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Roman wells of north-eastern Iberian Peninsula: Landscape and use of wooden resources

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Abstract

Preservation of wood and other archaeobotanical remains is quite common in Roman wells from urban contexts. Wood recovered inside these wells can offer extraordinary information about forest exploitation and management, woodworking and building technology. The aim of this paper is to discuss and present the results and methodological approach of the analysis of wood recovered from three Roman wells in the Northeast of the Iberian Peninsula. Paleoecological information, different uses of raw material, and technological as well as dendrochronological data obtained are presented and contextualized in relation to the period and the region. The main taxa used for manufacturing the goods and the structural elements of the wells were obtained in a wide catchment area. Besides local wood, non-local wood such as fir, birch and scots-black pine was transported to the sites.

Keywords

Wood ; Forest resources ; Wells ; Woodworking technology ; Roman times ; Dendrochronology

1. Introduction

Wells were one of the most common, because necessary, equipment in most historical settlements. In this type of structure, the presence of the water table enhances the possibility of wood preservation, the elements used for building the wells themselves, as well as waste materials or other debris thrown inside, providing valuable opportunities to study uncommon archaeological material. The study of archaeobotanical remains of wells has already provided interesting data of the economy and woodworking technology. The Roman wells of Lattara (Chabal and Feugère, 2005), Gasquinoy (Figueiral et al., 2010) and La Lesse-Espagnac (Figueiral et al., 2015), in France, are good examples of the relevance of data obtained. In these cases, remains of seeds and fruits, as well as furniture and household objects made of wood, branches, and twigs were recovered. In the southeast Iberian Peninsula, the wells of Tossal de les Basses (Carrión Marco and Rosser, 2010) have also provided a sample of wooden artefacts which have allowed an interesting approach to the woodworking technology in Iberian and Roman times (from 4th century BC to 3rd century AD), demonstrating the continuity of certain techniques.

Despite their recurrence in urban contexts, there is little tradition of study of wells in the NE Iberian Peninsula. The city of *Iesso* (Guissona), dated 1st BC-2nd AD, (Guitart and Pera, 2004) is the only case where wells were excavated, systematically sampled and studied until recent times (Buxó et al., 2004). However recent excavations carried out in the framework of commercial archaeology activities during the last decade has recovered several wells in urban contexts in the northeast Iberian Peninsula. In 2008, a well was discovered and excavated during the works in the train station of Estació Badalona-Pompeu Fabra (López Bultó, 2010) in the modern city of Badalona (*Baetulo* in the Roman era). In 2009, due to subway construction, another Roman well was discovered in Foneria Street in Barcelona (Ravotto and Juan, 2010). *Iesso* is located in the hinterland of

Catalonia, while Foneria Street and Estació Badalona-Pompeu Fabra are located on the coast (Fig. 1).

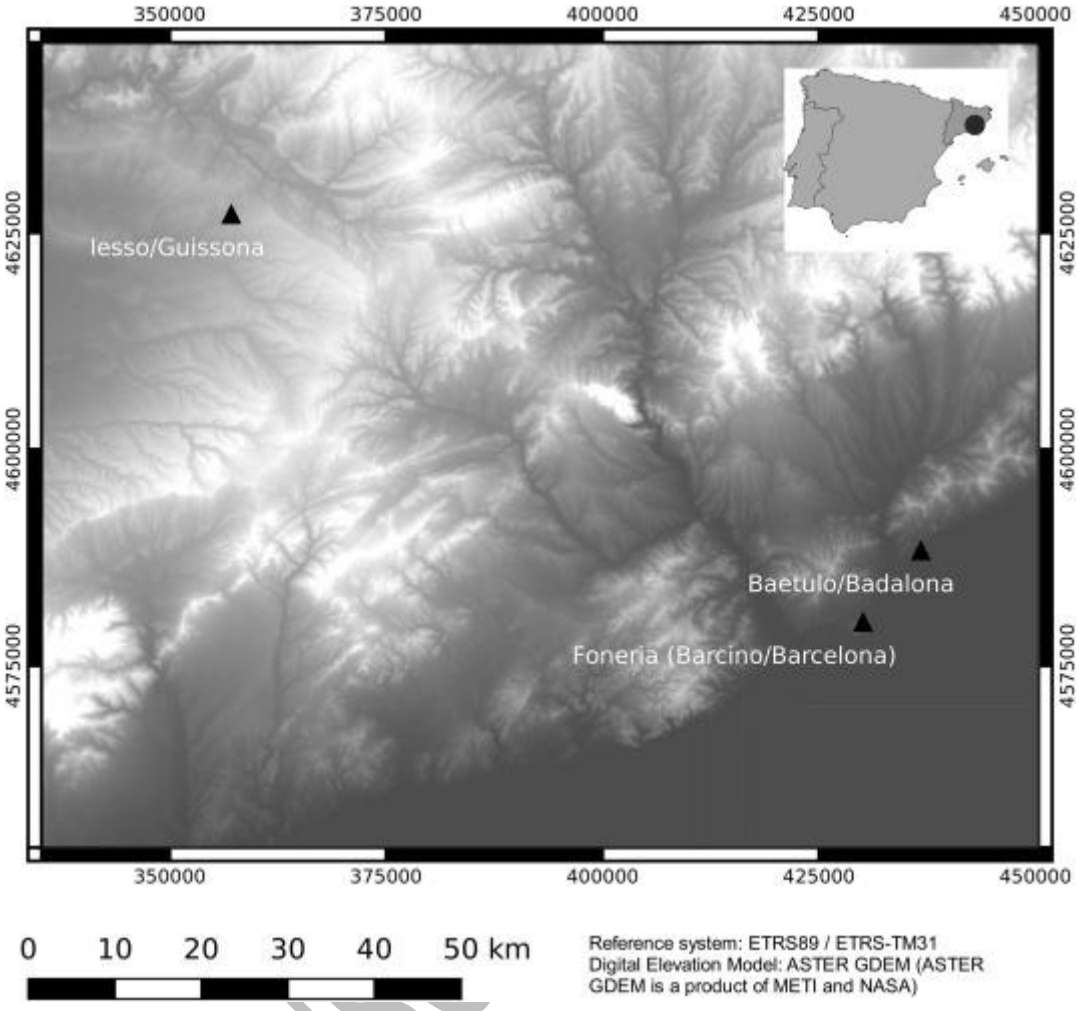

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Fig. 1. Locations of study sites.

In the three cases, archaeobotanical waterlogged remains were recovered. In this paper, attention is focused on the waterlogged wood from these wells. The first objective of this paper is to provide an overview of the contribution of the study of these wells to the knowledge of landscape, exploitation of territory, uses of wooden resources, and woodworking during Roman times in the northeast Iberian Peninsula.

