

World's oldest dendrochronologically dated archaeological wood construction

Michal Rybníček^{a,b,*}, Petr Kočár^{c,d}, Bernhard Muigg^e, Jaroslav Peška^c, Radko Sedláček^a, Willy Tegel^e, Tomáš Kolář^{a,b}

^a Department of Wood Science, Faculty of Forestry and Wood Technology, Mendel University in Brno, Zemědělská 3, 61300, Brno, Czech Republic

^b Global Change Research Institute of the Czech Academy of Sciences, Bělidla 986/4a, 60300 Brno, Czech Republic

^c Archaeological Centre Olomouc, U Hradiska 42/6, 77900, Olomouc, Czech Republic

^d Institute of Archaeology of the Czech Academy of Sciences, Letenská 4, 11801, Praha, Czech Republic

^e Institute of Forest Sciences, University of Freiburg, Tennenbacher Str. 4, 79106, Freiburg, Germany

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ABSTRACT

In 2018, during the construction of a motorway in the East Bohemian Region near the town of Ostrov (Czech Republic), archaeologists excavated a structure of a wooden water well lining with a square base area of 80×80 cm and 140 cm in height. Due to the excellent conservation of the oak timbers, studies of technological details and precise tree-ring dating were possible. The used trees were felled in the years 5256/55 BC, which makes this well the oldest dendrochronologically dated archaeological wooden construction worldwide. It is the third well from the Early Neolithic period that has been discovered in the Czech Republic within the last four years. The design consists of grooved corner posts with inserted planks. This type of construction reveals advanced technical know-how and, till now, is the only known type from this region and time period. Thanks to the combination of annually resolved and absolutely dated tree-ring widths (TRWs), the Czech oak TRW chronology has been significantly extended back to 5481 BC. Wood anatomical identification of fragments from the well filling show mainly oak (*Quercus* spp.) and hazel (*Corylus* spp.), indicating a local forest composition dominated by these taxa. The shape of the individual structural elements and tool marks preserved on their surface confirm sophisticated carpentry skills. Based on these observations, we established a model for the “chaîne opératoire” from forest utilization to the final artefact at the beginning of the Early Neolithic period.

1. Introduction

The increased building activities in the Czech Republic have recently led to an increased amount of archaeological discoveries. Currently, one of the largest construction sites in Czech Republic is the D35 motorway, which is supposed to connect Bohemia and Moravia through the northern part of the territory. During construction in 2018, the structure of a water well was found at the northern border of the town of Ostrov ($49^{\circ}58'35''\text{N}$, $16^{\circ}02'21''\text{E}$, 270 m ASL). The first archaeological pottery findings indicated that the well dates back to the Linear Pottery Culture (LBK), i.e., the Early Neolithic period. Today, over 40 Neolithic water wells are known in Europe (Rybníček et al., 2018). These wells represent the oldest dendrochronologically dated wooden structures in the world (Tegel et al., 2012). The design of the Ostrov well lining is exceptional for the period and thus far is limited to finds from Czech Republic

(Rybníček et al., 2018). Due to the uniqueness of this discovery, the well was removed en bloc and carefully excavated under laboratory conditions, dismantling the wooden structure.

The aims of this study are 1) to date the wood construction using dendrochronological methods, 2) to compare the age and design with other well linings, 3) to suggest a potential chaîne opératoire of the construction process, 4) to use the absolutely dated tree-ring widths series to extend the Czech oak TRW chronology.

2. Material and methods

The top rim of the well-pit was nearly square shaped, with dimensions 2.58×2.46 m. At the place of the wooden structure, the ground plan of the well-pit was circular, with 1.32 m in the diameter, and its total depth was 3.14 m. The wooden lining of the well was found

* Corresponding author. Mendel University in Brno, Zemědělská 3, 613 00, Brno, Czech Republic.

E-mail address: michalryb@post.cz (M. Rybníček).

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at a depth of 1.74 m below the surface. The well filling was poor as regards archaeological finds. Only the upper parts yielded one clay container and a fragment of an antler. Only exceptionally, small fragments of ceramics were found in the remaining parts.

The excellent conservation of the timbers from the well under waterlogged conditions allowed a detailed description of the structure and dating with dendrochronological as well as radiocarbon methods. Only the top horizontal planks and the tops of the corner posts could not be dated as they have substantially degraded due to the fluctuations of the groundwater.

