results of dendrochronologic analysis, based on numerous series of critically reviewed samples, became a basis for proprietary conclusions regarding the details of the layer structure, changes in construction techniques and spatial development of a town. The possibility of mass re-using of timber, especially when reinforcing the surface, was noted during the excavations of the streets of the Old Town in Wrocław (*fig. 1e*; *Konczewski – Piekalski 2011*, 156–159).

The excavations at Nowy Targ square in the years 2010–2012 brought new opportunities regarding applying dendrochronology in the studies of the town (*fig. 2*). They covered the area of 40 ares, and the thickness of layers containing well preserved timber reached up to 4 m (*fig. 3 and 4*; *Marcinkiewicz – Mackiewicz – Piekalski 2014*; *Piekalski 2016*; *Piekalski – Wachowski eds. 2018*).

For dendrochronological analyses selected were 286 timber samples. Anatomic identification of timber, conducted basing on macroscopic and microscopic observations, revealed that the analysed fragments represent oak (141 samples), beech (4 samples), ash (3 samples), elm (6 samples), alder (3 samples), pine (119 samples) and fir (10 samples). 168 samples met the requirements of dendrochronological method. They were subjected to a standard preparation and measurement of annual growth rings with the accuracy of 0,01 mm using the Dendrolab 1.0 dendrochronological measuring device (*Zielski – Krąpiec 2004*). For measuring and processing the measured sequences of annual growth rings the TREE-RINGS (*Krawczyk – Krąpiec 1995*) and TSAP (*Rinn 2005*) software packages were used. The absolute datings of the obtained sequences of deciduous wood were done basing on Lower Silesian oak standard and local dendrochronological scales (*Krąpiec 1993*; *1998*), while the sequences of coniferous trees were dated based on chronologies established by *E. Szychowska-Krąpiec (2010)*. As a result of the performed computer correlations and visual comparisons of dendrograms, datings of dendrochronological sequences for 111 oak samples, 47 pine samples, 7 fir samples and 3 ash samples were acquired.

Informative value of the stratigraphic system at Nowy Targ square is enhanced by its localisation in the area of constant development of settlement starting from 11th century, combining the layers related to the proto-urban crafts and trade settlement, traces of the town's transformation in the 13th century, late medieval market square and elements of the modern city infrastructure at one place. The earlier findings of Józef Kaźmierczyk after the excavations from the 1960s (*Kaźmierczyk 1966*; *1970*) and the mentioned research of Cezary Buško and Jerzy Niegoda (*Buško ed. 2005*) are also highly valuable. They are connected with the discussion that has lasted for over 150 years and has been focused on the relation of the Nowy Targ square area to other parts of the town and its role in the incorporation transformations. Ideas and hypotheses set in the discussion were different, sometimes even contradictory. It was thought that the name *novum forum* is the evidence of a temporary relation of the square to the previously existing proto-urban marketplace. The contradictory thesis stated that the name of the square describes its relation to Rynek, the main market square of the incorporated town. The discussion is well illustrated by the source literature, presented mostly by historians, art and architecture historians, less frequently by archaeologists (e.g. *Grünhagen 1861*; *Markgraf 1881*; *Młynarska-Kalety-*

nowa 1986, 48–123; Kaźmierczyk 1970, 22–31; Goliński 1997, 96; Zientara 2006, 162). Dendrochronological datings proved to be a breakthrough in the discussion.

The results of excavations of *novum forum* in 2010–2012 are not generally in contradiction to the earlier findings of J. Kaźmierczyk, C. Buśko and J. Niegoda. Nevertheless, the suggested datings are different. The first Author could not take advantage of dendrochronological analyses and based his conclusions on the features of artefacts and the sequences of the recorded layers (Kaźmierczyk 1970, 336–516). In the excavations from 1999–2000 dendrochronology was the main basis for dating the distinguished phases of the use of the area (Niegoda 2005b). In the most recent research after the excavations from 2010–2012 the decision was made to combine both methods, being at the same time equally critical towards all the acquired information. Thanks to the synchronization of diachronically appearing, functioning and established features and events, essential to organize the stratigraphic situation, subsequent phases of using the area were reconstructed.

Phase I marks the beginnings of settlement activity on the left bank of the Odra River in Wrocław. They are evidenced in the excavated area by features sunken into the natural layer of alluvial soils or sandy bedrock, or sometimes by what covered them. Most of them are pits of an undefined function, however, some may be considered as relics of sunken parts of pit houses, some as post traces. The phase was distinguished according to the criteria of stratigraphy. It lasted a couple of tens of years and some semi-dugouts or other pits overlapped one another, informing us about the structure changes that occurred over time. Dating of this phase is based on an analysis of artefacts, including technological and stylistic features of ceramic vessels. The technique of forming vessels, additives used for preparing the ceramic paste, the way bottoms were shaped and the frequency of particular vessel forms give us information that the collection formed over a long period of time, estimated to be mostly the 12th century, with the possibility to move the chronology to both the second half of the 11th century and the beginnings of the 13th century. Other artefacts, especially a Saxon cross-denarius emitted in the years 1070–1100, indicate the early 11th-century beginnings of settlement. At a higher stratigraphic position, probably a secondary deposit, there were three spurs of type I of *Zofia Hilczerówna* (1956, 30–31), dated no later than 11th century. Unfortunately, in the features connected with phase I no timber for dendrochronological dating was found, however, samples dated to the 12th century were present in the material from later phases. Placing the beginnings of settlement at Nowy Targ square in the 11th century, or rather its second half, does not contradict with the findings of J. Kaźmierczyk (1970, 343–444). Nevertheless, we keep some distance towards the extremely early chronology. The material we acquired does not allow to consider that the area could have been occupied before the 11th century as the scholar would suggest. However, we do not confirm the sceptical and overly careful opinion of C. Buśko and J. Niegoda who place the beginnings of settlement activity in the 1190s. They based their thesis on general reflections on the rhythm of development of building construction and it lacked a good justification in the results of dendrochronological analyses. Two dates from their excavations indicated that the area was occupied in the 12th century: after 1112 and 1198 (Niegoda 2005b, 69–70). The first date was considered to be incidental and the other one became a basis for establishing the chronology of the beginnings of settlement in the 12th century. The situation was observed in line trenches that do not provide the possibility of a broader spatial analysis. Presently, after excavating 40 ares of the surface we know that timber eligible for an analysis did not preserve in the oldest objects.

However, some early dates acquired by the team of C. Buško in higher layers are worth mentioning, especially that they come from a zone that directly neighboured the main axis of the settlement. Two samples were dated to the 11th century – after 1045 and 1070 (?). Eleven samples are associated with the 12th century – after 1115, after 1138, after 1142, after 1167, after 1168, after 1168, after 1176, after 1183, after 1183, after 1186(?), ca. 1188 (*Niegoda 2005a*, 55–68, tab. 1; according to an analysis of M. Krapiec). The value of dendrochronological analyses is therefore in this case rather disputable, as the samples came from secondary deposits of timber. We consider them as an indirect information that could confirm the early dating of the beginnings of settlement in the eastern part of the Old Town.