A second aim deals with the contribution of dendrochronology to the study of the wooden remains of wells. In Catalonia (Spain), dendroarchaeology has been a neglected field in comparison to other Mediterranean regions. At the present time we only have some floating chronologies from sites as La Draga (Banyoles), dated to the 6th millennium cal BC (Gassman, 2000) and a medieval shipwreck (Barcelona) (Soberón et al., 2012). Archaeological waterlogged wood of historical times is a unique opportunity for building the dendrochronological series in the

region. Other dendrological studies have been also applied to archaeological sites of other regions of the Iberian Peninsula in order to assess climate and patterns of human exploitation. Charcoal and wood remains of the prehistoric and Roman sites of Tres Montes (Navarra), el Cabezo de la Cruz and Segeda (Zaragoza) and O Castelo (Ourense) were studied with this objective (Carrión Marco, 2005).

2. Material and methods

The material studied come from four wells located in three Roman sites of North-east of Iberian Peninsula: *Iesso*, *Baetulo* and Foneria street.

Two of the wells are located at the archaeological site of *Iesso* (Guissona), one of the most important Roman sites in Catalonia. *Iesso* is located near the modern city of Guissona at 490 m asl. It was founded in the 1st century BC and was occupied until the 6th century AD. The more ancient one was constructed at an undetermined time in the republican age: in the 1st century BC it was surely in use, while it was definitely abandoned at the half of the 1st century AD. It was square at the top, where it had a lining of masonry. It measured 1.15 m per side and was formed by blocks of local stone, arranged in regular courses. Its height was 2.5 m, while the total depth of the well was 6.75 m. Under the lining of masonry, as the depth of the well increased, it tended to a somewhat circular form with a diameter of 0.90 m (Buxó et al., 2004). The second well was constructed at an undetermined time in the 1st century AD and remained in use until the second half of the 2nd century AD. It had a circular shape, and its upper part was provided with an internal lining of masonry 2.4 m high, made of irregular local stones bound by mud. The internal diameter of the lining was 1.2 m; below, the diameter of the well narrowed to 0.95 m. The total height of the structure was 7.7 m (Buxó et al., 2004).

The two wells of *Iesso* were excavated and systematically sampled and washed for recovering the archaeobotanical remains for analyses (Buxó et al., 2004). A total of 64 fragments of charcoal and 308 fragments of waterlogged wood were recovered: 72 had traces of manufacturing. They mainly correspond to small fragments of objects, obsolete artefacts, combustion residues, and branches and unshaped wood of unidentified function.

The second case is the well located in the ancient city of *Baetulo* (Badalona), funded in the 1st century BC and occupied until the 6th century AD. A partially preserved well was found during the construction of a new train station in Badalona. During the excavation, four large logs (approximately 100 × 30 × 20 cm), fitted together to form a square at the bottom of the well, and a fifth small piece of wood decontextualized inside this square were found. From the position in which they were found, it seems clear that the four main pieces of wood were intentionally placed in this position. These wooden elements correspond to the lower wooden lining below the masonry structure of the well. This position follows a specific function: to maintain the shape of the well and strengthen the walls in the base where the soil composition is unstable. The sediment inside the well was not sampled. The good preservation of wood encouraged the study of woodworking technology.

The third case of study is the well of Foneria Street, in Barcelona (Roman *Barcino*), about 4 km south-west from the city centre. This well was excavated in 2009, due to a subway construction. The historical site is located in the deltaic area of the Llobregat River, and corresponds to a long rural occupation from the Iberian age to the Late Antiquity. The first phase, prior to the 3rd-2nd centuries BC, cannot be dated precisely due to the absence of pottery sherds. From this moment onward, the site was frequented until the 6th century AD (Ravotto and Juan, 2010; Ravotto et al., in press).

The well from Foneria Street, although partially damaged by the subway construction, can be reconstructed as a square shaped building, measuring 1.80 m per internal side and with a total height of 3 m. Its internal lining was formed by three parts: from top to bottom, two superposed masonry structures, made with different techniques, and a lower wooden part. The walls of the upper masonry structure, 0.30 m thick, were formed by irregular stones bound with abundant mortar that, on the internal side, was accurately smoothed. This element was supported, at a lower level, by thicker walls (0.40 m), formed by blocks of local stones, reused from a previous undetermined structure, assembled without mortar. The lower part was composed of 13 wooden elements. As in the previous case, these wooden elements correspond to the lower lining wooden part below the masonry structure of the well.

The sediment inside the well of Foneria was sampled and washed for recovering archaeobotanical remains. A significant amount of wooden remains were recovered, and a sample of 50 pieces of wood recovered in the sediment was analysed in order to identify the taxa composition. According to the objectives of the research, all the manufactured items and a sample of the twigs and branches were studied. Moreover, 13 elements of the wooden structure of the well itself were recovered. The archaeological record is thus related to two different historical moments: the early phases of the Roman occupation of the site (dated between the 2nd and the 3rd century AD), when the well itself was built; and the second in the 6th century AD when the site was definitively abandoned.

Each site was studied at different times and for this reason the methods applied were different. In all cases one of the main objectives was the identification of taxa used for manufacturing structures and goods, as well as the unworked branches and twigs. The identification of taxa was carried out from the analysis of micro anatomical features of wood. With this purpose, for each sample thin sections of the three anatomical plans of the wood (cross, longitudinal-tangential and longitudinal-radial) were done and were observed with a microscope. The anatomical keys suggested by Schweingruber (1990) were used for the taxonomical classification of remains.

In the case of wood remains from *Baetulo* and Foneria, it was possible to characterize the morphology of the artefacts and the manufacturing process. With this objective, the shape and dimensions of the pieces of wood were accurately described. Secondly, the traces observed in the surface of these artefacts were recorded. These traces are the result of actions involved in the process of manufacturing. Actions as splitting, sawing, turning, or polishing left characteristic

marks on the surface of wood. Finally, the position of the planks in the stem was determined. In a like manner, use wear analyses of the artefacts, together with morphology, provide information on their function.

Special attention was paid to the structural elements of the well of Foneria. In this case, a dendrochronological analysis of the wood was also undertaken in order to determine if it was derived from the same or different trees and to reconstruct some characteristics of the original timber. Dendrochronology can be used for multiple purposes: environmental studies, climatic reconstruction, and dating of human-used wood remains (Fritts, 1976; Baillie, 1982; Schweingruber, 1996). However, the climatic signal of the patterns of growth can be easily masked or distorted as a consequence of age-related patterns, injury, or competition for nutrients and light. In order to minimize those undesirable effects, a statistical computation known as "detrending" is applied to the measured ring series belonging to different trees prior to the cross-dating operations (Fritts, 1976; Baillie, 1982).

Rings have been measured on high resolution scanned images of samples from each component of the well with dendrochronology-oriented software (CooRecorder, Cybis Elektronik & Data AB). Cross-dating of the series was achieved by visual and statistical evaluation (with CDendro software, Cybis Elektronik & Data AB) and finally submitted to a statistical quality control by COFECHA software (Holmes, 1983). Furthermore, an estimation of the distance from the innermost ring measured in each series and the pith of the tree has been attempted thanks to a facility offered by the measuring software that, ultimately, is a dynamic and enhanced version of a traditional visual method (Applequist, 1958).

