SAGVNTVM

PAPELES DEL LABORATORIO DE ARQUEOLOGÍA
DE VALENCIA
EXTRA-13

WOOD AND CHARCOAL
EVIDENCE FOR HUMAN AND NATURAL HISTORY

ERNESTINA BADAL – YOLANDA CARRIÓN – MIGUEL MACÍAS – MARÍA NTINOU
(COORDINATORS)

VNIVERSITAT DE VALÈNCIA
FACULTAT DE GEOGRAFIA I HISTÒRIA
Departament de Prehistòria i d'Arqueologia

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INTRODUCTION

Wood has been used since time immemorial, undoubtedly since the origins of humanity to the present. Wood has been preferred, being versatile and renewable, as well as abundant over most of the earth's surface. However the evidence for this use is sparse, due to the fragile and perishable nature of the material. Nevertheless, thanks to careful excavation, such remains are often retrieved in the form of preserved wood and charcoal. Once submitted to rigorous scientific analyses, they provide evidence for the diversity of vegetation over time and space as well as for the variable human behavior towards the environment and the diversified management of natural plant resources.

Woody plants are an important source of raw materials for a range of different purposes. Some of these are fundamental to everyday life, such as firewood for heat and light, cooking or socializing around the hearth. In the warmth of the fireplace, people work, exchange information, ideas and beliefs, and in so doing create culture. The remains of these common everyday activities, wood and charcoal recovered during excavation, are the subject of this volume. Past and present come together in the development of scientific methods through which we can interpret such organic remains, ultimately contributing to significant advances in wood and charcoal analysis. Various scientific domains draw from the increasing pool of data, hence the broad thematic framework of this volume, including amongst others, studies of wood anatomy, ethnography and taphonomy/preservation of plant remains.

Botanical identification of wood and charcoal combined with statistical analysis of the data, constitute a remarkable tool for the reconnaissance of past vegetation on a local scale and its relationship with global climate change. Moreover, since the studied materials originate from human activities, they are the product of cultural behavior and therefore provide us with key ethnographic information. Wood and charcoal are part of our biological and cultural heritage and it is through their study that we have the opportunity to document the diversity of this heritage through time and space.

Wood and charcoal from archaeological contexts has the potential to provide a range of information about ecology, ethnographic, taxonomic, chronological, etc. Some of the methods used to obtain this information are destructive, for example radiocarbon dating. Since the 1960s, archaeology and palaeoecology have used this method to date chrono-cultural sequences, climate change, or the appearance or disappearance of plants, amongst others. Wood and charcoal analysis follows a standard process in which no chemicals are used and therefore once the identification has been completed, the samples can be used for radiocarbon dating, during which they will be destroyed. By carrying out wood and charcoal analysis prior to dating, valuable data is secured. The analyses should be coordinated in such a way that none of the information is lost. This requires close collaboration between specialists who work with archaeobotanical materials and is one of the challenges for wood and charcoal analysis at present.

Wood and charcoal analysis focusing on a range of different issues has been consolidated and improved during the last 50 years. The scale of these advances was highlighted by the organization of the 5th International Meeting of Charcoal Analysis, in September of 2011 in Valencia (Spain). Ninety-four oral and poster presentations were made by participants from over thirty countries and five continents (see http://ojs.uv.es/index.php/saguntumextra/issue/view/108), demonstrating the enormous international interest that the discipline generates within the scientific community. The idea for the present volume was the natural outcome of such a productive meeting.

This volume includes contributions by researchers from the humanities and sciences, with papers that highlight the diversity of data recorded through wood and charcoal analysis. Regional studies which span the Paleolithic to Middle Ages are included. These provide local scale evidence for the effects of global climate change, as well as the interaction between humans and the environment, and the intensification of production and its effects on the landscape. Each paper is a window to these past landscapes and their relationship with the humans who settled and managed them.

The first part of this volume includes papers presenting wood and charcoal analyses from archaeological contexts. These are ordered chronologically from the oldest to most recent. The studies are also organized within broad geographic areas. The second part of the book includes methodological contributions. It is thanks to the development of these that the discipline has progressed and reached its present position as a key source of palaeoeclogical and paleotehnographic information.

The publication of this volume would not have been accomplished without the enthusiastic collaboration of our colleagues and the support of various institutions. We express our gratitude to all of them for their great effort. We are particularly indebted to the Department of Prehistory and Archaeology of the University of Valencia and the Spanish Ministry of Science and Innovation for generous funding provided by the HAR2011-12827-E project.

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Middle Palaeolithic wood charcoal from three sites in South and West Iberia: biogeographic implications

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Summary: *Stratified deposits at Gruta da Oliveira (35-70 ka BP), Cueva Antón (35-70 ka BP) and Abrigo de la Quebrada (>40 ka BP) provided the wood charcoal for the analysis, the first results of which are presented here. Our work offers a preliminary view of the local flora used by Neanderthals and of coeval climatic conditions in three regions of Iberia.*

Key words: *Wood charcoal, Neanderthal, fire, palaeoecology,* Pinus*.*

INTRODUCTION

Research projects for the study of the Middle Palaeolithic and new archaeological excavations carried out in Portugal and Spain provide data for a better understanding of the archaeology of Neanderthal groups in the area and in particular for their late persistence south of the Ebro River (Angelucci and Zilhão 2009; Zilhão *et al.* 2010a, b). Palaeoenvironmental studies form part of these research projects and within such a framework the analysis of wood charcoal collected from the archaeological deposits is included. The analysis of this material is particularly interesting since data concerning the exploitation of plant resources by Neanderthal groups are scarce in the Iberian Peninsula (Allué 2002; Uzquiano 2008; Badal *et al.* 2011; Gónzalez-Sampériz *et al.* 2012).

In this paper we present the first results of wood charcoal analysis from three caves, Gruta da Oliveira in Portugal and Abrigo de la Quebrada and Cueva Antón in Spain (Fig. 1). The long chrono-cultural sequences at these three sites span MIS 4 and MIS 3, although with hiatuses. The sites are located in regions that differ markedly in ecological conditions, namely in temperature and precipitation. Our main aim by means of wood charcoal analysis at these three sites

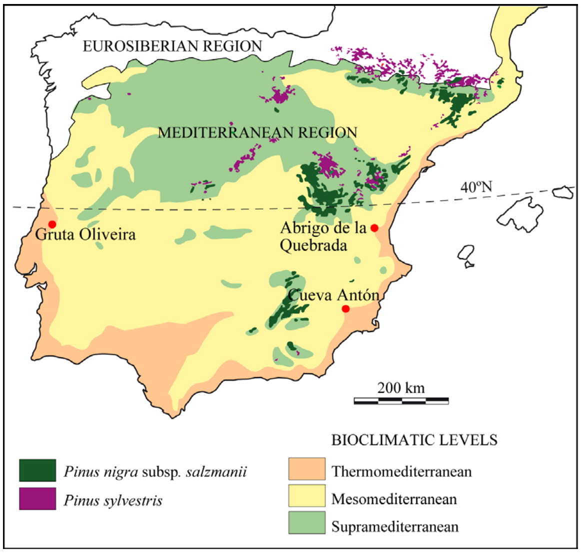


Figure 1. Location of the Middle Palaeolithic sites in the present-day bioclimatic map of Iberia, showing the current distribution of *Pinus nigra* and *Pinus sylvestris*.

is to provide new information concerning the use of wild plants by the Neanderthals during the Last Glacial. The wood charcoal results offer a picture of the local flora and ecological conditions at the time, and highlight the ecological contrasts then extant between these three regions. Furthermore, the analysis of wood charcoal helps us in the assessment of the potential impact of post-depositional processes.

Archaeological wood charcoal is a material that provides information of a rich and diverse nature: ecological, ethnographic, taxonomic, chronological, etc. Although some of the methods used to obtain this information are destructive, if the sequence of analyses is coordinated in an adequate manner no information is lost. The analysis of wood charcoal should follow this sequence: botanical identification should be conducted first and afterwards the material can be sent to the radiocarbon laboratory, where it will be dated. Such a procedure, which emphasises the history of the species and the detection of taphonomic problems (Carrión *et al*. 2010; Zilhão *et al*. 2010b), was followed in the Mousterian sites presented here. The radiocarbon dating results obtained are presented in Table 1.

The botanical identification of wood charcoal was followed by the selection of specimens for radiocarbon dating. Some dates fall outside the expected range for the Middle Palaeolithic: (a) the *Olea europaea* var. *sylvestris* from Gruta da Oliveira comes from a root-burrowed area in the uppermost level of the sequence; the date confirms that, in the area, the taxon should be ascribed to the Holocene flora (Carrión *et al*. 2010); (b) *Pinus halepensis* from Cueva Antón dates the inundation silts deposited over the site after construction

Site	Context	Species	Radiocarbon date (BP)	Method	Observation	Laboratory
Cueva Antón	DD	*Pinus halepensis*	98±23	(ABOx-SC)	Intrusive	OxA-20115
	I-k/II-d	*Pinus* sp.	31150±170 32890±200	(ABA) (ABOx-SC)		OxA-20881 OxA-21244
	I-k	*Pinus nigra*	31070±170	(ABA)		OxA-20882
	II-hi	*Juniperus* sp.	39650±550	(ABA)		OxA-18672
Gruta da Oliveira	8	*Olea europaea*	6055±45	(ABA)	Intrusive	GrA-29384
	12	*Pinus* sp.	26940/+270/-250	(ABA)	Unacceptable	GrA-24408
	13	*Erica* sp.	39540/+490/-410	(ABA)		GrA-24410
	14	*Pinus sylvestris*	42800/+2300/-1800	(ABA)		GrA-22024
	14	*Pinus sylvestris*	27850±550	(ABA)	Unacceptable	OxA-13137
	14	*Pinus sylvestris*	40900±1100	(ABA)		Beta-183537
	15	*Pinus sylvestris*	37520/+380/-330	(ABA)	Unacceptable	GrA-24407
Abrigo de la Quebrada	III - C-5	*Pinus nigra/sylvestris*	40500±530	(ABA)		Beta-244003
	IV - C-7	*Pinus nigra/sylvestris*	43930±750	(ABA)		Beta-244002
	IV - C-7	*Pinus nigra/sylvestris*	>50800	(ABOx)		OxA-24855

Table 1. Radiocarbon dates on wood charcoal from the three Middle Palaeolithic sites discussed.

of the La Cierva dam in the early 20th century; (c) the couple of age determinations for *Pinus sylvestris* from Gruta da Oliveira that are too young reflect incomplete decontamination of very small samples, not intrusion from (non-existent) Upper Palaeolithic levels. All intrusive taxa were excluded from fragment counts and are not shown in the relevant tables.

THE SITES

Gruta da Oliveira is located in the Almonda karstic system of central Portugal (39°30'19"N, 08°36'55"W, 115 m a.s.l.) (Fig. 1). The bioclimatic conditions are subhumid thermomediterranean (mean annual precipitation between 600 - 1000 mm) and the woody flora dominates. The most abundant species are: *Olea europaea var. sylvestris*, *Rhamnus alaternus*, *Pistacia terebinthus*, *Pistacia lentiscus*, *Myrtus communis*, etc. In the areas with deeper soils, *Pinus pinaster* and *Quercus* sp. evergreen grow. The Middle Palaeolithic levels analysed (7 to 22) are dated to *c*. 35-70 ka BP (Angelucci and Zilhão 2009).

The Abrigo de la Quebrada (39º48'25"N, 01º00'49"W, 708 m a.s.l.) is located in a narrow canyon (Fig. 1). Bioclimatic conditions are dry mesomediterranean (mean annual precipitation between 350 – 600 mm). Pine (*Pinus halepensis* and some *P. pinaster*) forests are dominant over most of the area. The understorey includes *Juniperus phoenicea*, *Pistacia terebinthus*, *Cistus albidus*, etc. *Quercus rotundifolia* grows in humid areas, and the riverine vegetation at the bottom of the canyon is composed of *Nerium oleander*, *Jasminum fruticans*, *Tamarix*, *Salix*, etc. This large rockshelter presents an important stratigraphy for the regional Mousterian. Eight archaeological levels with abundant Palaeolithic material were excavated (with an occupation hiatus in level VI). The upper part of the sequence documents an intense and repeated use of the site. The AMS dates for levels III and IV were obtained on *Pinus* type *nigra/sylvestris* charcoal fragments; the discrepancy in the results for level IV probably relates to the different pre-treatment methods (Table 1) (Eixea *et al*. 2011). In this paper, only the charcoal data from levels I to IV are considered because study of the rest of the material is still ongoing.

Cueva Antón is a rockshelter opened into the base of an E-W, 25-30 m high, Eocene limestone escarpment located towards the tail end of the La Cierva reservoir, on the Mula River (01°29'47"W, 38°03'52"N, 355 m a.s.l.) (Fig. 1). The current bioclimatic conditions are semiarid thermomediterranean (mean annual precipitation between 200 – 350 mm) and the vegetation is xerophytic scrub with *Rhamnus lycioides*, *Rosmarinus officinalis*, xeric grasses such as *Stipa tenacissima*, *Lygium spartium* and some scattered *Pinus halepensis*. In the riverside, *Tamarix* and *Phragmintes* are very abundant. Excavations at Cueva Antón exposed Middle Palaeolithic occupation levels. Abundant artifacts were distributed around hearth features in the lower levels of the sequence, while anthropogenic remains were scarce toward the top (Zilhão *et al*. 2010b).

MATERIAL AND METHODS

Wood charcoal was scattered in variable densities throughout the excavated deposits; only at Gruta da Oliveira did part of the charcoal come from hearth features, one in level 14 and another in level 21.

With variants, subsurface sampling of the sites took place in two phases. At Quebrada, for example, each unit was excavated in 5 cm levels and all sediment was screened through a set of nested dry screens of 5 mm, 2 mm, and 1 mm in size. Artifacts and charcoal were collected from these screens. Additionally, 2 liter sediment samples were collected from each level of each excavation unit for flotation and water screening to separate the coarse fraction with microartifacts from the fine fraction with organic materials. At Gruta da Oliveira and Cueva Antón, manual recovery of charred wood fragments ran parallel to the course of the excavation. This procedure may have affected the size of each sample given that dry screening usually provides a higher number of wood charcoal fragments (Badal 1992; Chabal 1997).

In general, wood charcoal remains were rather small, each fragment measuring less than 2 mm and showing clear signs of disintegration and alteration due to different biotic and physical factors.

We used a Nikon Optiphot-100 dark/bright field incident light microscope with 50-500X magnifications for taxonomic identification of wood charcoal. The specimens were identified with the aid of specialized plant anatomy bibliography (Schweingruber 1990) and the reference collection of modern charred woods of the Department of Prehistory and Archaeology, University of Valencia. Photography and detailed observation of microorganisms and minerals was carried out with a Hitachi S-4100 Field Emission Scanning Electron Microscope and the EMIP 3.0 (Electron Microscope Image Processing) software. The microanalysis was performed with the software Esprit 1.8 of Bruker.

RESULTS

Wood charcoal was scarce at all three sites, which precludes statistical treatment of the data for most of the archaeological levels. In the following, the results of the botanical identification of the wood charcoal material for each site are presented and a paleoenvironmental interpretation is proposed on the basis of the ecological requirements of the identified taxa. The Holocene taxa (*Olea europea* and *Pinus halepensis*) were not considered (Table 1).

GRUTA DA OLIVEIRA

Wood charcoal fragments at Gruta da Oliveira were extremely small (≤ 1 mm) and much altered, hence the low resolution of the botanical identifications. The high pressure applied by the sedimentary deposits on the fragile charred materials affected their preservation. Compressed plant tissues and fused cells were common features of the analyzed specimens, thus inhibiting the observation of the anatomical characteristics that would allow the discrimination of genera and species within the generic group of the Angiosperms (Fig. 4A). Furthermore, bio-deterioration due to microorganisms such as bacteria, fungi, etc., was very high. Only *Pinus* type *sylvestris* and *Juniperus* sp. specimens were securely identified (Table 2; Fig. 2). The remaining could only be referred to either the Gymnosperms or the Angiosperms.

If the wood charcoal fragments of the richer levels (level 14-15) (Fig. 2) are put together, we may observe that cryophilous Gymnosperms are the majority and only 20 % of the remains are of Angiosperms. Previous analysis of wood charcoal material from the site by P. Queiroz showed the presence of *Pinus sylvestris* in levels 10, 13, 14, 15 and 16. Moreover, *Erica* cf. *E. arborea* was identified in level 13 and its remains provided the date for this level (Table 1) (Zilhão *et al.*

LEVELS	*Pinus* type *sylvestris*	*Pinus* sp.	*Juniperus* sp.	Gymnosperms	Angiosperms	Seed	Bone	**TOTAL**
7					1			**1**
8	1				1			**2**
10	1				1			**2**
11	2			3				**5**
12	2			1	2	1	4	**10**
13	4			2	1		1	**8**
14	18	3	3	6	12	1	27	**70**
15	19	2	1	4	2		17	**45**
16	2			1				**3**
17	1							**1**
18					1			**1**
19	1		1	1				**3**
20	4						1	**5**
21	4		1				2	**7**
22	6						4	**10**
TOTAL	**65**	**5**	**6**	**18**	**21**	**2**	**56**	**173**

Table 2. Taxa identified at Gruta da Oliveira.

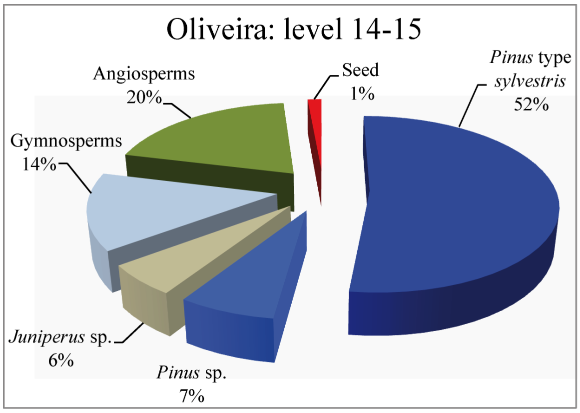


Figure 2. Frequency of taxa identified in levels 14-15 at Gruta da Oliveira.

LEVELS	*Pinus* type *nigra - sylvestris*	*Pinus* sp.	*Juniperus* sp.	Gymnosperms	Fabaceae	Angiosperma	*Quercus* sp. evergreen	*Rhamnus* sp.	Bone	**TOTAL**
I	2	2	5		1		2		2	**14**
II	5	1	7	2		1	1	1	3	**21**
III	22		1	1					7	**31**
IV	181	3		3			1		36	**224**
TOTAL	**210**	**6**	**13**	**6**	**1**	**1**	**4**	**1**	**48**	**290**

Table 3. Taxa identified at Abrigo de la Quebrada.

2010a). This shrub would have formed part of open areas or of the understorey of pine stands.

Two amorphous seed fragments were present in the samples from Gruta da Oliveira as well as 56 charred bone fragments. The latter could have been food remains discarded close to the hearths and charred by fires.

ABRIGO DE LA QUEBRADA

290 wood charcoal fragments from the four uppermost archaeological levels of Abrigo de la Quebrada were identified (Table 3). Level IV, compared to all other levels, showed greater density of charred wood, lithics and faunal remains, corresponding to a palimpsest of recurrent visits to the site (Eixea *et al.* 2011). In this level, combustion areas were observed, consisting of simple hearths and charcoal dispersed around them by mechanical action. Coupled with bio-alteration, this action probably explains the small size of the fragments, which, on average, was below 2 mm. Acari, bacteria and fungi (Fig. 4C) were the agents of deterioration of the organic material in the archaeological deposits. From their presence in wood charcoal samples that provided dates consistent with the associated stone tools (Table 1), we infer that these alterations occurred syn-depositionally in Middle Palaeolithic times, not recently.

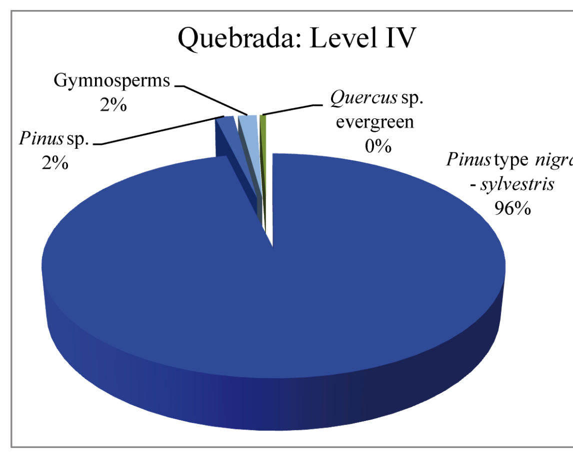


Figure 3. Frecuency of the taxa identified in level IV at Abrigo de la Quebrada.

One of these microorganisms (Fig. 4B) was very small and, probably, is an ubiquist forming part of the soil flora. It was identified in all three Mousterian sites discussed here, and has been found in many others of different chronologies and areas, from Iberia to Poland, and even as far away as the USA (Badal and Atienza 2005; Moskal 2010; Carrión *et al*. this volume).

The flora documented in the samples from Abrigo de la Quebrada is of low diversity. Only four genera (*Pinus, Juniperus, Quercus* and *Rhamnus*) were documented, and one fragment was attributed to the Fabaceae family. In the case of pines, species distinction was not always straightfoward. Nevertheless, it may be stated that all specimens belong to the group of cryophilous pines and are of either *Pinus nigra* or *Pinus sylvestri*s (Fig. 4G). In level IV, *Pinus* type *nigra-sylvestris* account for 90 % of the charred wood remains (Fig. 3). The dates for levels III and IV were obtained on three *Pinus* type *nigra-sylvestris* fragments (Table 1).

Angiosperms are very sporadic in the Abrigo de la Quebrada sequence; only *Quercus* sp. evergreen is represented by a few specimens in levels I, II and IV. These could be attributed to *Quercus rotundifolia* and/or *Q. coccifera*, whose present-day range spans the thermomediterranenan to the supramediterranean belts, although the mesomediterranean is the best ecological zone for both species. The scarcity of remains suggests that the species may have grown close to their survival threshold. The other Angiosperms, *Rhamnus* in level II and Fabacea in level I, could have grown either in cryophilous pine stands or in more thermophilous evergreen oak woodland.