Phase II represents the continuation of the development of the settlement, reflected by deposition of a layer during the excavations referred to as stratigraphic unit (further s.u.) 72 and features related to it. The layer overlapped the natural alluvial soil of the Odra River, strongly affecting its top. It is the oldest level from which timber suitable for dendrochronological analysis was acquired. From a long series of samples a clear outcome was obtained in 8 cases. It was considered as an insufficient basis for the right dating of a vast number of features that appeared over a long period of time. Nevertheless, we may say that they fall between 1184 (–6/+9) and 1199 (–2/+9), where most of the dates indicate that the trees were cut down in the 1190s. Two samples dated after 1287 and after 1276 were regarded as a result of a mistake made during the excavations. The features of ceramic vessels well correlate with dendrochronological dating of phase II. They do not differ from ceramics known from other parts of Wrocław in terms of technology and stylistic features. They are analogous to those described by J. Kaźmierczyk discovered at Drewniana Street and Nowy Targ square (*Kaźmierczyk 1966*, 86; *1970*, 272–329), dated to the turn of the 13th century. They can be also found in the publication of *Paweł Rzeźnik (2005*, 97–110), embracing materials acquired in the years 1999–2000. Therefore, considering stratigraphic relations, features of artefacts and the acquired dendrochronological dates and taking into account the possibility of movement of artefacts within the forming cultural layer, we can carefully date phase II to the last decades of the 12th century and the beginning of the 13th century.

Phase III. This stage of development of settlement is characterised by intensified exploitation of the area, reflected by the richness of complex stratigraphic sequence connected with the layer defined during the excavations as s.u. 16. It was recorded on the whole excavated area and its thickness ranged from 50 cm to 70 cm. The considerable thickness of the layer, being a result of the long forming process, made us decide to distinguish two stages of phase III – IIIa (earlier) and IIIb (later).

Trying to precise the time of functioning of the features of phase III, it should be stressed that defining its earliest chronological border, separating it from the features of phase II, is not simple. The correct identification of the border between the stratigraphic layers that separated those two phases, referred to as s.u. 72 and the subsequent s.u. 16, was not obvious on the whole surface of the excavated area. The consistency and structure of both units were highly similar or almost identical in some areas. At the same time it is obvious that the artefacts from the older layer were transferred to the new structures when digging pits or constructing houses. Using not reinforced surface, especially during wet seasons as well as uneven ground settlement over the older pits caused relocation of younger artefacts to the older layer. The end of phase II was dated by us approximately to

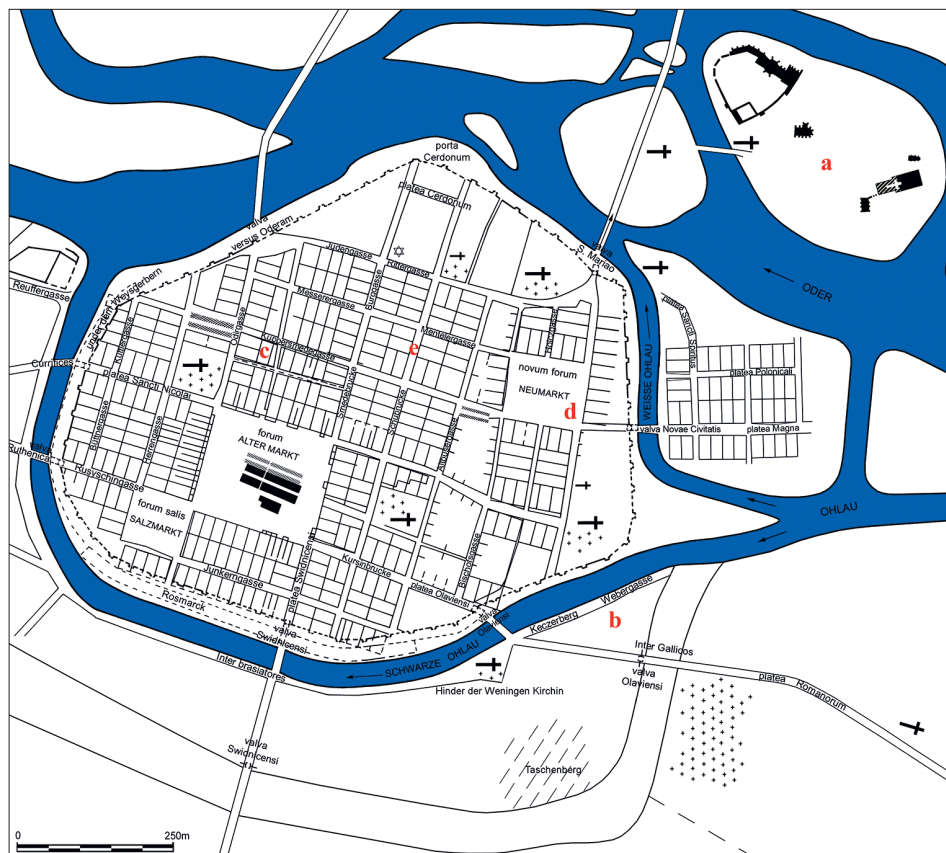


Fig. 1. Wrocław. The scope of dendrochronological studies included in the paper (drawn by N. Lenkow).
Obr. 1. Vratislav. Přehled dendrochronologických analýz ve Vratislavi, o nichž pojednává tento článek.
a Ostrów Tumski, b Dominikański Square, c Igielna Street, d Piaskowa Street and Nowy Targ square, e Szewska Street.

the beginnings of the 13th century, which at the same time opens the time of phase III. Stratigraphic indicator of the end of this phase is the demolition of all buildings and covering the area with a leveling layer of sand (s.u. 11). The clear picture of this phenomenon in stratigraphic system was already stressed by J. Kaźmierczyk. He dated the demolition of the buildings to the end of third quarter or the beginning of the fourth quarter of the 13th century (Kaźmierczyk 1970, 427, 471).

The collection of pottery acquired in a sequence representing this phase of occupation of the area gives only general information on chronology, even though it was the time of significant technological and formal changes. We associate it with the pottery acquired during the previous excavations and dated to the 13th century. Our phase IIIa and vessel fragments connected with it correspond with layers H–H1 (settlement levels VI–VII) in the earlier excavations on Nowy Targ (Kaźmierczyk 1970, 398–426) and phase IIIb with layers G/1–5 (settlement level VIII; Kaźmierczyk 1970, 427–471). P. Rzeźnik (2005, 97–110) dates technologically and formally analogous materials generally to the 13th century.

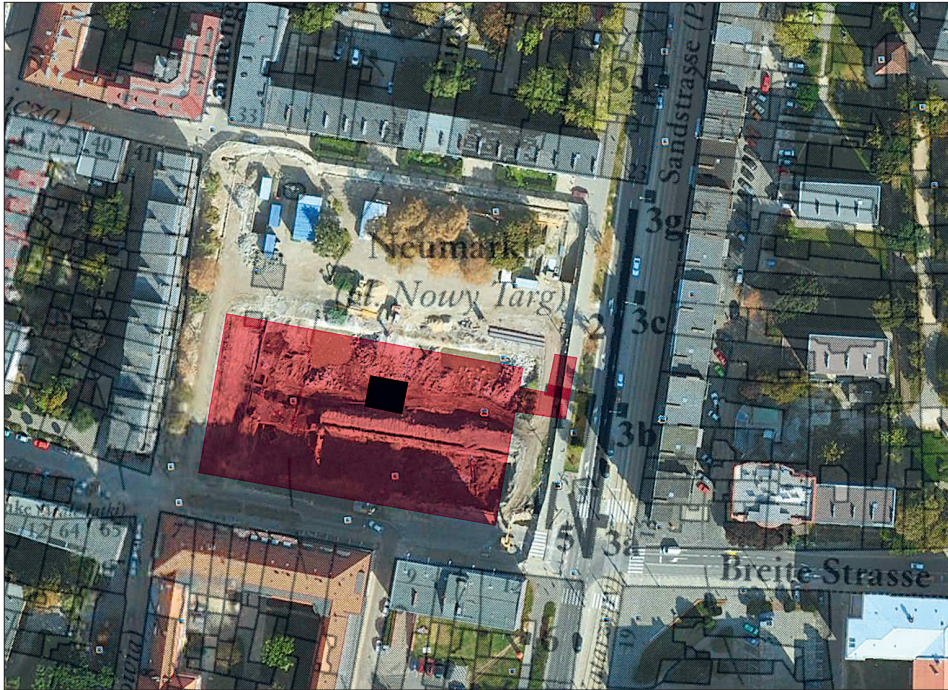


Fig. 2. Wrocław, Nowy Targ square. Excavations from the years 1963–1964, 1999–2000 and 2010–2012 against the background of the plan of the city from before 1945 (by M. Mackiewicz).