Some rings may be absent when bark is not present on the sample. Once the samples are cross-dated, in order to assess the falling date of the tree, it is important to estimate the number of outer rings not preserved in the sample. Theoretically, a first approximation can be obtained from the presence, or partial presence, of sapwood in the sample. In the Foneria wood, sapwood detection is problematic, as the effects of degradation and the conservative treatment make the colour-based criteria almost useless (Ravotto, 2014). Hence, an attempt to determine the presence of sapwood has been undertaken by observing the penetration of an alcoholic safranin solution into the end grains of the samples (Fig. 2; Bamber, 1987), the ratio of degradation (to which sapwood is more subject), and, to a minor extent, by visual evaluation, especially after digital filtering of scanned images. Those methods did not lead to a final and exact determination of the amount of sapwood and the results have to be considered with caution. However, they are compatible with those derived from recent studies on fresh samples of German Scots pines (Bieker and Rust, 2010).

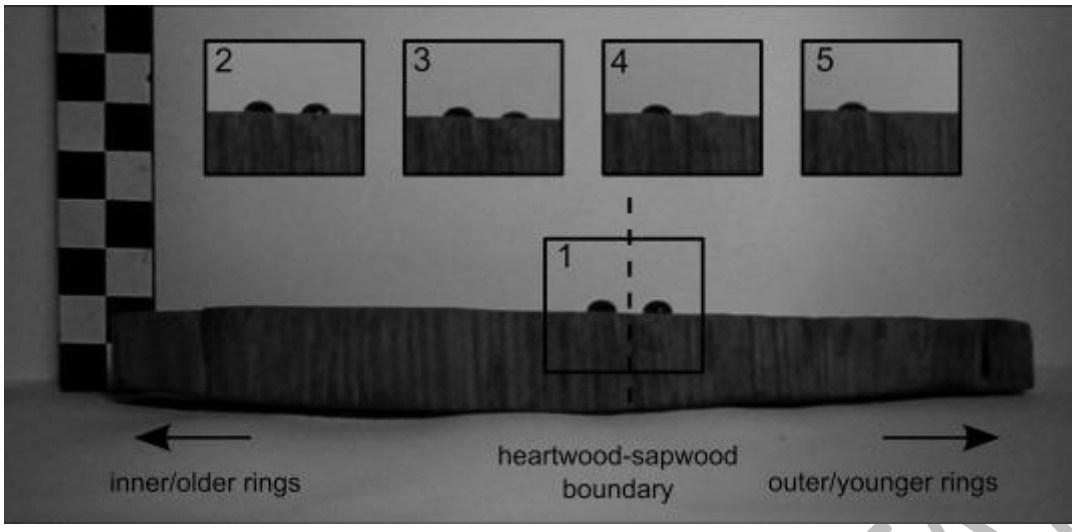

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Fig. 2. Determination of the sapwood in a Foneria sample (Fon 2) by penetration of an alcoholic safranin solution, as described by Bamber (1987). Ninety-eight seconds passed between frames n. 1 and 5.

3. Results

3.1. Iesso

A total of 19 taxa were identified in both wells: 13 in the first and 9 in the second. A summary of taxa and their distribution in the wells is presented in Table 1. The best represented taxa in both wells are *Quercus* sp. deciduous and *Pinus sylvestris-nigra* type. The representation of the other taxa is very heterogeneous between both wells.

Table 1. Distribution of taxa from the wells of *Iesso*. Grey: wood used for manufacturing goods

	Well 1		**Well 2**	
	Wood	**Charcoal**	**Wood**	**Charcoal**
Abies alba			1	
Acer sp.	2			
Betula sp.	21			
Buxus sempervirens	6			
Pinus sylvestris-nigra type	75	1	31	11

	Well 1		Well 2	
	Wood	**Charcoal**	**Wood**	**Charcoal**
Quercus sp deciduous	74		23	43
Salix sp.	6			
Ulmus sp.			2	
Corylus avellana			2	
Ficus carica	2			
Fraxinus sp.	30			
Juniperus sp.	1			
Leguminosae			13	
Pinus halepensis	5			
Pomoideae	2			1
Populus sp.	4			
Prunus sp.	1			
Quercus sp. sclerophyllous			1	7
Rosoideae			3	

A significant amount of remains had signs of manufacturing, and in some cases it was even possible to recognize shapes. The other residues corresponded to unworked branches. A third group includes unshaped fragments, which probably came from the decomposition of larger artefacts, and a fourth group corresponds to fully or partially charred wood. The woods that have clearly been used for the production of artefacts are *Acer* sp, *Betula* sp, *Buxus sempervirens*, *Pinus sylvestris-nigra* type and *Quercus* sp. deciduous, *Ulmus* sp., and *Salix* sp., also probably *Abies* sp. Other taxa represented in the unworked wood remains are *Corylus* sp., *Salix* sp., *Fraxinus* sp., *Ficus carica*, *Prunus* sp., *Juniperus* sp., Leguminosae, *Pinus halepensis*, Pomoideae, *Populus* sp., *Prunus* sp., *Quercus* sp. sclerophyllous and Rosoideae. In the charred remains, only a few taxa have been documented: *Pinus sylvestris/nigra* type, *Quercus* sp. deciduous, Pomoideae, and *Quercus* sp. sclerophyllous.

3.2. Estació Badalona-Pompeu Fabra (Baetulo)

All the timber elements were identified as *Quercus* sp. deciduous. Morphological study of the timber elements determined the presence of abundant traces and

marks and the position of planks in the stem. All the pieces of wood were half sawed (Fig. 3).

