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Edited by:
Alfredo Di Filippo, Gianluca Piovesan,
Manuela Romagnoli, Gerhard Helle
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Starting points for dendroarchaeology in Catalonia

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Introduction

Despite the fact that dendroarchaeology in Catalonia (Spain) has been a field somewhat neglected in comparison to other Mediterranean regions, nowadays there are the conditions for a relatively quick recover of such delay, thanks to mainly two factors. In the first place, the tradition of a series of fields complementary to dendroarchaeology has created a well established framework, which dendroarchaeologists could take advantage of: it's the case of dendroecological studies, that allowed the building of numerous chronologies from living trees (some of which are more than 600 years long, see Gutierrez et al 1998); pollen studies, that can reconstruct to some extent the ancient distribution of tree population from prehistory to recent times (Riera 2005; Miras et al 2007); and finally a series of localized studies about agriculture and tree culture in antiquity based on carpological data and plant remains (Buxò 2005).

In the second place, in Catalonia archaeology is a well integrated discipline in the development of urban planning and therefore a great quantity of archaeological digs are carried on. In this sense, it has to be noted that, even if from the point of view of climate conditions this territory is not among the most suitable ones for preserving organic material, wooden artifacts are being found more frequently in recent years. This is partly due to the fact that the so called "salvage archaeology" – that forms the immense majority of archaeological activity on the territory – deals with building activity, whose technological continuous improvement allows to always reach deeper strata. Here, the presence of the water table enhances the possibility of wood preservation, especially parts of wells, that, it has to be kept in mind, were one of the most common, because necessary, equipment in most of the historical settlements.

Previous dendroarchaeological experiences on the Catalan territory

Even if dendrochronological principles have been introduced from the archaeological point of view (Gutierrez 2008), until now the region suffers from a lack of professionals and the few cases of study were carried on by external laboratories.

The first and pioneering dendroarchaeological study was carried on La Draga Neolithic site, by Patrick Gassman at the Laboratory of Dendrochronology in Neuchatel (Switzerland), whose dig started in 1990 and is still on-going. Among hundreds of samples of oak wood, from rods and planks, dated by 14C to the sixth millennium B.C., some synchronized well to build a few floating chronologies (Gassman 2000).

We have to wait almost twenty years for a second dendroarchaeological experience: it concerned a shipwreck found in 2008, when a portion of the medieval port of Barcelona was archaeologically investigated. The construction technique, the analysis of the pollen contained in the sealing moss used in its construction and the investigation of the Late Medieval archives indicate that the ship was constructed in an area set between the North of Spain and the French region of Aquitania, probably in the Basque country. The construction of the ship was roughly dated to the year 1410 A.D., thanks to the 14C datings of the sealing moss used in the ship construction and the sediment below the shipwreck. The chronology obtained from several oak pieces of the ship, sampled and synchronized by Marta Dominguez of the Dutch Stichting RING Foundation, didn't fit to any dated master series from North and central Europe (Soberón et al 2012).

The Foneria site

Location of the site and type of data

In 2009, due to a subway construction, an archaeological dig was carried on in Foneria street, in Barcelona, about four kilometers south-west from the city center. The site, that refers to a long rural occupation from the Iberian age to the Late Antiquity, is located in the deltaic area of the Llobregat river (Fig. 1), whose humid sediment allowed to preserve a great quantity of organic material. Particular attention was paid to a well, partially built in wood, and to the wooden and carpological material contained in its inner deposit¹.

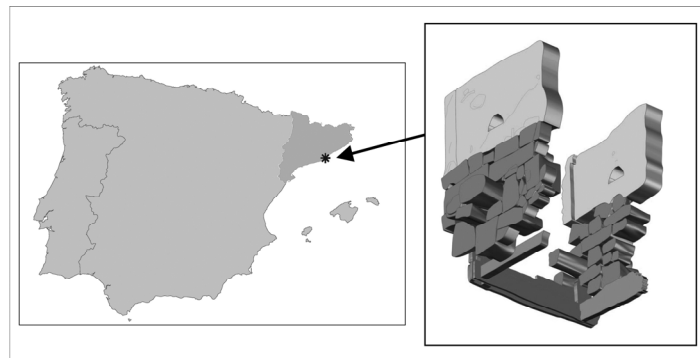


Figure 1: Location of the Catalan region and the Foneria site; 3D reconstruction of the well.