Obr. 2. Vratislav, náměstí Nowy Targ. Archeologické odkryvy z let 1963–1964, 1999–2000 a 2010–2012 v souběhu s plánem města ve stavu před r. 1945.

Chronological distinction between phases IIIa and IIIb is a separate issue. Trying to correlate this dividing line with the results of the earlier excavations, it should be assumed that the end of the older phase is connected with the Mongol invasion in spring 1241, while the beginning of the younger one with rebuilding of the town after the destruction. The problem is that the suggestions of J. Kaźmierczyk and later C. Buško (*ed.* 2005, 186) and J. Niegoda (2005b, 71–74) concerning the possibility of identifying the traces of the invasion in the layers of Nowy Targ square cannot be clearly confirmed. According to Kaźmierczyk (1970, 418), it was supposed to be a fire that put an end to settlement level VI he distinguished. The excavations from the years 2010–2012, however, revealed that most buildings in the area of Nowy Targ square, including its whole stratigraphic sequence, were destroyed by a fire. Dendrochronological analyses suggest that this applied to buildings erected both before and after the invasion. Determining the down stratigraphic border of phase IIIb was based on the mechanic criterion of the height of 116.4 m a.s.l. No traces of one huge fire, which would allow to clearly distinguish layers and features destroyed in 1241 from those that appeared as a result of reconstruction of the town, were recorded.

In this situation dendrochronological samples comprised a considerable part of dating base within phase III. The series of processed samples was in this case longer and consisted of 91 dates. The oldest sample was dated after 1140 and the youngest one was an oak wood sample dated after 1260. Seven of them come from trees cut down in the 12th century or at



Fig. 3. Wrocław, Nowy Targ square. Excavations from the years 2010–2012, view from the north (photo M. Mackiewicz).

Obr. 3. Vratislav, náměstí Nowy Targ. Archeologický výzkum z let 2010–2012, pohled od S.

the turn of the 13th century, which indicates re-using timber that had been earlier present in the constructions of phase II. In the case of 7 dated samples it was impossible to determine their connection with phase IIIa or IIIb.

Phase IIIa, so the layer and constructions discovered below the absolute altitude of 116.40 m a.s.l., includes 16 dates ranging from 1201 (–3/+9) and after 1201 to after 1234. The series consists of timber samples from 10 buildings erected using different constructions and 3 from the reinforcement of street surface destroyed by a fire (*fig. 5*). It is then possible that all those constructions were burnt in the war of 1241, however, we will never be absolutely certain in this matter.

Phase IIIb was associated with 68 dated timber samples from 27 buildings, 3 wells and 5 communication routes. The oldest one was determined to have come from a tree cut down after 1140, and the youngest one after 1260. From well preserved constructions several samples were taken. Thanks to that we are aware that for constructing one object building material from trees cut down at different times could have been used (*fig. 6* and *7*). Some of the buildings erected using timber acquired before 1241 did not bear traces of fire destruction. It is then possible that they survived the Mongol invasion in April this year and functioned in phase IIIb as well. On the other hand, we cannot exclude that it was built from old timber after the invasion. It is also worth noting that houses built from trees cut down after 1241 were equally prone to fire as before the date. War destructions have not left any clear traces then. We can well state that archaeological material confirms that in phase IIIb, so probably after the events of 1241, unprecedented dynamics of building development along with new elements of infrastructure took place. It should be added that

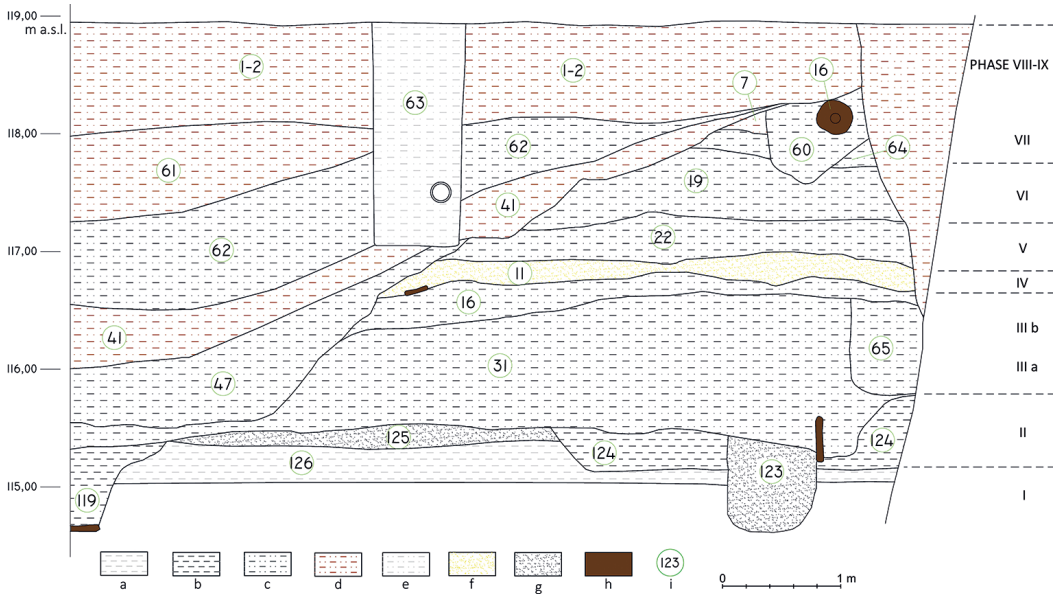


Fig. 4. Wrocław, Nowy Targ square, excavations 2010–2012. Fragment of the EW cross section; a light gray clay, b gray clay, c black humus, d brown humus, e gray humus, f yellow sand, g gray sand, h wood, i stratigraphic unit number (drawing M. Mackiewicz).

Obr. 4. Vratislav, náměstí Nowy Targ. Archeologický výzkum z let 2010–2012, část profilu V–Z; a světle šedý jíl, b šedý jíl, c černá humusovitá hlína, d hnědá humusovitá hlína, f žlutý písek, g šedý písek, h dřevo, i číslo stratigrafické jednotky.

the analysis of stratigraphic relations, a series of dendrochronological dates and features of artefacts together allow to determine that the end of phase III should be placed in the 1260s. It generally confirms the dating of the demolition of timber buildings proposed by *J. Kaźmierczyk* (1970, 471). After the event a deep reorganisation of space connected with the foundation of *novum forum* took place.