The composition of the Abrigo de la Quebrada flora and the proportions of the taxa in level IV (Fig. 3) suggest that the environmental conditions in the area would have corresponded to the dry or subhumid supramedittenanean type through the entire sequence, with no indication of warm episodes. From the scarcity of shrubs and small trees it may be inferred that the vegetation of the area was open pine parkland interspersed with patches of steppe.

In total, the analyzed samples yielded 48 charred bone fragments. Although, macroscopically, they resembled wood charcoal, microscopic inspection eventually revealed their animal origin. Similarly, charred bone was found at Gruta da Oliveira and Cueva Antón, possibly indicating the use of bones as fuel and/or the burning of residue from the clean-up of habitation areas. More likely, however, this burnt bone material reflects the palimpsest nature of the deposits, whereby, given the low sedimentation rate, previously accumulated faunal remains would have underwent heating by newly installed fire features.

CUEVA ANTÓN

Wood charcoal remains from Cueva Antón are in the course of analysis. The data presented here are all from the 2007 and 2008 field seasons. Although preliminary, these results are likely to be representative for the entire sequence. 123 wood charcoal fragments were identified. The levels with higher concentrations of wood charcoal (levels I-k, II-l and III-b/d) are those where human occupation is documented (Zilhão *et al*. 2010b). The other levels contained few fragments whose presence reflects either the occurrence of natural fires or the dismantlement of upriver soil sediments by the flooding episodes responsible for the accumulation of the deposits inside the shelter; a case in point is the *Pinus halepensis* determined in the silts that covered the Pleistocene sequence as a result of major flooding episodes occurring after construction of the La Cierva reservoir. Charred bone fragments were very few and they would have originated from processes similar to those mentioned above for the other two sites.

Compared to that from Abrigo de la Quebrada, the flora identified at Cueva Antón is more diverse; besides pines and junipers, it includes xerophilous (*Ephedra* sp.) and riverine (*Salix-Populus*) taxa, as well as *Quercus* sp. deciduous (Table 4). *Juniperus* sp. (Fig. 4H) is the most abundant in number of fragments and, together with pine and the presence of *Ephedra*, indicates the prevalence of dry or semiarid supramediterranean conditions in the area. The presence of riverine vegetation and deciduous oaks indicates that the water course may have been permanent.

Cueva Antón is located in a meander of the Mula River and its sedimentary fill is primarily of fluviatile origin. During the accumulation of the deposits, inundation during floods was frequent and, at times, the stream bed itself ran along the back wall of the shelter (Zilhão *et al*. 2010b). Many charcoal fragments included reddish spheres, which, after analysis and SEM microanalysis, were identified as aggregates of Fe crystals (Fig 4E, F). These fragments came from

LEVELS	*Pinus* type *nigra/sylvestris*	*Pinus* sp.	*Juniperus* sp.	Cf. *Juniprus*	Gymnosperms	*Ephedra* sp.	Angiosperms	*Quercus* sp. deciduous	*Salix/Populus* & cf. *Salix*	Bone	Indeterminate	**TOTAL**
I-k	1	3	28	2	4				3	2		**43**
II-a			2						1			**3**
II-c	2		5	1	1					1		**10**
II-b			1									**1**
I-k/II-d	1	1	5						1			**8**
II-h/i			1									**1**
II-i/II-k	1								1			**2**
II-k			1									**1**
II-l	2	3	5	1	3	1	2					**17**
II-u			1		1	2						**4**
II-y			1								2	**3**
III-b	2	3	5		2		4	1	5	2	3	**27**
III-e/h	1	1										**2**
III-i	1											**1**
TOTAL	**11**	**11**	**55**	**4**	**11**	**3**	**6**	**1**	**11**	**5**	**5**	**123**

Table 4. Taxa identified at Cueva Antón.

stratigraphic levels where syn-depositional water content was high. Crystals would have occurred in suspension in the water and, when the latter penetrated the plant tissues, spherical aggregates of Fe crystals were generated (Fig. 4E).

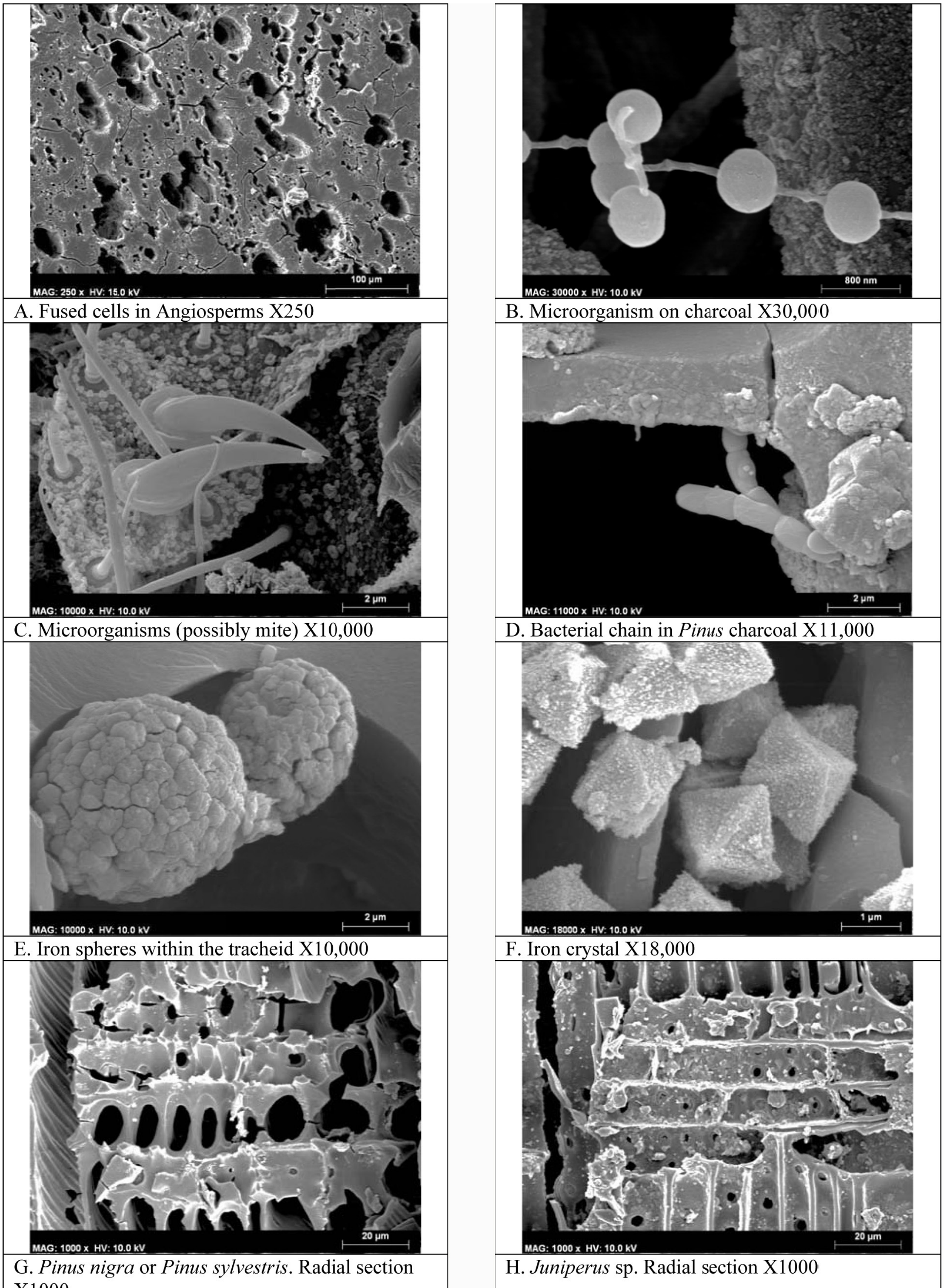
DISCUSSION

Marine cores in the Alboran Sea and the Atlantic Ocean document various abrupt climatic fluctuations during the Last Glacial with alternating cold (Heinrich Events) and warm events (Dansgaard/Oeschger) (Lebreiro *et al*. 1996; Cacho *et al*. 1999). According to the pollen data, these climatic changes affected the plant cover of Iberia during the Last Glacial (Fetcher *et al*. 2010; González-Sampériz *et al*. 2010; Moreno *et al*. 2012).

The wood charcoal data available for the Middle Palaeolithic are still few and they reflect the local vegetation; the agents primarily responsible for the accumulation of the material in the archaeological deposits were the Neanderthals who collected firewood for their hearths. It is probably due to the fact that they did not use caves during the warm periods that the warm events are not reflected in the botanical identification of archaeological wood charcoal. In general, the analyses of wood charcoal from Iberian Mousterian sites shows that a cryophilous flora is represented, with some bio-indicators helping to refine the record. On the basis of the presence of such taxa, two broader zones may be distinguished, separated by a boundary running at approximately latitude 40ºN, with climatic conditions to the south being in general warmer than to the north of it.

In Mediterranean regions to the south of latitude 40ºN, the wood charcoal record of sites located between sea-level and 700-800 m a.s.l. is dominated by remains of conifers and a few Angiosperms during MIS 4 and MIS 3. Among the conifers, cryophilous pines (*Pinus sylvestris-nigra*) and juniper contributed most of the wood charcoal recovered. The low diversity of shrubs and small plants possibly indicates the presence of open herbaceous steppe formations, in line with the pollen record (González-Sampériz *et al*. 2010). Pines are excellent climatic bioindicators. At present, *Pinus sylvestris* and *Pinus nigra* grow above 1000-1200 m a.s.l. on the mountains of Iberia (Fig. 1) and under supramediterranean (mean annual temperature 8-13ºC) or oromediterraenan (mean annual temperature 4-8ºC) conditions (Rivas-Martínez 1987). *Pinus sylvestris* is more cryophilous than *Pinus nigra* and requires more humid conditions. For these reasons it may be found on the highest and most humid mountains of the peninsula. In Portugal, it grows only on Serra do Gerês between 1200 and 1400 m a.s.l. (Fig. 1). These trees would have been well-adapted to the dry-cold climate that prevailed in the Iberian Peninsula during the Last Glacial. Pines, in particular, can store considerable water in their trunks to help them survive long periods of drought. The presence of these pines in MIS 4 and MIS 3 archaeological sites indicates a Mediterranean type precipitation regime defined by a summer hydric deficit.

According to the data from Gruta da Oliveira,



A. Fused cells in Angiosperms X250

B. Microorganism on charcoal X30,000

C. Microorganisms (possibly mite) X10,000

D. Bacterial chain in *Pinus* charcoal X11,000

E. Iron spheres within the tracheid X10,000

F. Iron crystal X18,000

G. *Pinus nigra* or *Pinus sylvestris*. Radial section X1000

H. *Juniperus* sp. Radial section X1000

Figure 4. A: Microphotographs of mechanical alterations. B, C and D: microorganisms present in wood charcoal fragments. E and F: Fe spheres. G: pine wood charcoal. H. Juniper wood charcoal. Gruta da Oliveira (A). Abrigo de la Quebrada (C). Cueva Antón (B, D, E, F and H).

the precipitation regime in central and western Iberia during the first past of Last Glacial would have been sub-humid or humid (mean annual 600-1000 mm) and *Pinus sylvestris* would have dominated in the forested areas. During the preceding interglacial, wood charcoal of *Pinus sylvetris* has been recorded, together with that of *Betula*, in the site of Cueva del Camino, at higher elevation (1114 m a.s.l.) (Arsuaga *et al*. 2010; González-Sampériz *et al*. 2010; Badal *et al*. 2011).

In the eastern and southern sites – Abrigo de la Quebrada, Cueva Antón, Cueva Foradada, Las Fuentes de Navarrés, El Salt, Gorham's Cave – two cryophilous pine species would have been present, namely *Pinus sylvetris* and *Pinus nigra* (Aparicio 1981; Badal 1984; Carrión *et al*. 2008). The driest conditions are denoted at Cueva Antón by the predominance of *Juniperus* sp. in association with *Ephedra* sp. This combination suggests an open, steppic landscape with scattered stands of mountain pine.

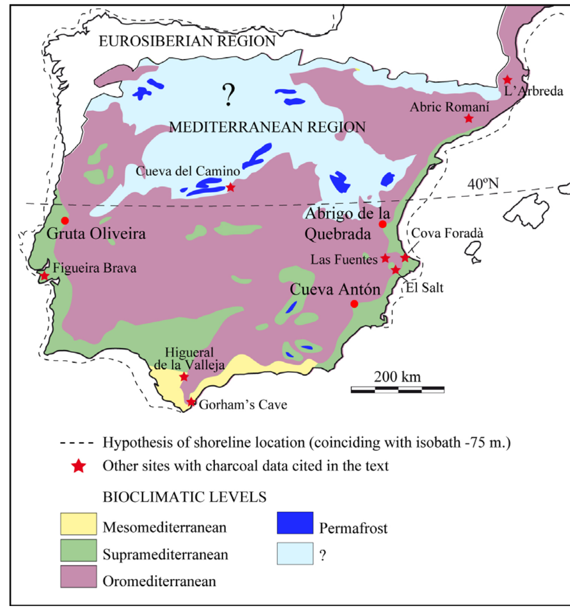


Figure 5. Hypothetical bioclimatic levels in Mousterian times.

When we compare the present day distribution of *Pinus nigra* and *Pinus sylvestris* in the Iberian Peninsula with the location of the Mousterian sites (Fig. 1), it becomes apparent that the sequence of bioclimatic belts would have been displaced approximately 1000 m in altitude, implying a 10ºC decrease in temperature (Fig. 5). Most of southern Iberia would have been characterized by oro-supramediterranean bioclimatic conditions, with a band of warmer conditions extending along the coastal areas of Andalusia and Portugal, where thermophilous species have been identified (cf. the wood charcoal and cones of *Pinus pinea* identified at Figueira Brava and Gorham's Cave, which indicate Neanderthal collection for the consumption of the seeds – Metcalfe 1958; Badal 1984; Carrión *et al*. 2008).

However, such termophilous taxa as *Pistacia lentiscus*, *Myrtus communis*, etc., have not been identified in wood charcoal samples dating to either MIS 4 or MIS 3. At Gorham's Cave, *Olea europaea* is present in Middle Palaeolithic levels where thermopilous pines (*Pinus pinea-pinaster*) dominate. Moreover, at Higueral de Valleja, an *Olea europaea* seed was identified and radiocarbon dated to 37220 ± 290 BP (ORAU-12272) (Carrión *et al*. 2008; Jennings *et al*. 2009). By these data it may be inferred that the southernmost part of Iberia would have been the warmest zone during the Last Glacial. Here, supra or mesomediterranean conditions would have prevailed between sea level and 200-300 m a.s.l.

The discrepancies between the wood charcoal and the pollen record derive from the local and regional scale that they, respectively, reflect. Eurosiberian taxa such as *Betula*, *Corylus*, *Juglan*s, *Fagus*, *Rhamnus cathartica*, *Hippophae rhamnoides*, etc., were never identified in the charred wood material from sites at low elevations or south of latitude 40ºN. However, these taxa are present in pollen sequences. At Gruta da Oliveira, J.S Carrión and N. Fuertes carried out the analysis of pollen samples from hyena coprolites in levels 9 and 11, where *Quercus*, followed by *Pinus*, dominates, while eurosiberian taxa such as *Betula, Corylus* and *Fagus* are sporadic (Zilhão *et al*. 2010a; Carrión *et al*. 2012). The discrepancy between pollen and charcoal data is due to the local image of the vegetation provided by wood charcoal, which reflects the settlements' surroundings; but it also relates to the distinct ecological conditions of each region. To the north of latitude 40ºN and in particular in the eurosiberian region, the wood charcoal record is dominated by *Pinus sylvetris* remains, although *Betula*, *Corylus*, *Fagus* and other genera characteristic of cold and humid climates are also present (Allué 2002; Uzquiano 2006, 2008).

The flora identified in the wood charcoal from Mousterian sites implies that cold climatic conditions were characteristic of the Iberian Peninsula during MIS 4 and MIS 3. Warm events were not documented in the studied archaeological levels. *Pinus sylvetris* woodlands would have constituted the most extended formation to the north of latitude 40ºN while, to the south, *Pinus sylvetris* and *Pinus nigra* stands would have co-existed. Thermophilous and xeric bioindicators such as *Pinus pinea*, *Ephedra*, *Juniperus*, *Fabaceae* and *Olea euro*pea would have found refuge in the southernmost parts of Iberia. The most xeric flora was recorded at Cueva Antón, suggesting that the southeast of Iberia was already one of the driest parts of the peninsula during the Late Glacial.

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Wood charcoal analyses from the Muge shell middens: results from samples of the 2010/2011 excavations at Cabeço da Amoreira (Santarém, Portugal)

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***Summary**: Wood charcoal analyses were carried out at Cabeço da Amoreira (Muge shell middens), a Mesolithic settlement dated from 8100 to 7500 cal BP. The charcoals were scattered in the sediments and samples were collected from different areas of the site. Here we present the results of the analysis of 1601 charcoal fragments retrieved during the 2010/2011 excavations from three different contexts. The results reveal a clear predominance of pine and conifer wood in the assemblage. Evergreen and deciduous* Quercus *are also present as well as one fragment of* Arbutus unedo *in one of the contexts.*

***Key words**: Charcoal analyses, Cabeço da Amoreira, Mesolithic, Muge shell middens,* Pinus.

INTRODUCTION/BACKGROUND

The Muge valley is located near the confluence of River Tagus and the Atlantic Ocean, 60 km northeast from Lisbon (Fig. 1). During the early Holocene, the landscape was affected by the rise of the sea level that transformed the Muge valley into an estuarine basin. Palaeogeographical studies in the Muge valley floor allow the understanding of its formation. These studies record a sudden drowning of the valley floor around 8200 cal BP (Shriek *et al*. 2008; Bicho *et al.* 2010). Regarding vegetation, Mediterranean taxa increased and occupied the areas upstream of the valley floor, the terrace levels, but the valley would have also been a refuge for more thermophilous taxa. Oak and pine forest developed but also herbaceous taxa, promoting an open landscape (Shriek *et al*. 2008).

Cabeço da Amoreira is a Mesolithic site, dated from 8100 to 7500 cal BP that integrates into the Muge shell midden complex. It was discovered in 1863 by Carlos Ribeiro and since then several teams have been investigating this site and other shell middens from the Muge valley, being the Mesolithic period one of the main research subjects in Portugal (Corrêa 1933; Roche and Veiga Ferreira 1967; Ribeiro 1884; Cardoso and Rolão 1999/2000). In 2008, within the framework

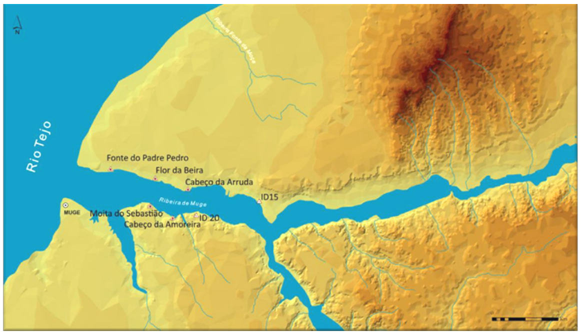

Figure 1. Location of Cabeço da Amoreira and Muge shell middens in Muge valley (Bicho *et al*. 2011).

of a new project named "The last hunters and gatherers of Muge valley" the excavation at Cabeço da Amoreira begun, aiming to investigate the complexity of society during the Mesolithic. The team, lead by one of the authors (NB), initiated investigations from an interdisciplinary perspective (zooarchaeology, physical anthropology, lithic technology, archaeobotany, SIG, DNA, etc.) in a new area of the shell middens (Bicho *et al*. 2011).

In previous archaeobotanical studies charcoal remains from the excavation of José Rolão were analysed and both *Pinus* sp. and *Quercus* sp. were identified (Wollstonecroft *et al*. 2006). In the study here presented, samples from the 2010 and 2011 excavation seasons at Cabeço da Amoreira that form part of the above-mentioned archaeological project, were analysed. Fire and the exploitation of woodland resources are important matters in the economy of past societies. Charcoal is the anthropogenic mark of these activities. In this sense, it becomes a very important tool in order to know how the Muge Mesolithic societies exploited their landscape and the available resources.

MATERIAL AND METHODS

The samples presented here come from three areas of Cabeço da Amoreira:

1) The North Profile in the area previously excavated by Jean Roche –this profile was recently (2010) cleaned and dated (7610-7850 cal BP at the base, 7570-7800 cal. BP at the top)– and 9 scattered charcoal samples (795 fragments >2 mm) that were retrieved from the sieved sediment;

2) The funerary context of a female burial found in the recent excavations of the shell midden and dated to *c*. 7600 cal BP. This charcoal material was found in a well preserved context. Various fragments (n=733) were individually handpicked and their three-dimensional location was registered with a total station together with the other artefacts and layers that covered the skeleton;

3) Squares in the main open area of the excavation. These samples were recovered through flotation and their analysis is still in progress therefore, the results presented here are preliminary. The low number of analyzed fragments is justified by the small size of the recovered charcoal material, with only 73 fragments near the required dimensions. This problem also affected the observation of the sections and that is why the identification of the pines was only carried out at the genus level.

Charcoal fragments >2mm were analysed with an incident-light microscope observing the three main sections (transversal, longitudinal tangential and longitudinal radial). The identification was made by comparing the archaeological wood with modern charcoal from the reference collection (UPV/EHU) and wood anatomy atlases (Shweingruber 1990; Vernet *et al*. 2001; García Esteban 2002).

The identification of the *Pinus* taxa was mainly based on the observation of the radial section: 1) in the case of *Pinus* cf. *pinaster* heterogeneous rays with conspicuously dentate walls were observed (Fig. 2); 2) in the case of *Pinus* cf. *pinaster/pinea* we recognized smooth dentate walls in the heterogeneous rays (Fig. 3). Due to the similarity between *Pinus pinaster* and *Pinus pinea* and the difficulty to confirm the absence of conspicuously dentate walls the identification remains as *Pinus* cf. *pinaster/pinea*; 3) in the case of *Pinus* cf. *sylvestris* tp. heterogeneous rays with fenestri-

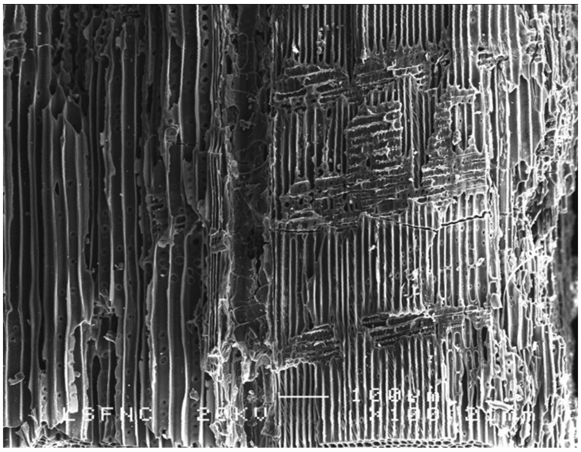

Figure 2. SEM image of the radial section of *Pinus* cf. *pinaster* from the North Profile.