In this study, we took samples from 21 of the wooden elements of the well for a dendrochronological analysis with an increment borer or sawing cross-sections. In total, 21 samples were measured using the VIAS TimeTable (Vienna Institute for Archaeological Science, Vienna, Austria) measuring system. The tree-ring width (TRW) series were measured with an accuracy of 0.01 mm and synchronized using software PAST4 (©SCIEM). The mean TRW series were dated according to the oak TRW chronology from Saxony (Tegel et al., 2012). The degree of similarity between the TRW series was assessed by t-tests (TBP - Baillie and Pilcher (1973); THO - Hollstein (1980) and Gleichläufigkeit (Eckstein and Bauch, 1969)).

To independently verify the dendrochronological results, a sample of the wooden structure as well as one hazel nut and one oak charcoal fragment from the well filling were selected for radiocarbon dating at the Isotoptech Zrt. in Debrecen (Hungary).

Fragments of wood and charcoals were separated from the sediments following the wet sieving procedure (Carcaillet and Talon, 1996). Wood pieces were manually selected from the sieved fractions. Wood anatomical analyses were only performed on fragments of the (>2 mm fraction). The samples were taxonomically identified based on wood anatomical features under an episcopic microscope at magnifications of 100, 200 and 300 × using the atlas for the identification of European wood species (Schweingruber, 1990) and a comparison with our wood and charcoal reference collection.

3. Results and discussion

3.1. Description of well construction

A chest-like well lining was formed by four oak corner posts, each with two longitudinal grooves, set at 90° to each other, in which oak planks were inserted horizontally in seven layers. The external dimensions of the water well were 80 × 80 cm (the inner dimensions were 66 × 58 cm) and 140 cm in height in total. The diameter of the posts

ranged from 15.5 to 22 cm and they had 33 to 80 tree rings. Their length ranged from 121 to 150 cm and their bottom ends were chamfered. The width of the longitudinal grooves was from 5.5 to 8.5 cm and the depth from 4.5 to 5.5 cm. The planks were split from tree trunks, and the length of the planks was between 49 and 58 cm, their width was between 14 and 24.5 cm, and their thickness was between 2 and 5.5 cm. The planks formed the wall of the well lining and additionally, reinforced it in the transverse direction (Figs. 1 and 2 and video 1).

Supplementary video related to this article can be found at <https://doi.org/10.1016/j.jas.2020.105082>.

3.2. Dating

The fifteen best correlated oak (*Quercus* spp.) TRW series create a site chronology covering 240 years with strong correlations to the Saxon oak TRW chronology. In total, 21 TRW series were measured, out of which, 18 TRW series could be absolutely dated. Five of the dated samples still contained sapwood and on one sample, the wany edge was preserved (Table 1), which improves the dating precision of the tree felling. The number of sapwood tree rings detected in the dated oak samples falls within the range (5–25 rings) defined by Rybníček et al. (2006) and Prokop et al. (2017). The trees used for the horizontal planks of the well were cut between 5256 and 5255 BC. It is interesting that at least two of the corner posts were made from trees felled earlier. The first post was made from a trunk felled in the autumn or winter of 5259/58 BC and the other was felled at least nine years earlier (Table 1). The similarity between Saxony TRW chronology and the mean TRW series from the Ostrov well is reliable (Fig. 3). When tree-ring series overlap by more than 120 rings, the critical value of Student's t-distribution with a 0.001% level of significance is 3.7 (Fowler and Bridge, 2017). The values of our t-tests are 5.96 and 5.48, respectively, and therefore exceed the threshold, which shows a high probability of the synchronization. The accuracy of the synchronization is also proved by the agreement of the average tree-ring series in most of the extreme values (Fig. 3) and confirmed by the results of the radiocarbon dating. Additionally, the radiocarbon dates of the hazel nut and charcoal from the well filling confirm the same period (Table 1). In addition, one plank (D33) found in the well is younger than the main construction and is most likely related to a later repair (5241–5224 BC). Dendrochronological dating certifies that the well from Ostrov is one of the oldest archaeological wooden constructions worldwide. The oldest dendrochronologically dated wells from Germany are known from Erkelenz (5091 BC), Altscherbitz (5098 BC) and Eythra (5205 BC) (Tegel et al., 2012). There are various archaeological wooden finds from earlier periods, one of the most