Phase IV is connected with an event of fundamental significance for the structure of the medieval town – founding Nowy Targ square, most probably with a regular network of street surrounding the square, preceded with a removal of older buildings. During the excavations it was clearly stated that the whole researched surface was evened with a layer of sand up to 60 cm thick (s.u. 11). Good state of preservation of the sand layer is the evidence that it was hardened at the top and protected from being spread all over during its use. Poorly preserved traces of a stone paving confirm the existence of this kind of protection. A sand layer brought as a result of one-off action did not contain any artefacts that could provide a reliable basis for dating. Its chronology is based on the stratigraphic relation, according to which s.u. 16 is earlier, and s.u. 22 – recorded above the sand – later. We can safely date it to the second half of the 13th century then. Precising the chronology to the third quarter of the century is possible thanks to dendrochronological dates and the features of artefacts from the adjacent phases. The first ones place s.u. 16 and phase III, which is connected with them, in the 1250s–1260s. The artefacts, in turn, allow to describe s.u. 22 as one containing material defined as late medieval. Thus, in this case dendrochronological analyses provided indirect chronological indicators.

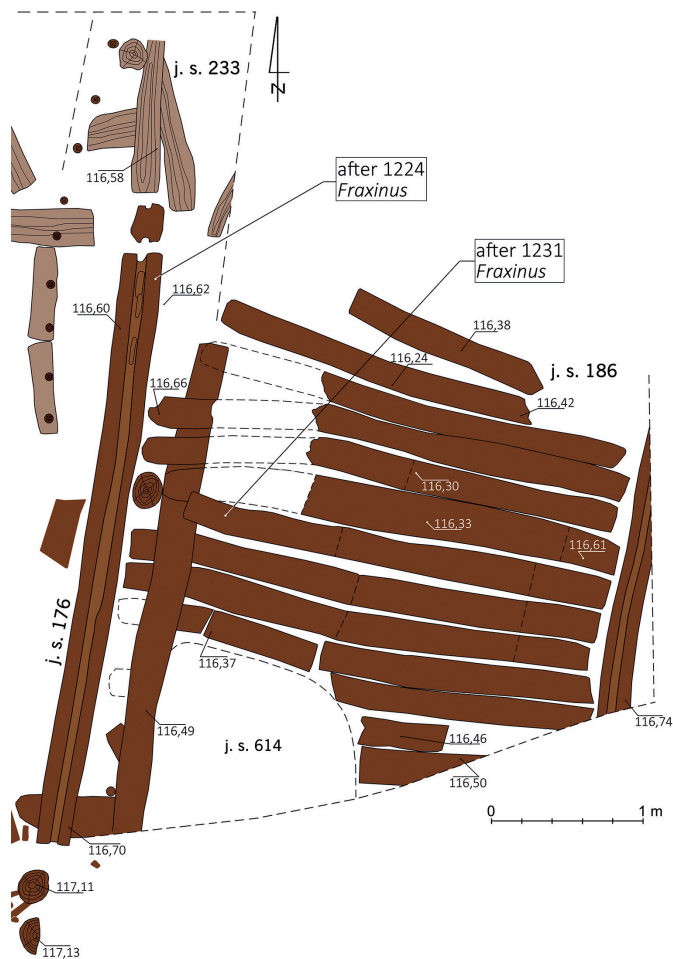


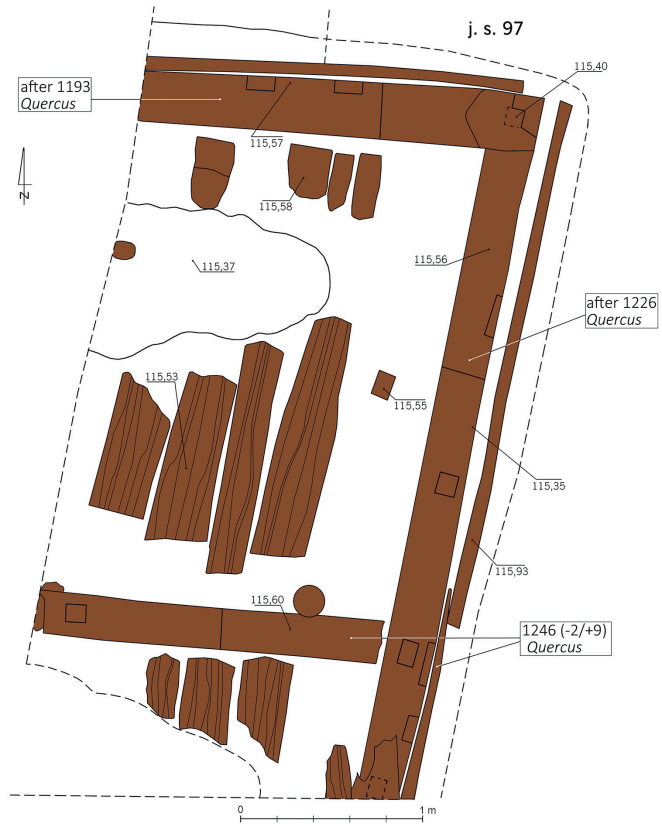
Fig. 5. Wrocław, Nowy Targ square, excavations 2010–2012. Stratigraphic units 176, 186 (drawing J. Nastaszyc and N. Lenkow).

Obr. 5. Wrocław, náměstí Nowy Targ. Archeologický výzkum z let 2010–2012. Stratigrafické jednotky 176, 186.

Phase V illustrates the early stage of functioning of Nowy Targ square. Its material evidence is represented by the layer referred to as s.u. 22 and the stratigraphic sequence connected with it. Defining its relation to the results of the excavations of J. Kaźmierczyk at Nowy Targ square, layer F in settlement level IX distinguished by the scholar may be undoubtedly associated with it. He defined it as sandy humus deposited directly on the remains of the oldest cobblestone paving (Kaźmierczyk 1970, 427–482). In the interpretation of J. Niegoda (2005b, 74) it includes in broadly understood phase VIII. The way the area was used in the early stage of its functioning is radically different from that described in the case of phase III that preceded the spatial transformations and – as we assume – legal and ownership changes. Communication routes cutting the area along the E–W axis that had been present earlier simply disappeared. Nevertheless, Piaskowa Street, forming then the eastern edge of the square, must have still played an important role. Several features sunken into the ground as well as timber constructions, including wattle-and-daub, post-in-ground and one log building were recorded. A new communication route formed in the

Fig. 6. Wrocław, Nowy Targ square, excavations 2010–2012. Stratigraphic unit 97 (drawing M. Mackiewicz and N. Lenkow).

Obr. 6. Vratislav, náměstí Nowy Targ. Archeologický výzkum z let 2010–2012. Stratigrafická jednotka 97.



area of the southern edge of the square. The preserved part of its wooden construction was ca. 20 m long (s.u. 528) and indicated that the first paving on Nowy Targ square was not really durable.

Trying to determine the duration of phase V, we can use stratigraphic findings related to the chronology of neighbouring sequences, artefacts and few dendrochronological dates. Its beginning is marked by the time of organisation of *novum forum* together with building the first paving. As it was mentioned earlier, it probably took place in the 1260s. The top chronological border is rather a convention. It does not separate another organisational breakthrough and it was distinguished only due to the stratigraphic structure that was recorded during the excavations. It contains features connected with the layer referred to as s.u. 22, and related dendrochronological dates indicated years 1297 (–6/+9) and after 1301. Artefacts, including ceramic fragments, are characteristic of late medieval material dated to the last decades of the 13th century and the beginnings of the 14th century.