Figure 3. SEM image of the radial section of *Pinus* cf. *pinaster/pinea* from the North Profile. Conservation problems may be observed.

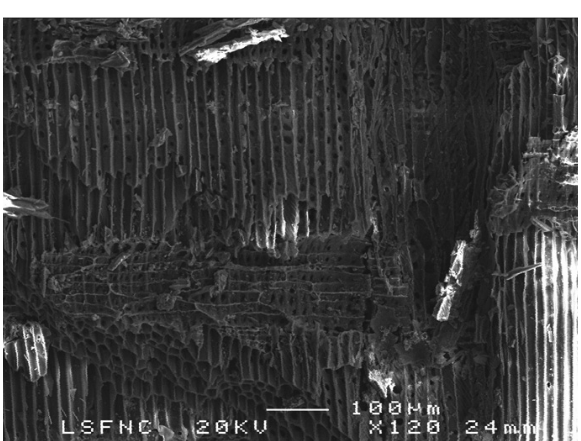

Figure 4. SEM image of the radial section of *Pinus sylvestris* tp. from the North Profile. Fenestriform apertures may be observed.

form apertures (window type) and dentate walls were observed (Fig. 4). There were some difficulties in determining different pine species due to their anatomical similarities and the general small size of the fragments which in many cases limited the observation of the radial section. Different types of alterations were also observed (degradation, vitrification, intrusions).

RESULTS

The results are presented in Table 1 and Figures 5 and 6. A total of 1601 wood charcoal fragments were analysed. The assemblages are dominated by different *Pinus* and *Quercus* taxa. Regarding the conifers, we identified *Pinus* cf. *pinaster, Pinus* cf. *pinaster/pinea* and *Pinus sylvestris* tp. Fragments identified as *Pinus* sp. and Gymnosperm are abundant. Among the Angiosperms, both evergreen (*Q. ilex / Q. coccifera*) and deciduous or semi-deciduous oaks (*Quercus subg. Quercus*) were identified. A single fragment of the strawberry tree (*Arbutus unedo*) was recognized in the burial context.

	North Profile	Burial	Open area
Pinus sp.	256	236	27
Pinus cf. *pinaster*	131	66	-
Pinus cf. *pinaster/pinea*	42	-	-
Pinus sylvestris tp.	13	103	-
Gymnosperm	234	207	18
Quercus subg. *Quercus*	2	9	3
Quercus ilex/Q. coccifera	10	18	6
Quercus sp.	3	-	-
Arbutus unedo	-	1	-
Angiosperm	19	25	5
Indeterminate	85	61	14
TOTAL	795	733	73

Table 1. Absolute numbers of the identified species in the three analysed contexts.

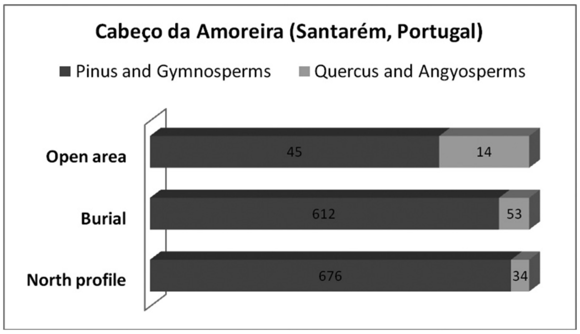

Figure 5. Summary of the results of wood charcoal analyses from the three areas (Mesolithic site of Cabeço da Amoreira). Gymnosperms and Angiosperms have been grouped for each area. Indeterminate specimens have been ignored.

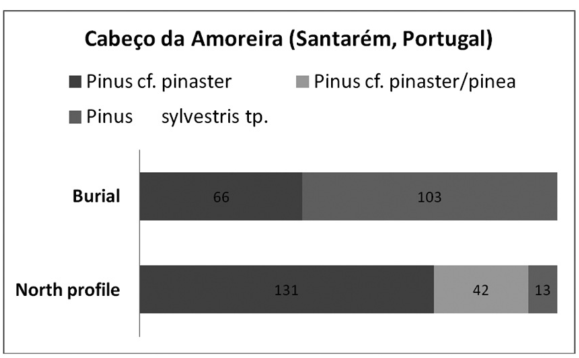

Figure 6. Relative importance of the main *Pinus* taxa identified in the North Profile and the burial (Mesolithic site of Cabeço da Amoreira).

As we can see, there is a clear predominance of pine and conifer wood in the contexts (over 90% in the North Profile and the burial, Fig. 5). Only in the samples from the general area, does angiosperm wood present a percentage over 20%. However, we must take into account that only 59 fragments were identified thus percentages may not be very reliable.

Regarding the relative importance of the different pine taxa identified, first we must consider that many fragments had a limited anatomical resolution. Many fragments were identified as *Pinus* sp. and indeterminate gymnosperms were also very frequent. Taking into consideration only those fragments identified as *Pinus* cf. *pinaster, Pinus* cf. *pinaster/pinea* and *Pinus sylvestris* tp., we can see that *Pinus sylvestris* tp. is quite important in the burial (103 fragments, 61%, Fig. 6) whereas in the North Profile, *Pinus* cf. *pinaster* is the most abundant (131 fragments, 70%, Fig. 6).

Among the angiosperms, both evergreen (*Quercus ilex*/*Q. Coccifera*) and deciduous type oaks (*Quercus* subg. *Quercus*) are present in the samples. The former are more abundant according to fragment number. The identification of one single fragment of *Arbutus* in the samples at least shows the presence of this tree in the vicinity.

DISCUSSION

The first point of the discussion must focus on the data and underline some limitations of the results. The general small size of the fragments, especially in the flotation and in the North Profile samples, restricted more precise identifications. Moreover, samples were not recovered with the same methodology and only in one area they were processed through flotation as it is usually recommended (Alonso *et al*. 2003). In spite of this, the three areas (North Profile, burial and general area) show a big similarity in the identified taxa and in their relative importance (Table 1, Fig. 5). Samples were scattered in the sediment and both for the North Profile and the open area we assume a likely origin as domestic fuelwood. In the North Profile the use of *Pinus* cf. *pinaster* is remarkable. More difficult to interpret is the burial context since the wood here might be connected with more specific activities (funerary, ritual, symbolic). Still, the genus *Pinus* (especially *Pinus sylvestris* tp.) is the most represented wood. *Arbutus unedo* is also present exclusively in the burial context. Oaks, although rare in all samples, are more frequent in the open area than in the other contexts.

Especially relevant for this study are previous studies carried out with wood charcoal and pollen since they allow us to compare different archaeobotanical data. Charcoal analysis from Cabeço da Amoreira shows the important presence of pine wood in the three contexts. Although identifications of spe-

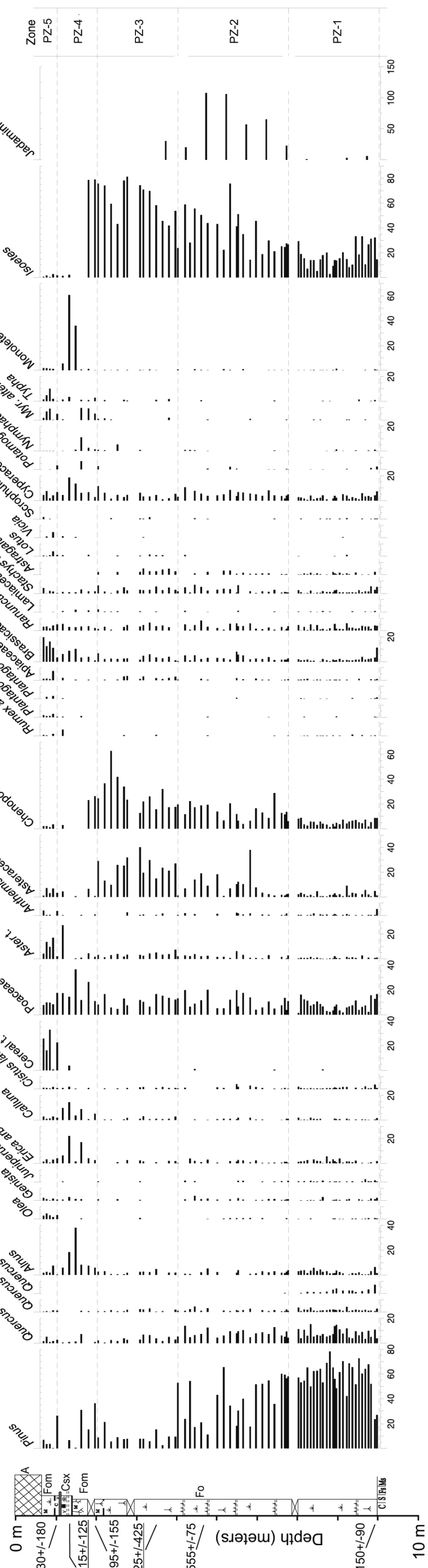

Figure 7. Pollen diagram from the Muge valley bottom (F. Franco Múgica in Shriek *et al*. 2008: 145).

cies were not possible in general, we may suggest the presence of two types of pines: Scots pine type (*Pinus sylvestris*) and Mediterranean pines (*Pinus pinaster/P. pinea*). The long history of Mediterranean pines in Portugal is attested by previous charcoal analyses which record their presence in Estremadura in Palaeolithic and Mesolithic sites (Figueiral 1995). *Pinus* tp. *sylvestris*, already established during the Lateglacial, resisted the Holocene environmental changes in the surroundings of the Muge valley. The taxon was also identified in Epipalaeolithic and Mesolithic contexts from Estremadura (Figueiral and Carcaillet 2005) and later along the country, proving its resilience.

Different palaeoenvironmental data from pollen, geoarchaeology and micropalaeontology studies give us an idea of the past environment of the Muge area (Schriek *et al*. 2008) and allow reconstructing the evolution of the floodplain and the surroundings where the vegetation would have grown. In the pollen diagram by F. Franco Mugica (Schriek *et al*. 2008: 145) we can see that during the period contemporary to Mesolithic Cabeço da Amoreira (PZ-2), *Pinus* is the most abundant taxon, followed by different types of *Quercus* (deciduous, evergreen and *Q. suber*), *Alnus, Olea, Juniperus* and different shrubby taxa (Fig. 7) which were not identified in our samples of macroremains (*Genista, Erica arborea, Calluna, Cistus ladanifer*). Non arboreal taxa probably indicate an open or semi-open landscape. During this period pine woodlands suffer progressive losses and more open spaces alternate with regeneration episodes.

In agreement with the pollen information, the most abundant taxa in the vicinity of the site (*Pinus, Quercus*) were also the ones used by the inhabitants of the site. We must take into account that, in spite of similarities, pollen and charcoal analyses provide different sets of data. Differential pollen rain, human selection of fuels, the different scales of the data (pollen may have a regional input and charcoal tends to be very local) are only some of the issues that may explain differences. In order to understand the preference for *Pinus* and *Quercus* in Cabeço da Amoreira, apart from the clear availability of these genera, we must consider that conifers tend to produce more dead wood. Dead wood would most probably have been preferred, as we can see in other archaeological examples (e.g., Théry-Parisot 2001). Deciduous forests produce less wood and disintegration is faster (Peterken 1996). Also, regarding their burning properties, the combination of conifer wood with oak might have been particularly efficient.

CONCLUSIONS

A total of 1601 charcoal fragments were analysed in this study. Charcoal was retrieved from different contexts of Cabeço da Amoreira, both habitation and burial. Pine and conifer wood, more precisely *Pinus* cf. *pinaster, Pinus pinaster/pinea* and *Pinus* tp. *sylvestris* were identified in the samples. Evergreen and deciduous *Quercus* were also present in all contexts. According to the fragments identified with higher resolution, the burial context might reflect a higher representation of *Pinus sylvestris* tp. and it is also the only one where *Arbutus unedo* was present.

According to pollen information (F. Franco Mugica in Schriek 2008), the most abundant taxa in the vicinity, *Pinus* and *Quercus*, are also the ones mostly used by the inhabitants of the site. However, our samples do not record the presence of other arboreal and shrubby taxa which are very abundant in the pollen record (*Alnus, Olea, Juniperus, Genista, Erica, Calluna*) and reflect the existence of open areas. Whether this is the result of: a) human selection, b) taphonomic questions related for example with a different behaviour of these taxa during combustion, or c) a different scale of both types of analyses with pollen including a regional component. This is something that will have to be assessed in the future under the light of the analysis of more plant macroremains from habitation areas.

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RETHINKING HUMAN IMPACT ON PREHISTORIC VEGETATION IN SOUTHWEST ASIA: LONG-TERM FUEL/TIMBER ACQUISITION STRATEGIES AT NEOLITHIC ÇATALHÖYÜK

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Summary: *Classic accounts of people-environment interactions in the archaeology and palaeoecology of Southwest Asia tend to conceptualize human impact on vegetation as an agent of significant, long-term negative change in the regional landscapes. In the case of archaeobotanical analysis, such approaches have been further influenced by ethnographic models of woodland exploitation positing sequential switches to "lower value" fuel species over time as "preferred species" are over-exploited. An additional influence form traditional accounts of vegetation ecology that describe climate and/or edaphic "climax" plant associations while attributing their decline or downright absence to long-term "destructive" human impacts. This paper summarizes recent results of macro-charcoal analysis from the long-term habitation (~7400-6200 cal BC) of Neolithic Çatalhöyük in south-central Anatolia indicating switches in fuel/timber exploitation that bring into question the assumptions of these models. Drawing on these results, alternative frameworks are proposed for conceptualizing prehistoric human impacts on woodland vegetation.*

Key words: *Neolithic, Central Anatolia, Çatalhöyük, human impact, charcoal analysis.*

BACKGROUND

The assumption that in Southwest Asia negative human impact on woodland and forest vegetation began as early as the Neolithic period is widespread. Archaeobotanical analyses of macro-charcoals have been used to argue that Neolithic communities exerted significant impacts on the landscape through clearance for cultivation, fuel collection for domestic and craft production, and livestock herding. However, such assumptions have found little or no support in off-site pollen and sedimentary records that (where available) have provided very little evidence of significant impacts on vegetation before the mid- to late Bronze Age. Particularly for fuel selection it has been argued, for example, that it is "selective" (cf. notions of "preferred fuel species") and thus that macro-charcoal sample composition is likely to reflect cultural filters. Both the Principle of Least Effort model (Shackleton and Prins 1992) and regional archaeobotanical analyses associate fuel ranking systems with changes in sample composition. Thus assumed "preferred fuel species" (e.g., dense and slow burning taxa) are thought to be eventually substituted by species with lower density and heat value, spiny or difficult to collect taxa, and/or non-wood fuels (animal dung) in response to the over-exploitation and depletion of high-valued wood fuel species (e.g., Miller 1985). More recent research (e.g., Théry-Parisot 2002; Zapata *et al*. 2003; Asouti and Austin 2005; Dufraisse *et al*. 2007) has questioned the expectations of such models. A key criticism relates to their implicit assumption of the separation of fuel collection from the general sphere of economic activities, and its operation primarily as "resource extraction" resulting in linearly developing negative impacts on woodland vegetation. This paper addresses these questions in the context of macro-charcoal analysis from the Neolithic site of Çatalhöyük in central Anatolia (Hodder 2007, in press). Recent analyses have extended the chronological range of the charcoal materials analysed from this site to its latest phases, thus providing the opportunity to examine a nearly complete macro-charcoal sequence covering its entire lifespan, in order to reconstruct long-term trends of fuel/timber resource management (Asouti 2005, in press).

THE STUDY AREA

The Konya plain of south-central Anatolia is a high-altitude (~1000 m a.s.l.) intramontane endoreic plateau, the now dry bed of the Late Pleistocene Konya palaeolake (Roberts *et al*. 2001; Fig. 1). Its climate is continental semi-arid with cold moist winters and hot dry summers, and evaporation rates always exceeding those of precipitation. Precipitation falls mostly as erratic showers in autumn and spring and snowfall in the winter, and ranges from <200 mm p.a. at the dry centre of the plain to ~300 mm p.a. towards its edges. The hills, terraces and the foothills of the surrounding uplands receive on average ~300/400-600 mm p.a. with precipitation values increasing with altitude. The plain is covered by snow for at least 3 months during the winter. It thaws rapidly in March often causing localised flooding. Temperatures range from below zero in the winter, to >20°C in the summer with daytime temperatures often rising above 35°C. Before the drainage and irrigation works of the 1920s the Konya plain

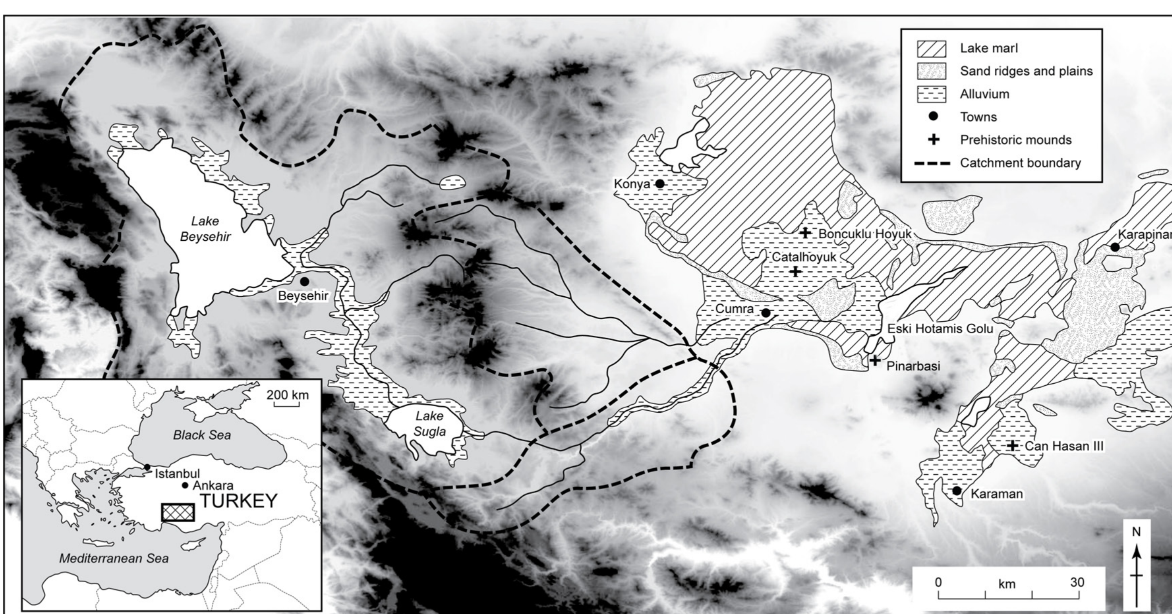

Figure 1. Map showing the location of excavated Neolithic sites in the Konya plain of south-central Anatolia, Turkey.

formed a heterogeneous, fragmented landscape comprising carbonate-rich marl steppe and a diverse array of wetland habitats: shallow and seasonally flooded lakes, karstic sinkholes, saline depressions, sand ridges, alluvial floodplains and fans, seasonal and permanent streams, and rivers which drained from the surrounding uplands into marshes and terminal swamps occupying low-lying depressions. Pollen, micro- and macro-charcoal evidence alongside observations on the present-day ecology, distribution and floristic composition of woodland vegetation indicate that during the early Holocene (with the exception of riparian vegetation comprising mainly Salicaceae, Ulmaceae, *Fraxinus* and *Tamarix* growing on alluvial soils, sand ridges and the drier parts of marshes) woodland was limited to well-drained, coarse-grained red-brown soils, clayey loams, the limestone terraces, volcanic colluvia, bajadas and the metamorphic limestone uplands bounding the plain, especially along its southern edge on the Taurus foothills (Asouti and Hather 2001; Asouti 2005, in press; Eastwood *et al*. 2007; Turner *et al*. 2010). Alluvial, lakeside and marsh habitats on the Konya plain itself formed the preferred ecological settings for Neolithic (~9300-6000 cal BC) habitation.

THE CHARCOAL RECORD

Recent excavations at Çatalhöyük have focused on the exploration of the later levels of the site, in the South Area and the summit of the mound [TP Area] where the latest phases of Neolithic habitation dating to the closing centuries of the 7th millennium cal BC have been unearthed, closing the chronological gap with the Chalcolithic West mound (Hodder 2007; in press). Another recent development has been the reworking of Mellaart's phasing of the site coupled with a new programme of radiocarbon age determinations. This has resulted in a major revision of the site's phasing and thus a more realistic appreciation of temporal and spatial variation in sample composition compared to the Mellaart's level system previously used (Hodder in press). Apart from phasing, anthracological work was faced with a number of other challenges as well. Contrasting with the early (aceramic and early ceramic Neolithic) phases of the site excavated in the South Area where no burnt structures were discovered, the later phases of the site in both the South and the North Areas contain a number of individually burnt buildings. Thus charcoal fragments from burnt structural timbers may have been deposited alongside fuel remains thus altering the archaeological signals of long-term domestic fuel use. Charcoal particles may also have moved vertically (between different layers) due to disturbance caused by quarrying of colluvium from the slopes of the mound and of midden layers for the manufacture of mud bricks. These factors may have caused the mixing and re-deposition of charred wood remains from different contexts and layers.

Furthermore in the case of Çatalhöyük the distinction traditionally drawn between 'domestic fuel' and 'timber' (Chabal *et al*. 1999; Asouti and Austin, 2005) is arbitrary. Timber preparation waste and defunct timber were fuel sources in their own right, integrated with the firewood supply provided by other locally available sources (wet woodland vegetation, steppe shrubs, wild fruit-producing trees of the woodland steppe, dung fuel) (Asouti 2005; in press). Still, and despite all these problematic issues, directional patterning is evidenced in sample composition across the different levels of the site (see Fig. 2, Table 1 and presentation of results below), which is also correlated with major temporal shifts observed in other classes of archaeological materials (e.g. pottery, ground stone, etc.) It seems therefore likely that the trends observed in taxon representation reflect genuine trends of wood use, including both timber and fuel, through time at Çatalhöyük rather than sample composition being biased by depositional (e.g. prevalence of timber) and post-depositional (e.g. stratigraphic disturbance) factors.