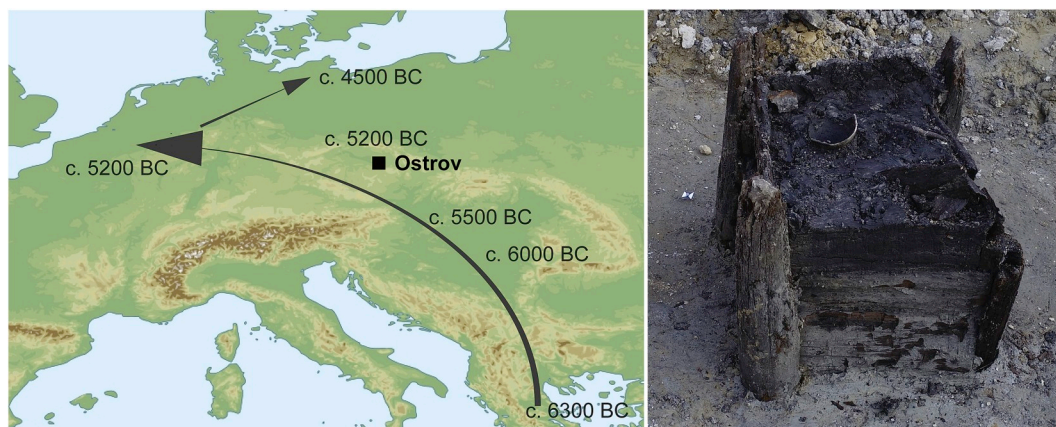


Fig. 1. Map with dates of the expansion of Neolithic things and practices into Europe from Western Asia. Copyright © Victor Jimenez Jaimez 2015 – Creative Commons Attribution-ShareAlike (CC BY-SA) 3.0 Unported. Source (with additions of my own): Guilaine, J. 2015. The Neolithization of Mediterranean Europe. In Fowler, C., Harding, J. and Hoffman, D. The Oxford Handbook of Neolithic Europe. Oxford University Press, pp. 81–98. The underlying topographic map of Western Europe derived from https://commons.wikimedia.org/wiki/File:Western_Europe_DEMIS_topographic_map.svg, originally a work of Wikipedia user Pethrus under a Creative Commons Attribution-Share Alike 3.0 Unported license and the picture of the Neolithic well from Ostrov.

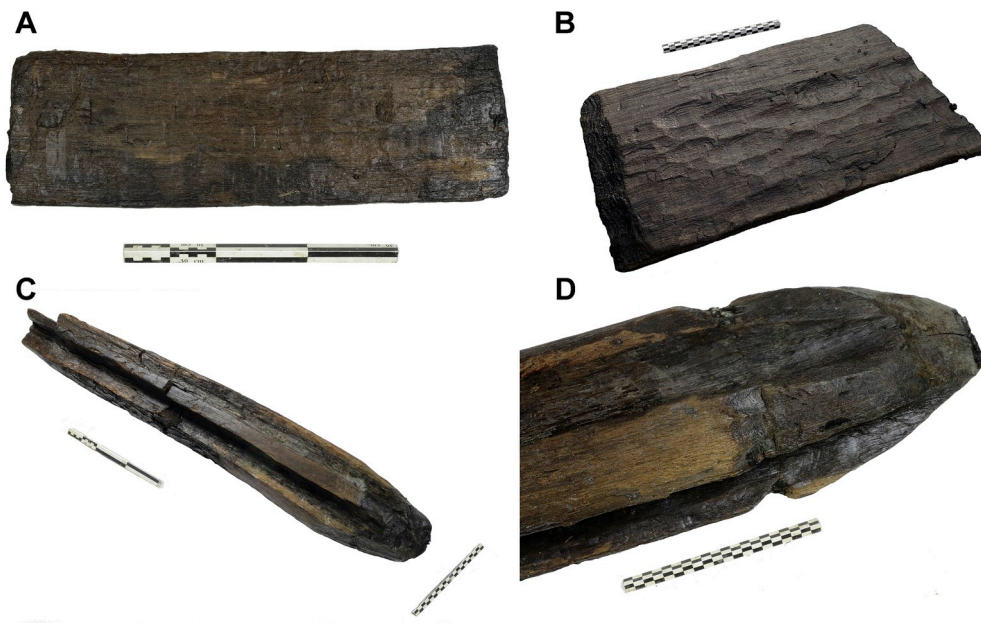


Fig. 2. Details of individual wooden parts from the Ostrov well: (A) radial plank, (B) detail of working, (C) a corner post, (D) grooves hewn along the post.