Phase VI is a reflection of continuation of using the market square. On its whole surface s.u. 19 gathered – a layer of dark brown, greasy manure, saturated with organic material, including mostly wood, leather scraps, animal hair, a considerable amount of animal bones and fragments of ceramic vessels. When correlating phase VI with the results obtained by J. Kaźmierczyk (1970, 482–493) we concluded that it corresponds with layer D, dated by the scholar to the first half of the 14th century. Its stratigraphic position reflects

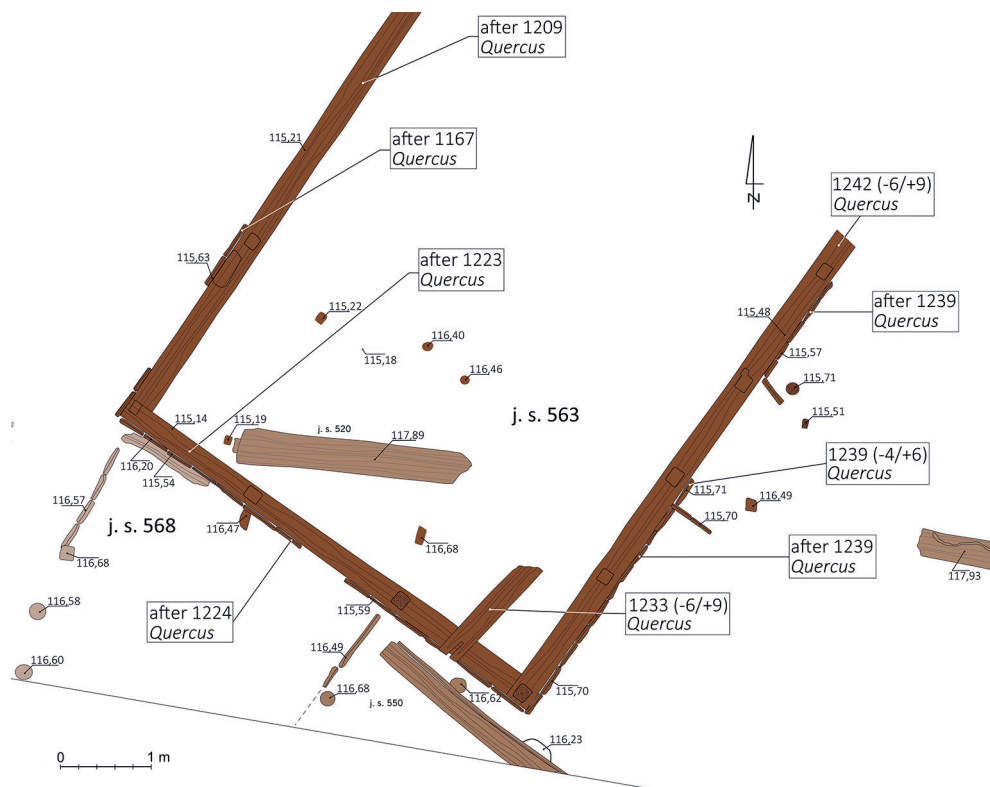


Fig. 7. Wrocław, Nowy Targ square, excavations 2010–2012. Stratigraphic unit 563 (drawing M. Mackiewicz and N. Lenkow).

Obr. 7. Wrocław, náměstí Nowy Targ. Archeologický výzkum z let 2010–2012. Stratigrafická jednotka 563.

our s.u. 19. According to the division proposed by *J. Niegoda* (2005b, 74) it would be placed in broadly understood level VIII.

Few features assigned to phase VI represent wooden market devices. However, a system of wells and pipes transporting water are new elements of urban infrastructure. Chronological relation of the discovered devices to the municipal water supply and sewage system known from the earlier excavations is an issue that requires some discussion. Wrocław belongs in this case to relatively well recognized centres, thanks to archaeological and literary sources. The discussion associated with that issue is also advanced (*Płonka – Wiśniewski* 1989; *Dwojak* 1993; *Berduła* 1994; *Buśko* 1995; 1996; *Wiśniewski* 1995; *Goliński* 2001; *Piekalski* 2004; *Janczewski* 2005; *Sowina* 2009, 235–368). A vague hint suggesting the early dating of the beginning of distribution of water in the town is also a falsified document of Henry IV Probus which informs about a privilege that was supposed to have been granted in 1272 “... in ductione aquarum ei in eius usibus ...” (*SUB*, Bd. 4, no. 448) – it would be an important information if the counterfeit dates back to the mid-14th century. The oldest water supply device in Wrocław, referred to as *rota aque*, was mentioned in 1386 (*Goliński* 1997, 78–79). Later accounts allow to identify it with a water wheel picking up water from the Odra River that was later distributed in the town

using gravity. It was located in the vicinity of Furta Młyńska (Mill's Gate), at the northern end of Kielbaśnicza Street/Herrenstrasse. The water was transported from it mainly to the western, wealthy part of the town – in the area of Kielbaśnicza Street, Rynek, Solny square, Ofiar Oświęcimskich Street/Junkerstrasse. *Piotr Janczewski* (2005, fig. 1), referring to the older, unpublished studies of Andrzej Kudła (based on an analysis of sources from the modern period), is inclined to extend the medieval reach of this water supply also to Kotlarska Street and the southern frontage of Nowy Targ square. Such an opinion seems to correspond with the description of Barthel Stein from 1512, which indicated that the whole net of waterworks in the town was supplied by the Wasserhaus (water house) at Furta Młyńska (Mill's Gate: *Stein* 1995, 32, 35). Some sources, however, suggest that medieval chronology has also the Wasserhaus at Kacerska Górka/Ketzerberg, at the south-eastern end of the town, drawing water from the Oława River, at its outlet to the inner town moat (*Goliński* 1997, 208; 2001; *Piekalski* 2004, 13). The third water house drew water from the Odra River at the end of Szewska Street/Schuebruecke, close to the Island of St. Matthias. The Wasserkunst located there was the youngest one, built in the 1530s (*Grewe* 1991, 65). Water was distributed through pipes placed in the ground under the surface of the streets, having been installed by the municipality. They supplied public wells at streets and squares, however, there were also private sections that led to burgage plots. In medieval Wrocław ceramic pipes consisting of 36–60 cm long wheel-thrown segments were used most often. The oldest ones are dated to the 14th century, or rather its second half. From the beginning of the decline of the Middle Ages they were gradually replaced with wooden pipes made from tree trunks with a drilled channel (*Dwojak* 1993, 292–295; *Piekalski* 2004, 14–17). In the north-eastern zone of the Old Town no ceramic pipes have been discovered so far. However, wooden ones in the form of troughs are known. They were first described by Józef Kaźmierczyk, based on his discovery at Kotlarska Street. The scholar was inclined to date them as early as the 13th century, associating them at the same time with the water wheel mentioned in the 1380s, i.a. *rota aque* (*Kaźmierczyk* 1970, 68–69). Another discovered sections of troughs were gathered by Piotr Janczewski who participated in the excavations at Nowy Targ square in 1999–2000. He pointed out to an unpublished find from a place where Kotlarska Street intersects with Szewska Street – a trough consisting of three planks and covered with the fourth one. Another device of such construction was recorded at the south-eastern corner of Nowy Targ square in the years 1999–2000 (*Janczewski* 2005, 68, fig. 5). We are aware that it corresponds with s.u. 496 from the excavations from the years 2010–2012, i.e. with a trough located east of the well s.u. 527. The authors of the excavations from 1999–2000, having line trenches of a limited depth at their disposal, assumed that the pipe was fitted with a wooden bottom. After the most recent excavations we know that the bottom was not present on the whole length of the trough, which is perceived as a considerable difficulty in the interpretation. Janczewski, like Kaźmierczyk earlier, associated water supplying devices distributing water along Kotlarska Street and the southern edge of Nowy Targ square with the large water wheel *rota aque*. He is also inclined to accept the early dating of the discovered troughs, which is the 13th century (*Janczewski* 2005, 92–96). He refers to analogies from other Silesian towns, and also further located centres of Central Europe. The latest excavations generally confirm the findings of P. Janczewski, suggesting at the same time that the dating should be corrected. The artefacts would indicate that the s.u. should be dated to the 14th century. The acquired series of dendrochronological dates allows to precise the time of constructing