Figure 2 presents in summary form the charcoal data by phase. Although charcoal counts for midden samples from the TP and South Area is work in progress, as more samples are analysed, preliminary

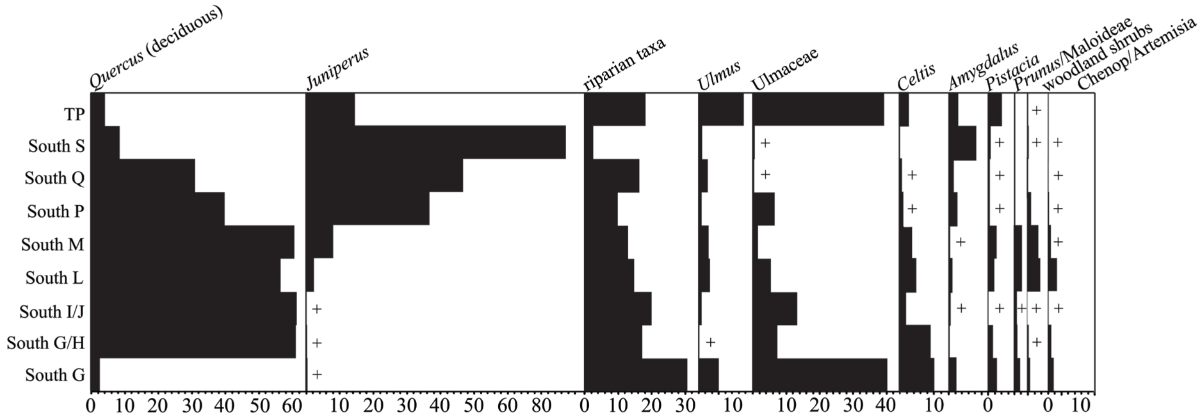

Figure 2. Percentage charcoal fragment counts for major taxa and groups of taxa present in Çatalhöyük external refuse deposits (middens) from South Area phases South G (aceramic Neolithic c. 7400-7000 cal BC), South G/H-M (early ceramic Neolithic; c. 7000-6500 cal BC), South P-S (late ceramic Neolithic; post-6500) and the TP Area (transition Late Neolithic-Chalcolithic) (+ denotes taxon frequencies <1%).

results have indicated some interesting patterns that depart from patterns previously reported (Asouti and Hather 2001; Asouti 2005).

During the earliest (aceramic) levels (Level South G) at Çatalhöyük, firewood gathering focused on locally available riparian vegetation (Salicaceae, *Ulmus*, *Fraxinus*) followed by undifferentiated Ulmaceae (elm/hackberry), *Celtis* (hackberry) and a significant (by comparison to the later phases) component of dry woodland fruit-producing taxa such as *Amygdalus* (almond), *Pistacia* and members of the Maloideae subfamily of the Rosaceae. Maloideae cannot be positively identified beyond the family level on the basis of their wood anatomy alone; their most characteristic representatives in the local flora are the Anatolian hawthorn (*Crataegus orientalis*) and the wild pear (*Pyrus eleagrifolia*).

The first important disjunction in the charcoal sequence is observed in Levels South G and H (i.e. the end of the aceramic Neolithic phases; equivalent to the stratigraphic division previously reported in Asouti 2005 as Level pre-XIID-Pre-XIIA [4846]). Two major changes are observed in sample composition: (a) the abrupt rise of *Quercus* (from ~2 per cent to >60 per cent) and (b) the apparent reduction in the contribution of the riparian taxa. This shift predates the occurrence in the excavated sequence of the earliest known mud brick structures at Çatalhöyük in Mellaart's Level XII. The contribution of oak charcoals to sample composition (at ~60 per cent) remains remarkably stable through Levels South I-M. *Quercus* values reduce in Level South P at ~40 per cent and at ~30 per cent in Level South Q, while by Level South S they drop to ~8 per cent. *Juniperus* values are negligible in Levels South G-I (<1 per cent), but increase from Levels South L-M. In Level South P they are just below those of *Quercus* (~36 per cent) while from Level South Q, *Juniperus* dominates charcoal sample composition.

After an early peak (~36 per cent) in the aceramic Neolithic phase (Level South G) the values of riparian taxa drop but fluctuate between ~11-21 per cent through the rest of the South Area sequence, except for its latest sampled phase (Level South S at ~3 per cent). Hackberry (*Celtis*) also registers higher values in Levels South G-H (~10 per cent) but drops thereafter to <5 per cent and <1 per cent in Levels South P-Q. No *Celtis* charcoal was found in Level South S samples. *Pistacia* also registers very low (<1 per cent) values in Levels South Q-S. Collectively, minor components of the charcoal samples (*Pistacia*, *Celtis*, shrubs including Chenopodiaceae and *Artemisia*, and members of the Rosaceae-Maloideae families such

	Level South G	%	Level South G/H	%	Level South I/J	%	Level South L	%	Level South M	%	Level South P	%	Level South Q	%	Level South S	%	TP Area (all)	%
Quercus	32	2.44	724	60.99	514	61.34	614	56.49	353	60.55	220	39.78	131	30.97	28	8.46	20	4.02
Juniperus	9	0.69	6	0.51	3	0.36	28	2.58	48	8.23	203	36.71	197	46.57	255	77.04	73	14.66
Acer	-	-	-	-	-	-	5	0.46	2	0.34	-	-	-	-	2	0.60	-	-
Caprifoliaceae	6	0.46	-	-	-	-	-	-	1	0.17	-	-	-	-	-	-	-	-
Salicaceae	390	29.75	200	16.85	154	18.38	148	13.62	63	10.81	41	7.41	8	1.89	2	0.60	77	15.46
Alnus	-	-	-	-	-	-	1	0.09	2	0.34	-	-	-	-	-	-	-	-
Vitex	2	0.15	2	0.17	-	-	4	0.37	1	0.17	-	-	-	-	-	-	-	-
Tamarix	4	0.31	-	-	-	-	1	0.09	4	0.69	1	0.18	-	-	-	-	3	0.60
Fraxinus	2	0.15	1	0.08	13	1.55	6	0.55	6	1.03	13	2.35	61	14.42	7	2.11	10	2.01
Platanus	-	-	-	-	-	-	1	0.09	0	-	-	-	-	-	-	-	-	-
Ulmus	81	6.18	4	0.34	9	1.07	38	3.50	18	3.09	6	1.08	12	2.84	4	1.21	68	13.65
Ulmaceae	531	40.50	90	7.58	114	13.60	62	5.70	11	1.89	38	6.87	3	0.71	3	0.91	197	39.56
Celtis	133	10.14	108	9.10	15	1.79	53	4.88	21	3.60	5	0.90	2	0.47	-	-	13	2.61
Pistacia	38	2.90	19	1.60	2	0.24	22	2.02	16	2.74	4	0.72	3	0.71	3	0.91	22	4.42
Maloideae	23	1.75	13	1.10	8	0.95	17	1.56	11	1.89	-	-	-	-	-	-	-	-
Amygdalus	27	2.06	-	-	2	0.24	9	0.83	1	0.17	13	2.35	5	1.18	27	8.16	13	2.61
Prunus	2	0.15	-	-	-	-	10	0.92	3	0.51	-	-	-	-	-	-	-	-
Rosa	3	0.23	-	-	-	-	1	0.09	1	0.17	-	-	-	-	-	-	-	-
Ficus carica	-	-	-	-	-	-	1	0.09	-	-	1	0.18	-	-	-	-	-	-
Leguminosae	-	-	6	0.51	-	-	30	2.76	14	2.40	-	-	-	-	-	-	2	0.40
Chenopodiaceae	7	0.53	3	0.25	2	0.24	18	1.66	3	0.51	-	-	1	0.24	-	-	-	-
Compositae	16	1.22	10	0.84	-	-	11	1.01	2	0.34	2	0.36	-	-	-	-	-	-
Labiatae	5	0.38	-	-	2	0.24	7	0.64	2	0.34	2	0.36	-	-	-	-	-	-
Capparis	-	-	1	0.08	-	-	-	-	-	-	4	0.72	-	-	-	-	-	-
Total	**1311**	**100.0**	**1187**	**100.0**	**838**	**100.0**	**1087**	**100.0**	**583**	**100.0**	**553**	**100.0**	**423**	**100.0**	**331**	**100.0**	**498**	**100.0**

Table 1. Detailed presentation of percentage charcoal fragment counts for all taxa present in Çatalhöyük midden samples (domestic refuse deposits) from the South Area and the TP Area

as *Amygdalus* and *Prunus*) were proportionally more abundant in Levels South L-M compared to the later phases of the ceramic Neolithic. Their regular presence in these samples contributes to the perception of the Levels South L-M midden deposits as taxonomically 'more' diverse by comparison to both earlier and later middens, while some very rare taxa such as maple (*Acer*) and fig (*Ficus*) were also present in these charcoal samples (Table 1; Asouti 2005).

The TP Area deposits represent the latest deposits excavated to date at Çatalhöyük and bridge the gap between the Neolithic and Chalcolithic habitation phases. TP charcoal samples illustrate the third major disjunction in the charcoal sequence. While *Quercus* drops to its lowest values (<5 per cent) since the aceramic Neolithic (Level South G), *Juniperus* also shows a significant reduction compared to Levels South P-S and Levels 4040 H/I. By contrast, there is an increase in the values of the riparian taxa and undifferentiated Ulmaceae (together for >70 per cent of the sample composition). Thus TP Area charcoal sample composition resembles closely that of the aceramic levels (Level South G). The sole difference is that a significant part of the wet woodland taxa in the case of the late samples consists of *Ulmus*, while positively identified *Celtis* charcoals appear very infrequently in them. It is therefore possible that a large proportion of the TP Ulmaceae undifferentiated charcoals have derived from *Ulmus* instead of *Celtis* wood.

There are several potential explanations for these seemingly contradictory patterns. If South G and TP samples were omitted from the analysis, percentage fragment counts would surely suggest the progressive expansion of *Quercus* in the early part of the sequence, followed by its replacement by *Juniperus* as the main source of timber and firewood, and the over-exploitation of the local riparian vegetation. However, such a conclusion is contradicted by the high percentages of riparian taxa in the TP samples. Similarly, the low percentages of *Quercus* and *Juniperus* in the earliest and the latest phases of Çatalhöyük might suggest the limited use of these taxa as sources of timber and fuel during these phases. Although it is possible that a small proportion of *Quercus* and *Juniperus* charcoal was introduced as a result of building destruction by burning in the later ceramic Neolithic levels, it should also be pointed out that there is no evidence of burnt buildings before South Area Levels P-S. This offers additional support to the argument made previously that old defunct structural timber and timber preparation waste were regularly used as fuel (Asouti 2005).

DISCUSSION

These patterns are subject to further investigation (the gaps in the stratigraphic sequence continue to be filled up with further analysis of more samples from the South and TP areas). However they do indicate temporal changes in charcoal sample composition that cannot be explained as the result of either climate-induced changes or progressively negative anthropogenic impact on past vegetation. A pattern of localized woodland management appears to be the case during the earliest (aceramic) and the latest phases of Çatalhöyük. For the greater part of the ceramic Neolithic phases firewood collection integrated local vegetation sources and recycled defunct timber and timber preparation waste from oak and juniper that were procured from more distant habitats. By comparison to the aceramic levels, the later ceramic Neolithic phases appear to represent an even greater contraction of firewood collection radii focusing almost exclusively on local vegetation catchments (riparian woodland plus economically important taxa such as *Pistacia* and *Amygdalus*) which seem to have formed, despite centuries of fuel collection, sustainable wood sources. The gradual shift from oak to juniper through the later phases could be equally understood as a culturally-induced switch in the choice of timber species, considering also pollen evidence that has indicated the expansion of oak woodland during this period in central Anatolia (Roberts *et al*. 2001; Eastwood *et al.* 2007). Indications for the cultural nature of timber use have been provided for example by the absence of evidence for the structural utility of vertical *Juniperus* timber posts. Such evidence is naturally limited to the later levels of the site whereby there is *in situ* preservation of burnt structural timbers. *Juniperus* posts were overall of small size and diameter, were encased in plaster and did not reach high enough to be interpreted as actual roof supports or even supports for a second storey (Asouti, in press). At the same time, building techniques and plan changed during the TP phases with the increasing use of buttresses and the gradual phasing out of timber. Again based on the combined evidence from charcoal and pollen data there appears to be no environmental or anthropogenic cause for this shift in building practices, timber use and coeval shifts in charcoal sample composition. It is also worth noting here that at no point during the long archaeobotanical sequence sampled at Çatalhöyük it is possible to discern a trend supporting classic models for the progressive depletion of wood fuel resources by large sedentary communities, and the substitution by dung fuel. On the contrary, the use of wood and dung fuel appears to have been structured along culturally determined principles, with wood being the preferred fuel in domestic hearths whereas dung was probably used more extensively in non-domestic settings (e.g. courtyards and other open spaces, "bonfires", etc. Asouti in press; Bogaard *et al*. in press).

The implication of these observations is that with the passage of time the organization of ceramic Neolithic firewood collection appears to have become increasingly localized. It started like this in the earliest phases of the site, with catchment areas expanding during the early ceramic Neolithic. After the mid-7th millennium cal BC formerly spatially extensive procurement networks began to contract gradually. At the same time, small-scale localized impacts in woodland vegetation with the exertion of selective pressures on certain taxa (e.g., Rosaceae, Maloideae, other shrubs) cannot be excluded, and these might have played an important role in the continuous expansion of other taxa such as *Quercus* in the lower upland zone surrounding the high-altitude steppe plains of central Anatolia as suggested by pollen analysis (Roberts *et al*. 2001; Woldring 2002; Woldring and Bottema 2001/2; Eastwood *et al*. 2007; Asouti, in press).

CONCLUSION

The evidence on the temporal developments observed in the Çatalhöyük Neolithic charcoal sequence, indicates that firewood gathering evolved from predominantly local procurement during the late 8th millennium cal BC aceramic Neolithic, to a mixed pattern of local and distant collection that was closely associated with the seasonal fluctuations of other landscape practices (house building, ground stone and shell sourcing, clay extraction, hunting, foddering, etc.) during the 7th millennium ceramic Neolithic phase (the main period of the Neolithic habitation of the east mound). Towards the end of the 7th millennium and the transition to the Chalcolithic it is possible to observe a return to a predominantly local pattern of resource management that focused on riparian woodland habitats. The charcoal record is also consistent with several changes observed during the same chronological horizon in caprine herd size and herding strategies, material culture production and architecture (see discussion by Asouti, in press). It is possible that these developments reflect changes in the structure and composition of the Çatalhöyük households through time, with increasing household autonomy during the later phases of the site, and were linked to changes in material culture, the built environment, the organisation of subsistence production, and the ownership of and/or access to the land and its resources.

Firewood collection forms an integral part of the social and economic life of pre-modern (in the economic sense of the term) societies (Asouti and Austin 2005). Therefore, just as it happens with other activities situated in the economic sphere, it is conditioned by socio-cultural considerations that are not dependent on individual fuel species properties or their net availability in woodland vegetation. In light of these observations and theoretical arguments it follows that models linking resource availability, use value and handling costs (e.g., Marston 2009) and those positing unilinear negative impacts on past vegetation (e.g., Miller 1985) must take into account the broader cultural and socioeconomic contexts of fuel use and consumption when modeling "optimal" firewood collection practices. Such variables include cultural preferences, risk avoidance, compatibility with other economic tasks, seasonal fluctuations in resource availability, and storage or the lack thereof.

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Charcoal analysis at Drakaina Cave, Kephalonia, Ionian Islands, Greece. A case study of a specialized Late Neolithic and Chalcolithic site

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Summary*: The paper presents the results of wood charcoal analysis from Drakaina Cave, Kephalonia, Ionian Islands, Greece, for the Late Neolithic and the Chalcolithic period. The site is located at the south-eastern part of the island in the Gorge of Poros. According to the wood charcoal analysis, a rich environment would have existed in the gorge where evergreen and deciduous species as well as some conifers would have grown. Phillyrea and both evergreen and deciduous oaks would have been the most abundant taxa. No significant changes occurred in the vegetation of the area from the Late Neolithic to the Chalcolithic. Microenvironments existing in the gorge would have supported the preservation of dynamic and rich ecosystems but the critical factor would have been the discontinuous, specialized use of the cave.*

Key words*: Neolithic, Chalcolithic, vegetation, microenvironment, specialized site.*

INTRODUCTION

The Neolithic habitation of the Ionian Islands has been documented by means of a few rescue excavations and surveys, especially on Kephalonia (Stratouli 2007 and references therein). The recent excavations at Drakaina Cave on Kephalonia have documented its early prehistoric use for the Late Neolithic (*c*. 5600/5500 – 4900/4800 cal BC) and the Chalcolithic (*c*. 4900/4800 – 3700 cal BC) (Stratouli 2005). Stratouli (2005) proposed that during that time the cave served as a specialized site related to communal gatherings of special significance for the Neolithic communities.

The excavated prehistoric deposits of Drakaina Cave were rich in archaeobotanical remains recovered through systematic flotation of soil samples during which a large number of wood charcoal samples were recovered. Thus, the site provided a unique opportunity to study the prehistoric vegetation in the area in relation to the specialized activities that took place at the cave during the Late Neolithic and the Chalcolithic. The results of wood charcoal analysis at Drakaina Cave are presented in this paper.

THE SETTING

Drakaina Cave (38° 8'31" N, 20° 6'49" E) is located in the south-eastern part of the island of Kephalonia in the Ionian Sea, Greece (Fig. 1A and B). At an altitude of c. 70 m it is situated within the steep sided Gorge of Poros (Fig. 1C), close to the modern village of the same name located on the nearby coast (Fig. 1D). The site lies along a natural passage that connects the coastal area with an interior fertile basin (Fig. 1D and E).

The bioclimatic conditions of the coastal areas of Kephalonia range between weak thermomediterranean in the SW and mesomediterranean in the rest of the island. The winters are mild with mean lowest temperatures of the coldest month above 7^{o}C in the coastal zone, while the number of dry days during the warm and dry period is less than 125 (Museum of Natural History, Cephalonia and Ithaka 1998, bioclimatic maps 3 and 4: 114).

The plant cover in the study area is maquis in various stages of development consisting mainly of *Quercus coccifera*, *Pistacia*, *Phillyrea*, *Arbutus* and other undershrubs. To the west of the gorge the fertile Tzannata basin is located where cultivated groves are found (Fig. 1E). A central feature of the island is the Ainos mountain range (1628 m) that runs NW-SE for a length of 10 km and borders the broader study area to the west (Fig. 1D). Diversified topography creates variable ecosystems and on the eastern slopes *Abies cephalonica* forest grows as well as a great variety of evergreen and deciduous trees and bushes (Museum of Natural History, Cephalonia and Ithaka 1998: 117-118).

THE SITE AND ASPECTS OF ITS SPECIAL USE

Drakaina rockshelter covers an area of approximately $90m^2$ (Fig. 2). The site was systematically excavated between 1992 and 2005 by the Hellenic Ministry of Culture and Tourism – Ephorate of Palaeoanthropology-Speleology of Southern Greece. Human activity at the site began around the middle of the 6th millennium cal BC and continued until the beginning of the 4th millennium cal BC (Late Neolithic – Chalcolithic), based on radiocarbon dating (Stratouli *et al.* 1999). The cave contains evidence for periodic use

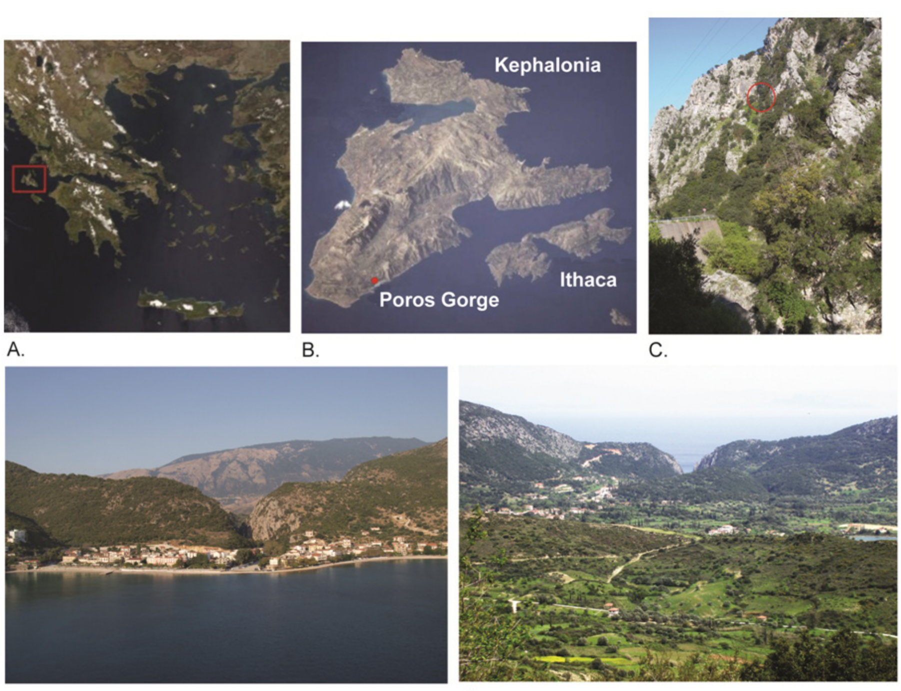

Figure 1. Location of Drakaina Cave: A. Kephalonia, Ionian Islands, Greece, B. Poros Gorge on the south-eastern part of the island, C. Drakaina Cave on the southern slope of the gorge, D. The gorge from the east; Poros village on the coast, Mount Ainos at the back, E. The gorge from the west, from Tzannata basin).