Table 1

The results of the dating of samples from the Ostrov well (the samples contain heartwood rings (ak – Außenkante), sapwood rings (ks – Kern/Splint), or waney edges (wk – Waldkante)). For oaks in the territory of the Czech Republic, sapwood usually contains at least 5 and at most 25 tree rings based on the tree age and location (Rybníček et al., 2006; Prokop et al., 2017). Samples marked with * are samples from the same trunk.

Sample no.	Element	Tree species	Number of rings	Outermost ring	Final year	Dendrochronological dating (yr BC)	14C age (yr BP)	Cal. age (2 sigma yr BC)
D40	plank	oak	158	+1 ak	5279	after 5273	–	–
D27*	plank	oak	98	+1 ak	5295	after 5289	–	–
D14	plank	oak	163	+1 ks	5257	5256–5246	–	–
D16*	plank	oak	159	+1 ak	5287	after 5281	–	–
D48*	plank	oak	139	+1 ak	5296	after 5290	–	–
D33	plank	oak	172	+1 ks	5242	5241–5224	–	–
D34	plank	oak	160	+1 ks	5260	5259–5254	6298 ± 34	5341–5214
D41*	plank	oak	135	+3 ak	5305	after 5297	–	–
D47*	plank	oak	91	+6 ak	5391	after 5380	–	–
D3	plank	oak	90	+2 ak	5305	after 5298	–	–
D10*	plank	oak	156	+1 ak	5289	after 5283	–	–
D23*	plank	oak	112	+1 ak	5290	after 5284	–	–
D5	plank	oak	87	+16 ak	5295	after 5274	–	–
D8	plank	oak	70	+38 ak	–	undated	–	–
D37	plank	oak	29	+1 ak	–	undated	–	–
D29*	plank	oak	189	+2 ak	5286	after 5279	–	–
D17	plank	oak	147	+3 ks	5264	5261–5255	–	–
D55	post	oak	70	+5 ks	5287	5282–5268	–	–
D52	post	oak	32	+1 wk	–	undated	–	–
D45	plank	oak	125	+6 ks	5267	5261–5241	–	–
D54	post	oak	78	+4 wk	5260	5259/5258	–	–
–	nut	hazel	–	–	–	–	6100 ± 31	5207–4934
–	charcoal	oak	–	–	–	–	6243 ± 31	5307–5076

famous examples being the Palaeolithic hunting spears from Schönningen, Germany (Thieme, 1997) with an estimated age of 337,000–300,000 years (Richter and Krbetschek, 2015). Some sources indicate that Shigir Idol is the oldest known wooden sculpture in the world, made during the Mesolithic period, approximately 9500 BC (Zhilin et al., 2018). The Pesse canoe is believed to be the world's oldest known boat, and certainly the oldest known canoe. Dating indicates that the boat was constructed during the early Mesolithic period between 8040 BCE and 7510 BCE (Zeist, 1957). However, neither of these archaeological wooden findings was dated by dendrochronological methods. In cases of absolute dates, less precise dating techniques such as radiocarbon or thermoluminescence dating were used. The well from Ostrov is not the oldest water well in the world; there are, e.g., two wells from Jezreel Valley and Atlit in Israel from 6500 BC (<https://embassies.gov.il>; Galili et al., 1993).

Furthermore, there are two wells in Cyprus from 7500 BC (<http://news.bbc.co.uk>), which were hewn into the rock, i.e., without a wooden structure. As the Neolithization expanded from the Middle East to Central Europe via the Balkan Peninsula (Fig. 1), we can assume that older wells with wooden structures might be discovered along this path. There have been reports on wells found in Sajószentpéter (5400–5200 BC) (Király and Tóth, 2015) and Tiszakürt (5600–5400 BC), both in Hungary (<http://www.visegradgroup.eu>). However, there are no absolutely dated regional tree-ring chronologies long enough to date these findings by dendrochronological methods. Therefore, the well from Ostrov is the oldest dendrochronologically dated wood construction in the world.