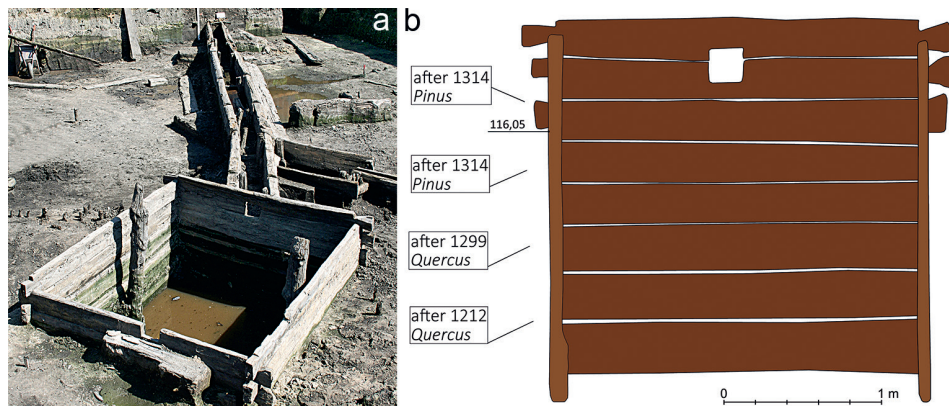


Fig. 8. Wrocław, Nowy Targ square, excavations 2010–2012. Stratigraphic unit 253. a view from the west, b SE wall from the inside (photo M. Mackiewicz, drawing M. Mackiewicz and N. Lenkow).

Obr. 8. Wrocław, náměstí Nowy Targ. Archeologický výzkum z let 2010–2012. Stratigrafická jednotka 253. a pohled od Z, b pohled na vnitřní stranu severovýchodní stěny dřevěné konstrukce.

wells and troughs to the first half of the century. Oak and pine wood was used as building material. In oak wood planks troughs were drilled and they were later covered with a plank, usually made of pine wood. The troughs set of three and four planks are made of pine wood and oak wood was sporadically used in that case. The main building material of waterwork wells was pine.

Additionally, some findings regarding the value of dendrochronological dates in studies on such devices were made. The acquired series of 30 dates informs about sometimes considerable discrepancies in dating of oak and pine wood used in the same constructions. Thus, a trough (s.u. 96) made of an oak tree cut down after 1294 was covered with a pine plank dated after 1327, which makes us date the whole device to the end of 1320s, or rather 1330s. In the construction of the well (s.u. 253), oak wood acquired after 1212 and pine samples dated after 1299 and 1314 were recorded (fig. 8). A trough joined to it from the east (s.u. 262) was made of pines cut down after 1280, in 1333, after 1343, after 1346, after 1359 and after 1385. It leads to a well (s.u. 525) made of pine wood acquired after 1310 r, in which an oak element from 1225 was also recorded. A pine trough transporting water, in turn, to the east from that well (s.u. 496), corresponding with the one described by Janczewski in his trenches no. 2, 4, 5, indicated the dates after 1344 and 1406. A well and a trough, defined as s.u. 317–318 and located at the eastern edge of the trench close to Piaskowa Street, also made of pine wood, was constructed using trunks cut down in the years 1281 – after 1317. This implies a conclusion that oak wood present in the waterworks was re-used, and the real time of construction of the waterworks is rather indicated by younger dates acquired from fragile pine wood. Large part of pine samples indicate the first half of the 14th century as the time of the realization of the venture.

Phase VII illustrates the continued use of the square. A layer marked as s.u. 7, present on the whole surface of the square, severely disturbed by present-day trenches, is what remained after it. It corresponds with layers C, B and A in settlement levels XI–XIII distinguished earlier by J. Kaźmierczyk (1970, 493–508). It is associated with leveling layers under pavings that were replaced several times. In the division of J. Niegoda (2005b, 74)

it is still settlement level VIII. The state of preservation of layers and constructions included in phase VII does not allow for an extensive reconstruction of the picture of the square at that time. Few relics of market devices preserved in the western part of the studied area. Those were stalls, divided into separate stands, a lightweight building in post-log construction and a spacious shed supported by posts placed in the ground. A basis for dating of phase VII are mainly stratigraphic hints and artefacts. The possibility to utilise dendrochronological analysis is limited in this case. In the discovered lower parts of the building re-used timber with traces of earlier working was used. The acquired dates are placed in the late 13th century and the first half of the 14th century. Considering all available aspects, we date our phase VII to the second half of the 14th and the beginning of the 15th century.

Phase VIII is connected with the use of the square in the modern times. The main part of layers that are the remains of that phase are connected with s.u. 1–2 and features related to them. They formed a complex consisting of mounds, the content of trenches dug for the elements of infrastructure and paving leveling layers repeatedly mixed. The dating of this phase was confirmed by several dendrochronological dates. However, they were rather irrelevant, as the phase lasted for a very long period of time.

Conclusions

In the reflections on the relation between stratigraphic findings and the results of dendrochronological analyses we were aware of limitations set by both categories of finds and methods of their analysis. Particular carefulness in the interpretation applies to medieval towns with its specific way of using timber. Timber discovered during urban excavations usually comes from the lowest parts of buildings, their foundations, wells and cesspits constructions as well as reinforcements of the surface of streets and squares. Observations made in Wrocław until now indicate that in those parts of constructions timber retrieved after demolitions was most often used, which means that trees cut down tens of years earlier could have been utilised (*Konczewski – Piekalski 2010*). Such characteristic of the way timber was used in the Middle Ages makes it more difficult to make use of dendrochronological analyses in dating archaeological discoveries. The series of samples taken from different elements of one construction often bring results that cover a vast chronological range, reaching even a hundred years. Re-used timber was used on a mass scale also in solid constructions of timber framed houses.

At Nowy Targ square in Wrocław all those phenomena were confirmed during the large-scale excavations from the years 2010–2012, and in the line trenches from 1999–2000 as well. Similar conclusions apply to other towns of Central Europe (*Kulessa 2001; Boschetti-Maradi – Kontić 2012; Schultze 2014; Krauskopf – Wiese 2014; Harder 2014*). It is worth stressing that the possibility of relatively safe dating of a construction is provided only by a long series of dates, and single samples might be misleading. Samples of fragile wood of coniferous trees have a significant informative value, while oak wood is less safe, as this durable wood could have been re-used several times. This proves that dendrochronology should not be treated as the only or even main basis for dating complex stratigraphic systems. In this respect a multi-directional analysis using also cultural indicators of chronology is essential. Large series of dendrochronological dates give, in turn, the possibility to study timber industry in a medieval town.