Those archaeological records relate to different historical moments: the well itself, that is being studied from the dendrochronological point of view, was built in the first phases of the Roman occupation of the site, and presumably its construction could be dated between the first and the second century AD; on the other hand, the stratigraphic unit contained in its interior was dated, by the presence of pottery sherds, to the sixth century AD, when the site was definitively abandoned. Both sets of evidences give us important information for the knowledge of the landscape and forest management in the Roman era: nevertheless, considering that the framework in which this contribution is presented is mainly focused on the tree-ring discipline and the fact that the carpological and other small wood remains will soon be object of a specific presentation in another context², here we will pay special attention to the well.

The well

The well, built mostly in masonry, with a squared shape, had an internal wooden lining in its lower extreme (Fig. 1), as per an already well-known technique, of which more examples are documented in Catalonia (Lopez Bultó 2010).

Almost all of the wood used in the well construction was identified as *Pinus sylvestris/nigra*, except one piece made of *Abies alba* (Lopez & Piqué 2010).

The wooden part was partially affected by the subway walls before the archaeological dig started, therefore it could not be entirely documented. However, it could be reconstructed as formed by four vertical elements, located at every angle of its square shape, and two opposite vertical sides

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² Several landscape aspects other than dendrochronological ones have been presented at the XVIII International Congress of Classical Archaeology, held in Merida (Spain) in May 2013, by A. Ravotto, R. Piqué and J. Ramos under the title of "Arqueologia espacial en el delta del Llobregat" and will be object of publication in the related proceedings.

formed by a series of planks that constitutes the internal lining of the well; on the other two sides, two big horizontal elements (a beam on one side, a thick plank on the other one) were used to keep the shape of the structure, while neither lining planks, nor hints of their presence could be found. Nails and a couple of types of joints (“mortise and tenon”, “half lap”) were used to assemble such structure. Several smaller pieces of wood were used to improve effectiveness of the joints between sets of planks that had different thickness.

This variety in thickness, as well as the diversity in the overall dimensions and shape among elements with similar structural function, and the presence in one of them of an unused hole for a joint, suggest that part of the wood was reused from a previous undetermined structure. While the morphological study of this one, in a hard attempt to achieve a hypothetical reconstruction, is still in course, it can be deduced at this stage that it was painted white. Residues of a patina of this color was documented in a couple of pieces, one of them being the one with the unused joint hole and both being part of the set of elements that could be crossdated.

Methodology

The wood from Foneria, like most of the examples of pre-modern times wood discovered in Catalonia during an archaeological dig, was preserved in a waterlogged state. Waterlogged wood characteristics and treatment are already described in general biography (Bunning & Watson 2010). It's well known that while conserved in a saturated environment, it maintains its shape even if it is degraded by fungi and bacteria, since moisture fills the damaged structure. However, when water evaporates, its own surface tension causes cell collapse and shrinks the decayed wood (Brown 1991, Unger et al 2001). In the case of Foneria wood, and thanks to the availability of a great quantity of material that allowed to use a minor part of it for destructive analysis, a series of variables implied in the process of decay have been monitored. First, the water content of the wood has been calculated on small fragments of wood according to the “U max figure”, that can be used for a preliminary estimation of the state of preservation of the wood structure: depending on the piece considered, the result for the pines was between 247% and 620%, with an average value of 418%. This values denote a degraded wood, since in the case of pines such degrade is revealed by the presence of more than 250% of water content (Bunning & Watson 2010). The “U max figure” is, nevertheless, a very approximate indicator of the state of preservation of the wood. In order to relate it to an analytical evaluation of the decay, the cellulose still present in a sample with a content of water of 612% was determined in the Laboratory for radiocarbon dating of the University of Barcelona: it corresponded to the 8,2%, while the original content would have to be between 40% and 50% (Blanchette 2000).

At this stage, the main purpose of this investigation was not to identify the type of microbial attack that concerned the wood, but how the decay could affect a dendrochronological analysis and how this latter could be undertaken in the least expensive and most effective way. It has to be considered that the only way to integrate dendrochronology in ordinary “salvage archaeology” is limiting the costs of the entire process, a major part of which is represented by the chemical treatment necessary to the stabilization and preservation of wood.

While the wood was conserved in an appropriate tank filled with water, the effects of this decay have been monitored on a couple of fragments. In figure 2a it is shown the variation of dimensions of a sample of wood while naturally drying, at a temperature of 25°C and 65% of humidity. Those variations were measured along four axis on the transverse plane of the stem: one along the radial direction and three along tangential directions, two of which corresponded to the directions given by the sides of the piece and determined by woodworking.