The question of how and why Neolithic things and practices reached all of Europe from South-Western Asia is one of the key debates in the

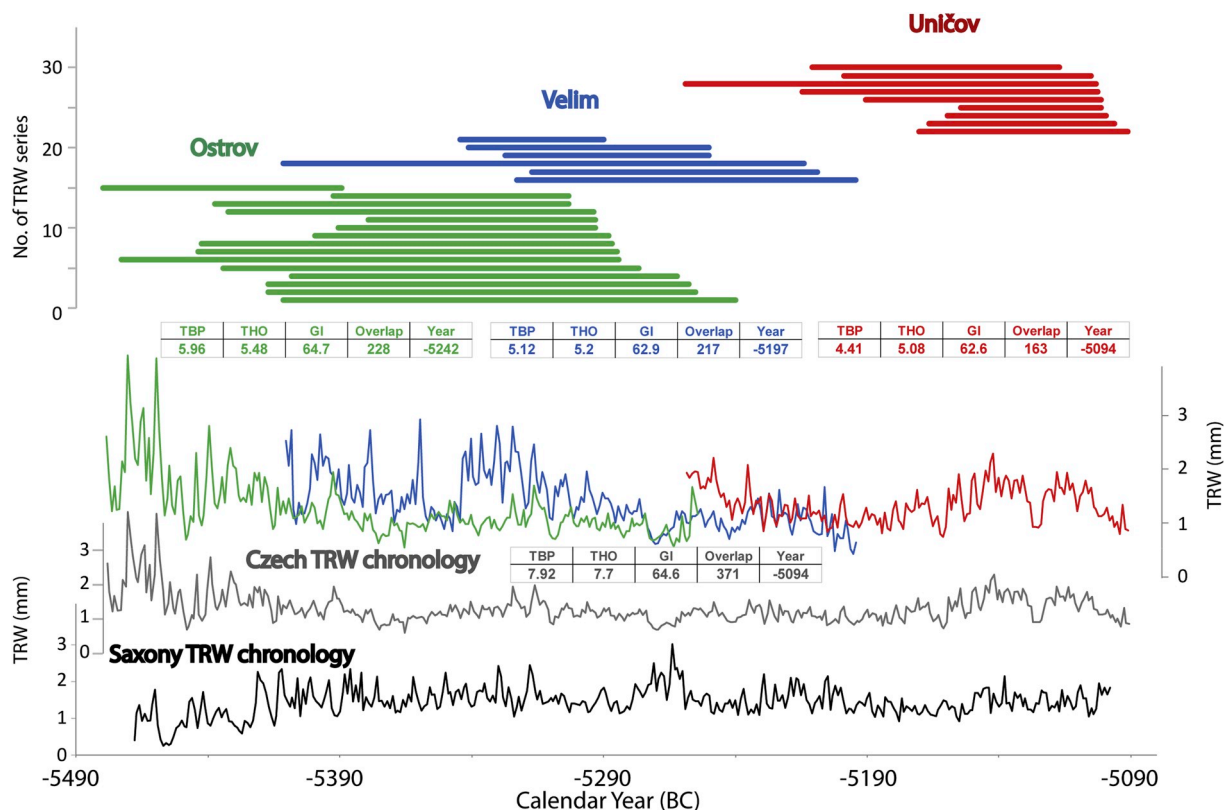


Fig. 3. Temporal distribution of the oak ring width series: the Ostrov well (green), the Velim well (blue) and the Uničov well (red), synchronization of mean TRW series from Czech Neolithic wells – Ostrov (green), Velim (blue) and from Uničov (red) (Rybníček et al., 2018) with Saxony TRW oak chronology (Tegel et al., 2012) (t-test according to Baillie & Pilcher (TBP), t-test according to Hollstein (THO), synchronization of tree-ring series in % (Gleichläufigkeit). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

discipline of archaeology (Price, 2000; Gronenborn and Dolukhanov, 2015). The wells with a wooden structure found in Hungary, Czech Republic and Germany might be structures brought by Southwestern Asian inhabitants, or they might be structures developed to suit the specific conditions and needs of the inhabitants of the European regions mentioned. Studies into the hydroclimate reconstruction in Central Europe report dry and wet seasons (Büntgen et al., 2010, 2011; Dobrovolský et al., 2018). One of the studies even indicated an extraordinarily high frequency of severe dry and wet spring-summer seasons during the entire LBK, with particularly high year-to-year variability from 5400 to 5101 BC (Pechtl and Land, 2019). Thus, the need to make wells is very likely, both due to the drought and pollution of surface water by floods in this period.

By combining the newly gained absolutely dated TRW series with the earlier dated TRW series from the Early Neolithic wells from Uničov and Velim (Rybníček et al., 2018), a unique dataset was created, substantially extending the Czech oak TRW chronology. Currently, the TRW series cover 389 years, from 5481 to 5093 BC (Fig. 3).