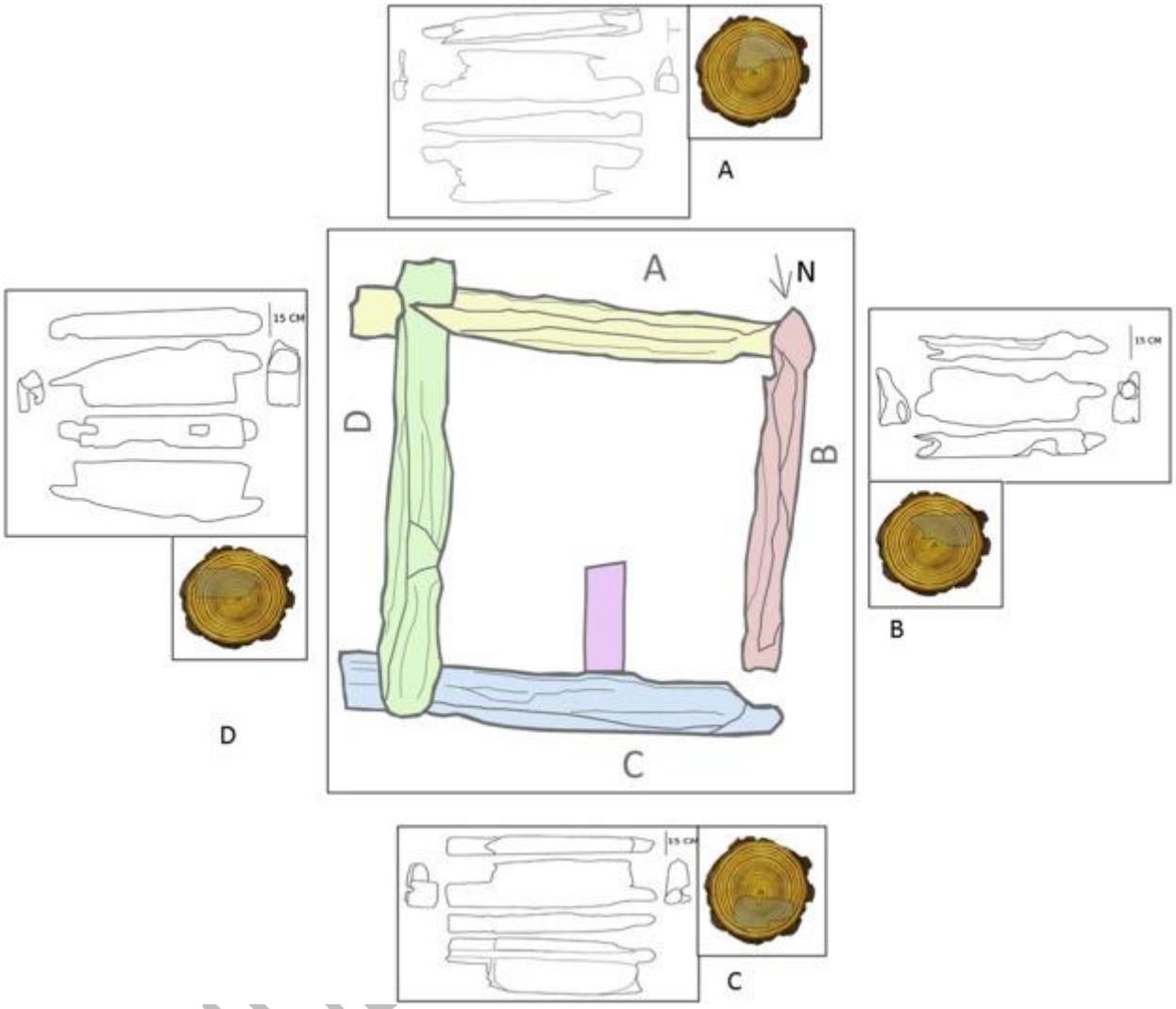

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Fig. 3. The structural elements of the well of Estació Badalona/Pompeu Fabra. The transversal section of the stem shows the hypothetical disposition of the elements within the logs from which they were cut (representation, not to scale).

The pieces of wood joined together using only wood elements. All the logs had appendixes at the end that fit one another. This type of joining, called “half lap”, was quite common in the Roman era and has been identified also in other wells (Ulrich, 2007).

The logs had also other evidence of joints with the objective of creating a longer element. The positions of these joints are not functional in the structure of the well. These joints, called “mortise and tenon”, have a tongue of wood (the tenon) inserted into a recess (the mortise). Usually, once the joint has been made, both mortise and tenon are hidden. In the case of the logs of the well of Badalona, only the mortise has been preserved. Other types of marks are consistent with a groove

joint. The presence of these joints together with holes, striations, and wear seems to indicate the reuse of the wood.

3.3. Foneria

3.3.1. Well structure

Taxonomic analysis revealed that two different species were used: Scots-black pine (*Pinus sylvestris-nigra* type) and fir (*Abies* sp.), the first being the most commonly used (12 elements).

Although partially damaged, the shape of the lining wooden part can be reconstructed (Fig. 4) as two opposite sides lined with planks (Fon 1, 2, 4, 6 on the preserved side), while two single, more consistent, elements (a thick plank and a beam, Fon 7 and 9) were situated along the other two sides. The quadrangular shape of the structure was sustained by four vertical planks positioned at the corners (Fon 3 and 8 conserved). The assembly was secured by nails (Fon 4, 5, 10, 12) and two types of joints, the "half lap" (Fon 3, 4, 6 and 8, 9) and the "mortise and tenon" (Fon 4, 6 and 7). An unnecessary and unused hole for joint (in Fon 6), some small residues of white paint (on Fon 4, 6) and, overall, different shapes and dimensions of elements with the same structural function, suggest that part of the wood was reused from at least one previous structure. Probably for this reason, a set of smaller pieces (Fon 5, 10, 11, 12, 13) were used to add thickness where needed, improving robustness of the final product.

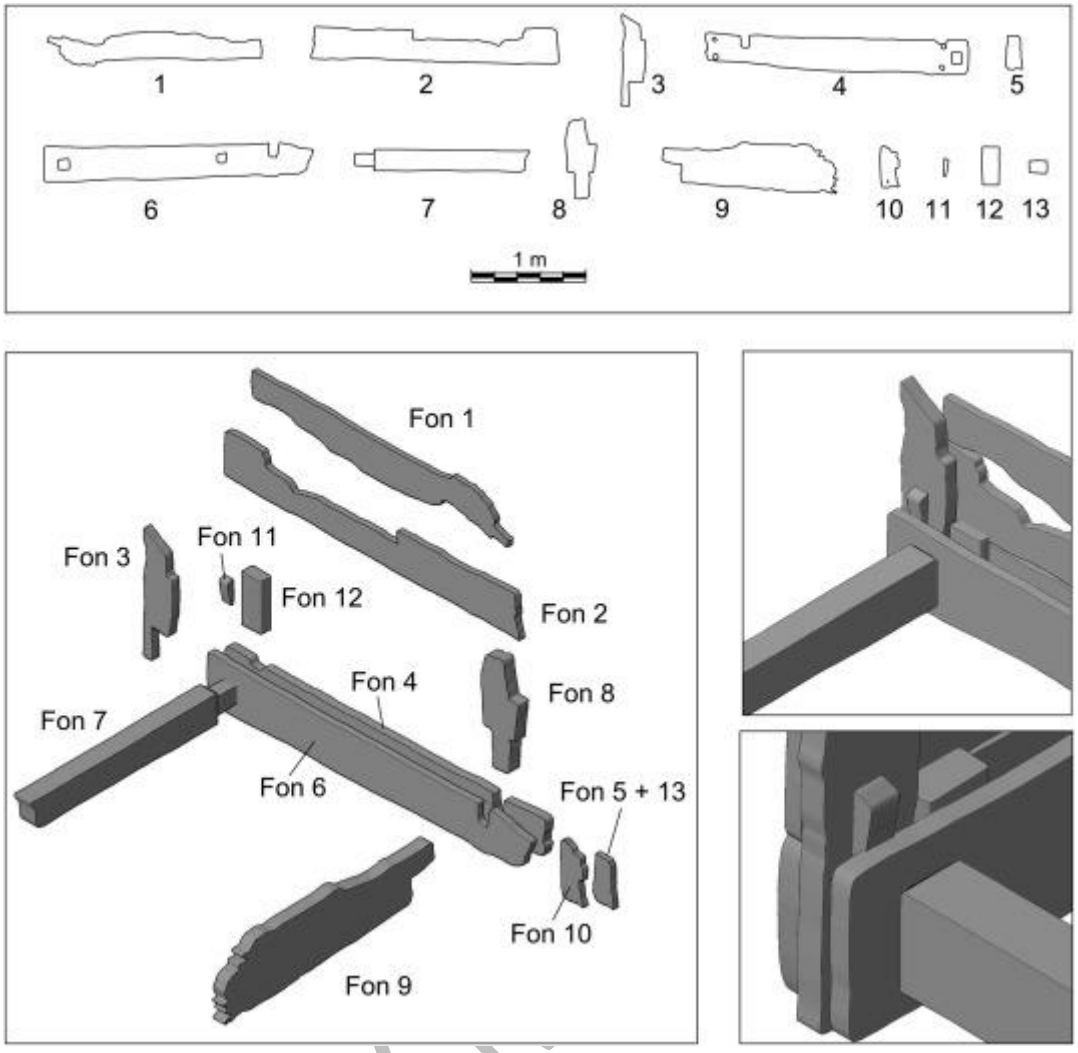

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Fig. 4. Wooden elements used in construction of the Foneria Street well and their arrangement in the structure.