The diagram shows that the smallest shrinkage is produced along the radial direction, while the biggest is produced along the perpendicular to it. This decrease is partly due to the normal process of wood shrinkage when moisture evaporates, which also occurs on the fresh wood, but it is

accentuated by the collapse of the cells of archaeological wood. Furthermore, due to the dispersion of the fungal action, shrinkage is not homogeneous and, even if series of ring measurements undertaken on damaged wood can often be synchronized, especially if they are carried out during the first 48 hours of drying, a stabilization treatment is required in order to assure the possibility of their repetition.

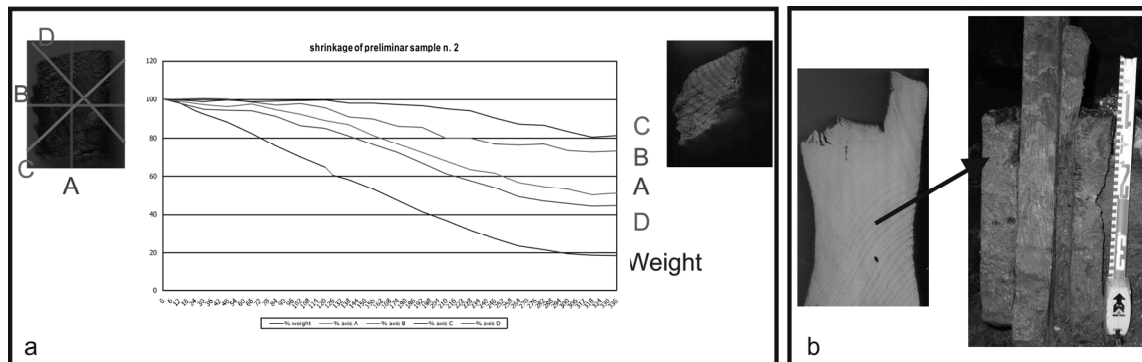


Figure 2: a) Percentages over time (in hours) of the shrinkage of a waterlogged wood fragment when dried naturally. b) A treated element that has maintained its "L" shape (left), as it results from the comparison with the same element in situ (right).

The standard stabilization and conservative treatment of wood, at present days, recourses to the freeze-drying and impregnation of PEG. If this technique seems to be almost essential in the case of large pieces of wood, it has the disadvantage of high cost and, from the dendrochronological point of view, it may make it difficult to read tree rings (Brunning & Watson 2010) and it makes ^{14}C datings impossible (Unger et al 2001).

In the case of Foneria samples, the dewatering process was accomplished by a series of baths in hygroscopic solvents, since their lower surface tension with respect to water (dyn/cm 75,64) allows natural drying without destructive effects on the wood. Ethanol (dyn/cm 22,27) or acetone (dyn/cm 23,7) were used and no difference was noted in the final result.

Although bibliography usually considers this drying method as a part of consolidating treatments with rosins (Unger et al 2001), it has been noted that, in the case of small objects, such as dendrochronological sliced samples, the impregnation can be omitted, removing the risk of contamination that could affect subsequent analysis, like ^{14}C dating.

The results were satisfactory. Not only shrinkage was reduced to minimal levels and rings remained clearly visible but also, as it can be seen in fig. 2b, it was possible to preserve the details of the piece even when its shape was somewhat complex, as is the case of the parts used in joints. However, even if during the four years following the treatment the treated samples didn't show any appreciable change, it has to be remarked that such treatment was not aiming to obtain pieces for long term conservation, as those that will be indefinitely stored in a museum. The purpose was actually to ensure the availability of samples for a reasonable period in order to undertake various analysis and even reproduce them for quality control.

Measurements of tree rings were taken on high resolution (4800 dpi) scanned images of slices of each piece of the well by CooRecorder software (Cybis Elektronik & Data AB). When it was possible, measurements along two opposite radii of the samples have been done. Cross dating operations were undertaken using the Cdendro software (Cybis Elektronik & Data AB) and later, after a visual confirmation of the matching of the curves, submitted to COFECHA quality control.

The chronology

Of the 13 pieces that composed the well, 8 clearly match (COFECHA series intercorr.: 0,62) to form a chronology of 130 years length (mean length of series: 73,3). Another one well matches to most of the types of correlation coefficient but it is too short (27 years long) and it's therefore not included in the chronology. One more piece might be aligned but, due a to a severe microbial degradation, the rings sequence is not entirely readable and is waiting to be re-measured on samples from other parts of the planks. The silver fir sample cannot be crossdated with any of the pine sample.

