Journal of Archaeological Science 96 (2018) 106–116

Contents lists available at ScienceDirect

Journal of Archaeological Science

journal homepage: www.elsevier.com/locate/jas

Dendroarchaeological dating of Renaissance Mudejar artefacts in western Spain

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ARTICLE INFO

Keywords:
Cultural heritage
Mudejar
Pinus
Dendroarchaeology

ABSTRACT

The absence of precise dates in Extremadura's Renaissance heritage can generate ambiguities that hinder the cultural interpretation of regional history. The analysis of the duration of the art styles, the date of construction of buildings and artefacts or the exact determination of restoration periods are severely affected by the absence of specific chronological information. Dendrochronology can help to resolve these unknowns. We analysed historical woods from timbers, painting panelings, ceilings, furniture and art objects, all from two Renaissance monumental buildings: the San Vicente Ferrer church in the city of Plasencia and the Las Veletas palace in Cáceres, both in Spain. We used a local chronology of living trees as reference. This living chronology was developed with tree-ring data hosted in the International Tree Ring Data Bank (ITRDB) but reinforced with recent wood samplings from the Sierra de Gredos, a mountainous area close to the historic sites. After a step-by-step crossdating process, the historical timbers were dated and a floating chronology was built. The comparison between this floating chronology and that obtained from living trees reached a Pearson-r correlation of 0.65 with a temporal overlap of 106 years. Thus the living tree-ring chronology was extended 253 years into the past (from 1769 CE to 1516 CE), allowing the dating of new historical materials that may arise in the future for this period and confirming that tree-ring dating is a feasible technique to use in the dating of historic buildings and artefacts in western Spain. The results indicate that it is feasible to admit that Mudejar art, a mixture of Arab and Christian styles, remained in active development in Extremadura for much longer than in any other regions of Spain.

1. Introduction

The Renaissance was a cultural and artistic movement originated in Italy during the 15th century (Rabil, 1988). This cultural expression spreads to the rest of Europe in a non-uniform and slow process (Mayhew, 2001). In Spain, the first evidence of the Renaissance dates from the late 15th century (Sánchez, 1988) and began to disappear slowly towards the beginning of the 17th century (Rabil, 1988). However, in the Extremadura region (western Spain), presence of this cultural heritage appears to have decreased more slowly than in the rest of the country. This characteristic in the speed of incorporation of new cultural styles in Extremadura is associated with the secular historical, cultural, political and intellectual isolation of this region. This may explain the irruption of the Gothic style from the Late Middle Ages without transition stages (Sánchez, 1988). The Renaissance period in Extremadura has two moments of expansion linked to population growth: the first one between 1500 and 1515 and the second one between 1545 and 1560. During both periods there was intense military, civil and religious activity that brought an increase in the construction of houses and monumental buildings (Sánchez, 1988). Simultaneously, the Muslim influence continued in the Mudejar art style. The term *Mudejar* (adaptation of the Arabic word *Mudajjan* مدجن), refers to the Muslims who obeyed to the Christian kings, but conserved their cultural heritage. Mudejar art partially coexisted during the period between the 13th and 17th centuries with combinations of Romanesque, Gothic and Renaissance styles (Mogollón-Cano, 2006). The style combines elements of Islamic art with different construction techniques linked to Christian culture, a synthesis that is evident in the Iberian Peninsula (Sarasa, 2006). Within this cultural crucible, an exact time period delimitation of each style is of great importance for understanding this phase of the Iberian history. In this sense, different dating methods could be used such as radiocarbon, identification of styles, determination of craftsmanship periods, analysis of documentary sources and dendrochronology. These methods have, however, different levels of dating accuracy that can influence the historical reconstruction of the human society development. Radiocarbon permits dating around 50 ka

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https://doi.org/10.1016/j.jas.2018.06.003
Received 3 April 2018; Received in revised form 24 May 2018; Accepted 9 June 2018
0305-4403/

years BP, but with relative low and variable resolution. Art and documentary methods are appropriate but could be erroneous in certain areas with less or complex historical information, as the Extremadura region. Dendrochronology is the only technique that yields an annual resolution dating of historic pieces of wood (Fritts, 1976). In this sense, this method is a powerful tool to solve dating related to archaeological and art history studies (Baillie, 1995; Grabner et al., 2007; Szántó et al., 2007). In fact, dendrochronology has been widely used to date the origin of different art objects, architectural wood pieces, panel paintings (Fraiture, 2009), musical instruments (Topham and McCormick, 2000), roof constructions (Haneca and Debonne, 2012) or trunks (Thuna and Alsvikb, 2009). Dendrochronology can also help infer the geographic origin of historic wood objects (Fraiture, 2009; Romagnoli et al., 2016). Furthermore, dendrochronology has also served for calibrating radiocarbon method (Leavitt and Bannister, 2009), which in turn helps in dating dendroarchaeological wood samples that are so far beyond the living chronologies. The dendrochronological dating potential in the Iberian Peninsula has been evaluated in detail by Domínguez-Delmás et al. (2015).

The aim of this study is to date wood pieces from two historical buildings related to the Mudejar style in Extremadura (western Spain), by applying dendrochronological methods. Additionally, the possible geographic origin of the wood samples and the historic implications of this origin is suggested. Moreover, the results will allow a better understanding of the Mudejar cultural influence and the duration of this historical period in western Spain. Since this region has not been previously studied from a dendroarchaeological perspective, and given that long tree-ring records of reference in the area are relatively scarce (Patón et al., 2009; Roig et al., 2009), we highlight the importance of the results found here and their potential to extend dendroarchaeological studies in this region of Spain.