Dendrochronological analysis of the 13 wooden elements shows, on the basis of visual and statistical correlation of the series prior to detrending, that they were obtained from at least 6 stems. Stems A, C, D and F were plain sawed, while stems B and E could have been quarter sawed (Fig. 5).

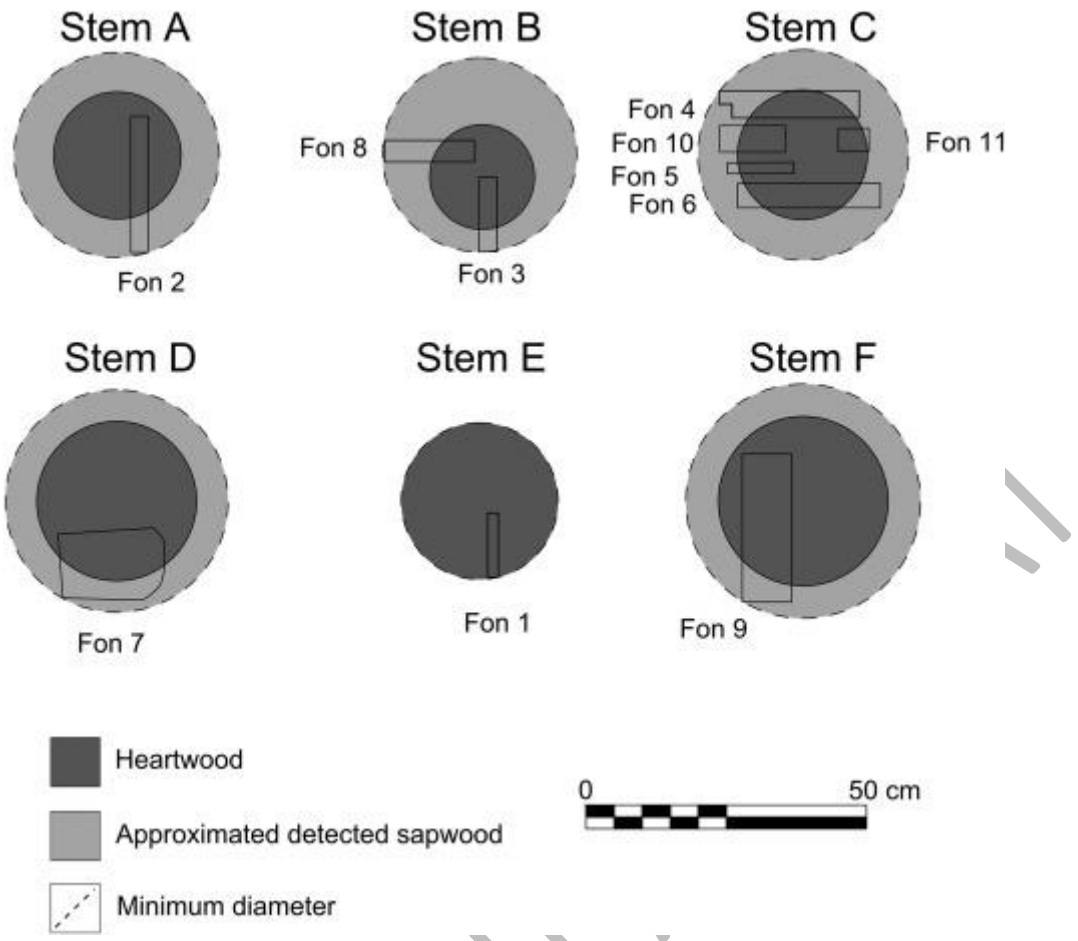

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Fig. 5. Disposition of the elements used in the Foneria well within the logs from which they were cut. Dimensions refer to dry samples.

In stem B (Fon 3, Fon 8), 88 years were measured. In the dry sample, the pith is estimated to be less than 1 cm away from the innermost ring preserved (in Fon3), corresponding to a couple of additional rings. The minimum diameter estimated for the stem is 32 cm. The different proportion of rings and dimension between the two pieces indicates that the radial growth of the tree was not symmetrical. The sapwood can be estimated as about 8 cm on the longest radial axis (approximately 60 rings).

In stem C (Fon 4, 5, 6, 10, and probably Fon 11), 101 rings were measured. The pith can be estimated some 3 or 4 years from the innermost ring preserved, at a distance of 2 or 3 cm. The minimum radius is estimated to be 18 cm, 7 of which seem to correspond to sapwood (52/56 rings).

For the other stems, more uncertain results have been obtained due to the characteristics of the growth or the fact that measurements cannot be compared between planks from the same log. In stem A (Fon 2), 130 rings were measured. The pith can be estimated as some 5/6 years from the innermost ring preserved, at a distance of 2.5 cm. The radius of the stem at the sample height was 18 cm, 6.5 of

which correspond to sapwood (approximately 80 rings). On stem D (plank Fon 7) 117 rings were measured, the inner one being approximately 8 cm from the pith; about 70 rings were part of the sapwood. A minimum radius of 20 cm can be estimated. The plank (Fon 1) from stem E preserved only 67 rings, probably all belonging to heartwood. Distance to pith could be estimated to be about 4 cm. On the plank (Fon 9) from stem F, 72 rings were measured. The inner one was some 3–4 cm from the pith, and the outer 21 rings probably belonged to sapwood; the minimum radius can be estimated to be 21 cm.

Corss-dating of the wood is one of the major objectives of dendrochronology. Eight of the 13 elements of the well, belonging to three stems, could be cross-dated (COFECHA series intercorr.: 0.62). Fig. 6 shows the visual match between the series grouped by stems, each stem detrended by fitting a negative exponential curve. The cross-dated series belonged to the reused structure mentioned above, not to the moment of construction of the well. Stem A was the oldest of the three, although its more recent ring adds 8 years to the chronology defined by the last ring measured on the other stems. This difference could be due to the fact that stems B and C did not preserve all sapwood, or that Fon 2 did not form part of the reused structure and was cut down some years after.

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Fig. 6. Visual cross-dating of the dendrochronological curves obtained from three stems, detrended by fitting a negative exponential curve. Older times are on the left.

