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# AN OVERVIEW OF THREE DECADES OF DENDROCHRONOLOGY APPLIED TO ANCIENT MEDITERRANEAN SHIPWRECKS IN SOUTHEASTERN FRANCE

Frédéric GUIBAL, Alba Ferreira DOMÍNGUEZ, Giulia BOETTO, Lisa SHINDO, Sandra GRECK and Patrice POMEY

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## Abstract

Three decades of dendrochronology applied to ancient Mediterranean shipwrecks in southeastern France have resulted in a considerable improvement in knowledge about the wood resources used in ancient shipbuilding. However, in terms of dating, the success rate of dendrochronological analyses is still very low. The possible causes of this low rate are discussed through two case studies: the first pertaining to the shipwrecks from the ancient harbour of Toulon (1<sup>st</sup>-3<sup>rd</sup> centuries AD); the second to a couple of fluvial barges discovered in the Rhône River (mid 1<sup>st</sup>-beginning of the 2<sup>nd</sup> centuries AD).

## Keywords

Dendrochronology, Mediterranean, Rhône River, Roman, shipbuilding, Toulon

## Résumé

Trois décennies de dendrochronologie appliquée aux épaves antiques de Méditerranée dans le sud-est de la France ont permis une amélioration considérable de nos connaissances sur les ressources en bois utilisées dans la construction navale antique. Cependant, en termes de datation, le taux de réussite des analyses dendrochronologiques est encore très faible. Les causes possibles de ce faible taux sont discutées à travers deux études de cas: la première concerne les épaves du port antique de Toulon (I<sup>er</sup>-III<sup>e</sup> siècles apr. J.-C.); la seconde s'intéresse à un couple de barges fluviales découvertes dans le Rhône (milieu du I<sup>er</sup>-début du II<sup>e</sup> siècle apr. J.-C.).

## Mots clés

Dendrochronologie, Méditerranée, Rhône, époque romaine, construction navale, Toulon

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Any study of the ships that shaped the world would be incomplete without an understanding of the materials required to build these ships, more particularly, wood (Pomey, Rieth 2005, p. 133-134; Creasman 2010). Wood has been the commonest material by far for most of the material culture from early prehistory to the present. In studies of boat and ship architecture wood anatomy supplies information on the selection of tree species: the study of wood anatomy and wood morphology is also extremely relevant to extracting cultural information from ship timbers. The age of wooden objects can be determined by means of dendrochronology, which makes it possible to accurately date the formation of tree-rings and the felling of the tree from which wooden pieces were produced (Farrell, Baillie 1976; Baillie 1982).

Dendrochronology has been applied for the last 30 years on more or less well preserved remains from ancient ships located along the French Mediterranean coastline and also in French Mediterranean inland waters (Guibal, Pomey 2009). Indeed, it was in 1991 that the first dendrochronological and dendromorphological study programme on ancient shipwrecks of the Mediterranean was launched by the Centre Camille Jullian and the Mediterranean Institute for Marine and Terrestrial Biodiversity and Ecology, with the support of the DRASSM (Département des recherches archéologiques subaquatiques et sous-marines) (Guibal, Pomey 2002, 2003, 2004). Totally innovative for the time, this programme has since given

rise to systematic dendrochronological studies on ancient shipwrecks.

If they are not too badly damaged by shipworms (*Teredo navalis* or other wood borers) shipwrecks will yield suitable timbers for dendrochronological analysis. The aims of these studies are (i) to date the felling of the trees used for ship construction, (ii) to estimate the geographical origin of the timber, and (iii) to implement dendromorphological analyses. These latter analyses are intended to assess how timber was processed and to understand basic wood economy patterns by paying particular attention to timber ages, timber volumes and timber conversion.

In total, during the last three decades, dendrochronology has been applied to more than 60 ancient shipwrecks located along the southeastern coast of France, of which only 5% have been so far successfully dendro-dated. The purpose of this article is to review the reasons why this success rate is so low.

## 1. SOME POSSIBLE EXPLANATORY FACTORS

It must never be forgotten that dendrochronology dating is an iterative process, which makes it a constantly evolving process. Indeed, when the dating attempt of a mean site chronology is not successful at time *t*, it is considered a failure because the chronology remains floating. Later, however, as a result of

the improvement and extension of floating and/or master chronologies, this mean site chronology may be dated.