3.3. Possible chain of operations (chaînes opératoires)

The surfaces of the horizontal planks showed tool marks typical for stone adzes (Petrequin and Petrequin, 2011; Walter et al., 2012; Elburg et al., 2015; Hein, 2015). Tool marks of polished stone tools – such as axes and shoe-adzes – which were most commonly made from metabasites can be observed, especially on the notches on each post and the ends and surfaces of the horizontal planks. Generally, more marks are visible on the external sides of the planks due to mechanical abrasion on the inside of the well. The tool marks show widths between 2.9 and 4.3 cm. They are arranged in up to eight parallel lines.

The possible chain of operations consists of several steps. First,

suitable trees, i.e., oaks with a sufficient diameter and a straight trunk, were selected a) for the corner posts and b) for the planks. The trees were then felled. The corner posts required stem diameters of approximately 20 cm. An oak with a 20 cm diameter at breast height can reach a height of up to 15 or 25 m (Seidel and Kenk, 2003). Theoretically, when the crown/trunk ratio is at least 50%, the useable tree trunk length might be 7.5–12.5 m. The number of tree rings was 33 in the first post (D52), 75 in the second post (D55), and 82 tree rings were found in the third post (D54). No sample was taken from the fourth post (D53) because of the necessary destructive intervention, but the number of tree rings was roughly estimated on the top of the post (50 tree rings). This would suggest that the posts were made from at least two different tree trunks: posts D53 and D52 from one and posts D54 and D55 from another. However, the dendrochronological dating of posts D54 and D55 has indicated that the tree used for the production of post D55 was felled at least 9 years earlier than the tree used to produce post D54. Therefore, they could not be made from the same tree trunk. Only a similarity of the tree-ring series of the posts could reveal how many different trunks the posts were made of. Such a comparison could not be done as no sample for dendrochronological analysis was taken from post D53, as mentioned above, and the TRW series from post D52 is too short for reliable comparison. In two posts, there are grooves hewn along the perimeter, which were probably made for the transport of the trunks by means of a rope (Fig. 2). The above-mentioned findings show that at least two trunks must have been used. It is likely that the trunks were not cut to the required length immediately after felling but were transported in larger lengths corresponding to the production of at least two posts (approximately 4 m). The density of the pedunculate oak (*Quercus robur*) and the sessile oak (*Quercus petraea*) increases with moisture content and can range from 650 kg/m³ at zero moisture content up to 1000 kg/m³ in the case of freshly felled oak wood (Wagenführ, 2000; Kolář et al., 2014;

Vavřík and Gryc, 2012). This means that the weight of a trunk with the estimated dimensions would be approximately 125 kg, which can be transported without difficulty. After dragging the trunks to the well construction site, the trunks were shortened to the required length. Since large remains of bark have been found on one of the posts, we assume that the tree trunks were not debarked. It is not quite clear whether the post ends were deliberately worked to form tips or whether the shape of the post ends was slightly pointed due to the technology used to shorten the trunks to the desired length. The next step was the construction of longitudinal grooves (Fig. 2). The grooves were made as late as during this stage, as evidenced by the way the grooves go over the previously done tool marks created by shortening the trunks to the required length. In the next step, the posts were inserted in a dug hole. The total length of the posts could be slightly greater than the preserved length of the highest post - 150 cm. This is indicated by the heavily degraded upper parts of the posts, which were located in an environment affected by a fluctuating groundwater level compared to the lower parts of the posts.

For the production of the well lining, 200-year-old oaks with a diameter of at least 60 cm were used. These trunks were probably not transported in their entire length. To produce 28 radially split planks approximately 60 cm long, including at least 20 cm required for the transverse division of the trunk, a trunk of at least 3 m in length would be necessary. Such a trunk would weigh approximately 850 kg. However, by comparing the tree-ring series of the planks used to form the well lining, we can conclude that a minimum of 8 planks were made from the same tree trunk (TBP and THO higher than 10). In addition, all the planks used for the construction of the well lining were produced from at least three different tree trunks, of which the oldest tree reached an age of nearly 200 years. Technically, the necessary 28 planks could have been produced out of three trunks approximately 2 m long, but such trunks would weigh more than 500 kg. Therefore, the trunks had to be felled either in the immediate vicinity of the well, or the trunks were divided into approximately 0.8 m long pieces, which could be transported more easily. Subsequently, the trunks were split lengthwise several times in the radial direction. In one case, a tangential plank was used. However, we assume that the trees were cut and split fresh on site. Only the planks were transported and then cut to the final length just before or during the installation of the planks between the two corner posts. The transport of planks instead of trunks would be far easier. This theory is confirmed by the tool marks at the ends of the horizontal planks. As the width of the longitudinal grooves in the posts was 5.5–8.5 cm and the thickness of the planks was not more than 5.5 cm, the plank ends did not have to be chamfered. The tool marks at the plank ends thus correspond to a process of shortening the plank lengths rather than a deliberate chamfering of the planks for a better installation in the grooves. The planks were gradually inserted between the posts, which meant a gradual reinforcement of the entire construction. From the outside, the well lining was fixed only by the pressure of the soil. It means the space between the walls of the well and the pit had to be filled immediately after the assembly of the lining.

