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Dendroarchaeological evidence of early medieval water mill technology

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ABSTRACT

The use of hydropower provides an important technical advancement over hand-operated grain mills, which steadily increased over large parts of Europe from the early Middle Ages onwards. Since written information on the technical design of early medieval water mills is generally missing, archaeological evidence may provide unique insights into their evolution. Well-preserved wooden finds from continental Europe are, however, extremely rare. Here we present dendroarchaeological results from an exceptional number of structural elements of the Audun-le-Tiche water mill in northern France. Taxonomical identification, tree-ring dating and observations of technical features provide a detailed picture of milling technology as early as the Carolingian period in the mid-9th century. A well-preserved waterwheel segment allows the reconstruction of an undershot start-and-float wheel. Numerous wooden paddles reveal a technological evolution from one-piece paddles to composite forms. Placing our results in the context of other early medieval mills, suggests a rather uniform consruction design within, though different beyond the Frankish Empire. This study provides a detailed description of early medieval water milling technology that possibly contributed to the success of agriculture as well as cultural and economic growth of the Carolingian Empire.

1. Introduction

The processing of grain for food production is essential in all sedentary cultures. The use of hydropower provides a decisive technical advancement over hand-operated grain mills. Water mills are the first machines in a narrow sense, since their drive does not rely on human or animal labour. They represent one of the most important technical achievements of mankind. In pre-industrial times the use of hydromechanic power was applied for various production processes, among other things, for grinding grain (Lucas, 2005). In the Early Middle Ages with an essentially agricultural economy, this must be considered as the main use of water mills. From this period on, a steady increase of water mill use can be observed inside, as well as outside the former Roman provinces (e.g. Rynne, 2015; Czycz, 1998; Böhme, 1999b).

The first evidence of water-powered mills in Central Europe derives from written sources for the Roman period (e.g. Böhme, 1999a). From the Early Middle Ages on, the written sources accumulate, which has been regarded as an indication of a technical innovation boost in the early Middle Ages among experts of technical history for a long time (Bloch, 1935; Mumford, 1934; Wikander, 1984, recapitulatory Lucas, 2005). More recent studies on sites and finds from the roman provinces, which are interpreted

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as water mills (e.g. Gähwiler and Speck, 1991; Harding, 2013; Castella et al., 1994 Böhme, 1999a; Maisant, 1994; Champagne et al., 1997), in turn, suggest a milling tradition from antiquity onwards. In recent years, a greater number of roman sites have been excavated, leaving no doubts about the existence of water mills in roman times (recapitulatory Brun, 2016).

Despite the controversial debate on whether the roots of Central European milling tradition reach back to roman or early medieval times, the prominent role of water mills in the Early Middle Ages manifested in various written sources from the 6th and 7th century AD, e.g. Gregory of Tours' Liber vitae patrum, 18,2 (James, 1991), the Fundatio monasterii Aquicinctini (Waitz, 1883), the Vitae sanctae Brigidae (Hochegger, 2009) as well as law regulations (e.g. Lex Salica, 6th c. AD, Lex Ripuaria, 7th c. AD, Edictus Rotharii, 643 AD (Rivers Th, 1986; Azzara and Gasparri, 2005). Although the written sources on water-powered flour mills consolidate in the Early Middle Ages, the number archaeologically documented mills in Central Europe from this period remains limited (Lorquet, 1994; Czycz, 1998; Höckmann, 1994; Kind, 2007; Rügner, 2013; Liebert, 2015; Rollier et al., 2016; Rohmer et al., 2016; Viau, 2016).

The structural remnants of water mills are mostly found in waterlogged sediments, which means an increased probability of preserved wooden structures in relatively large amounts. The waterlogged environment prevents decomposition by aerobic microorganisms and strongly slows down the biodegradation. Under such circumstances, woods can survive for millennia (Tegel et al., 2012). The saturation with water leaves the outer shape of the artefact intact for technological observations and allows for microscopic identification of species.

Numerous parameters such as water volume, flow rate, seasonal or year-round usability, agricultural catchment area, traffic connection and local ownership structures have defined a location suitable for setting up a water mill. Therefore, in many cases a mill site was used in several phases or periods. Archaeological discoveries of mill sites frequently present pile groups without recognisable structures or ground plans. Notably wooden parts from the rising structure (e.g. parts of the roof or wooden partitions) have often been exposed to dislocations caused by water stream and the shifting of river banks and scattered randomly across the excavation site.