First, we shall consider the usual causes that hamper the chances of successful dating. On the one hand, a low number of tree rings makes the chronologies too short to obtain reliable statistical correlations between ring-width series. Long series with high environmental sensitivity generally have a higher potential for dating than short and complacent series (Haneca *et al.* 2005). On the other hand, too few pieces of wood may be insufficient to build up a representative mean site chronology. And even when the number of elementary series included in a mean site chronology is high, the representativeness of the latter is sometimes low due to the fact that most of the elementary series may come from a single tree, as often happens for most of the strakes that make up the hull. This was deliberately practiced by ancient shipbuilders in order to optimise the timber conversion (Guibal, Pomey 2004).

Second, there is the very nature of the object that is analysed: ships are mobile objects which may have sailed long distances from their places of origin and, wherever the site of the wreck may be located, the place where the ship was built and the geographical origin of the wood might remain unknown (Farrell, Baillie 1976; Pomey, Rieth 2005, p. 139-142). Bridge (2011) reports a few examples in which dendrochronology has provided evidence of an unsuspected geographical origin of ship timbers. Moreover, ships could be built with timber from different tree species originating from different, sometimes distant, geographical areas, and they may also contain reused or refitted timbers. Accordingly, wood from different species, periods, and geographical areas could be present in the same shipwreck (Domínguez-Delmás *et al.* 2018).

Third, we must recognise the specificity of Mediterranean dendrochronology in relation to Mediterranean biogeography. Considered as a biodiversity “hot spot” (Médail, Diadema 2006), the Mediterranean basin shelters more than 100 tree species in an area that represents only 1.8% of forests worldwide. Comparatively, European temperate forests contain less than 30 tree species over an area that is four times as large (Fady-Welterlen 2005). Although not all of these tree species occur in Mediterranean shipbuilding, our studies reveal that a large amount of species were used in ancient times for ship construction. Twenty-eight species representative of three biogeographical units have been identified. Among these species, 22 are suitable for dendrochronological studies (Guibal, Pomey 2002). Similarly, Allevato *et al.* (2010) found 15 species used in the architectural elements of three Roman shipwrecks discovered in *Neapolis* harbour (Naples). A number of species was also identified in ancient shipbuilding along the Mediterranean coast of Israel (Liphshitz 2012). In Turkey, the Yenikapi (Istanbul) ancient ships have also revealed a high number of tree species used in ship construction during the Byzantine Period (Liphshitz, Pulak 2007-2008; Akkemik, Kocabaş 2013).

Consequently, the key to the success of the dendro-dating process, *i.e.* the construction of master chronologies, is somewhat problematic. Indeed, given this multiplicity of tree species and bioclimatic conditions, the number of master chronologies to build is much higher than in other geographical areas.

Lastly, there is some analogy between timber supply in the Mediterranean area and ships, in the sense that both are mobile. Timber has been imported, generally by floating on rivers, for centuries into the Mediterranean area because of the early



Fig. 1: Location of the case studies in southern France (map G. Boetto).

historic depletion of Mediterranean forests (Meiggs 1982). This timber importation explains how mountain and subalpine tree species may be found in ancient shipbuilding. Therefore, cross-dating tests must be carried out, not only against local tree species master chronologies, but also against extra-Mediterranean master chronologies. This increases the complexity of the study and these specificities make Mediterranean ancient shipwrecks a most challenging research object.

As already mentioned above, the dendro-dating success rate in the Mediterranean is low. In addition, even the cross-dating success among different ancient shipwrecks is also low (Guibal, Pomey 2009).