No sample retained the bark. Sapwood detection is somewhat problematic, because of the state of preservation of the waterlogged wood and the effect of the drying treatment, that tends to light the overall color. Anyway, the suspected sapwood has been confirmed by observing the penetration of an alcoholic safranin solution into the end grains of the samples (Bamber 1987). The sample with the most recent rings in the chronology (Fon02) probably retains the most part of the sapwood, which corresponds to a number of outer rings between 80 (judging by visual observation) and 90 (by considering the penetration of the stained solution), for a total thickness, respectively, of 6.5 and 7.5 cm.

Thanks to a preliminary ^{14}C dating of the wood, the structure reused into the well construction can be dated roughly to the I century AD. Unfortunately, due to the lack of adequate references for conifers in the region, the chronology cannot be dated more precisely by correlation. For this reason, a series of ten ^{14}C datings of two untreated and synchronized samples, on consecutive groups of five rings each, is being undertaken by the Laboratory of radiocarbon dating of the University of Barcelona in order to achieve a ^{14}C "wiggles matching". The results will be appropriately divulged in the future.

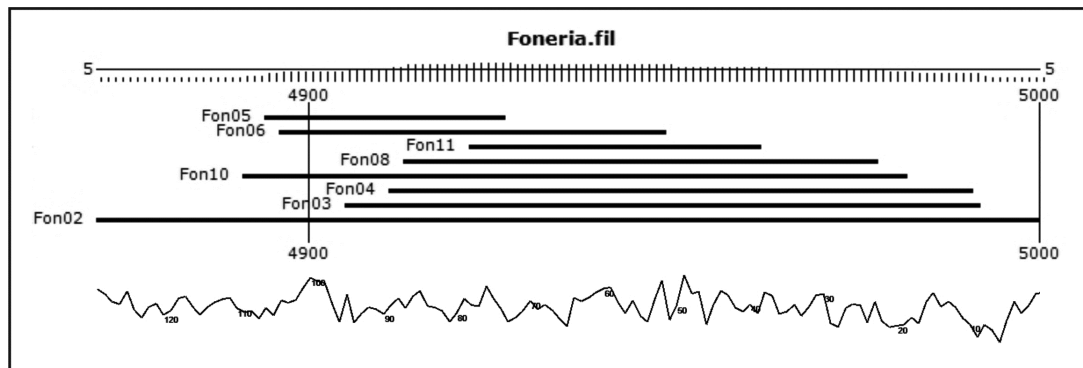


Figure 3: Chronology from Foneria. The tree ring curves of each series have been detrended by fitting a negative exponential curve, before the mean values chronology were plotted. Older times are on the left. The timelines of each series and the sample depth are in the upper part of the figure.

Some aspects of forest management during Roman times in Catalonia.

Before illustrating the punctual contribution of the Foneria data to the study of forest exploitation in Roman times, some words must be spent about the state of the knowledge on the subject in the Catalan territory. Research on this subject has been undertaken mostly thanks to carpological and pollen studies: since the publication of a couple of papers that summarize data scattered throughout the territory collected in the past (Buxò 2005, Riera 2005, where all the previous relevant bibliography appears), some new data can be deduced from more recent studies accomplished in mountain territory (Palet et al 2006, Riera et al 2011), where also studies on carbonized fragments of wood could be undertaken (Euba & Palet 2010), as well in the coastal

zone (Palet et al 2010a; Palet et al 2012), where archaeobotanic records are integrated in a multidisciplinary archaeological approach.

Generally speaking, the present state of knowledge interprets human impact on woodland during Roman times mainly from the point of view of the relationship of the increase of farming, livestock and other productive activities with the decrease of forest surface, due to fires or tree felling. Although this association cannot lead to a homogeneous model applicable over the entire Catalan territory – deforestation is not a generalized process (Palet et al 2010) and landscape is characterized by several specific forms according to the chronology and the localization of the site studied, with special consideration to the difference between coast and mountain regions – we can assume that, in the Roman period, forest management had a greater importance compared to previous eras.

From the point of view of economic interests directly related to woodland or tree culture, for the time being the evidences allow to speak of several contexts for exploitation of trees.

In the first place, thanks to data scattered over the entire Catalan territory, the exploitation of tree for fruit production, either in the form of cultivated – autochthon or introduced - fruit trees (*Prunus avium*, *Ficus carica*, *Prunus persica*, *Prunus domestica*, *Prunus amygdalus*, *Corylus avellana*, *Juglans regia*) or in the form of recollection of wild products (*Prunus spinosa*, *Quercus sp.*, *Sambucus nigra*) (Buxò 2005) is well known during all the Roman times.