Dendroarchaeological studies, based on technomorphology and dendrochronological dating, deliver annually resolved, absolute data. This precision of dating makes it possible to identify individual phases of construction within one mill site. Other dendrological observations provide information on the timber used (e.g. species selection, tree age and growth rates). On the preserved wooden remains, constructional solutions can be recognised. Based on the wood species utilised and technical details, we can provide a differentiated picture of contemporary milling technology. This is all the more important, since no iconographical sources for the appearance and design of water mills exist for the early Middle Ages, i.e. the period 500–1000 AD, roughly between the disintegration of the Roman Empire and the comprehensive implementation of milling technology in Central Europe (Berthold, 2016). Fundamental economic and technological directions have been set during this timespan, yet little is known about the development of mills. Therefore, the present study aims to fill this knowledge gap.

Here, we present the dendroarchaeological analysis of a Carolingian water mill from Audun-le-Tiche, Dép. Moselle (F). Thanks to its excellent conservation condition, remnants of the mill building and technical elements such as parts of the waterwheel, as well as numerous paddles provide unique insights. With a multidisziplinary approach from archaeological, dendrochronological and technical perspective, we broach various fields of humanities and sciences and place our local results in a wider, European context.

2. Material and methods

North of the village of Audun-le Tiche, close to the border between France and Luxembourg, structures of wood were discovered in 1995 at the banks of the Alzette River (Rohmer, 1996). Overall, 328 wooden objects were excavated on the site (Rohmer et al., 2016). A total of 183 samples were taken for dendroarchaeological studies. The material includes round piles from the mill building, split wood piles, mostly from the revetment of the mill race and construction elements such as pegs, a segment of the waterwheel and numerous paddles.

All investigations were carried out on the excavated objects prior to any stabilisation treatment. In most cases, samples with a thickness of about 4 cm were prepared for dendrochronological analysis. For the most significant pieces, stabilisation treatment was carried out post analysis at the Grenoble Nuclear Research Center (France). After the analyses, all samples were preserved in the musée de la Tour aux Puces at Thionville (France).

The identification of wood species was performed on all wood samples taken. Thin sections in tangential and radial orientation as well as cross sections were analysed under a transmitted light microscope with magnification 40× to 400×. The taxonomical classification followed standard identification keys (Schweingruber, 2011; Grosser, 2007).

In the interest of museum presentation, the wheel segment and some of the best-preserved paddles were not part of the dendrochronological analysis. Therefore, dendrochronological analysis focused on 100 samples, 86 of oak and 14 of beech. The samples were cut along the cross section to obtain an undistorted ring pattern. For better visibility, the sample surface was prepared with razor blades and if necessary, stained with chalk to highlight the vessels. Ring-width measurements were performed, using binocular microscopes, measuring table and the software PAST4 (www.sciem.com). The tree-ring series were cross-correlated and synchronised with regional and supraregional reference chronologies and dated by acknowledged statistical methods and visual verification (Baillie and Pilcher, 1973; Baillie, 1982).

3. Results

3.1. Taxonomy

A total of six species could be anatomically distinguished (Fig. 2). The microscopic species identification of 183 samples show a majority of oak (*Quercus sp.*) wood used for the construction of the mill. The other important species for construction is beech (*Fagus sylvatica*). Other species have been used for piles and logs found in the immediate vicinity of the mill. Five individuals were identified as pomaceous trees (*Maloideae*). Hornbeam (*Carpinus betulus*) was identified in three cases. Furthermore, three long timbers found in horizontal position represent lightweight wood species. Two examples of poplar (*Populus sp.*) and one of willow (*Salix sp.*) were identified.

3.2. Dendrochronology

A total of 77 samples could be dated, 67 of which are oak series and ten beech. The measured tree-ring width series allowed a generation of a mean chronology of 242 years for oak and 298 years for beech (Fig. 3A and B). These chronologies were correlated and synchronised with regional reference chronologies between 708 and 949 AD for oak and between 625 and 922 AD for beech based on high statistical significance (Fig. 3A and B).