## 2. TOULON SHIPWRECKS: DATING FAILURE AND PROVENANCE HYPOTHESES

An illustrative example of this ship timber diversity is provided by the five shipwrecks that were found in 1987-1988 during the excavation of the ancient harbour of Toulon (Brun 1999) (fig. 1). Toulon 1 and 2 were rowing boats, 6 and 8 m long, scuttled and filled with stones before being reused for the construction of a jetty at the end of the 1<sup>st</sup> century AD. Due to their transom bows, these boats belonged to the *horeia* type vessel family and were working boats. The three other wrecks, Toulon 3-4, 6 and 7, were small sailing ships, 15-20 m in length, that were abandoned in the harbour basin in the first half of the 3<sup>rd</sup> century AD (Boetto 2009, forthcoming). Following the notion of architectural types and the concepts of principles and methods of construction (Pomey 2004; Pomey, Rieth 2005, p. 29-33; Pomey *et al.* 2012, 2013), all the wrecks belonged to keeled vessels with flush-laid carvel planking and mortise-and-tenon joints. Their construction principle was based on a shell concept for the hull structure, and on a longitudinal strake-oriented concept for their shape, while the building process was shell-first.

For conservation reasons, by the time of the excavation, dendrochronological analysis was not allowed because the wrecks were intended for restoration and later display in a museum

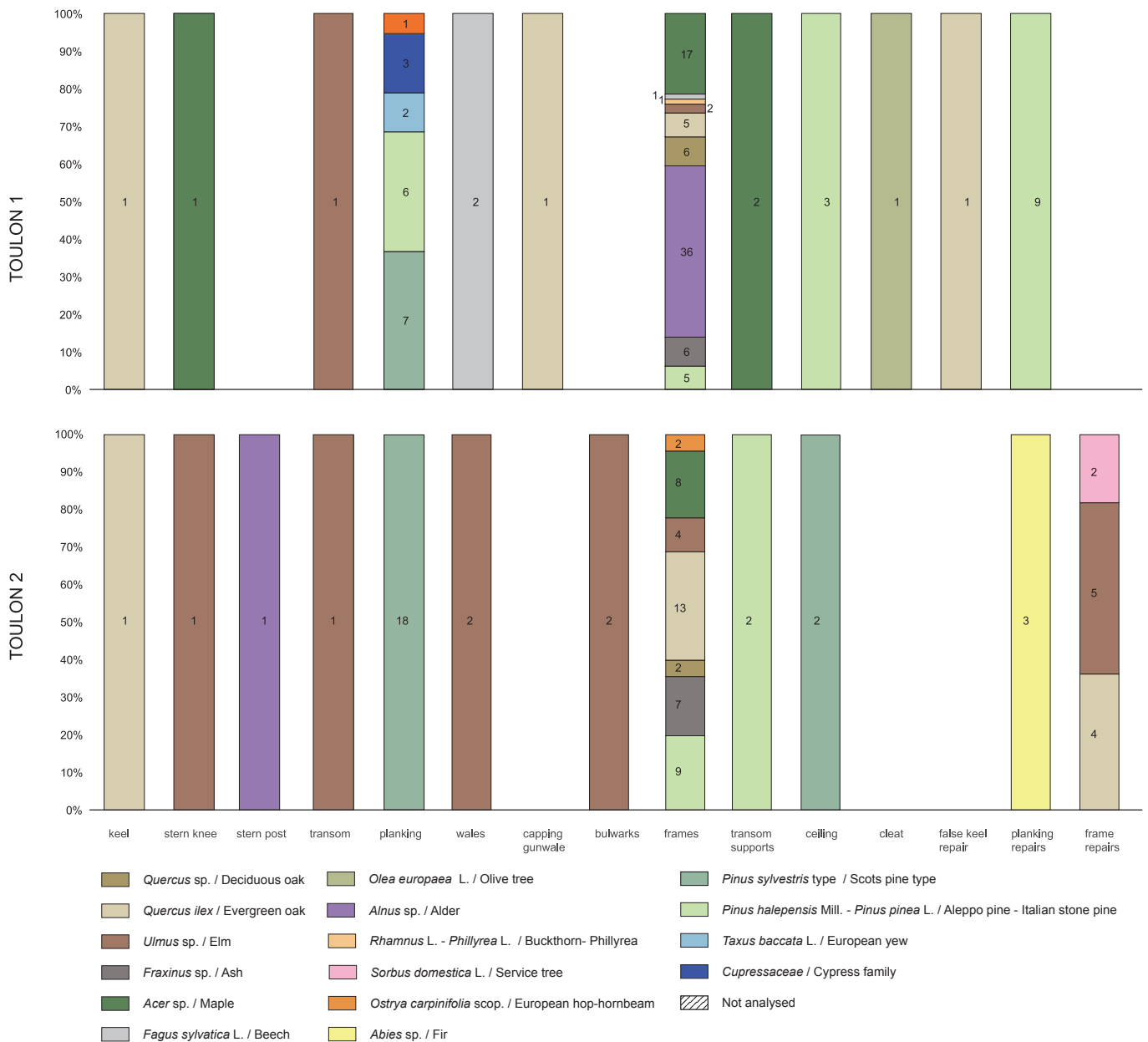


Fig. 2: The wood species identified on Toulon 1 and 2 (graphic A. Ferreira Domínguez).