Considering the above remarks, the representativeness of sampling of the studied timber constructions is a significant issue. An analysis of some selected construction elements of discovered objects is a mistake that can cause interpretation difficulties. Sampling that embraces a relevant number of samples, first of all elements containing the longest sequences of growth rings and those with preserved sapwood growth rings, which enable dating with one year precision, should be a standard (see also *Bolka – Krapiiec 2012*).

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Bibliography

- Berdula, L. 1994:* Wyniki badań archeologiczno-architektonicznych we Wrocławiu przy ul. Świdnickiej 21/23. *Silesia Antiqua* 36/37, 77–94.
- Berdula, L. – Karst, M. – Fabisiak, W. – Zaleski, S. 1993:* Wyniki badań archeologiczno-architektonicznych na posesjach Kacerska Górka nr 6, 8, 10, 12, 14, 16 i Zaulek Koci nr 17, 19, 21, 23, 25, 27. *Silesia Antiqua* 35, 102–129.
- Biller, T. 1993:* Die Adelsburg in Deutschland. Entstehung, Form und Bedeutung. München: Deutscher Kunstverlag.
- Bolka, M. – Krapiiec, M. 2012:* Dendrochronological and radiocarbon dating of the medieval stronghold in Ujście (Poland). *Geochronometria* 39/1, 30–39.
- Boschetti-Maradi, A. – Kontic, R. 2012:* Möglichkeiten und Schwierigkeiten dendrochronologischer Untersuchung in Mittelalterarchäologie und Bauforschung. *Mitteilungen der Deutschen Gesellschaft für Archäologie des Mittelalters und der Neuzeit* 24. *Holzbau in Mittelalter und Neuzeit*, 49–60.
- Brather, S. 2008:* Archäologie der westlichen Slawen. Berlin – New York: De Gruyter (2nd edition).
- Bresch, J. – Buško, C. – Lasota, C. 2001:* Zachodnia pierzeja Rynku. In: C. Buško red., *Rynek wrocławski w świetle badań archeologicznych*. Part 1. *Wratislavia Antiqua* 3, Wrocław: Uniwersytet Wrocławski – Instytut Archeologii, 15–22.
- Buško, C. 1995:* Zaplecze gospodarcze kamienicy mieszczańskiej. Urządzenia wodno-kanalizacyjne. In: J. Rozpędowski ed., *Architektura Wrocławia 1: Dom*, Wrocław – Wydawnictwo Politechniki Wrocławskiej, 89–104.
- Buško, C. 1996:* Urządzenia wodno-kanalizacyjne w średniowiecznych i renesansowych miastach śląskich. *Archeologia Historica Polona* 3, 93–121.
- Buško, C. 1997:* Nawierzchnie ulic średniowiecznego Wrocławia. *Archeologia Historica Polona* 5, 117–132.
- Buško, C. ed. 2005:* Wschodnia strefa Starego Miasta we Wrocławiu w XII–XIII wieku. *Badania na placu Nowy Targ*. Wrocław: Gajt Wydawnictwo s.c.
- Buško, C. – Piekalski, J. 1993a:* Stratygrafia nawarstwień w obrębie parceli mieszczańskiej Kacerska Górka 18 / Zaulek Koci 29. *Silesia Antiqua* 35, 130–151.
- Buško, C. – Piekalski, J. 1993b:* Średniowieczna i nowożytna parcela mieszczańska przy ul. Kacerska Górka 20/ Zaulek Koci 31. *Silesia Antiqua*, 35, 152–175.
- De Meulemeester, J. – O’Conor, K. 2007:* Fortifications. In: J. Graham-Campbell – M. Valor, eds., *The Archaeology of Medieval Europe*. Vol. 1. Aarhus: Aarhus University Press, 316–341.
- Dwojak, A. 1993:* Kompleksowe badania archeologiczne w obrębie ulic Kacerska Górka i Zaulek Niski. *Silesia Antiqua* 35, 258–307.
- Goliński, M. 1997:* Socjotopografia późnośredniowiecznego Wrocławia (przestrzeń – podatnicy – rzemiosło). Wrocław: Wydawnictwo Uniwersytetu Wrocławskiego.
- Goliński, M. 2001:* XV-wieczny opis wrocławskiej sieci wodociągowej. In: R. Żerelik ed., *Studia i materiały z dziejów Śląska i Małopolski*, Wrocław: Arboretum, 105–123.
- Grewe, K. 1991:* Wasserversorgung und -entsorgung im Mittelalter. In: *Die Wasserversorgung im Mittelalter*. *Geschichte der Wasserversorgung* 4, Mainz am Rhein: Von Zabern, 11–86.
- Grünhagen, C. 1861:* Breslau unter den Piasten als deutsches Gemeinwesen. Breslau: Josef Max & Komp.
- Harder, J. 2014:* Vom Gebrauch des Gebrauchten. Beispiele der Wiederverwendung von Hölzern anhand aktueller Befundlagen der Hansestadt Lübeck. *Mitteilungen der Deutschen Gesellschaft für Archäologie des Mittelalters und der Neuzeit* 26, 143–150.