2. Material and methods

2.1. Sampling

Two types of wood sample data were used: 1) tree-ring widths from living trees collected for the purpose of this study (Fig. 1) and a complementary set of living tree-ring width data housed in the International Tree Ring Data Bank (ITRDB), and 2) ring width measurements from historical woods (Figs. 2–5, Table 1). Samples from living trees were obtained in two pine populations from the south face of the Sierra de Gredos (Fig. 1), a mountainous area 60 km away from San Vicente Ferrer church (Plasencia) and 115 km away from Las Veletas palace in Cáceres, the other two main sources of historical wood samples. Consequently, living trees and local historic woods can be considered as belonging to the same macro-climatic region.

In the Sierra de Gredos, there are two pine tree species, *Pinus sylvestris* L. and *Pinus nigra* Arnold, which are difficult to differentiate anatomically from their xylem characteristics (Akkemik and Yaman, 2012; Martin-Benito et al., 2013; Schoch et al., 2004). The first species is clearly dominant in the area and grows in acidic soils whereas the second grows as isolated patches on calcareous soils (López-Sáez et al., 2016). Both species present similar response to climate and can be treated as a unique group for crossdating purposes (Richter et al., 1991). As indicated in Table 1 and Fig. 1, living trees from both pine species were collected from standing individuals, and between two to three transverse wood cores were taken from each tree (with increment borer of $\varnothing = 5$ mm) at breast height to capture potential variability in tree growth around the stem. These samples have served to update the tree-ring width series of *P. sylvestris* and *P. nigra* hosted in the ITRDB and originally derived from trees growing in the south face of the Sierra de Gredos.

The historical woods considered in this study were recovered from Las Veletas palace and San Vicente Ferrer church. These samples are stored in the Cáceres Museum (Spain) and consist of pine wood samples from different sources: timbers, furniture, picture frames, upper sides of doors, benches, looms, Mudejar ceilings, polychrome panels and a codex (Figs. 2–5). Because most of these samples cannot be intervened (e.g. polished or cut) due to their historical value, images of cross sections with sufficient quality to distinguish the growth rings were obtained according to procedures described by Bridge and Miles (2011). Sequential high-resolution photographs (1 px = 100 μm) were taken at a short distance (10 cm), through a scan of the surface on a horizontal plane with a metric scale as reference. We used a Canon SX-30 camera with 15 megapixels of resolution. Similar digital techniques have been used with historic pieces of wood that cannot be physically altered (Bernabei et al., 2010; Thuna and Alsvikb, 2009). Wood material with a minor historical value, such as church roofs extracted after refurbishing or upper sides of doors, was carefully polished using belt sanders in a grit sequence from 40 to 1500. Sapwood was not a problem because the analysed living trees were not too old, not exceeding 300 years in any case. All the photographs and the polishing of wood material were made in the facilities of the Cáceres Museum Laboratory.

2.2. Crossdating and measuring

Crossdating is the most important principle of dendrochronology (Fritts, 1976). It establishes that the matching patterns in ring widths or any other tree ring characteristic between samples allows the identification of the exact year in which each tree-ring was formed. This technique helps to identify false or missing rings and any other possible errors during both the ring boundary recognition and the measuring stage of the ring widths. In an initial dating control stage it is advisable to make a visual crossdating. This procedure allows us to easily detect missing or false rings prior to performing the correct ring width measurements. Consequently, we followed the Yamaguchi method that consists of classifying the rings according to their relative characteristics in their widths, tracheid diameter and/or any type of anomaly present in the wood (Yamaguchi, 1991). Thus, we built an initial calendar plot taking advantage of the coincidences of the ring characteristics from different wood samples. Subsequently, we measured the ring widths at a resolution of 0.01 mm using ImageJ (http://rsbweb.nih.gov/ij/) image analysis software in a Slackware (http://www.slackware.com) Linux environment. The pixels were converted to millimetres using the metric scale included in each image.

In the case of historic woods, the innermost growth rings were dated at a relative age, waiting for a later correction by comparison with the living tree-ring chronology. Each historical wood sample/photograph was classified individually according to their archaeological origin and measurement data was transferred to a spreadsheet (LibreCalc) using the sample code in columns. A second crossdating procedure through visual inspection was conducted by simple comparisons of the measurement profiles transformed in figures, following Stokes and Smiley (1968). This procedure helps to detect more accurately dating problems not previously discriminated by the Yamaguchi method. Once an error is detected, it is resolved by re-examination of the wood samples, identifying the possible mistakes and making a new measurement of the corresponding wood portion. When missing rings were detected they were assigned a value of 0.001 in order to avoid mathematical artefacts during the final statistical phase of crossdating (Leland et al., 2016).

Once all samples (living and historic woods) were visually controlled, the statistical crossdating performance was verified with the facilities of the free computer COFECHA routine (DPL suite, Holmes, 1983). The primary function of COFECHA is to verify the crossdating of the tree-ring series, assessing the quality of the cross-match procedure and measuring accuracy of the tree-ring series. Basically, the dated and measured ring series were filtered by a 32-year cubic spline, and then each data set was divided by its corresponding value of the spline curve. The procedure transforms raw data in normalized indexes facilitating the subsequent correlation between single series and the master chronology. Thus, COFECHA provides information of segments having