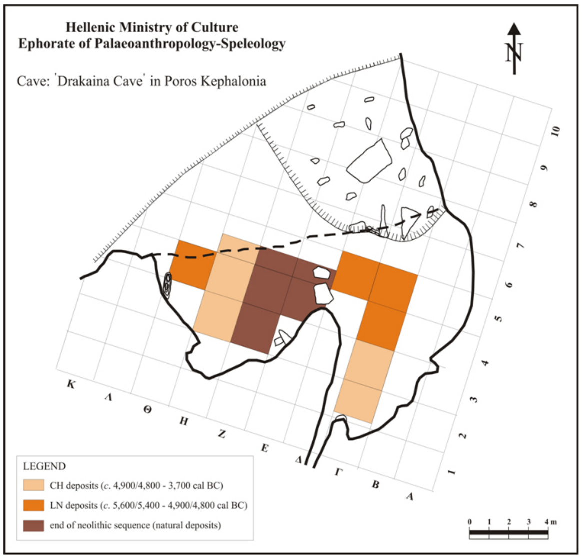

Figure 2. Cave plan with the excavated trenches in which the Late Neolithic and Chalcolithic phases were identified.

up until the mid of the 3rd millennium cal BC (Early Bronze Age II). A long period of inactivity followed indicated by the accumulation of a naturally-induced layer lacking any evidence of archaeological remains. Renewed use of the cave is began during the late 7th century BC until the beginning of the 2nd century BC when it became a cult site dedicated to the Nymphs and Pan. The cave was then abandoned until recently when it was used as a sheepfold (Chatziotou and Stratouli 2000).

The earliest chrono-stratigraphic phases (Fig. 2) are attributed to the Late Neolithic (LN: *c.* 5600 – 4900/4800 cal BC), a transitional Late Neolithic/ Early Chalcolithic phase and the Chalcolithic (CH: *c.* 4900/4800 – 3700 cal BC). The corresponding deposits are 1.50 to 1.70 m thick and have been the focus of intensive research that has revealed the following:

- The stratigraphic evidence and the composition of the cultural material indicate intermittent use of the cave and for short periods of time (Stratouli 2007).

- A series of lime plastered 'floors' or living surfaces were constructed during the LN and more intensively during the CH (Karkanas and Stratouli 2008). The relaying of these surfaces over more than 1000 years, a difficult and time consuming activity which is unusual for caves, suggests communal planning and the special significance of the site (Stratouli 2005, 2007).

- Various plant foodstuffs were consumed in the cave although food preparation on-site was limited and there is no evidence for grain storage (Sarpaki forthcoming).

- Livestock could have been managed on-site but the evidence mainly suggests on-site emphasis on consumption strategies parallel to hunting that probably held a social role in negotiating the cultural landscape (Kotjabopoulou, forthcoming).

- A large number of unbroken tools, e.g. ground stone tools and projectile points, as well as numerous ornaments were deposited in the cave (Stratouli 2007; Bekiaris forthcoming; Metaxas forthcoming). Certain objects and raw materials (e.g. obsidian from Melos island in the Aegean, gabbro tools and talc beads from the mainland) suggest the existence of wider networks of communication and exchange (Stratouli 2007; Stratouli and Melfos 2008).

- Evidence for on-site pigment processing was identified (Stratouli 2007).

- High levels of pottery fragmentation were observed in particular of decorated ware pointing to the practice of deliberate breakage and/or deposition (Stratouli 2005, 2007).

All these characteristics may be read as a system of signs of particular meaning that attribute a symbolic significance to the cave for the Neolithic/Chalcolithic community of the region. The contents from Drakaina Cave could have been related to ceremonial and ritual events such as feasting or other kinds of gatherings, by small groups that would have taken place periodically and which would have contributed to the formation of the character of the site and its identity. This may also be supported by the specific location of the cave in the Poros Gorge, which links the coastal zone with the small basin of Tzannata (Fig. 1E), rich in several resources, including farming and grazing land, water sources, woodlands and a variety of rocks (Stratouli 2005, 2007).

METHOD AND MATERIALS FOR ANALYSIS

Systematic soil sampling of the excavated prehistoric layers as well as hand-collection of carbonized remains during excavation yielded significant amounts of wood charcoal from the LN, the LN/ECH and the CH deposits at Drakaina. Water flotation was used for the soil samples in order to separate organic from inorganic material. The material subjected to analysis includes the wood charcoals collected from the coarse flot and the residue fraction of the water flotation as well as those recovered directly from the sediment.

A total of 150 wood charcoal samples were analyzed. For botanical identification we used a Nikon Optiphot 100 dark/bright field incident light microscope (x100 - x500 magnifications), specialized plant anatomy bibliography (Schweingruber 1990) and the comparative collection of modern charred woods at the Laboratory of the Department of Prehistory and Archaeology, University of Valencia, Spain.

Wood charcoal remains were scattered throughout the sediments of the cave representing long-term firewood collection. As such they provide the dataset for the palaeoecological analysis (Chabal 1988; Asouti and Austin 2005). The samples from the units that comprised the three phases identified in the sequence were grouped together to form the wood-charcoal assemblages of the LN, the LN/ECH and the CH. The frequency values of the taxa identified in the assemblages were measured as a percentage of fragment counts (Chabal 1988).

	LN		LN/ECH		CH	
TAXA	**n**	**%**	**n**	**%**	**n**	**%**
cf. *Abies cephalonica*	3	0.30			1	0.12
Acer sp.	5	0.50				
Angiosperm	24	2.40	27	2.81	42	5.20
Arbutus sp.	64	6.39	128	13.32	62	7.68
Carpinus/Ostrya	2	0.20	1	0.10		
Cistus sp.	3	0.30	2	0.21		
Cistaceae	3	0.30	1	0.10	1	0.12
cf. *Clematis* sp.	2	0.20				
Conifer	4	0.40	1	0.10	6	0.74
Erica sp.					3	0.37
cf. *Erica* sp.	1	0.10				
Fabaceae	1	0.10			3	0.37
Ficus carica	1	0.10			2	0.25
Fraxinus sp.	1	0.10				
Juniperus sp.	35	3.50	10	1.04	14	1.73
cf. *Juniperus* sp.	1	0.10				
Labiatae	3	0.30	4	0.42	1	0.12
Laurus nobilis			2	0.21		
Maloideae	9	0.90	19	1.98	3	0.37
Monocotyledoneae	1	0.10				
Olea europaea	8	0.80	1	0.10		
Phillyrea/Rhamnus alaternus	257	25.67	285	29.66	179	22.18
Pinus halepensis	1	0.10	11	1.14	5	0.62
cf. *Pinus halepensis*	3	0.30	1	0.10	2	0.25
Pinus halepensis/P. pinea					1	0.12
Pinus nigra			1	0.10		
*Pinus*sp.			7	0.73		
cf. *Pinus*	1	0.10				
Pistacia terebinthus	25	2.50	43	4.47	46	5.70
Pistacia lentiscus			2	0.21		
Pistacia sp.	7	0.70	5	0.52	2	0.25
Populus sp.	2	0.20	1	0.10		
Prunus amygdalus	24	2.40	33	3.43	46	5.70
Prunus amygdalus/P. spinosa tp.	5	0.50	5	0.52	11	1.36
Prunus amygdalus/P. webbii tp.	2	0.20	2	0.21	3	0.37
Prunus spinosa tp			2	0.21	2	0.25
Prunus webbii	4	0.40	1	0.10	6	0.74
Prunus sp.	4	0.40	4	0.42	17	2.11
Quercus sp. deciduous tp	144	14.39	124	12.90	80	9.91
Quercus sp. evergreen tp	240	23.98	150	15.61	118	14.62
Quercus sp.	103	10.29	86	8.95	149	18.46
Ulmus/Celtis	1	0.10				
Unidentified 1			1	0.10		
Unidentified 2	1	0.10				
Unidentified 3	1	0.10				
Nut shell	3	0.30	1	0.10	2	0.25
Bark	2	0.20				
Sub-total	**1001**	**100**	**961**	**100**	**807**	**100**
Unidentifiable	13	1.28	6	0.62	5	0.62
TOTAL	**1014**	**100**	**967**	**100**	**812**	**100**

Table 1. Qualitative and quantitative results of the Late Neolithic, Late Neolithic-Early Chalcolithic and Chalcolithic wood charcoal assemblages.

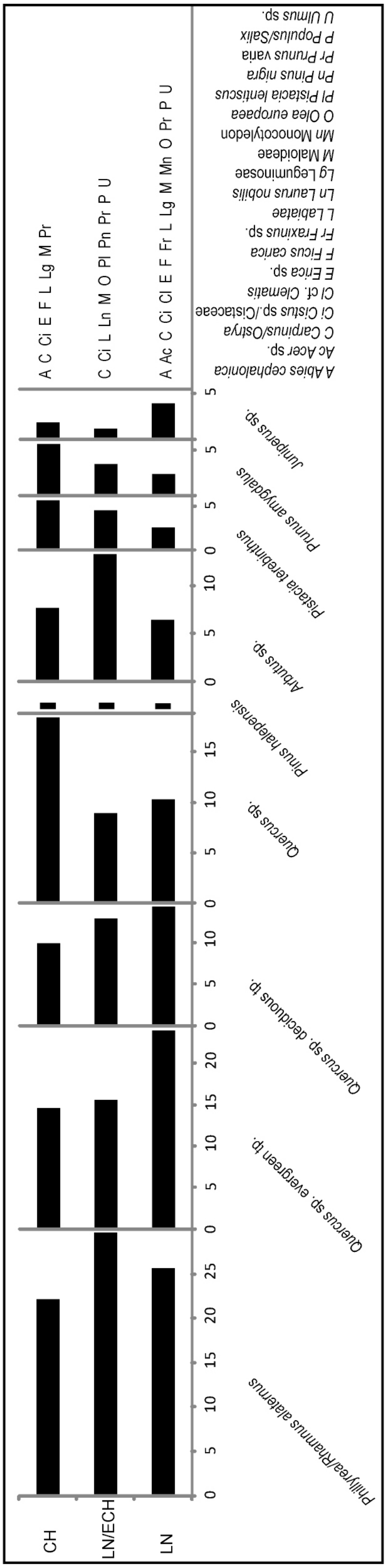

Figure 3. The charcoal diagram from Drakaina Cave showing the relative frequency of the most abundant taxa as well as the presence of *Pinus halepensis* and all other taxa in successive phases.

RESULTS

A total of 2793 wood charcoal fragments were analyzed making up a rich plant assemblage in which thermophilous, mesophilous and riverside taxa as well as mountain conifers are represented (Table 1). At least 27 plant taxa were identified amongst which we can distinguish between those that would have probably formed the tree level of the formations, the components of the understorey (bushes and shrubs) and possible climbers. The qualitative and quantitative results of the analysis are presented in Table 1 and in Fig. 3. The assemblages of all three phases are very similar in composition and indicate that a large number of both evergreen and deciduous species would have grown in the gorge, amongst which *Phillyrea/Rhamnus alaternus* and both evergreen and deciduous oaks would have been the most abundant.

The taxon *Phillyrea/Rhamnus alaternus* includes different plants with very similar anatomy. In western Greece, from sea-level to mid elevations, as well as hinterland locations with microclimates, *Phillyrea media*/*P. latifolia* is very abundant, while *R. alaternus* is very rare. *Phillyrea media* with *Q. coccifera* are characteristic of the phillyreo-cocciferetum association in central Greece (Quezel and Barbero 1985: 20-21) and *P. latifolia* thrives in Kephalonia on the slopes of Ainos (Museum of Natural History, Cephalonia & Ithaka, 1998, 118) and on the opposite Greek mainland (Sadori *et al.* 2011: 123). For these reasons we believe that the specimens of *Phillyrea/R. alaternus* at Drakaina mainly correspond to the first genus, *Phillyrea*. This is also supported by pollen analysis results from both high and low altitude areas in western Greece, i.e. Rezina (Willis 1997) and Ziros (Turner and Sanchez Goñi 1997), that record the expansion of *Phillyrea* early in the Holocene. Moreover pollen cores from Mljet Island (Croatia) and the nearby mainland coast of Dalmatia show a distinct phase of

Phillyrea expansion in this part of the Adriatic during the Middle Holocene, around the second half of the 6th millennium cal BC (*c*. 7500 cal BP) (Brande 1989; Sadori *et al.* 2011 and references therein).

The proportion of *Quercus* sp. in the assemblages is high (Table 1, Fig. 3) due to insufficient anatomical criteria to distinguish between the evergreen and deciduous types. Assuming that the specimens of this taxon correspond most probably or in large part to the evergreen oak that in all assemblages is more abundant than its deciduous counterpart (Table 1, Fig. 3), we may suggest that evergreen oak/*Phillyrea* woodland grew in the gorge. These trees together with deciduous oaks and sparse Aleppo pines would have constituted the tree-level of the formation. A very rich understorey is represented by a large number of smaller trees and shrubs amongst which *Arbutus*, turpentine and the almond hold a special place (Fig. 3). The watercourse at the bottom of the gorge could have been perennial in prehistory supporting lush riverside vegetation including poplar, elm and ash (Table 1). However, the representation of such vegetation in the wood-charcoal assemblages is very low. Riverside species would have been restricted to a narrow belt along the watercourse and they would not have been easily accessible given the steepness of the slopes. Firewood collection at the bottom of the gorge and transportation up-slope would not have been an easy or effective task and this may account for the meager representation of riverine plants.

During the three occupation phases at Drakaina, the LN, the LN/ECH and the CH, the same plants would have been predominantly collected for firewood (Fig. 3). There is no significant change in the proportion of the taxa. A slight decrease in the proportion of *Phillyrea* is observed in the CH accompanied by a small increase of *Arbutus*, *Pistacia* and *Prunus amygdalus*. However, *Quercus* (evergreen, deciduous and *Quercus* sp. taken together) remains stable in all phases. The mixed evergreen and deciduous woodland would have been quite dense while the steepness and orientation of the slopes would have probably affected the distribution of the plant species. We may thus suggest that deciduous oaks, hop hornbeam, maple, ash and elm would have grown in greater numbers in the shadier and more humid lower part of the gorge and on the deeper soils present there. Most evergreen taxa, the heliophilous *Prunus* species, turpentine tree and various Labiatae and Fabaceae shrubs would have formed a dense cover on the stonier and sunnier upper part of the slopes.

Of the taxa with a minor representation in the assemblages it is worth-mentioning the presence of *Laurus nobilis*, *Olea*, *Abies* and *Pinus nigra*. The identification of the former is in agreement with the present distribution of the species on Kephalonia (Boratynski *et al.* 1992) and testifies to its long history on the island. The presence of the olive is worth-mentioning given that it is one of the earliest so far identified in Greece. The few *Olea europaea* specimens in the LN levels are thus dated to the late 6th millennium cal BC. The only other earlier evidence comes from the Cave of the Cyclops on the Aegean island of Youra dated to the late 7th millennium cal BC (Ntinou 2011). The presence of the olive in mixed formations in the gorge is interesting in terms of its absence/low presence during the earlier part of the Holocene. It is possible that the species grew in small numbers in special micro-environments, in particular riparian habitats, where it found refuge during the Pleistocene (Carrion *et al*. 2010). It did not become a prominent feature until much later and only through cultivation. It is interesting at this point to mention that such a scenario has been proposed for the late appearance of the olive in Crete (Moody *et al.* 1996) while it is probable that the species could have grown in very small numbers in deciduous oak woodland (cf. Bottema 1990).

A few wood charcoal specimens of *Abies cephalonica* (Kephalonia fir) were also found, a mountain conifer at present growing on Mount Ainos to the west of the study area. The presence of *Pinus nigra* in LN/ECH contexts supports the long but rare survival of the taxon on the island that has only recently been identified (Efthymiatou-Katsouni and Phitos 2011). In prehistoric times, as present, this species would have grown on Mount Ainos together with the Kephalonia fir. Both the fir and the black pine would not have originated from strictly local habitats. In the more wooded prehistoric environment, they could have grown at lower altitude or within the catchment of local watercourses therefore reaching the site as driftwood.

DISCUSSION AND CONCLUSIONS

A very rich plant environment was highlighted by the wood charcoal analysis. Thermophilous evergreen oak-*Phillyrea* woodland with various undershrubs and scattered *Pinus halepensis* trees would have grown within the gorge. Various mesophilous plants would have also been present amongst which deciduous oaks would have been the most abundant. *Carpinus/Ostrya*, *Acer*, *Fraxinus* and *Ulmus* would have found favourable conditions in the lower parts of the gorge, on deeper and moister soils and in generally shadier and cooler habitats, while on the stream banks *Populus* would have grown. The vegetation of the Kephalonia mountains would have rarely reached the cave either as collected driftwood or as raw material/fuel from (hunting?) excursions to the nearby mountains by the Neolithic/Chalcolithic inhabitants.

The island of Kephalonia enjoys favorable climatic conditions due to its geographical location to the west of the great Pindus massif and its southern latitudinal position. In general, the broader Ionian Sea area receives abundant rainfall (mean annual 750-1000 mm) while the winter temperatures are mild (January average 10-15°C) (Polunin 1980: 18-19). Similar conditions would have also prevailed in the area during the Middle Holocene (*c*. 5000 – 1000 cal BC, *c*. 7000 – 3000 cal BP). The predominance of AP and deciduous *Quercus* in the pollen diagram from Voulkaria Lake (Acarnania, western Greece) on the mainland coast opposite to Kephalonia, indicates that the aridification events observed in other parts of the central Mediterranean did not affect western Greece (Sadori *et al.* 2011). Moreover, the existence of microenvironments in the Poros Gorge would have offered optimal conditions for the growth of a great number of species.

The vegetation that Neolithic and Chalcolithic people used would have been very similar and only very small changes are observed in the wood charcoal sequence (Fig. 3). In general, the plant formations show a similar composition as far as the most abundant and dominant species are concerned while the majority of the secondary components are present diachronically. Therefore, a stable image of the vegetation at the gorge emerges from the Drakaina wood charcoal results.

The pollen record from the central Mediterranean area indicates that during the Middle Holocene coastal western Greece and the Balkans were not subject to major climate-induced vegetation changes and were less affected by the aridification process that began in the late 7th and culminating in the late 3rd mill. cal BC (*c*. 8000 cal BP - 4000 cal BP) (Sadori *et al.* 2011). Deciduous oak woodland was preserved until at least 2300 cal BC (4400 cal BP) in protected coastal areas of western Greece not affected by climatic variations and it was only with the Bronze Age that human-induced changes became prominent (Sadori *et al.* 2011). Within this framework the wood charcoal results from Drakaina Cave support the suggestion that the vegetation at Poros Gorge did not suffer severe climate-induced changes between 5600 and 3700 cal BC.

Nonetheless, the vegetation composition in the gorge would have been influenced by the types of activities carried out by the inhabitants of the cave and in particular the frequency, continuity and intensity of these. The preservation of the vegetation cover during almost two millennia of human presence at the cave indicates that either its use as a residential site was sporadic or that it was used for specialized activities. The lack of evidence for food storage and processing of cereals on site (Sarpaki forthcoming) alongside the small number of constructed floors indicate that the cave was not a regular habitation site and that it was used sporadically and for short periods of time. The wood charcoal evidence does not suggest use of the cave as a regular animal pen. Such practices would have caused changes to the vegetation especially if they had been continuous for a long period of time. The micromorphological study of the sediments also precludes the possibility of regular stabling activities given that not even microscopic remains of animal dung have been observed in the samples (Karkanas and Stratouli 2008).

As far as other specialized activities are concerned, it has been suggested that the cave was used as a hunting site and/or as a place of periodically significant social activity (Stratouli and Metaxas 2008). Large quantities of wood charcoal in relation to phosphate alterations observed on the floor surfaces may be attributed to the processing of animal carcasses (Karkanas and Stratouli 2008). Abundant firewood for meat processing and food preparation would have been used in the case of specialized hunting expeditions, in social gatherings and feasting or a ritual combination of the two. The wood charcoal results cannot provide conclusive evidence for the type of activity. However, what is key to all the suggested specialized activities at the site is the periodic and non-continuous use. Despite the large quantities of firewood needed on each occasion, if the use of the cave was periodic and not for livestock management, all other activities would have had little impact on the surrounding vegetation. Despite almost two millennia of human presence in the gorge, the vegetation was preserved with little change.

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Late Neolithic vegetation around three sites in the Visoko basin, Bosnia, based on archaeo-anthracology – spatial variation versus selective wood use

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***Summary**: The interdisciplinary investigation of Neolithic settlements in the Visoko basin, Bosnia and Herzegovina, permitted the collection of wood charcoal from archaeological contexts. Three contemporaneous sites, Okolište, Kundruci and Zagrebnice, were selected for the presented study. The fuel wood assemblages provide information on the Late Neolithic vegetation of Central Bosnia for the first time. A wide range of taxa was identified and proves a manifold landscape in the Bosna valley. The collected data are used to trace distinct vegetation types within a small area and discuss the issue of conscious use of the landscape and its vegetation by the Neolithic farmers.*

***Key words**: Late Neolithic, Bosnia and Herzegovina, Charcoal analysis, Woodland vegetation.*

INTRODUCTION

During the last years, intensive research has been carried out in the Visoko basin to get insight to Late Neolithic settlement processes (e.g. Hofmann *et al*. 2007; Furholt 2012; Hofmann 2012). In connection with the archaeological investigations many studies have been carried out in neighbouring disciplines (e.g. Kučan 2007; Dreibrodt *et al*. submitted; Kroll in prep.). Although several attempts have been made to collect palynological data in the Visoko basin (Bittmann and Wolters 2007; Dörfler 2007), no information is available for the Late Neolithic. In the wider region, several palynological studies are available (e.g. Beug 1967; Jahns and van den Bogaard 1998), but these works do not contribute to the picture of the Visoko basin during the Late Neolithic, since the investigated sites are too far away and located close to the Mediterranean Sea.

In the presented study, charcoal from archaeological context is used to trace the Late Neolithic vegetation of the Visoko basin. The fuel wood assemblages from three sites are used to study the vegetation in a distinct settlement region and provide data on the woody vegetation in Central Bosnia for the first time.

AREA OF INTEREST

As part of the archaeological research project "Reconstruction of settlement processes in Central Bosnia" several late Neolithic sites have been excavated. These sites offer an excellent opportunity for the investigation of spatial variations in the regional vegetation cover.