(Pasqualini *et al.*, forthcoming). The wrecks were treated with polyethylene glycol (PEG) then freeze-dried in the ARC-Nucléart restoration laboratory at Grenoble, and in 2008 the dismantled architectural pieces came back to Aix-en-Provence for long-term storage, awaiting a future display project. Nearly 30 years after the ships' excavation, as part of a project for the final publication of the harbour excavation, the systematic wood identification analysis and the dendrochronological analysis of the vessels were performed. As a consequence of the conservation process, wood identification was hindered and some anatomical uncertainties remained (Ferreira Domínguez 2014; Ferreira Domínguez *et al.* forthcoming) (fig. 2).

Only two of the Toulon wrecks offered the sample quality that would allow a dendrochronological study. Indeed, too few timbers and too few rings were available among the three other shipwrecks. Tree-ring series were analysed for the ships Toulon 2 and Toulon 3-4. In total, three mean chronologies

were constructed: Toulon 2 provided an oak mean chronology, 167 years long, and a type Scots pine<sup>1</sup> chronology, 151 years long. Toulon 3-4 provided a fir/spruce chronology 138 years long.

So, three rather long mean chronologies were built, but no significant cross-correlation could be obtained between them. In fact, even if there may be some overlap between the ring series, no cross-dating was obtained because the ecological requirements of these three tree species are too different and their ring patterns are obviously also different. Attempts have been made to cross-match these mean chronologies with others from marine or continental (western Provence) sites, but so far they have failed (Shindo, Guibal forthcoming).

1. Because it is impossible to distinguish the anatomy of the wood of Scots pine (*Pinus sylvestris* L.), black pine (*Pinus nigra* Arnold) and Swiss mountain pine (*Pinus uncinata* Ramond) these species are hereby gathered under the term 'type Scots pine'.

For Toulon 2 and 3-4, due to the limited dendrochronological study and the failure of cross-dating, it was impossible to determine the origin of the timber used for shipbuilding. Nevertheless, at least for Toulon 1 and 2, given the current distribution of tree species in the mountainous and hilly areas situated in a range of 20-40 km to the north and northwest of Toulon (for example, on the north slopes of the Sainte-Baume ridge or in the Esterel mountains), it is probable that the wood used for their construction was locally grown and transported to a coastal shipyard (fig. 2). Given the ease of transporting all these woods to a shipyard situated near the ancient port of Toulon, and taking into account the small size and function of these boats, the use of local wood originating from the surrounding areas of *Telo Martius* seems quite probable. Thus, the results obtained from the analysis of the wood used in the construction of Toulon 1 and 2 confirm the assumption of a local origin of these ships, agreeing with the theory previously proposed from analysis of their construction characteristics coupled with consideration of their function as harbour lighters or for fishing (Boetto 2009, forthcoming).

### 3. ARLES SHIPWRECKS: DATING AND TIMBER PROVENANCE SUCCESS

The rare French Mediterranean study cases in which dendro-dating succeeded involve two shipwrecks both located in the Rhône River in the city of Arles: Arles-Rhône 3 and 5. Arles-Rhône 3, a 30-m long barge transporting a cargo of building stones during its last voyage, sunk in the river in the middle of the 1<sup>st</sup> century AD (Marlier 2014a). Arles-Rhône 5, a similar barge, 30-35 m in length, was probably abandoned in a ship graveyard located downstream, the fluvial harbour dump of the city (Marlier *et al.* 2019).

These Gallo-Roman barges were built according to a flat-bottom principle with a construction process in which the shape and the structure were dictated by and organised around the flat bottom, which was laid first with carved bilge planks (or carved transition strakes). Perhaps built in the same shipyard, Arles-Rhône 3 and 5 belong to the Rhône-Saone shipbuilding tradition (Pomey 2011; Rieth 2011) characterised by Mediterranean maritime influences on a specific continental shipbuilding tradition (Marlier *et al.* 2019, p. 487-489).