The eight cross-dated series form the first Roman dendrochronological curve, 130 years long, from Catalonia (Ravotto, 2014). Due to the lack of reference curves in this region, as in the neighbouring ones, the curve from Foneria Street cannot be dated by dendrochronological correlation. For this reason dating by ^{14}C wiggle matching was planned. Wiggle matching (Bronk Ramsey et al., 2001; Galimberti et al., 2004) consists in obtaining a series of ^{14}C dates at known intervals, determined by ring counting, in order to fit them to a constraining model and thus achieve a more precise dating than one or more unmodelled dates. Ten adjacent groups of five rings each, from ring 54 (younger) to ring 103 (older) of the 130 rings that form the dendrochronological curve, were dated at the Radiocarbon Laboratory of the University of Barcelona (UBAR-1283 to UBAR-1292) and will be soon processed further.

In order to present some preliminary results, the ten dates were submitted to the wiggle matching facility of the OxCal calibration software (Bronk Ramsey, 2009),

using the INTCAL13 calibration curve. The date of the outermost ring of the dendrochronological curve can be approximated between 55 and 113 AD (95.4% confidence). Due to the steady gradient of the ^{14}C calibration curve in this era, this is the maximum achievable precision, far more precise than the traditional ^{14}C dating (i.e., the unmodelled date of the last five rings would be in the range of 163 years of precision, while the same dating fitted to the model gives a date of the last ring in the range of 58 years, both cases at 95.4% confidence).

The other series could not be cross-dated. Fon 12 and 13 most probably belong to the cross-dated wood, but the ring counting is too small to achieve a trustworthy synchronization. Regarding Fon 1, 7 and 9 (the latter being the only fir element of the set), as the archaeological sub-phase to which the well belongs can be approximated between the 2nd and the 3rd century AD (Ravotto and Juan, 2010), it seems probable that they are more recent than the elements of the reused structure.

3.3.2. Wood remains inside the well

The anatomical study of the wood remains allowed the identification of 16 trees and shrubby taxa: *Abies alba*, *Arbutus unedo*, *Cornus* sp., *Ficus carica*, *Fraxinus* sp, *Juglans regia*, *Pinus halepensis*, *Pinus sylvestris/nigra* type, *Pistacia lentiscus*, *Prunus* sp., *Quercus* sp. sclerophyll, *Quercus* sp. deciduous, *Rosmarinus officinalis*, *Rubus* sp., *Ulmus* sp. and *Vitis vinifera* (Table 2).

Table 2. Distribution of taxa from Foneria 6th century AD remains. Grey: wood used for manufacturing goods.

Taxa	Number of remains
Abies sp.	2
Cornus sp.	1
Ficus sp.	12
Juglans regia	2
Pinus halepensis	1
Prunus sp.	1
Quercus sp. deciduous	1
Ulmus sp.	4
Arbutus unedo	1
Fraxinus sp.	1

Taxa	Number of remains
Pistaceae	1
Quercus sp sclerophyllous	3
Rosmarinus officinalis	1
Rubus sp.	7
Vitis vinifera	3
Undetermined	9

Evidences of manufacturing traces are present in the 28% of the fragments of the sample. They are probably disused objects that were thrown into the well: planks and undetermined objects, sometimes branches with cuts in longitudinal direction or in the ends. These fragments with signals of work were of *Abies* sp., *Quercus* sp. deciduous type, *Prunus* sp. and *Cornus* sp. It has also been possible to recognize a fragment of bowl made of *Juglans* sp. Foreign taxa are only present in manufactured items.

Fragments of *Rosmarinus* sp., *Pistacia lentiscus*, *Fraxinus* sp., *Arbutus unedo*, *Quercus* sp. sclerophyllous type, *Vitis vinifera* and *Rubus* sp., do not show evidence of manufacturing. Therefore, these taxa could have been natural or cultivated local trees in the area.

4. Discussion

4.1. Landscapes and their exploitation

The wood recovered in the Roman wells has provided new insights to the knowledge of local vegetation and the management of territory in the northeast Iberian Peninsula. Considering the current geographical distribution of taxa and their presence in the sites, several issues can be discussed.

In the case of *Iesso*, the taxa represented at the site probably grew in different environments. At the present time the vegetation is scarce in the region, the area is at the present time a grain-growing region and the landscape is dominated by shurbland and agricultural fields (Gracia et al., 2000–2004). However, pine (*Pinus halepensis* and *Pinus nigra*) and oaks, both evergreen and deciduous (*Quercus* sp. deciduous, *Quercus* sp. evergreen) still grow in the region. According to the modern distribution of taxa we can assume that the majority of taxa represented inside the wells were local or grew not far from the site. Typically Mediterranean taxa, such as *Quercus* sp. evergreen (evergreen-kermes oak), *Pinus halepensis* (Aleppo pine) and *Juniperus* sp. (juniper) could have grown in dry and sunny areas and lower altitudes. The supra-Mediterranean species, represented by *Quercus* sp. deciduous (oak), *Buxus sempervirens* (boxwood), *Acer* sp. (maple), *Pinus sylvestris*-

nigra type (Scots-black pine), could have occupied more humid and shaded areas at low altitude, but could have also grown at higher altitudes, although these species also grow in the Atlantic region of the Iberian Peninusla. The riparian vegetation is also well represented by *Populus* sp. (poplar), *Fraxinus* sp. (ash), *Salix* sp. (willow), *Ulmus* sp. (elm) and *Corylus* sp. (hazel). Meso and Supramediterranean forest or riparian communities still grow in the vicinity of the settlement. Nevertheless, special mention is required of the presence of *Abies* sp. (fir) and *Betula* sp. (birch), species that thrive today in the high mountains and upland. According to the modern distribution of fir and birch, the collection of these taxa occurred far from the site. At the present time, they grow more than 100 km from the site in mountainous areas of the Pyrenees.

Species as *Ficus carica*, Rosaceae/Maloideae and *Prunus* sp. are also present. These taxa which live in Mediterranean forests as wild species have been historically cultivated. Unfortunately, the anatomical study of wood does not allow the differentiation of wild and cultivated varieties. The presence of fruit remains of *Ficus carica*, *Prunus domestica*, *Prunus persica* and *Prunus amygdalus* in the site (Buxó et al., 2004) suggest the cultivation of these taxa.

In the well in *Baetulo*, local vegetation was also exploited for obtaining the wood used in its construction. According to pollen analysis undertaken in the Barcelona area, oaks were present in the area during Roman times (Riera, 2005; Riera and Palet, 2005). Furthermore oak still grows in the shady areas of the hills near the city of Badalona, which strengthens the idea of use of local resources for the construction of the well.

