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Impact of carbonization on growth rings: Dating by dendrochronology experiments on oak charcoals collected from archaeological sites

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ABSTRACT

To understand the impact of carbonization on the acquisition of dendrochronological dating, several experiments were conducted. The shrinkage of ring widths from woods measured before and after carbonization was first characterized. To determine whether the dendrochronological signal was affected by carbonization, joists from a 16th-century building were dated both before and after carbonization. Case studies on archaeological charcoals were also carried out, using a protocol developed to enhance the visibility of growth rings. The fragmentation inherent to charcoal required in some cases a more complex approach to reconstruct the growth of charred wood from the pith to the periphery. These experiments were used to characterize the dating potential of dendrochronology based on charcoals from archaeological excavations.

1. Introduction

Charcoals are usually dated by radiocarbon analysis. Charcoal dating by dendrochronology, though seldom practised, is very interesting in an archaeological context, however, as it makes it possible to refine the chronological ranges of radiocarbon dating. The acquisition of a more precise chronological phase is particularly relevant for certain archaeological structures related to craft activities, such as kilns, metallurgy and mining activities, coal mining, and, of course, building construction (Py, 2009; Marguerie et al., 2010; Eschenlohr, 2012; Paradis-Grenouillet, 2012). Dendrochronological dating experiments of archaeological charcoals have already been conducted in the past, for example on architectural wood from the oppidum of Bibracte (Saône-et-Loire) (Lambert and Lavier, 1996, pp. 57–68; Durost, 2005; Blondel, 2015, pp. 183–189), the Neolithic site of La Hersonnais (Île-et-Vilaine) (Marguerie et al., 2010, pp. 340) and charcoals used in an iron reduction workshops in the Jura (Eschenlohr, 2012). These are isolated cases, however, as the number of rings on the charcoals is often insufficient for dating and no methodological review has yet been published on the topic. The number of rings on oak charcoal is generally small, probably due to the porous areas which are more prone to fragmentation. Differences in the burial processes of various taxa can also lead to a further fragmentation of some charcoals (Chrzavzez, 2013).

Although the dating method for charcoals is the same as that used for dry and waterlogged wood, their conservation status involves a more complex preparation protocol. It is essential to characterize the process of carbonization and wood shrinkage, especially on the ring widths. Samples need to be prepared so as to ensure good visibility of rings before their measurement and dating. Based on experiments carried out in several archaeological sites, the present study aimed to explore the possibilities and limitations of dendrochronology dating on charcoal. The analysis is based on the method described in Marguerie et al. (2010, pp. 339–341). This study is part of a broader research program currently being carried out on the dimensional analysis of wood and growth rates (Ludemann and Nelle, 2002; Dufraisse and Garcia-Martinez, 2011; Thery-Parisot et al., 2011; Paradis-

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Grenouillet, 2012).

Dating by dendrochronology is based on a common signal, mainly climate (Lambert, 1998). To understand the success or failure of dendrochronology dating on charcoal, it is necessary to take into account the carbonization process and its impact on growth rings. Many experiments on wood shrinkage due to drying or carbonization have already been conducted and are summarized in Théry-Parisot (Théry-Parisot, 2001, pp. 58). Shrinkage is on average 15.5% in the radial plane (McGinnes et al., 1971). In the present study, the experiment was based on archaeological wood, which contains less internal moisture than green wood (Théry-Parisot, 2001; Théry-Parisot et al., 2016; Paradis-Grenouillet and Dufraisse, submitted). The first step in the analysis presented here was to measure the widths of rings and attempt to date dry wood from studies on building timber from a half-timbered house dating from the fifteenth until the eighteenth century. The operation was then repeated on the same sections of charred wood. The main effect of carbonization is to induce radial wood shrinkage which can vary with the characteristics of the wood. The study also aims to demonstrate whether the shrinkage is constant throughout the growth of the wood or whether it varies with cutting (Quarter, fiber and half-fiber), the presence of the pith or the sapwood. This step provides information on the impact of carbonization on the dendrochronological signal, making it possible to differentiate the quality of dating before and after carbonization.

The decision to use structural timbers was motivated by the need to recreate a situation of architectural elements destroyed by fire in order to come as close as possible to the context of destruction of old buildings. However, a large number of parameters come into play in a fire, and our laboratory experiments were necessarily limited in scope. Wind, humidity, hydrometry at the time of carbonization, and the volume of the buildings are parameters that are difficult to quantify in an archaeological context. In the case of timber destroyed by fire and potentially datable (large section, sufficient number of rings), carbonization is slowed or partly so by the lack of oxygen, probably due to the collapse of the building.