- Henning, J. 1998: Archäologische Forschungen an Ringwällen in Niederungslage. Die Niederlausitz als Burgenlandschaft des östlichen Mitteleuropas im frühen Mittelalter. In: J. Hennig – A. Ruttkay Hrsg., Frühmittelalterlicher Burgenbau in Mittel- und Osteuropa. Tagung Nitra 1998, Bonn: Habelt, 9–29.
- Hensel, W. 1987: Słowiańszczyzna wczesnośredniowieczna. Warszawa: PWN.
- Hernbrodt, A. 1958: Der Husterknupp. Eine niederheinische Burganlage des frühen Mittelalters. Köln – Bonn: Böhlau Verlag.
- Hilczarówna, Z. 1956: Ostrogi polskie z X–XIII wieku. Poznań: Państwowe Wydawnictwo Naukowe.
- Hinz, H. 1981: Motte und Donjon. Zur Frühgeschichte der mittelalterlichen Adelsburg. Köln: Rheinland-Verlag; Bonn: Habelt.
- Janczewski, P. 2005: Urządzenia wodno-sanitarne we wschodniej części Starego Miasta we Wrocławiu. In: C. Buśko ed., Wschodnia strefa Starego Miasta we Wrocławiu w XII–XIV wieku. Badania na placu Nowy Targ, Wrocław: Gajt Wydawnictwo s.c., 85–96.
- Kaźmierczyk, J. 1966: Wrocław lewobrzeżny we wczesnym średniowieczu, part 1. Wrocław: Ossolineum.
- Kaźmierczyk, J. 1970: Wrocław lewobrzeżny we wczesnym średniowieczu, part 2. Wrocław: Ossolineum.
- Kaźmierczyk, J. 1991: Ku początkom Wrocławia, pt. 1. Warsztat budowlany i kultura mieszkalna Ostrowa Tumskiego od X do połowy XI wieku. Wrocław – Warszawa: Volumen.
- Klápště, J. – Kyncl, J. – Kyncl, T. 2000: Dendrochronologie mostecké studny 1/80 a předpoklady objektivní archeologické datace. Archeologické rozhledy 52, 679–687.
- Konczewski, P. – Piekalski, J. 2011: The streets of medieval Wrocław – methods of construction and functions. In: J. Piekalski – K. Wachowski eds., Ulica, plac i cmentarz w publicznej przestrzeni średniowiecznego i nowożytnego miasta Europy Środkowej – Strasse, Platz Und Friedhof In dem öffentlichen Raum der mittelalterlichen Und frühneuzeitlichen Stadt Mitteleuropas. Wratislavia Antiqua 13, Wrocław: Uniwersytet Wrocławski. Instytut Archeologii, 155–162.
- Krauskopf, Ch. – Wiese, J. 2014: Altholz oder Stapelholz? Wiederverwendung und Lagerung von Bauholz im Mittelalter am Beispiel der Holzbefunde aus Eberwalde. In: Mitteilungen der Deutschen Gesellschaft für Archäologie des Mittelalters und der Neuzeit 26, 131–142.
- Krawczyk, A. – Krapiec, M. 1995: Dendrochronologiczna baza danych. In: Materiały II Krajowej Konferencji „Komputerowe wspomaganie badań naukowych”, 14.–16.12.1994 r., Wrocław: Wrocławskie Towarzystwo Naukowe, 247–249.
- Krapiec, M. 1993: Analiza dendrochronologiczna drewna z Placu Dominikańskiego. Silesia Antiqua 35, 364–381.
- Krapiec, M. 1998: Oak dendrochronology of the Neoholocene in Poland. Folia Quaternaria 69, 5–133.
- Kulessa, B. 2001: Dendrochronologische Datierung und die Deutung der Ergebnisse im archäologischen Befund an Hand ausgewählter Beispiele aus der Hansestadt Stralsund. In: J. Pfromen – R. Schreg Hrsg., Zwischen den Zeiten. Archäologische Beiträge zur Geschichte des Mittelalters in Mitteleuropa, Rahden/Westf.: Verlag Marie Leidorf GmbH, 379–395.
- Marcinkiewicz, K. – Mackiewicz, M. – Piekalski, J. 2014: Excavations at Nowy Targ (New Market) Square in Wrocław, preliminary report. Śląskie Sprawozdania Archeologiczne 55, 303–318.
- Markgraf, H. 1881: Breslau als deutsche Stadt vor dem Mongolenbrande von 1241. Zeitschrift des Vereins für Geschichte und Alterthums Schlesiens 15, 527–544.
- Młynarska-Kaletynowa, M. 1986: Wrocław w XII–XIII wieku. Przemiany społeczne i osadnicze. Wrocław: Ossolineum.
- Mruczek, R. 2000: Kurzy Targ we Wrocławiu. Uwagi o pierwotnym planie miasta. In: J. Piekalski – K. Wachowski eds., Centrum średniowiecznego miasta. Wrocław a Europa Środkowa. Wratislavia Antiqua 2, Wrocław: Uniwersytet Wrocławski. Instytut Archeologii, 260–278.
- Niegoda, J. 2005a: Układ stratygraficzny. In: C. Buśko ed., Wschodnia strefa Starego Miasta we Wrocławiu w XII–XIV wieku. Badania na placu Nowy Targ, Wrocław: Gajt Wydawnictwo s.c., 18–68.
- Niegoda, J. 2005b: Zmiany w zagospodarowaniu przestrzeni w rejonie placu Nowy Targ w XII–XIV w. In: C. Buśko ed., Wschodnia strefa Starego Miasta we Wrocławiu w XII–XIV wieku. Badania na placu Nowy Targ, Wrocław: Gajt Wydawnictwo s.c., 69–84.
- Piekalski, J. 1995: Ze studiów nad drewnianą zabudową Wrocławia w późnym średniowieczu. In: J. Rozpędowski ed., Architektura Wrocławia 1: Dom, Wrocław: Wydawnictwo Politechniki Wrocławskiej, 75–87.
- Piekalski, J. 2004: Die Infrastruktur der mittelalterlichen und frühneuzeitlichen Stadt Breslau. In: M. Gläser ed., Lübecker Kolloquium zur Stadtarchäologie im Hanseraum IV. Die Infrastruktur, Lübeck: Schmidt-Römhild, 343–358.

- Piekalski, J. 2016: Stratygrafia a dendrochronologia na placu Nowy Targ we Wrocławiu. In: G. Nawrońska et al. eds., *Archeologia miast Pomorza w kontekście ziem polskich*, Gdańsk: Muzeum Archeologiczne w Gdańsku, 107–123.
- Piekalski, J. – Wachowski, K. eds. 2018: Rytm rozwoju miasta na kulturowym pograniczu. Studium strefy placu Nowy Targ we Wrocławiu. *Wratislavia Antiqua* 23. Wrocław: Uniwersytet Wrocławski. Instytut Archeologii.
- Płonka, T. – Wiśniewski, Z. 1989: Odcinek Kociego Wodociągu na terenie Nowego Miasta we Wrocławiu w świetle badań archeologicznych przy ulicy Bernardyńskiej w roku 1988. In: S. Januszewski ed., *Zabytki techniki wodociągowej Polski*, Wrocław: Komitet Ochrony Zabytków Techniki, 51–68.
- Rinn, F. 2005: TSAP-Win. Time series analysis and presentation for dendrochronology and related applications. User Reference. Heidelberg: Rinntech.
- Rzeźnik, P. 2005: Ceramika naczyniowa z wykopu nr 1 na placu Nowy Targ. In: C. Buśko ed., *Wschodnia strefa Starego Miasta we Wrocławiu w XII–XIV wieku. Badania na placu Nowy Targ*, Wrocław: Gajt Wydawnictwo s.c., 97–110.
- Schultze, J. 2014: Die Aussagemöglichkeiten der Dendrochronologie zur Wiederverwendung von Bauholz am Beispiel von Haithabu. Mitteilungen der Deutschen Gesellschaft für Archäologie des Mittelalters und der Neuzeit 26, 113–121.
- Sowina, U. 2009: Woda i ludzie w mieście średniowiecznym i wczesnonowożytnym. *Ziemie polskie z Europą w tle*. Warszawa: Instytut Archeologii i Etnologii PAN.
- Stein, B. 1995: Bartłomiej Steina renesansowe opisanie Wrocławia (Die Beschreibung der Stadt Breslau der Renaissancezeit durch Bartholomaeus Stein, published by R. Žerelik). Wrocław: Arboretum.
- SUB: Schlesisches Urkundenbuch, Bd. 1: 1963–1971, hg. Heinrich Appelt. Wien – Köln – Graz: Hermann Böhlau; Bd. 2: 1977, hg. Winfried Irgang. Wien – Köln – Graz: Hermann Böhlau; Bd. 3–4, hg. Winfried Irgang, Köln – Wien: Böhlau Verlag 1984–1988; Bd. 5: 1993, hg. Winfried Irgang, Köln – Weimar – Wien: Böhlau Verlag.
- Szychowska-Krapiec, E. 2010: Long-term chronologies of pine (*Pinus sylvestris* L.) and fir (*Abies alba* Mill.) from the Małopolska region and their palaeoclimatic interpretation. *Folia Quaternaria* 79, 1–122.
- Urbańczyk, P. ed. 2004: Polish Lands at the Turn of the First and the Second Millenia, Warszawa: Institute of Archaeology and Ethnology Polish Academy of Sciences.
- Wiśniewski, Z. 1995: Przyczynek do studiów nad średniowiecznym i renesansowym zaopatrzeniem Wrocławia w wodę. In: K. Wachowski, *Kultura średniowiecznego Śląska i Czech. Miasto*, Wrocław: Wydawnictwo Uniwersytetu Wrocławskiego, 183–206.
- Zielski, A. – Krapiec, M. 2004: Dendrochronologia. Warszawa: Wydawnictwo Naukowe PWN.
- Zientara, B. 2006: Henryk Brodaty i jego czasy. Warszawa: Wydawnictwo Trio.