Regarding the wood recovered inside the well of Foneria, the diversity of taxa provides a picture of the landscape diversity during the 6th century AD, when the well was abandoned. According to the current ecology of the species in the region the flora composition is compatible with the proximity of marshes and wet environments, and with the presence of mixed forests of oak. The meso/supra Mediterranean vegetation is represented by evergreen-kermes oak, strawberry tree (*Arbutus unedo*), mastic (*Pistacia lentiscus*), Cistaceae, Aleppo pine (*Pinus halepensis*), rosemary (*Rosmarinus officinalis*), brambles (*Rubus* sp.), and deciduous oak. According to pollen data, that kind of vegetation would be dominant in the area (Riera, 2005; Riera and Palet, 2005). The majority of these taxa grow in open spaces and degraded forests. The riparian vegetation is also well represented. Elm (*Ulmus* sp.), dogwood (*Cornus* sp.) and ash (*Fraxinus* sp.) could have grown in the deltaic area of the Llobregat River. Fragments of *Abies* sp., (a foreign species that grows at high altitudes), were also found in the sediment. Nevertheless the more abundant type of remains in the sample are cultivated and/or introduced. These are species that are not native in the region under study, and/or species that usually only appear if they are cultivated. In this cultivated group, we can include the grape (*Vitis vinifera*), walnut (*Juglans regia*), and fig tree (*Ficus carica*), and possibly *Prunus* sp. The anatomy of wood does not allow determining whether taxa were cultivated or not, and some of them are native in the region, but domestic fruits and seeds of these taxa were also identified in the sample (Ravotto et al., in press). The presence of wood and fruits of these taxa suggests their cultivation in the settlement.

In summary, the local wood (Meso-Supramediterranean and riverside) is well represented, although the cultivated woody species are dominant. Taxa identified also reflect an environment where human impact is clearly appreciable, mainly due to the presence of woody species characteristic of degraded environments and the cultivated species that indicate the presence of vegetable patches and practice of arboriculture.

The data obtained at *Iesso* and Foneria demonstrate the importance of arboriculture in Roman times. The presence inside the wells of wood of potentially domestic trees together with the presence of remains of domestic fruits of these taxa reinforces the hypothesis of their cultivation. *Iesso* and Foneria have provided remains of *Ficus carica* and *Prunus* sp; while *Vitis vinifera* and *Juglans* sp. are present in Foneria. These species were introduced by Romans and Greeks and are well documented in Roman sites in the Iberian Peninsula (Buxó, 1989, 1997; Peña-Chocarro and Zapata Peña, 1996, 1997, 2005; Buxó and Piqué, 2008).

4.2. Trade and the transport of timber

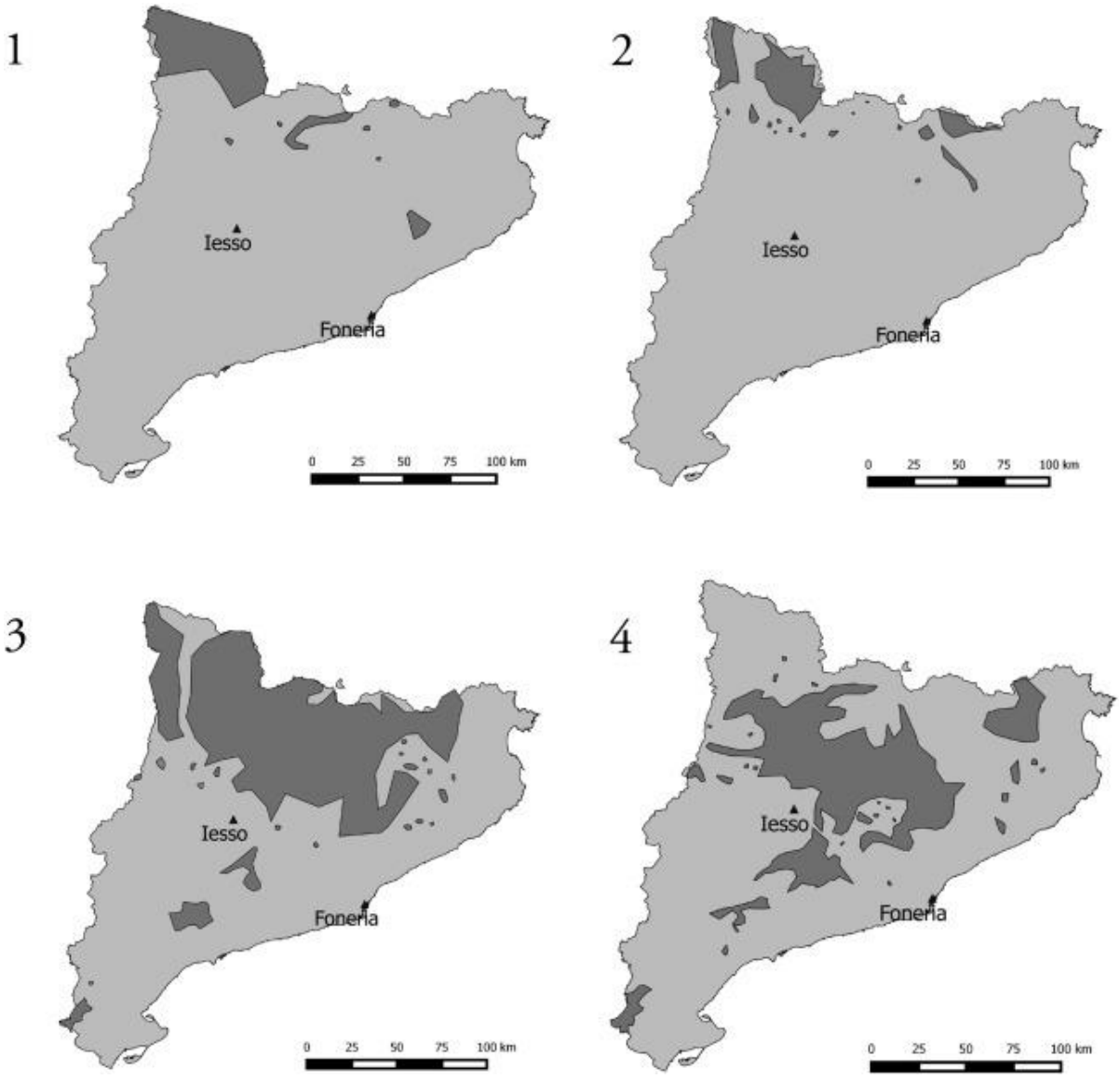
Despite the fact that in all the wells local vegetation is represented, in two of them (*Iesso* and Foneria) manufactured items made with non-local wood are also present, including *Betula* sp and *Pinus sylvestris-nigra* type. In the case of *Abies* sp. manufacturing traces are clear in Foneria but doubtful in *Iesso*, where only a small unshaped fragment has been recovered.

Fir is a typical species of high mountain areas that prefers a cold climate, shade and moisture, living well in cool and deep soils. In the northeast Iberian Peninsula it can be found in shady areas, mainly in the Pyrenees, but also in the Montseny Mountains, and has its optimum between 1000 and 2000 m asl, above beech forests, with which it is often mixed. Its light wood without resin and high strength is highly valued, and is suitable for a variety of uses, including walls of alpine buildings, creation of musical instruments and woodworking. As well, it can be used as beams and piles for building activity. Fir is quoted in the classical sources (Vitruvius and Teofrastus) for different uses, including house and boat construction (Ulrich, 2007).

Scots pine is found in all cold regions of Eurasia. In northern areas it is a lowland tree, while in the southern ones it mainly lives in mountain areas. In the northeast Iberian Peninsula, it lives in the mountains, from 500 m upward. In the Pyrenees area it forms large forests up to 1600 m, below the black pine, with which it often mixes. It is a wood with medium density and hardness, compact and resinous. It is used in carpentry and construction: as its trunk is characterized by a straight form, it is a very versatile wood.