Regarding the direct exploitation of tree wood, in north-east Pyrenees, between the I century BC and the II century AD, *Pinus sylvestris* and *uncinata* were used, probably in the form of charcoal, for combustion in metallurgic furnaces (Palet et al 2010b; Euba & Palet 2010) and, around the II-IV century AD, for the production of rosin (Palet et al 2010b; Orengo et al 2013). Recently, thanks to archaeobotanical analysis that allowed to reconstruct the environment of one of the major necropolis of Barcelona, researchers have pointed out the fact that, among local documented species (*Quercus ilex*, *Quercus robur*, *Olea*, *Pinus pinea* and *Pinus spp.*, *Corylus avellana*, *Salix spp.*, Cupressaceae), some had specific ritual values (particularly oak and pines) and could be used especially for the arrangement of funerary gardens (Beltran de Heredia et al 2007). Other activities that had to be very extended but are harder to document in archaeological contexts, since they cannot be proved by small charcoal or pollen record, such as manufacture of working tools (Euba & Palet 2010:179-180) or structural elements from *Pinus nigra*, *Abies alba* (Euba & Palet 2010: 180) and oak (Lopez Bultò 2010) are also known.

In the area around Foneria site, located at the bottom of the hill of Montjuïc promontory, on the edge of the deltaic plain of the Llobregat river, Roman landscape was reconstructed on the basis of pollen records as mainly forested, occupied by evergreen oaks, pine trees and deciduous trees, with several clearings for farming activity. It will only be from the Late Antiquity onward that deforestation acquires major proportions, thanks to the use of repeated wildfires in order to obtain more space for breeding, in correspondence to a decline of agricultural practice (Palet et al 2010a, Palet et al 2012).

Foneria archaeobotanical data add substantial information to the state of the knowledge of landscape management and plants distribution of this area, but, like we said before, carpological data and small plant remains are worth a specific presentation.

In this context, anyway, the Foneria well allows to set out an issue related to economic implications of the use of wood in the early Roman era. Mainly due to the limits of the set of data in previous studies of wood employment on the Catalan territory, researchers could not face the eventuality of wood supply from sources other than the local environment. Where the use of wood has been documented, it has always been related to the exploitation of woodland adjacent to the archaeological site. The sole, hypothetical, exception, negligible from the economic point of view, would be represented by handcrafted tools made of silver fir and boxwood that could have been

transported by shepherds during transhumance for their personal use, dropped and burnt during summer stays, when unable to accomplish their function (Euba & Palet 2010:180).

The wood used in the well construction at Foneria, *Pinus sylvestris/nigra* and *Abies alba*, today cannot be found closer than, according to the species, 30 or 50 kilometers north and north-east in straight line from the archaeological site (see i.e. Moser et al 2013, fig. 4). Even if there is some evidence, like in other parts of southern Europe (Moser et al 2013), that silver fir was more widespread during the Roman period than it is today (Riera 2005), the pollen records of this era don't include it in places closer to the site than those of our time, since, like for European black pine and Scots pine, their natural environment is set from 500 m. above sea level upward.

This strongly suggests the hypothesis that those species, highly appreciated by Roman carpenters for structural woodworking (Ulrich 2007) were object of trade to Barcelona. They could arrive from the backcountry overland and, probably, given the proximity to the navigable Llobregat river (Izquierdo 2009), partly by fluvial transport, as it seems the case of silver fir transportation from the mountains of Etruria and Umbria to Rome through the Tiber River and its tributaries (Ulrich 2007). Nevertheless, for the time being, the possibility that structural wood could arrive by sea trade cannot be ignored: it's the way by which other types of construction material documented in the Foneria site were imported, like *tegulae* and water pipes. Even if it's not necessary to consider a more distant origin, sea routes could have been more practical for transporting wood from some northern coastal ports closer to the Pyrenees mountains.

Conclusions

The archaeological dig of Foneria site has provided useful information for landscape reconstruction in the coastal zone of central Catalonia. From the dendroarchaeological point of view, a well built in the early Roman empire times allowed to build the first chronology of Roman times on the territory and to deduce some assumption about wood transportation from inland. The find helped to raise awareness of dendroarchaeology with the relevant Catalan authorities for cultural heritage preservation, that funded subsequent analysis. Therefore it is hoped that, in the future, the potential of this discipline could be fully exploited thanks to the collaboration between the many qualified local dendrochronologists and the archaeological community, in order to improve the multidisciplinary approach to the everyday historical investigation.

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