The aim of this study was to assess how the rings are affected by this shrinkage, whether constant or not, while also determining whether the behavior varied according to the situation in the wood (pith, heartwood, sapwood) or the type of cutting used on the timber. A specific protocol for charred archaeological hardwood is also proposed. The study, although preliminary, enriches already acquired data and provides a partial answer to the effect of carbonization on the dendrochronological signal.

2. Study areas and material

The wood came in part from three archaeological sites in Auvergne where anthracological studies revealed the presence of charcoal that could be dated by dendrochronology (Fig. 1). The remainder of the wood came from a survey of a building in Franche-Comté (Fig. 2). This site was chosen as it provided abundant material for experimentation without affecting the conservation policy. Several sections of the same wood were cut, one for our analysis and one for the construction study and conservation.

The ‘La Couronne’ site is located in the municipality of Molles (Allier) (Fig. 1a). It is placed on a naturally fortified plateau in the Montagne Bourbonnaise. The site was occupied in late antiquity, from the late 4th to the 7th century AD (Martinez and Chabert, 2012). It is of great dendrochronological interest because charred wood is the only material available to create a reference for this region during the period. A rectangular edifice was built in the southwestern part of the plateau. During the 5th century, the building was turned into a church and was maintained until the 11th century, while the rest of the site was gradually abandoned in the late 7th century (Martinez and Chabert, 2012). Several charred joists were discovered outside the church. So far, only one has been sampled and analyzed.

The ‘Chemin de la Naute’ site, located in the municipality of Saint-Paulien (Haute-Loire), is a Gallo-Roman settlement dating from the 2nd to the mid 3rd century AD (Fig. 1b) (Collas and Martinez, 2015). The habitat consists of a courtyard surrounded by galleries. The site was gradually abandoned in the 3rd century but was then used as a graveyard during the 5th and 6th centuries. Several large charcoals were collected in a layer of ancient embankments against one of the walls of the Domus. The context of the archaeological layer is difficult to characterize because it is on the margin of the excavation.

The ‘Pont Ognon’ site is located in the municipality of Laroquebrou (Cantal) (Fig. 1c). Archaeological excavation revealed a large oval pit with rubefied edges directly dug into a granitic arena (Fournand, 2015). The pit is 8 m long and 7 m deep. The function of this pit is difficult to ascertain, but it could be an ore reprocessing system. The thick carbonaceous layer in the bottom of the pit was sampled and one of the charcoals was radiocarbon-dated to the Middle Ages (Cal 1040 CE–1220, Beta - 405609).

At 10 rue de Pontarlier in Besançon (Doubs), a study of the joists from a half-timbered house was carried out (Munier et al., 2010) and a further study for dendrochronological dating of wood from the building (Mélot and Viellet, 2012) (Fig. 2). The dismantling of the building facilitated the choice of the timber to be sampled or collected in full. The construction of the house dates from the late fifteenth or early sixteenth century. In the early years of the eighteenth century, a major overhaul was carried out on the building. Many of the 16th century timbers used may have be reused, making it difficult to date some of the timber (Mélot and Viellet, 2012, p. 29–32). We collected a batch of nine oak timbers named: A4, A5, A7, In order to diversify the origins, they were taken from two different sites: one from a house in Chemin des Tilleroy in Besançon, and one from an abbey in Marast (Haute-Saône). Three cutting have been recognized: on quarter, on half-fiber and on fiber (Fig. 3). These different cutting can be obtained by sawing or splitting. The woods on quarter are the result of a cutting of the tree in four quarters. The timber on half-fiber are just the result of a cutting half a tree. Finally, the woods on fiber are worked directly in the tree.

3. Methods

3.1. Dendro-anthracological dating of archaeological wood

To quantify the impact of carbonization on the dendrochronological signal, an experiment was carried out on the archaeological wood. The wood sections were first sanded to obtain as readable an area as possible for carbonization. After this stage, the ring widths were measured to perform dendrochronological dating.

As the dating protocol has already been well documented, only the main points are summarized (Schweingruber, 1988; Lambert, 1998, 2006, pp. 16–69; Lambert et al., 2010, pp. 205–216.). The ring widths were measured in hundredths of a millimeter by means of an optical measuring system (Lintab) and software (Tsap Win, Rinn, 1989–1999). These measurements were performed two to three times along measurement paths (elementary series) to compensate for any errors. To compare data before and after carbonization, the measurements were carried out according to the same paths. Due to shrinkage and splitting of the wood, it was sometimes necessary to deviate from the initial measurement path, which may result in some cases in differences in ring widths. These elementary series were then synchronized to obtain a representative set of each individual sample for dating. Statistical calculations

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