Betula sp. grows naturally in western and central Pyrenees between 600 and 1800 m a.s.l. in humid areas. The wood of birch is light and easy to work. It has been used traditionally for making furniture and veneer. Pliny cited the use of birch for manufacturing hoops and baskets (Ulrich, 2007).

The present day distribution of these taxa shows the long distance between the sites where they have been identified and their natural distributions (Gracia et al., 2000–2004) (Fig. 7). *Iesso* is located more than 100 km from the area of present distribution of birch and fir. In the case of Foneria, black/Scots pine types and fir cannot be found closer than 30 or 50 km north and northeast from the archaeological site. This strongly suggests the hypothesis that those species, highly appreciated by Roman carpenters for woodworking (Ulrich, 2007), were transported from long-medium distances and probably were objects of trade.



1. Download high-res image (380KB)
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Fig. 7. Present distribution of *Abies alba* (1), *Betula* (2), *Pinus sylvestris* (3) and *Pinus nigra* (4) forests in Catalonia. Data retrieved from CREAF (www.creaf.uab.es).

At least in the case of structural wood from Foneria site, the stems of pine from which the elements were obtained tend to have a similar diameter, which could indicate a selection of raw material for commercial purpose during the imperial

period. Furthermore, stems B and C, when detrended, show an extremely similar pattern of growth, indicating that they proceeded from the same capture area, from which stem A was probably not distant. The timbers, perhaps already crafted in planks and beams, could have arrived at *Barcino* from the backcountry overland and, probably, partly by fluvial transport, or even along a coastal maritime route from some northern port closer to the Pyrenees Mountains (Ravotto, 2014).

Transport of timber from long-medium distance has been suggested for explain the presence of non-local wood inside other Roman wells in southeast France and the southeast Iberian Peninsula. In Tossal de les Basses (Carrión Marco and Rosser, 2010), the transport of boxwood, ash, scot black pine, juniper, cypress, and cork oak has been suggested. In some cases the timber was transported from 50 to 100 km. Timber trade has been also suggested at the site of La Lesse–Espagnac and Gasquinoy (Hérault, France), dated the end of the 1st century BC to at least the beginning of the 3rd century AD, where *Fagus sylvatica*, *Abies* sp. and *Larix decidua/Picea abies*, which do not grow in the zone, are present. The presence of wood has been interpreted as evidence of timber trade between the sites and the highlands (Figueiral et al., 2010, 2015). In the site of Lattes, the hypothesis of transportation is not excluded for the explanation of the presence of fir and beech (Chabal and Feugère, 2005).

The comparison of taxa documented in the wells of Foneria and *Iesso* with the data obtained from charcoal analysis of Roman sites in the northeast Iberian Peninsula provides a better comprehension of the meaning of the presence of fir, black/Scots pine, and birch. The presence of non-local taxa is not rare in Roman sites, although they always are present in low frequencies. Fir has been documented among charcoal remains in several sites located at low altitudes, at Can Feu (Sant Quirze, Valles Occidental) at 1st century AD (Piqué et al., 2000; Piqué, 2009), Illa d'en Reixac 5th-4th century BC (Ros, 2000), Vilauba 2nd-3rd century AD, and Mas Castellar de Pontós (Empordà) 2nd century BC (Piqué, 2002; Ros and Piqué, 2002). Charcoal remains of Black/Scots pine have been also documented at the site of Can Feu between the 2nd century BC and 2nd century AD (Piqué, 2009) and the Roman city of Ilerda between 1st century BC and 4th century AD. In all these areas, fir and black/Scots pine are absent in the charcoal remains record of previous chronologies, which confirms the change in territory management and raw material uses from the Roman period. *Betula* sp. has been documented only in the waterlogged wooden remains. All the waterlogged remains of these taxa recovered at *Iesso* and Foneria had technological wear. Probably some of them arrived at the site already manufactured, and for this reason always appear in low frequencies or are missing among the charcoal remains.

4.3. Woodworking and use of wood

The taxa documented demonstrate the selection of wood for specific uses. Local species are represented both in unworked and worked wood. In some cases, they are barely worked: only some cut branches and twigs or unshaped fragments with cut marks. In other cases, they are used for specific purposes. Maple and walnut were used for manufacturing recipients, boxwood for awls, oak for a ladle and planks. Non-local wood is only represented in the manufactured items. Scots-black

pine and fir were used for construction purposes and other undetermined objects. Birch was used for producing thin planks of wood engraved with incisions, probably the remains of veneered furniture. Wood of Scots-black pine and oak showed in some cases holes caused by insects, which suggest that they were thrown into the wells probably after a certain period of exposure to environmental agents.

The technological approach has provided evidence for woodworking technology. The study of the structural elements of wood, where preserved, demonstrates the use of planks for building the structure of the wells. The planks were obtained by sawing the logs in half or quarters. However these planks were not originally sawn with this purpose. In both cases (Foneria and *Baetulo*) where wood was part of the well structure, the reuse of elements has been deduced from the presence of some unused joints, of striations and wears, of traces of paint and, in some cases, by a difference in cutting directions, shape and dimensions among planks with the same structural function. In the construction of wells, functional character comes first and aesthetic criteria did not play any role, so it was probably quite common to use recycled materials.

The dendrochronological approach applied to the Foneria well has provided new insights into how wood was obtained and worked. It has been possible to relate individual planks to specific logs and to obtain a better understanding of how the latter were sawed. Unfortunately, this approach could only be applied in the case of Foneria.

For the manufacture of structural wood, older trees with a diameter about 40 cm were preferred. According to the hypothetical reconstruction of cuts (Fig. 5), three, four or more planks of the same dimensions could have been obtained from stems A, C and D by plain sawing. Fon 5 and 11 from stem C are minor elements used to adjust the assembling of the well, and probably were obtained by adapting the shape of larger planks. No plank consists only of sapwood, which because of its lower density, would have been less suitable to deal with structural loads. Stems B and E were quarter sawed.

5. Conclusions

The study of wooden remains from three Roman wells in the northeast Iberian Peninsula has provided new insights into the landscape knowledge, the use of forest resources and the woodworking technology. Both unworked and manufactured wood provide information about the landscape during the Roman Period. The main Mediterranean forests as well as riparian vegetation are represented in the wells. Cultivated trees are also present, which confirms the importance of arboriculture during the Roman Times.

The main taxa used for manufacturing the goods and the structural elements of the wells were obtained in a wide catchment area, and both local and non-local woods are represented. The present-day distribution of fir, birch, and Scots-black pine is a substantial distance from the sites studied, which suggests transport over long distances.

Technological processes of production of planks used for the structural elements of wells have been documented. Planks were mainly quarter and half sawed. Reuse of wood is also well documented. Some of the wood pieces from the structure of the wells show joints, traces and marks that relate to the previous functions of these elements. The dendrochronological approach provided some suggestion about selection of raw materials in capture areas as well as woodworking technology. It has been possible to determine the size of original stems and how the stems were exploited.

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