The Visoko basin reaches northwest from Sarajevo, the Capital of Bosnia and Herzegovina. The basin was formed during the Tertiary and later on filled up with glacial and limnic sediments until the Quaternary (Hrvatović 2006). The today valley is shaped by the river Bosna. It covers about 48 km^2 with an approximate length of 20 km and a maximum width of 10 km (Fig. 1).

Three sites, Okolište, Kundruci and Zagrebnice, provide the basis of the presented study. The settlements belong to the Butmir Group, a Late Neolithic archaeological culture. The central settlement, Okolište, is situated at the banks of the Bosna River (Fig. 1), a link in the route reaching from the Adriatic coast to the Danube Area (Müller 1994: 212).

Sarajevo is approximately 30 km southeast of Okolište. Excavations in the years from 2002 – 2009 revealed a structured residential area in several phases in the time between 5200 and 4700 cal BC. Botanical and faunal records indicate a mixture of agriculture and animal husbandry (Müller-Scheessel *et al*. 2010: 185).

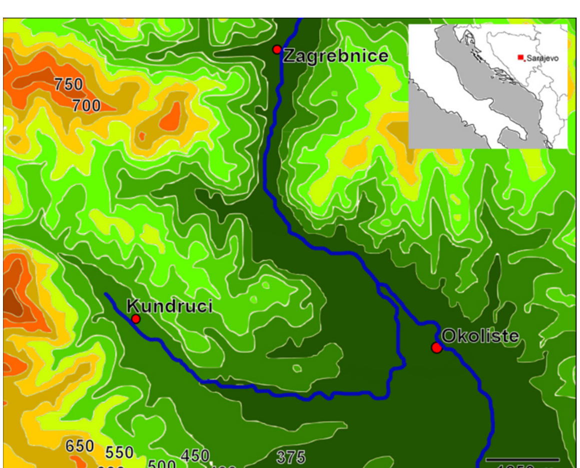

Figure 1. Map of the Visoko-basin with the investigated sites.

Zagrebnice is also located in the valley, approximately 5 km north of Okolište in a relative narrow part of the basin (Fig. 1). The botanical and faunal remains indicate a similar basis of daily life as observed in Okolište, although the topographical situation implies a lack of areas for cultivation. The site was established slightly earlier than Okolište (5450 cal BC), but was abandoned around 4700 cal BC (Müller-Scheessel and Hofmann in prep.).

In contrast to the former, Kundruci is located in a side valley, around 70 m higher in elevation and in close vicinity to steep slopes, exposed to the east and north (Fig. 1). The site was occupied for a shorter timespan than Okolište (ca. 4900 – 4700 cal BC) (Furholt, in prep.). The low amounts of chisels and grinding stones in combination with high phosphate values in the sediments suggest an emphasis on animal breeding in this settlement (Furholt 2012).

MATERIAL AND METHODS

For this paper 61 sediment samples were used with a total amount of 1451 charcoal pieces. The overall weight of the investigated material was 20.61 g (Table 1). To prevent the use of charcoal from archaeological features connected with architecture, only samples from archaeological layers with scattered charcoal, like roads or open space were taken into account. These are supposed to reflect a more reliable picture of the surrounding vegetation (Thiébault 1997).

The sampling strategy was the same for all sites. Every archaeological feature was sampled during excavation. The sediment samples were processed with floatation or wet sieving (Jacomet and Kreuz 1999: 118). The mesh size was 300 µm, sample size 10 l. During the laboratory treatment of the macro-botanical remains, the charcoal pieces were handpicked from the sample material. All charcoal pieces with at least one edge length exceeding 1 mm were selected.

Site	Calculation	*Abies*	*Acer*	*Alnus*	*Carpinus*	*Cornus*	*Corylus*	*Euonymus*	*Fagus*	*Fraxinus*	*Maloideae*	*Ostrya/Carpinus*	*Picea*	*Pinus*	*Prunus*	*Quercus*	*Quercus/Castanea*	*Sambucus*	*Ulmus*	*Viburnum*	Indet.	No wood anatomical features	Sum identified	Total sum	Total weight per site
Okolište	frequency	20	27	27	30	30	50	10	47	17	60	0	0	80	10	87	3	10	10	23	80	47			
Zagrebnice	frequency	23	31	15	15	77	54	0	31	62	38	0	0	85	0	77	0	0	54	0	62	31			
Kunduci	frequency	89	100	33	17	33	72	0	89	78	89	6	17	33	0	100	17	0	28	11	61	39			
Okolište	sum	13	16	13	12	21	50	3	33	9	83	0	0	115	5	181	6	4	3	11	74	18	578	670	7,03 g
Zagrebnice	sum	8	16	5	11	22	11	0	5	36	7	0	0	83	0	64	0	0	22	0	11	5	290	306	5,54 g
Kunduci	sum	58	70	8	3	11	33	0	62	27	69	2	8	10	0	76	3	0	6	3	18	8	449	475	8,07 g
Okolište	count%	2	3	2	2	4	9	1	6	2	14	0	0	20	1	31	1	1	1	2	13	3	100	116	
Zagrebnice	count%	3	6	2	4	8	4	0	2	12	2	0	0	29	0	22	0	0	8	0	4	2	100	106	
Kunduci	count%	13	16	2	1	2	7	0	14	6	15	0	2	2	0	17	1	0	1	1	4	2	100	106	

Table 1. Summarized results of the anthracological investigations at Okolište, Zagrebnice and Kundruci, top: frequency of taxa, middle: absolute number per taxon and site, bottom: count percentages per taxa and site. Weights are given for the sum of material per site.

The average edge length was 2-3 mm. For each sample 30 identifications were aspired, if available. The presentation of the results is done by number for the single samples (Tables 2 and 3). For the total amount per site, total numbers of the taxa are given, as well as the frequency of detection for the taxa and the count percentages (Table 1).

The identification was done on genus level. As reference material the relevant literature (Grosser 1977; Schweingruber 1990a and b) was used, as well as the reference collection of charred wood of the Palaeoecology research group at the Institute for Ecosystem Research, Christian-Albrechts-University of Kiel. Additionally two types were introduced due to the limitations of identification of small charcoal pieces. The *Quercus*/*Castanea* type and the *Ostrya*/*Carpinus* type were used where a precise distinction between the two taxa was impossible. In the following, the *Quercus*/*Castanea* type will be referred to as *Quercus*, the *Ostrya*/*Carpinus* type as *Carpinus.* The Rosaceae family was distinguished in Maloideae and *Prunus* according to Schweingruber (1990b). Pieces without identifiable wood anatomical structures were classified as "no wood".

A temporal congruence of the investigated sites allows for the comparison of charcoal assemblages from different areas of a limited region. To minimize the bias caused by selection and taphonomy (Heinz and Thiébault 1998: 57) only assemblages from archaeological layers with scattered charcoal were selected. All material presented in this study was taken from fire places or roads and open space, which accumulated over a longer period of time. In contrast to architectural features, the selected archaeological layers are assumed to represent the majority of species present in the surrounding vegetation similar to their actual proportions.

An important issue is the possible selection of species and, resulting, the comparability of the charcoal records in terms of a representative sample of the existing past vegetation. Due to the spatial and temporal relationship of the investigated sites, we assume similar requirement/gathering strategies for fuel wood collection for all three sites. That means, although the charcoal record does not necessarily reproduce the actual past vegetation, the main elements of the surrounding vegetation can be traced by investigating cultural layers and fire places. Deviations in the taxa combination between the investigated settlements are supposed to indicate different vegetation types in the vicinity of the sites. Uniform assemblages in all the investigated dwellings would suggest a strong selection of fuel wood.

Find no.	Feature category	*Abies*	*Acer*	*Alnus*	*Carpinus*	*Cornus*	*Corylus*	*Euonymus*	*Fagus*	*Fraxinus*	*Maloideae*	*Ostrya/Carpinus*	*Picea*	*Pinus*	*Prunus*	*Quercus*	*Quercus/Castanea*	*Sambucus*	*Ulmus*	*Viburnum*	Indet.	No wood anatomical features	Sum identified	Total sum
10068	open space	.	3	.	.	.	.	.	6	2	6	.	.	9	.	7	.	.	.	.	1	.	33	34
10082	open space	.	.	2	.	.	1	1	1	1	8	.	.	4	.	6	.	.	.	.	3	2	24	29
10086	open space	.	.	.	1	.	8	.	1	.	7	.	.	3	.	24	.	.	.	.	6	.	44	50
10087	open space	.	1	2	.	.	3	.	3	.	1	.	.	1	.	3	6	.	.	.	4	1	20	25
11062	open space	.	4	.	.	.	3	.	.	.	6	.	.	.	.	19	.	.	1	1	3	.	34	37
11063	open space	.	.	.	.	.	.	.	1	.	.	.	.	2	.	1	.	2	1	2	2	2	9	13
11098	open space	.	1	.	.	1	1	1	.	.	2	.	.	10	.	20	.	.	.	.	1	.	36	37
11106	open space	.	2	.	.	.	4	1	2	.	3	.	.	4	.	16	.	.	.	2	.	1	34	35
12070	open space	.	.	1	1	.	10	.	3	.	.	.	.	15	.	4	.	.	.	2	.	.	36	36
31256	open space	.	.	.	.	.	.	.	2	4	2	.	.	3	.	6	.	.	.	1	3	1	18	22
31333	open space	.	1	3	1	.	1	.	.	1	1	.	.	.	.	2	.	.	.	.	6	1	10	17
32276	open space	.	.	.	1	2	2	.	3	.	9	.	.	6	1	8	.	.	.	.	5	.	32	37
32277	open space	.	.	.	.	6	.	.	.	.	1	.	.	1	.	1	.	.	.	.	1	3	9	13
32278	open space	.	.	1	.	3	1	.	.	.	.	.	.	.	.	1	.	.	.	.	3	1	6	10
33084	open space	.	.	.	1	5	.	.	.	.	.	.	.	.	.	5	.	1	.	1	7	1	13	21
40081	ditch	1	.	.	1	.	.	.	1	.	.	.	.	3	.	.	.	.	.	.	3	.	6	9
40136	ditch	1	3	.	1	1	4	.	2	1	2	.	.	15	.	10	.	1	.	.	4	1	41	46
40160	ditch	4	.	1	.	1	.	.	.	.	5	.	.	8	.	.	.	.	.	.	5	.	19	24
40190	ditch	2	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	4	.	4	8
41068	ditch	.	.	.	.	.	.	.	2	.	.	.	.	3	.	2	.	.	.	.	1	.	7	8
41190	ditch	.	.	.	.	.	.	.	.	.	.	.	.	2	2	.	.	.	.	.	.	.	4	4
43017	ditch	.	.	.	.	.	.	.	.	.	15	.	.	6	.	1	.	.	.	.	.	1	22	23
44095	ditch	.	.	.	.	.	.	.	.	.	1	.	.	2	.	.	.	.	.	2	.	.	5	5
44096	ditch	.	.	2	3	.	.	.	.	.	1	.	.	1	.	17	.	.	.	.	1	1	24	26
44126	ditch	4	.	.	.	1	1	.	.	.	.	.	.	3	.	5	.	.	.	.	1	1	14	16
44139	ditch	.	1	1	.	.	5	.	2	.	9	.	.	4	.	5	.	.	.	.	.	.	27	27
44154	ditch	1	.	.	2	.	5	.	4	.	4	.	.	2	2	5	.	.	1	.	3	1	26	30
71071	open space	.	.	.	.	.	1	.	.	.	.	.	.	.	.	3	.	.	.	.	2	.	4	6
5E+05	open space	.	.	.	.	.	.	.	.	.	.	.	.	6	.	5	.	.	.	.	3	.	11	14
5E+05	open space	.	.	.	.	1	.	.	.	.	.	.	.	2	.	3	.	.	.	.	2	.	6	8

Table 2. Results of the anthracological investigation at Okolište (total numbers).

The reconstruction of possible vegetation types in the vicinity of the settlements is orientated on Horvat *et al*. (1974). The nomenclature of the genera and species correlated with the wood anatomical taxa follows Tutin (1969). Although the environmental settings may have changed since the Late Neolithic, it can be presumed that in general the same species contributed to the vegetation as is the case today. This assumption is underlined by the fact that the majority of species were present in the region from the early Holocene onwards (Willis 1994).

Site	Find no.	Feature category	*Abies*	*Acer*	*Alnus*	*Carpinus*	*Cornus*	*Corylus*	*Euonymus*	*Fagus*	*Fraxinus*	*Maloideae*	*Ostrya/Carpinus*	*Picea*	*Pinus*	*Prunus*	*Quercus*	*Quercus/Castanea*	*Sambucus*	*Ulmus*	*Viburnum*	Indet.	No wood anatomical features	Sum identified	Total sum
Kunduci	20017	open space	2	3	.	1	3	1	.	7	1	1	.	.	3	.	10	1	.	1	.	3	1	34	38
	20082	open space	3	6	.	.	1	2	.	8	3	10	.	.	3	.	3	.	.	.	.	1	.	39	40
	21018	open space	3	3	1	.	.	.	.	5	3	.	.	.	.	.	4	.	.	.	.	.	.	19	19
	21019	erosion area	.	7	.	.	.	1	.	.	.	.	.	.	.	.	1	.	.	.	.	1	.	9	10
	21020	erosion area	1	2	.	.	.	1	.	4	2	1	2	.	.	.	1	1	.	.	.	1	.	15	16
	21021	erosion area	.	5	.	.	.	.	.	1	1	1	.	.	.	.	1	1	.	.	.	2	.	10	12
	24106	open space	3	4	.	.	.	.	.	1	2	3	.	.	.	.	1	.	.	.	.	.	.	14	14
	24259	open space	3	6	1	.	3	.	.	3	1	5	.	3	.	.	5	.	.	.	.	2	1	30	33
	24297	open space	5	5	.	.	1	3	.	3	.	8	.	.	.	.	4	.	.	1	.	.	1	30	31
	24375	open space	3	5	1	.	.	.	.	5	.	5	.	.	.	.	10	.	.	.	.	.	.	29	29
	24539	open space	4	5	1	.	.	1	.	8	2	2	.	2	.	.	5	.	.	1	.	.	.	31	31
	24543	open space	4	3	.	1	.	5	.	2	4	3	.	3	.	.	5	.	.	.	1	2	2	31	35
	24552	open space	5	1	3	.	.	2	.	3	.	8	.	.	1	.	1	.	.	.	.	.	.	24	24
	24554	open space	6	4	.	.	.	2	.	2	2	6	.	.	.	.	7	.	.	.	.	2	1	29	32
	25264	open space	3	1	1	1	.	1	.	.	1	2	.	.	1	.	5	.	.	.	.	1	.	16	17
	25265	open space	8	3	.	.	2	5	.	1	2	6	.	.	.	.	1	.	.	.	2	1	1	30	32
	25266	open space	2	1	.	.	1	5	.	4	1	4	.	.	1	.	8	.	.	2	.	2	1	29	32
	25333	open space	3	6	.	.	.	4	.	5	2	4	.	.	1	.	4	.	.	1	.	.	.	30	30
Zagrebnice	10184	cultural layer	.	8	.	9	.	2	.	1	2	1	.	.	.	.	15	.	.	2	.	.	.	40	40
	10209	cultural layer	.	.	.	.	4	1	.	.	3	.	.	.	1	.	5	.	.	1	.	.	.	15	15
	10221	cultural layer	.	4	1	2	5	.	.	.	5	.	.	.	19	.	3	.	.	.	.	1	.	39	40
	10237	cultural layer	6	3	4	.	1	.	.	.	4	.	.	.	19	.	3	.	.	3	.	1	1	43	45
	10274	cultural layer	.	1	.	.	2	2	.	2	.	2	.	.	3	.	6	.	.	.	.	2	.	18	20
	10286	cultural layer	.	.	.	.	1	1	.	.	.	.	.	.	3	.	1	.	.	.	.	1	.	6	7
	10296	cultural layer	1	.	.	.	.	.	.	.	2	.	.	.	1	.	2	.	.	1	.	1	.	7	8
	10307	cultural layer	.	.	.	.	1	.	.	1	.	2	.	.	9	.	7	.	.	9	.	.	1	29	30
	10390	cultural layer	.	.	.	.	.	1	.	.	10	.	.	.	9	.	8	.	.	3	.	3	1	31	35
	10402	cultural layer	.	.	.	.	2	3	.	.	5	.	.	.	7	.	.	.	.	.	.	1	2	17	20
	32023	cultural layer	.	.	.	.	2	1	.	1	5	.	.	.	10	.	14	.	.	3	.	.	.	36	36
	33161	open space	.	.	.	.	1	.	.	.	.	1	.	.	2	.	.	.	.	.	.	.	.	4	4
	33162	open space	1	.	.	.	3	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1	.	5	6

Table 3. Results of the anthracological investigations at Zagrebnice and Kundruci (total numbers).

DATA AND RESULTS

The charcoal assemblages of the investigated sites show a wide range of species and thus indicate a diverse landscape. Altogether, 19 wood anatomical taxa were detected. The total amount of successfully identified charcoal pieces was 1317, 578 in Okolište, 449 in Kundruci and 290 in Zagrebnice (Table 1). Diagrams of summarized results for the three sites, based on count percentages, are shown in Figure 2.

In Okolište, fifteen taxa were identified in the material from this site, representing a wide range of different species with varying stand characteristics (Table 2). The dominant taxon in terms of count percentages and frequency is *Quercus* (31%, resp. 87%), followed by *Pinus* (20%, resp. 80%) and Maloideae (14%, resp. 60%) (Table 1).

In descending order also *Corylus*, *Fagus*, *Cornus*, *Acer*, *Abies*, *Alnus*, *Carpinus* and *Fraxinus* are present. Of minor importance are *Viburnum*, *Prunus*, *Sambucus*, *Ulmus* and *Euonymus*.

In Kundruci, 14 taxa were identified (Table 3). At this site, again, *Quercus* is the prevailing species, but is roughly half of that seen in Okolište: around 17% instead of 31%. The frequency of detection was 100% for *Quercus*. Nearly of equal importance are *Acer* (16%, resp. 100%) and Maloideae (15%, resp. 89%). *Fagus* (14%, resp. 89%) and *Abies* (13%, resp. 89%) are more important compared to Okolište. *Corylus* is also proven, as well as *Fraxinus*, *Cornus*, *Pinus*, *Picea*, *Alnus* and *Ulmus*. Rarely, *Carpinus* and *Viburnum* were identified.

In Zagrebnice, the charcoal assemblage includes 12 taxa (Table 3). *Pinus* (28%, resp. 85%) is the dominating taxon, followed by *Quercus* (22%, resp. 77%). *Fraxinus* is quite frequent, but less abundant (12%, resp. 61%). Also *Ulmus* is present (8%, resp. 54%). Again in descending order *Cornus*, *Acer*, *Carpinus*, *Corylus*, *Abies*, Maloideae, *Alnus* and *Fagus* are present.

DISCUSSION

The charcoal assemblages allow for an approximate insight into the neolithic vegetation. Palynological investigations from a prehistoric oxbow lake (Dörfler 2007) and the fen Seoce Jezero (Bittmann and Wolters 2007) did not reach back to the time of interest, but provide information on later phases. The record from Seoce Jezero starts around 1600 cal BC, the data from the oxbow lake starts around 1400 cal BC.

The comparison of these temporal deviating archives shows some variation in the pollen/charcoal assemblages documented. Although methodological constraints diminish the value of such comparison, some insights may be gained. It is assumed that the oxbow lake reflects a local pollen assemblage by trend, while the Seoce Jezero is dominated by a more regional pollen signal. Another factor is the possible selective preservation of pollen due to changes in soil moisture. *Salix, Tilia* and *Betula* are missing in the neolithic charcoal record while *Pinus* seems to be overrepresented in comparison to the work of Bittmann and Wolters (2007). The pollen record from the oxbow lake, investigated by Dörfler (2007) shows much higher percentages for *Pinus*. Up to 50%, while *Quercus* does not reach more than 35%. Also *Tilia* and *Betula* show lower values in contrast to the Seoce Jezero. Whether the differences are caused by human selection in the Neolithic or they reflect variations in the composition of the vegetation cannot be answered.

In Bosnia and Herzegovina and the adjacent countries palaeoenvironmental data are scarce. Only two anthracological studies from the wider region are available. The work on the charcoal assemblages from Kovaćevo, Bulgaria (Marinova and Thiébault 2008) fits quite well to the results from Okolište, while the results from the Drina valley (Schroedter *et al*. 2012) are of minor importance for the Visoko basin.

Additional palaeoenvironmental data have been gathered in connection with the excavations in the Visoko basin. Geomorphological investigations, conducted on alluvial and colluvial sediments near the river Bosna, suggest main sedimentation phases in the early Holocene and from 2,500 cal BC onwards. This implies that during the Late Neolithic we can assume slightly drier conditions (Dreibrodt *et al*. submitted).

The striking differences in species percentages between Okolište, Zagrebnice and Kundruci could have different reasons.

Either an unequal use of wood or differences in vegetation cover in the surrounding of the sites may have caused the observed deviations.