3.4. Comparison of the structure

Until recently this construction design with grooved corner posts and inserted planks was only known from the Bronze Age, Roman times and the Middle Ages (Gollnisch-Moos, 1999; Rágeš, 1986; Tegel et al., 2012). The existence of this type of construction in the Early Neolithic Period, i.e., a few thousand years earlier, was confirmed by the dendrochronological dating of the well from Uničov, Czech Republic (5093–5085 BC) (Rybníček et al., 2018). The dendrochronological dating of the Ostrov well even further confirms the existence of this design at least 150 years earlier.

However, the dimensions of the Ostrov well are much smaller, as documented for the Uničov well. The maximum length of the side planks is 58 cm. At a depth of grooves approximately 5 cm on both sides, the maximum internal width is 48 cm. The maximum length of the planks in

Uničov is 85 cm; at roughly the same depth of grooves, the internal width of the well is approximately 75 cm (Rybníček et al., 2018). Another difference is the diameter of the corner posts used. The posts of the Uničov well are of a smaller diameter than those of the Ostrov well. This may also be the reason why a further five vertical posts, which could serve as an auxiliary structure, were found in Uničov. The posts of the Uničov well were from much younger individual trees (20–30 years of age), the age of the trunks used for the Ostrov well posts, except one of them, was significantly higher (50–80 years of age). The Uničov posts show no traces that the trunks were transported.

The ends of the horizontal planks of the Uničov well were chamfered, whereas this is not the case of the Ostrov well. As mentioned above, the tool marks at the plank ends are likely tool marks caused by shortening the planks to the required length. This also corresponds to the slightly wider grooves in the corner posts of the Ostrov well compared to the width of the grooves in the Uničov well. The chamfering of the plank ends from the Uničov well was necessary because thicker planks (up to 9 cm) were used than in the Ostrov well, where the thickest planks reached 5.5 cm in width.

3.5. Anatomical identification of the wood fragments

A large amount of plant residues have been preserved within the well filling. For example, pollen of higher plants, spores of lower plants, stems of mosses, glumes of prehistoric einkorn and emmer wheats, and rarely found flax and poppy seeds. In addition, a large amount of charcoal fractions and non-carbonized wood were found. The results of anatomical identification of the wood fragments from the well content show a clear dominance of oak (*Quercus* spp.) (272 samples out of 293). Simultaneously, the anthracological analysis has revealed that oak is the second most represented tree species in the set of charcoals from this well, after hazel (*Corylus* spp.). The rest of the set of charcoals is formed by birch (*Betula* spp.) and maple (*Acer* spp.). These results are a strong indication for the dominance of oak in the surrounding forest, which corresponds to the hypothesized contemporary regional forest species composition at lower elevations, i.e., mesophilic oak forests. Hazel populations reached their Holocene maximum in this period (Rybníčková, 1985; Novák et al., 2017).

4. Conclusions

Although this is already the second finding of the same structure from the Early Neolithic Period in the Czech Republic, it is still true that this is a completely unique structure, which is not known from another territory across Europe from this period (Rybníček et al., 2018). Our observations are in agreement with Tegel et al. (2012) regarding the technical skills of the first sedentary societies in Central Europe. The available technology, i.e., tools made of stone, bones, horn or wood, was sufficient for sophisticated carpentry. Comparing the structure of the Ostrov well with examples of carpentry from later periods raises nothing less than admiration for the perfectly precise work. Dendrochronological dating (5256/55 BC) has confirmed that this is not only the oldest discovered wooden well in Europe but also the oldest dendrochronologically dated archaeological wood in the world.

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