Arles-Rhône 3 involves oak and fir chronologies (Guibal, Greck 2014a), and Arles-Rhône 5 involves oak chronology (Marlier *et al.* 2019, p. 473). Felling ranges of the trees were 50-60 AD and 110-140 AD, respectively. All of these mean chronologies could be dated against oak and fir master chronologies representative of more northerly regions (eastern and northeastern France). Arles, situated in the lower Rhône valley, held a strategic position for the river trade on the Rhône River. It was there that merchandise from Rome, the Iberian Peninsula and North Africa was stored before being loaded onto other fluvial vessels sailing up the Rhône River to Lyon and forwarded to the northern provinces or to Geneva. Conversely, the Rhône River, and in extension its confluent the Saône River, made the whole corridor to Arles a way of supplying materials such as timber from the hinterland.

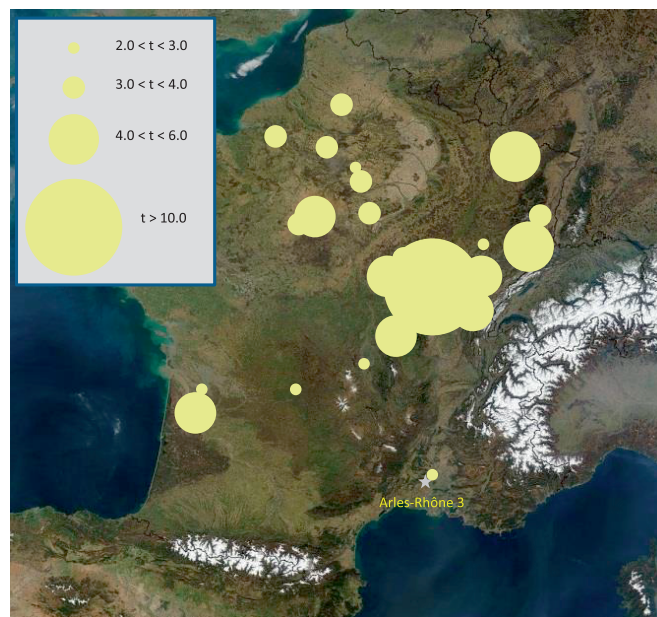


Fig. 3: Arles-Rhône 3 barge. Map showing the distribution of correlation (*t*-values) achieved between the mean for Arles-Rhône 3 and site chronologies from Northern Europe (F. Guibal).

The analysis for Arles-Rhône 3 went well beyond dating the felling of the trees, and confirmed that dendrochronology can successfully serve as a tool to determine the origin of timber used for shipbuilding (Bonde *et al.* 1997; Wazny 2002; Haneca *et al.* 2005; Daly 2007; Domínguez-Delmás *et al.* 2018; Rich *et al.* 2017). Dendroprovenancing was successful: thanks to a gradient in correlation coefficients (fig. 3), a geographical origin of timber utilised could be determined, attesting an origin in the Burgundy part of the Saône valley, 350 km north of Arles (Guibal, Greck 2014b). Timbers could have been floated downstream and used for the construction of the Arles-Rhône 3 barge. Thanks to a multi-proxy analysis, it is probable that this shipyard was situated in Arles or its surroundings (Marlier 2014b).

### 4. CONCLUSION

Shipwrecks are the last chapter of a complex story and much of the information unrelated to a ship's final voyage remains a mystery. However, a part of that mystery can be exposed by an examination of the timbers (Creasman 2010). Dendrochronology has become well established in the field of nautical archaeology studies because it is able to provide answers to the crucial research questions of place and date of the building of a ship. The date and geographical origin of timber utilised for ship construction can provide valuable information on the building period of the ship and the wood resources used. In the north-western Mediterranean area, despite the progress that has been made during the last decades, the success rate of ship dendrochronological analyses is still very low. More site chronologies that cover the period of the last 25 centuries are needed in countries around the Mediterranean Sea. This requires the supplementary systematic application of dendrochronology in Mediterranean boat and ship archaeology.

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