In the following it will be argued that the latter is the case. Especially Kundruci and Zagrebnice, situated in different altitudes, show only weak accordance in terms of proportions in the charcoal record, except from the

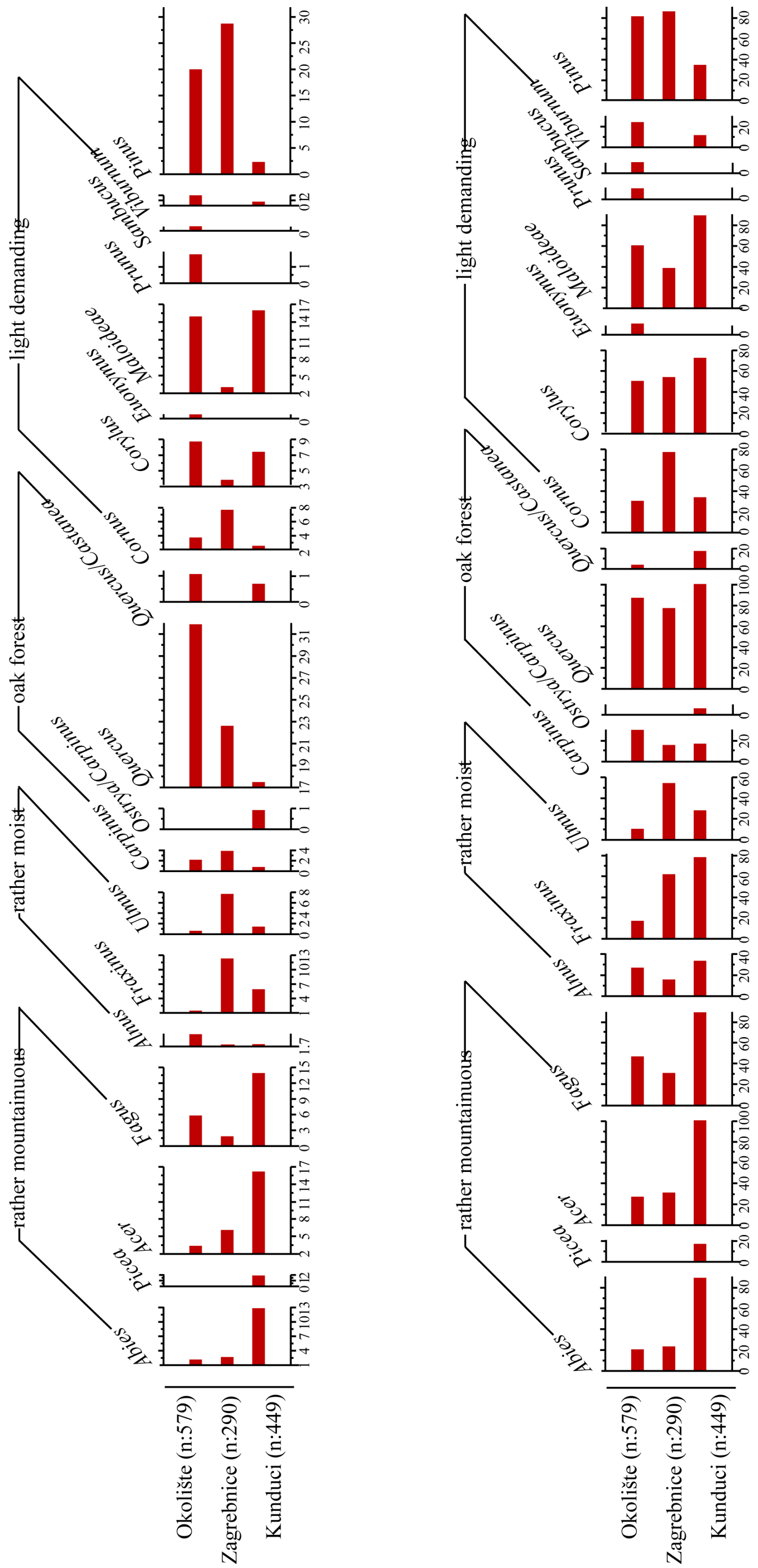

Figure 2. Left: diagram of the count percentages of the taxa in the charcoal assemblages from the investigated site Okolište, Zagrebnice and Kundruci; Right: diagram of the frequencies of the taxa in the investigated sites.

high percentages of *Quercus* charcoal in the assemblages.

Too many factors are unknown for an environmental reconstruction, such as precipitation during the Neolithic, the prehistoric soil properties and the degree of selective wood use. But due to the temporal and local vicinity of the investigated sites trends in the composition of woody vegetation should be reflected in the charcoal assemblages. Similar gathering strategies and use of the environment can be supposed for all sites because of their archaeological uniformity. Although the "human filter" has to be taken into account (Théry-Parisot *et al*. 2010), it is argued that the differences in the charcoal assemblages reflect different vegetation types used by the inhabitants of the single sites.

In the following the charcoal assemblages of the single sites will be discussed. As references for possible stands for the single species, reflected in the wood anatomical taxa, mainly Horvat *et al*. (1974) and Hegi (1935-36) were used. Additional information was taken from Hayek (1927). These works underlie the categorisation of taxa, provided in Figure 2. Although the identified taxa contain several species, the simplification was assumed to be justifiable, since several taxa contain only one or two species with similar stand requirements.

The charcoal record of Okolište proves variable vegetation within the vicinity of the site. Several taxa indicate open landscape (*Cornus, Corylus, Euonymus,* Maloideae, *Sambucus, Viburnum*). Other species reflect moist stands (*Alnus, Fraxinus, Ulmus*) or mixed deciduous forests (*Quercus, Fagus, Carpinus*). All these taxa may be easily explained by the situation in the broad valley bottom.

The high amount of *Pinus* is hard to explain, several scenarios are possible. *Pinus* might have acted as pioneer plant in open areas, cleared by human activities. Another explanation could be the occurrence on poor stands in the forest or even on gravelly stands in the flood plain of the river Bosna. *Abies* might have also grown in the mixed forest or might have been brought to the settlement as animal fodder during winter.

In Kundruci, *Quercus* is dominant, but other taxa play a more important role. Especially *Abies*, *Acer* and *Fagus* are present in nearly equal percentages (Fig. 2). These might be interpreted as indicators for stands of more "mountainous" character, compared to *Quercus* and *Carpinus*. The topographical situation in the side valley, slightly higher and in close vicinity to steep slopes may be a reason for their ubiquity. Also *Picea* can be interpreted in this way. *Abies,* in contrast, might well be overrepresented for the same reason as in Okolište, the animal husbandry. The low values of *Fraxinus*, *Ulmus* and *Alnus* may be connected with the missing of moist stands in the steep side valley. The vicinity of the small creek today can be disregarded, since the geomorphological investigations suggest less water transport for the Bosna and its tributaries (Dreibrodt *et al.*, submitted). Light demanding taxa like *Corylus* and the group of Maloideae prove open areas in the vicinity.

Zagrebnice is situated in a narrow part of the valley and in the same elevation as Okolište. The charcoal assemblage is characterized by relative low amounts of light demanding taxa (*Corylus*, Maloideae) compared to the previous sites. *Quercus* and *Carpinus* play a more important role compared to Kundruci. This fits well to their interpretation as dominant trees in the valley. The absence of *Picea* and the low values of *Abies*, *Acer* and *Fagus* support their interpretation as taxa of more mountainous character. *Fraxinus* and *Ulmus* show the highest values for all investigated sites. This may be connected with the existence of ash and elm rich woodland stands at moist sites near the river Bosna, although the low values of *Alnus* seem to contradict the widespread presence of riparian vegetation in the vicinity. A possible reason could be the occurrence of *Ulmus* and *Fraxinus* species on steeper slopes, probably together with *Acer*. This possibility is neglected, since these species are nearly missing in Kundruci. It is assumed that the relative low amount of water in the river was sufficient for stands of *Ulmus* and *Fraxinus* but not for *Alnus*. Again, the high percentages of *Pinus* are puzzling. The most likely explanation is its occurrence on poor sites in the mixed forest or the colonisation of flood plain sites in close to the river. The pioneer character of *Pinus* seems less convincing, when the percentages are compared to the proportions of the other light demanding taxa. The relative low amounts of all other light demanding taxa in Zagrebnice (14%) are accompanied by very high amounts of *Pinus* (28%). In Okolište the light demanding taxa (*Cornus*, *Corylus*, *Euonymus*, *Maloideae*, *Prunus*, *Viburnum*) represent almost one third of the assemblage (30%) and *Pinus* one fifth (20%). Especially the low amount of *Pinus* in Kundruci (2%) supports this interpretation, whereas the other light demanding species reach 25% altogether.

Populus and *Salix* are completely missing at all settlement sites. This can be explained by selective wood use or the absence of stands in the vicinity of the river Bosna. The latter seems to be more likely, considering the low quantities of *Alnus* in Zagrebnice and Okolište.

The role of the Maloideae group cannot be explained easily. All species of the Maloideae prefer edge situations (Kreuz 1988; 1992). The species of *Malus*, *Pyrus* and *Sorbus* may have been used as collectable fruits as shown by single finds of charred remains of apples in Okolište (Kroll in prep.). Also *Corylus* and *Cornus* as collectable fruits indicate stands with sufficient amounts of sunlight, so the existence of hedges or other kinds of protected stands have to be taken into consideration. The macrobotanical material with high amounts of *Corylus*, *Cornus* and finds of apple seed and charred dried apples supports this assumption (Kroll in prep.). The high amounts of light demanding taxa in the charcoal record might then be connected with a regular cutting of these plants in order to support flowering and fruiting. In contrast, *Crataegus* could be interpreted as a weed of meadows and pastures (Jansen and Nelle in press). A possibility, which is also likely in connection with cattle breeding and the use of *Abies* as winter fodder, indicated by finds of *Abies* needles in the macrobotanical material (personal communication, Kroll). Since the single genera and species cannot be distinguished anatomically, no decision can be made.

Summarizing, an open and manifold neolithic landscape must be expected in the Visoko basin. As the charcoal assemblages suggest, the Late Neolithic inhabitants did not use the wood very selectively. The deviations in the taxa percentages and combination can be explained by the topographic situation.

The broad valley bottom was probably dominated by mixed deciduous woods with *Quercus* as prevailing tree. Taxa with a slightly more “mountainous” character as *Acer*, *Fagus*, *Picea* and *Abies*, which are completely or almost missing in the broad valley around Okolište can be localized on steep slopes of the side valleys,. At these higher elevations, *Quercus* still seems to be dominating, but other taxa gain more importance, probably due to the growing deviation of slopes exposed to the north and south. The existence of moist stands seems probable in vicinity of the river Bosna, as reflected in the charcoal assemblages of Okolište and Zagrebnice.

CONCLUSION

The presented investigation offers insight into the past vegetation of a defined region by means of charcoal analysis. Although a human filter distorts the actual percentages of the single taxa in the vegetation, distinctions between the wood assemblages used at the single sites are visible. These can best be explained by the topographical situation of the investigated sites. The charcoal record from the Visoko basin indicates the existence of different vegetation types. The archaeological differences between the sites suggest conscious use of the manifold landscape during the Late Neolithic in the Visoko basin, while the charcoal data witness the use of fuel wood according to the availability. High amounts of light demanding taxa in connection with their regular occurrence in the macrobotanical record might indicate a maintenance or protection of their stands. The archaeologically traced foci of the different settlements may have been connected with their varying exposition in the region. A more detailed analysis of soil types and slope orientation and angle might lead to a more elaborate reconstruction of the prehistoric vegetation.

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ALEXA DUFRAISSE

Firewood and woodland management in their social, economic and ecological dimensions. New perspectives

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***Summary**: In this paper, we assume that fire production is a technical act and that firewood management is a human eco-technology with its own limiting factors. The analytic approach of technologists is first adopted to propose an analytic grid in order to frame wood supply and woodland management in their social, economic and ecological dimensions. Then we focus the analysis on three principal variables: species, diameters and territory, based on methodological, ethnobotanical and archaeological perspectives.*

***Key words**: Anthracology, wood use, human ecology, Neolithic, Alps.*

INTRODUCTION

The aim of this paper is to explore wood supply and woodland management as representing technical acts within their social, economic and ecological dimensions as an approach to refine the interpretation of archaeological charcoal analysis. Two main questions are raised: 1) how particular cultural, technical or economical features can have crucial consequences both on the *chaine opératoire* which lead to the production of fire and on the charcoal assemblage? 2) how can the study of carbonized wood in archaeological contexts document this technical act and the processes of "reciprocal influences" between environmental and social systems in a given ecotechnological structure?

A *chaîne opératoire* from wood supply to fire production is first proposed to present an adapted analytic grid of the socio-economic aspects of firewood management. Our intention is not to propose a general model but rather a methodological framework for developing models that will deal with small-scale processes of vegetation-culture interactions as proposed by E. Asouti and P. Austin (2005). We base our reflection on methodological, ethnobotanical and archaeological perspectives and on three approaches: species, diameters and territory. Anthracological examples are drawn from prehistoric communities, especially Neolithic ones, from a period which foreshadows numerous aspects of modern social organisation, especially related to technical evolution and transformation of the environment. We turn especially to the very well-preserved Neolithic lakeshore settlements from the Alps.

FROM FIREWOOD GATHERING TO FIRE PRODUCTION

In this part, the analytic approach of technologists is adopted in order to deconstruct a "total fact" (Mauss, 1950) –here the production of fire– and to propose an adapted analytic grid which facilitates a systematic collection of data suitable for clarifying a particular aspect of the technical world of a group.

From firewood resources to the production of fire, the *chaine opératoire* is represented as a succession of tasks (Fig. 1):

1- Firewood selection (possible choices)

2- Extraction of firewood (collecting, breaking, felling, etc.);

3- Transport of firewood (distances, modes of transport);

4- Firewood sectioning/splitting;

5- Firewood drying (cut wood, standing wood, etc.);

6- Firewood storage (short or long term);

7- Ignition (elaboration of hearths is considered here as belonging to another *chaîne opératoire*);

8- Production of fire (production of flames, embers, etc. depending on the use).

Some of these tasks are "strategic" and "*cannot be altered, cancelled, or replaced without causing a significant perturbation*" (Lemonnier 1980: 9), such as extraction, transport and ignition. Furthermore, each stage represents a distinct operation, which at the same time combines with the others to form a well-organized succession. For instance, wood drying can occur before transport or after storage, it depends on

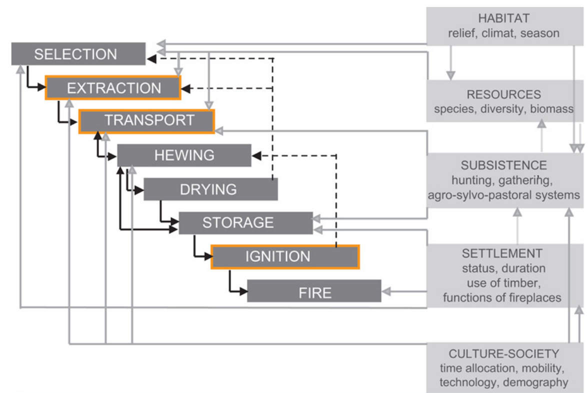

Figure 1. Proposition of an analytic grid for the socio-economic aspects of firewood management.

the availability of dry wood in the environment and on the method of wood extraction.

In order to understand the social, economic, or symbolic dimensions, each task can be contextualized with regard to other activities or contingencies specific to the environment.

The wood resources that are present (biomass, species diversity, forest productivity, presence of standing/dead woods, etc.) condition directly, but only partially, the use of the species and the diameters that are exploited. Availability and proximity of resources have an impact on the distances that must be travelled.

The modes of subsistence could condition the choices made in gathering (fruit trees can be avoided as fuel sources) and the distances that will be travelled (cf. time allocation). Because they have an impact on the environment, modes of subsistence themselves can determine the wood resources that are available (grazing pressure may constitute a significant factor).

The status and duration of a settlement can also influence wood storage and the types of wood extraction used. Wood discarded from architecture can be reused as fuel. Hearths themselves and their functions play a fundamental role in the collection of wood.

Lastly, culture can be framed by technology, population density and time allocation. Technology for instance includes tools to cut trees but also their other uses (axes can be both tools and prestige items).

Therefore, the production of fire for heating, defense, light, cooking and production of goods constitutes in itself a socio-economic activity dependant on the social context. In this sense, firewood supply is a technical act. While the various stages that lead to the production of fire are shaped in part by numerous environmental constraints, humans may still choose, more or less consciously, from among technologically and functionally viable alternatives (raw materials, source of energy, tools, actors, where and when things should take place) (Lemonnier 1993).

Even if notions of efficiency and performance function derive from cultural conventions, which render them unpredictable and infinitely variable (Lemonnier 1993: 1-35), the major issue for anthracology is to investigate the intrinsic and extrinsic characteristics of the complex ecological and cultural processes affecting species availability and firewood management, and for which the mechanisms of adaptation and feedback are still poorly understood. This raises important theoretical and methodological issues.

FIREWOOD SPECIES MANAGEMENT

ETHNOBOTANICAL PERSPECTIVES

Generally, we consider two opposite plant management strategies: selection and opportunism. Moreover, we assume in archaeological charcoal analysis that there exists a deterministic relationship between species collected for firewood and their occurrence in the environment according to the Principle of Least Effort (e.g. Shackleton and Prins 1992; Théry-Parisot *et al*. 2009). However, the situation is much more complex as several intermediate degrees of management for wild botanical resources are possible: gathered plant, plants under incipient management and cultivated plant (Gonzalez and Caballero 2007). Different forms of incipient management exist to increase the frequency and guarantee the availability of plant resources. These strategies include tolerance (preserving plant) and protection (eliminating competitors). There are additional practices that lead to an increase in population density such as pruning, shearing or trimming. In this sense, we can assume that firewood gathering could also be a form of incipient management when it includes actions such as selection of desirable species or adoption of rotational use of different gathering areas to allow for generation of favored species.

In the 1990's, an important movement in ethnobotany sought to develop new methods to permit the researcher to describe and quantitatively analyze management strategies. O. Phillips and A. Gentry (1993) proposed a relatively simple data-processing technique that can be applied to large ethnobotanical data sets, to generate a quantitative use-value index (UV). Later, many ethnobotanical studies tested the *apparency hypothesis*, using UV and diversity indices (e.g. Begossi 1996; Cunha and Albuquerque 2006; Lucena *et al*. 2007).

While the relationship between relative importance measured by use-value and plants' local availability has been confirmed in some parts of the world, other studies have not identified such close relationships between these variables, indicating that the relationship is not so simple or even always present (e.g. La Torre-Cuadros and Islebe 2003). For instance, Salick and colleagues (1999) demonstrate that: i) useful species are a function of species diversity, ii) when there are more useful firewood species, there are also more unused species, iii) the number of kinds of uses correlate with the total number of plant species.

Finally, both ethnological and ecological factors contribute to patterns of people's use of plants. Similar conclusions can be reached from archaeological contexts.

ARCHAEOLOGICAL APPLICATIONS

Lakeshore settlements where uncarbonized and carbonized plant assemblages are preserved are especially suitable for testing this approach.

Charcoal analysis of Clairvaux XIV dated to the end of the fourth millennium and attributed to the Middle Neolithic shows the exploitation of 20 taxa.

The floristic list and the percentages are coherent with the vegetal ecology, the past vegetation reconstructed from the pollen data and the modern vegetation of the current landscape of Combe d'Ain. Nevertheless, if we add the ligneous taxa used for twigs, timber, production of objects and fruits/seeds, we count a total of 40 woody taxa. Therefore, it is clear that all of the taxa present in the surroundings of the site were not used as firewood (Dufraisse *et al*. forthcoming).

At this point, it becomes interesting to apply the UV index (Fig. 2). For that, we adapted the equations of Philipps and Gentry (1993) to archaeological data as follows:

$$\text{UV of a species: } UV(s) = cF(s) * uF(s)$$
$$\text{UVs per kind of use: } UV(s)_{use1} = UV(s)_{use1} / \Sigma\, taxa_{use1}$$
$$\text{UVs per vegetal community: } UV(s)_{veg1} = UVs / \Sigma\, taxa_{veg1}$$

where UV = Use-Value index, use = kind of use, s = species, cF = frequency calculated from absolute counts, uF = frequency calculated from ubiquity, veg = vegetal community.

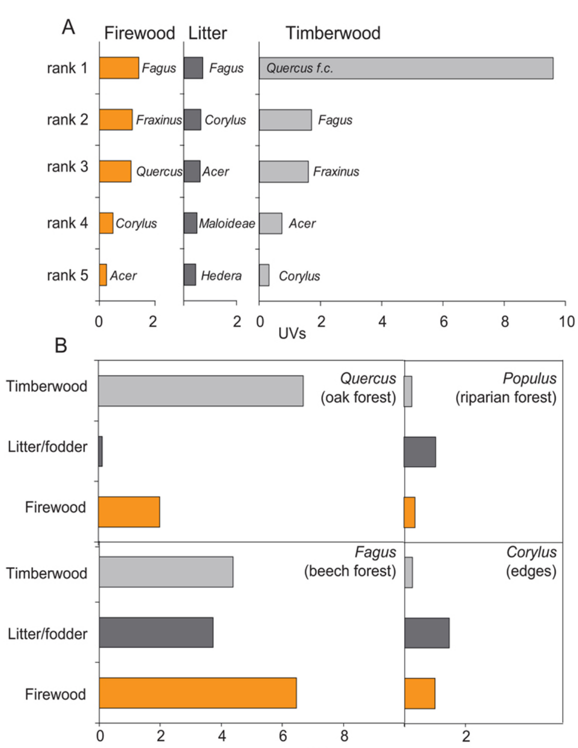

Figure 2. Results according to UV index calculated at Clairvaux XIV. A- UVs of the 5 first species according to the use B- UVs per vegetal community and according to the use.

It appears that: i) the highest UVs are associated with oak forest in the category of construction wood due to a strong selective preference. In contrast, the weakest UVs are connected to the category of litter and fodder which reflects a more diverse collection carried out in several different vegetal communities. For firewood, we note an intermediate strategy, with a relatively diverse collection in the mixed oak forest but a rather selective use of the beech forest, where only 2 taxa are represented. ii) Within a vegetal formation, it is not necessarily the same species that are exploited, and the main species do not have the same importance according to their use. Thus, some taxa were favored for use as firewood, such as beech, even when it was necessary to cross greater distances to obtain it. In contrast, other taxa seem to have been carefully preserved, such as the hazelnut, which appears to have occurred abundantly in the environment, according to pollen data as well as thousands of nuts found at the site of Clairvaux XIV.

Moreover, the use of diversity indices and ecological indicators allows us to demonstrate that wood management strategies can be connected to a qualitative change of the forest environment according to the conceptual model published by C.M. Shackleton and F. Prins (1992) (Dufraisse forthcoming). The study, based on 9 sites and 18 occupation levels, brings to light two strategies of wood management: first, a selective strategy connected with pioneer/post-pioneer phases of habitat, and a second more exhaustive strategy linked to phases of strong density of villages and of occupational continuity.

To sum up, the exploitation of firewood is not independent from other activities that require wood. Rather, it is incorporated into the overall exploitation of woody resources. The selection of taxa for firewood should not necessarily be perceived in terms of wood fire properties or the ease of collection, but rather in a broader socio-ecological context. Consequently, firewood and more globally plant management appears clearly as a significant filter conditioning the charcoal assemblage.

WOOD DIAMETERS

THEORETICAL AND METHODOLOGICAL PERSPECTIVES

While the attributes of woody taxa as raw material used for timber, litter, fodder (mechanical properties, size, diameter, nutritive value, waterproof qualities and so on) should be crucial criteria for understanding wood gathering, the selection of firewood could be carried out without taking into account species properties but instead by integrating diameter and rate of humidity (Chabal 1994). Therefore wood diameter may be a variable for characterizing the technical system of wood acquisition. Technological choices concern modes of wood procurement, tools, criteria of selection, actors, in order to effectively manage a fire with regard to the particular uses of the fireplace.

Thereby, combined with species lists, diameters appear to be a criterion which should be taken into account more systematically in charcoal analysis. Thus, in the program DENDRAC (financed by the French National Research Agency, for more information, see http://dendrac.mnhn.fr), we have been developing the study of wood diameter at two levels: dendrometric tools and data processing (for a state of the art, see Dufraisse and García 2011). The testing of measurement tools on different taxa show that the trigonometric tool is always much more reliable than the circle tool and can be applied to fragments larger than 2 mm. Nevertheless, it overestimates diameters less than 10 cm while it underestimates more significantly, diameters greater than 10 cm. Henceforth the establishment of correction factors linked to species and shrinkage is in progress (García and Dufraisse this volume).

ARCHAEOLOGICAL PERSPECTIVES

Archaeological application contributes to a better understanding of firewood management and thereby brings new hypothesis to the interpretation of charcoal assemblages and firewood management.

The study of wood diameters carried out at lacustrine Neolithic sites surrounding the circum Alpine area and focused on the main taxa (ash, beech, oak), show that the diameters exploited are most often less than 10 cm (e.g. Dufraisse and Leuzinger 2009; Dufraisse 2011). These studies lead to several remarks:

1) Dead wood in the beech forests rarely occurs in small diameters. Estimation of available diameters for fallen and standing dead wood through modern research in northwest Europe indicates that whatever the age of the forests, diameters greater than 25 cm occur systematically and they represent a significant volume of wood per hectare (Christensen *et al*. 2005).

2) The exploitation of small wood could reflect a very specific technological demand, related to accommodating a hearth inside a wooden construction in order to control the height of the flame, temperature and projection of sparks. When the communities were forced to exploit new areas and select larger diameters for firewood, we note a simultaneous increase in the frequency of splitting mauls in the archaeological strata (Dufraisse 2008).

3) Stone axes do not constitute a technical limit. Nevertheless, experimental works indicate that, compared to a steel axe, a stone axe took much more time and energy in order to accomplish the same task (Mathieu and Meyer 1997). Ethnographic work shows that axes and adzes are used only when it is absolutely necessary (Pétrequin and Pétrequin 1993). Thus, wood that is less than 10 cm in diameter could easily come from the snapping of young trees - by hand or foot -, waste from stumps, or from branches.

4) This exploitation strategy could also have a social significance. According to ethnoarchaeological studies in Papua, axes and adzes are mainly intended for men (Pétrequin and Pétrequin, 1993). This raises the possibility that firewood gathering (and perhaps fireplace management) is the responsibility of women and children, as it is often mentioned in current studies.

Therefore, studies of firewood supply strategies enlighten the processes of "reciprocal influences" between choices made by man, technical and environmental constraints.

FIREWOOD GATHERING AND THE SOCIO-ECONOMIC ORGANIZATION: A TERRITORIAL APPROACH

THEORETICAL AND ETHNOBOTANICAL PERSPECTIVES

This part focuses on a territorial approach toward firewood economy and its integration to the socio-economic context. C. Vita-Finzi and E. Higgs (1972) defined the "exploitation territory" of a site as "*the territory surrounding the site which is exploited habitually*". The same authors defined site catchment analysis as "*the study of the relationships between technology and those natural resources lying within economic range of individual sites*". T. Carlstein (1981), studying human ecology and ideas of carrying capacity, explained the need for models and methodological stamina in order to help to articulate many of the mechanisms and socio-environmental processes involved. For this, he proposed the notion of carrying capacity of terrestrial space-time and defined it as the limited ability of a given area to accommodate space-demanding people, organisms, artefacts, materials and the activities associated with them. Since space can be more or less continuously occupied over time, we must deal with *terrestrial space-time* which may also be called *settlement space-time* for an area settled by people. In consequence, time, like space, can serve as a descriptive framework for human activity and interaction. Thus T. Carlstein proposed the notion of daily itineraries which can be described as a graphic system (Fig. 3). This time space area contains the social system and is the setting of everyday life. Depending on the observation period, individual-paths can be referred to as day-paths, year-path or life-path.

We think that firewood collection and management can be thought of in terms of daily-itineraries. Like water, firewood is a resource so basic and vital that the distance to obtain it must be minimized. In this sense, current studies of firewood gathering allow us to conclude that: i) wood collection has the potential to conflict with the demands made by child-care on women's time and energy (Biran *et al*. 2004), ii) firewood collection articulates around 3 criteria: where to collect, how often to collect, how much time to spend on collection (Brouwer *et al*. 1997). Therefore, for instance, when communities are faced with decreasing fuelwood availability, several responses are possible. These may include collection at longer distances away, spending more time on collection, enlisting younger or older members, and adjusting the weight of the bundle collected. Adaptations may also occur in the type of fuel used, by switching to fuel of inferior quality to reduce the collection time.

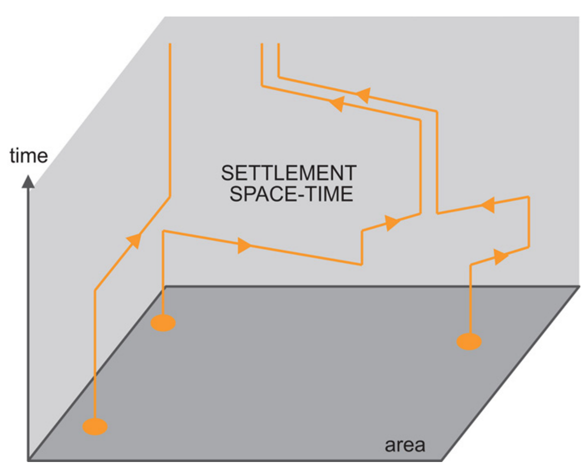

Figure 3. Three individual-paths in time-space (according to Carlstein 1981).

ARCHAEOLOGICAL PERSPECTIVES

In archaeological contexts, only a few of these responses can be observed with charcoal analysis, such as increase in distance travelled, switching to twigs or fruit trees or using the by-product of timber shaping. Distances can be distinguished in the archaeological context when sufficiently contrasting topographic conditions are present.

According to the concept of daily itineraries, our "working hypothesis" is that firewood gathering can be partially linked to agro-sylvo-pastoral activities. Different arguments are presented for this hypothesis.

At Lake Chalain and Clairvaux (Jura, France), studies of wood acquisition areas show that the locations of the gathering areas depend on the position of the village on the lakeshore (Dufraisse 2005). In addition, a close spatial convergence between firewood gathering areas and potential cultivated land could be shown (Dufraisse 2006). At Lake Chalain, the extension of the firewood gathering areas could be correlated with both the progressive increase of the number of houses in the village (which is a good picture of the population density) and the number of contemporary villages on the lakeshore. At the same time, dendrochronology (Lavier 1996) and pollen data (Gauthier 2004) do not indicate a decrease of woodland resources. Therefore, the enlargement of the gathering areas may correspond to a new organisation itself linked to the cultivated areas (Dufraisse 2008).

Firewood management within villages at the level of different domestic units brings also interesting points. Inside a single village, at Arbon/Bleiche 3 for instance, where acquisition areas are very near to the village, we can observe statistically significant variations in the percentages of taxa among contemporaneous houses (Dufraisse and Leuzinger 2009). This would suggest that: i) each domestic unit looks after its own needs for firewood, ii) as the vegetation associations are not represented in the same proportions, houses could gather their firewood at short distances while others had to travel to more distant zones. In the same way, macro-remains analysis indicates that: i) each house is an independent economic unit, ii) each house is characterized by a different assemblage of weeds which suggests that the houses exploited different territories based on their location and exposition (Jacomet *et al*. 2004). Analysis of charcoal and seed remains at Torwiesen II, a Neolithic site in Federsee (Germany) lead to similar conclusions (Schlichtherle *et al*. 2010)The distance travelled must be minimized, but nevertheless, it is the reflection of a socioeconomic organization which depends on time allocation. There exists then, a threshold beyond which the collection of firewood can no longer be integrated into the daily activities of a community and other responses must be adopted. Thus, they are relevant parameters both to characterize firewood management and to interpret the charcoal assemblage.

CONCLUSIONS

Because we need the development of a more coherent theory of the complex ecological and cultural processes affecting species availability and firewood management, the new challenge for charcoal analysis consists nowadays in modelling the wood acquisition strategies based on human behavioural ecology (e.g. Shakleton and Prins 1992; Asouti and Austin 2005; Marston 2009).

Ethnobotanical and dendrometrical methods offer considerable promise tools for improving our understanding of the different forms of selection and use of wood. Supported by concepts, these methods provide a deeper understanding of the use of different wood fuels and their availability in the local environment. Ethnoarchaeology applied to the management of plant resources also begins to enrich our frames of reference (Picornell 2011) and should permit us to understand and interpret the functions and mechanisms that underlie *the chaine opératoire* of fire production.

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From agricultural to pastoral use: changes in the neolithic landscape at Cova de l'Or (Alicante, Spain)

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Summary: *Cova de l'Or is an important site for the Neolithic of the western Mediterranean. A complete cultural and environmental sequence for the Early and Middle Neolithic allows studying the management of forest resources since the arrival of the first farmers and until the intensification of herding activities that took place a few centuries later. Our research focuses on the analysis of wood charcoals recovered from the dung levels in trench K-34, which we integrate with the available relevant data from trench J-4.*

Key words: *Neolithic, charcoal, Alicante, landscape, fodder.*

INTRODUCTION

The beginning of the Neolithic in eastern Iberia is dated to *c*. 6550 BP (approximately 5520 cal BC). "Impresso" cardial ware constitutes the sign of identity of the first farmers in this area. Small groups of fully-fledged farmers expanded across the coasts of the Mediterranean sea and the islands until they reached the eastern coast of the Iberian Peninsula. The material culture of these first neolithic groups in the area indicates that the contacts between them were close enough to ensure their survival. In the region of Alicante where Cova de l'Or de Beniarrés is located there is no evidence for "societies in transition" since no significant Mesolithic presence is documented immediately before the appearance of the first farming communities. In the case that mesolitihic groups existed in this area these would have been rapidly acculturated. The hypothesis that in the Mediterranenan area a desequilibrium between population and resources was the cause for the expansion of neolithic groups has been rejected. It has been suggested that in the easternmost place of origin of the Neolithic, farming groups fissioned in smaller communities as a result of social tension generated in large settlements (Bernabeu 1996, 2002; Martí and Juan-Cabanilles 1997; Bernabeu *et al.*

2001; Zilhão 2001; Juan-Cabanilles and Martí 2002).

In the area of Alicante, the first farming communities consisted of a small number of families and lived in two types of sites; small open-air settlements with a few huts as Mas d'Is and Benàmer or natural caves as Cova de l'Or, Cova de les Cedres, Cova d'En Pardo, Abric de la Falguera and Cova de la Sarsa. During the earliest part of the Neolithic these caves were either used as proper settlements or as auxiliary and satellite sites of other settlements. Cova de l'Or was an excellent place for habitation and there is abundant evidence that farming and herding, including the exploitation of dairy products, was taking place there (Martí *et al*. 2009). Hunting, fishing and gathering were complementary activities in both the caves and the open-air settlements. Therefore, the first neolithic groups would have needed and exploited the versatile productive territory that could have supported an autosuffcient farming economy (Martí *et al.* 1980, 1983; Badal 1999; García and Aura 2006; Bernabeu and Molina 2009; García *et al*. 2011; Torregrosa *et al*. 2011).

In this paper, through the analysis of wood charcoals we present the dynamics of the plant environment around Cova de l'Or and their association with the subsistence activities and other environmental data from the site.

Relevant results from other sites in the area provide evidence that 500 years after the first neolithic occupation, which corresponds to the Cardial and Epicardial Neolithic (Neolithic IA and IB), herding activities in caves intensified and culminated during Neolithic II in the 5th millennium BC. At the same time the number of open-air settlements in valleys increased and a tendency towards the specilization of the territory began; herding would have been the main activity in caves while production in open-air settlements would have been more diversified. Caves would have been either independent pastoral territories that exchanged products with open-air settlements or most probably animal pens associated with the villages.

Pastoral caves are well-known in the central and western Mediterranean: Arene Candide, Grotta de la Madona, Baume de Ronze, Cova de les Cendres, Abric de la Falguera, Los Husos, etc. (Beeching and Moulin 1983; Maggi 1997; García and Aura 2006; Bernabeu and Molina 2009; Scarciglia *et al*. 2009; Polo and Fernández 2010). The Neolithic I and especially the Neolithic II levels of Cova de l'Or may add the site to the list.

THE SITE AND THE ARCHEOLOGICAL SEQUENCE

Cova de l'Or is located on the eastern foothills of the Benicadell mountain range (38°50'40.71"N – 0°21'50.32" W) at 650 m a.s.l. (Fig. 1). A dissymmetry in temperature and precipitation is characteristic of the slopes of this mountain range, the southern being warmer and drier. The prevalent bioclimatic conditions in the area are mesomediterranean with mean annual temperatures between 13 and 17ºC and 500 mm average rainfall. The flora on the northern slopes is more humid (*Quercus faginea, Q. rotundifolia, Fraxinus ornus, Viburnum tinus,* etc.) while drought-resistant plants grow on the southern slopes (*Olea europaea* var. *sylvestris*, *Q. coccifera, Pinus halepensis, Rosmarinus officinalis, Erica multiflora,* etc.). The cave is oriented to the south and offers good conditions for habitation.

We present here the wood charcoal results from

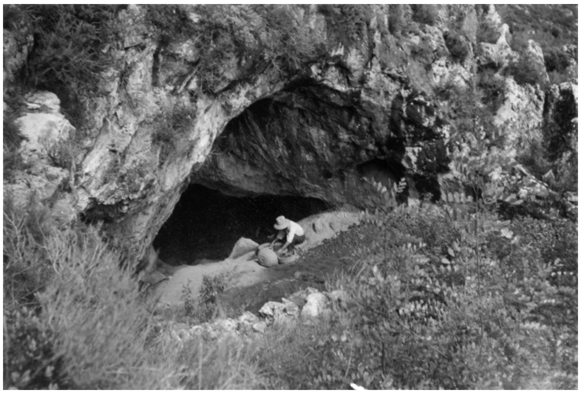

Figure 1. Cova de l'Or of Beniarrés (Alacant). Field work in 1955. SIP Archive.

sector J (Martí *et al.* 1980) and sector K (Martí *et al*. 1983; Bernabeu 1989). Both trenches were located close to the cave entrance, one at each side of its longitudinal axis.

Table 1 includes the radiocarbon dates from sectors J and K. All dates are coherent to each other and with respect to the cultural sequence of the site. Short-lived samples were selected for dating with the AMS technique; *Triticum aestivum-compactum* seeds, *Ovis aries* bones and a *Pinus halepensis* wood charcoal from the fully pastoral levels of the cave. The conventional radiocarbon dates from cereal samples from sector H are also included in Table 1.

The arqueological sequence of Cova de l'Or starts with the Neolithic of the "Impresso" cardial ware, which is associated with the farming groups that around 6550 BP expanded from the eastern Mediterranean. Two phases are distinguished: the first one, Early Cardial Neolithic (Neolithic IA), which shows high percentages of these decorations and the second one, Early Cardial/Epicardial Neolithic (Neolithic IB), which is characterized by the increase of incised, grooved or impressed with tool decorations.

The deepest layers of sector J (levels VI and V) and K (level D2) correspond to Neolithic IA. The material culture from these levels is variable and fully-fledged farming economy is attested. The date 6475 ± 75 BP was obtained from an *Ovis aries* bone from these levels in sector K.

Neolithic IB layers correspond to levels IV in sector J and D1 and the bottom of H4 in sector K. The dates indicate the development of cardial/epicardial contexts during the second half of the 6th millennium BC (Table 1). The archaeological data provide evidence for a slight increase of herding activities.

The following phase, Neolithic IC or Middle Neolithic, corresponds to epicardial *sensu lato* and post-cardial contexts. From 5000-4900 BC undecorated ware predominates although there are some examples with combed surface, cords, incised, grooved or impressed with tool decoration. During this period there was a change in the use of the cave. The interpretation of levels H4, C2 and H3 in sectror K and II in sector J leads to the conclusion that the cave was no longer a habitation area but a space used by herders. The date 6290 ± 40 BP was obtained from a wheat seed from the lower part of level H4, which was initially interpreted as a hearth of the habitation layer. However, it is now accepted that it corresponds to the combustion of the sediments (dung layers) of an animal pen. Therefore, level H4 marks the beginning of the change in cave use during the last centuries of the 6th millennium BC. This change would have fully concluded in the early centuries of the 5th millennium BC.

Herding activity would have persisted from 4300 BC and during the Late Neolithic, Neolithic IIA, that is characterised by incised/carved ceramic ("*esgrafiada*"). The date 5120 ± 40 BP obtained from a *Pinus halepensis* wood charcoal from level H3 in sector K34 corresponds to this period. Wood charcoal material from this phase was collected from level II in sector J.

Material	Level	Layer	Year BP	Method	Cal. BC 1 σ	Cal. BC 2 σ	Ref. Laboratory	Reference
Cereal (aggregate)	Base	H3/C-7	6510 ± 160	Conventional	5616 - 5324	5768 - 5075	KN-51	Martí 1978
Ovis aries	D2	K35/24	6475 ± 25	*AMS*	5480 - 5383	5484 - 5374	UCI-AMS66316	Martí 2011
Triticum aestivum-durum	V	J4/17a	6310 ± 70	*AMS*	5366 - 5216	5469 - 5075	OxA-10192	Zilhão 2001
Cereal (aggregate)	Base	H3/C-7	6265 ± 75	Conventional	5321 - 5078	5463 - 5018	H-1754/1208	Martí 1978
Triticum aestivum-durum	D2	K34/C-22	6200 ± 40	*AMS*	5218 - 5068	5296 - 5045	Beta-298126	García *et al*., 2011
Triticum aestivum-durum	D2	K34/19	6340 ± 40	*AMS*	5370 - 5230	5465 - 5219	Beta-298125	García *et al*., 2011
Triticum aestivum-durum	IV	J4/14	6275 ± 70	*AMS*	5326 - 5079	5464 - 5046	OxA-10191	Zilhão 2001
Triticum aestivum-durum	H4	K34/14	6290 ± 40	*AMS*	5309 - 5225	5367 - 5085	Beta-298124	García *et al*., 2011
Pinus halepensis	H4	K34/10	5120 ± 40	*AMS*	3970 - 3940	3980 - 3900	Beta-303420	

Table 1. Radiocarbone dates from Cova de l'Or.

MATERIAL AND METHODS

New wood charcoal results from sector K are presented in this paper together with the results of previous analysis from trench J-4 (Badal *et al.* 1994). Moreover, pollen and sedimentological analyses were carried out in trench K-34 (Martí *et al*. 1983; Fumanal 1986; Dupré 1988). In this paper, we integrate the two sequences (sectors J and K) aiming to evaluate the management of the woodland from the middle of the 6th to the 5th millennium cal BC, when intensification of pastoral activities, reflected in dung levels in the cave stratigraphy, took place. New data of the faunal analyses from sector K confirm the use of the cave as animal pen during the Neolithic.

In sector J at Cova de l'Or the whole Neolithic sequence was studied. However, wood charcoal analysis was limited to the Neolithic IA and IB (Charcoal Phase Or 1 and Or 2) while only one layer of Neolithic IIA (Charcoal phase Or 3) was included (Badal *et al*. 1994). A total of 3787 charcoal fragments were analysed from this sector, but there was a gap between Neolithic I and II (see Badal *et al*. 1994: 162). This gap can now be bridged with the new data from trench K-34.

The 2 m long sequence of trench K-34 includes 4 successive dung levels within the upper 120 cm. Wood charcoal was scattered throughout the excavated deposits. We have analyzed material from the layers between 260 and 320 cm in which burnt dung levels were separated by non-burnt deposits. 900 wood charcoal fragments recovered from spits 15 to 10 (approximately 10 cm thick each) were processed for wood charcoal analysis.

The results of wood charcoal analysis from sector J and trench K-34 are integrated in a diagram (Fig. 2) that covers the entire sequence of the cave from the beginning of Neolithic I (6475 ± 75 BP) until well into Neolithic II (after 5120 ± 40 BP). Levels D1 in trench K-34 and part of level IV in J-4 are considered contemporary as it is shown in the diagram.

For the taxonomic identification of the specimens we used a Nikon Optiphot-100 dark/bright field incident light microscope with 50-500x magnifications, specialized plant anatomy bibliography and the reference collection of modern charred woods of the Laboratory of the Dept. of Prehistory and Archaeology, University of Valencia, Spain.

RESULTS

The list of identified plants and their proportion in succesive levels allowed us to distinguish 3 phases in the wood charcoal sequence (Fig. 2).

Phase Or 1. It corresponds to the base of the sequence, namely levels VI, V and the beginning of IV in sector J-4. According to the radiocarbon dates from sector K34, layer 24 (6475 ± 25 BP) and sector H (6510 ± 160 BP), this phase is contemporary with the first 400 – 500 years of farming activities in the territory. The most recent part of this phase was dated to 6275 ± 70 BP at the bottom of level IV in sector J-4 and to 6290 ± 40 in K34, layer 14.

The results of wood charcoal analysis show high percentages of *Quercus,* both evergreen (approximately 50% of the charred wood remains) and deciduous (10-15%), followed by ash (10-15%) and a small proportion of riverine vegetation. Thermophilous flora is represented by *Olea europaea* (10-15%) while *Arbutus unedo*, *Erica multiflora*, Fabaceae, *Juniperus*, etc. appear in low percentages. The low proportion of *Pinus halepensis* in these archaeological levels is notable.

This phase of the wood charcoal sequence reflects the existence of well-developed Mediterranean woodland in the area indicating that the biogeographical conditions at the time were similar to the present. Mesomediterranean conditions would have prevailed with mean annual temperatures between 13 and 17ºC and precipitation of the sub-humid type (mean annual 500-800 mm). To judge from the remains of *Olea*, termomediterranenan influence would have reached the southern slopes of the Benicadell Range. The re-

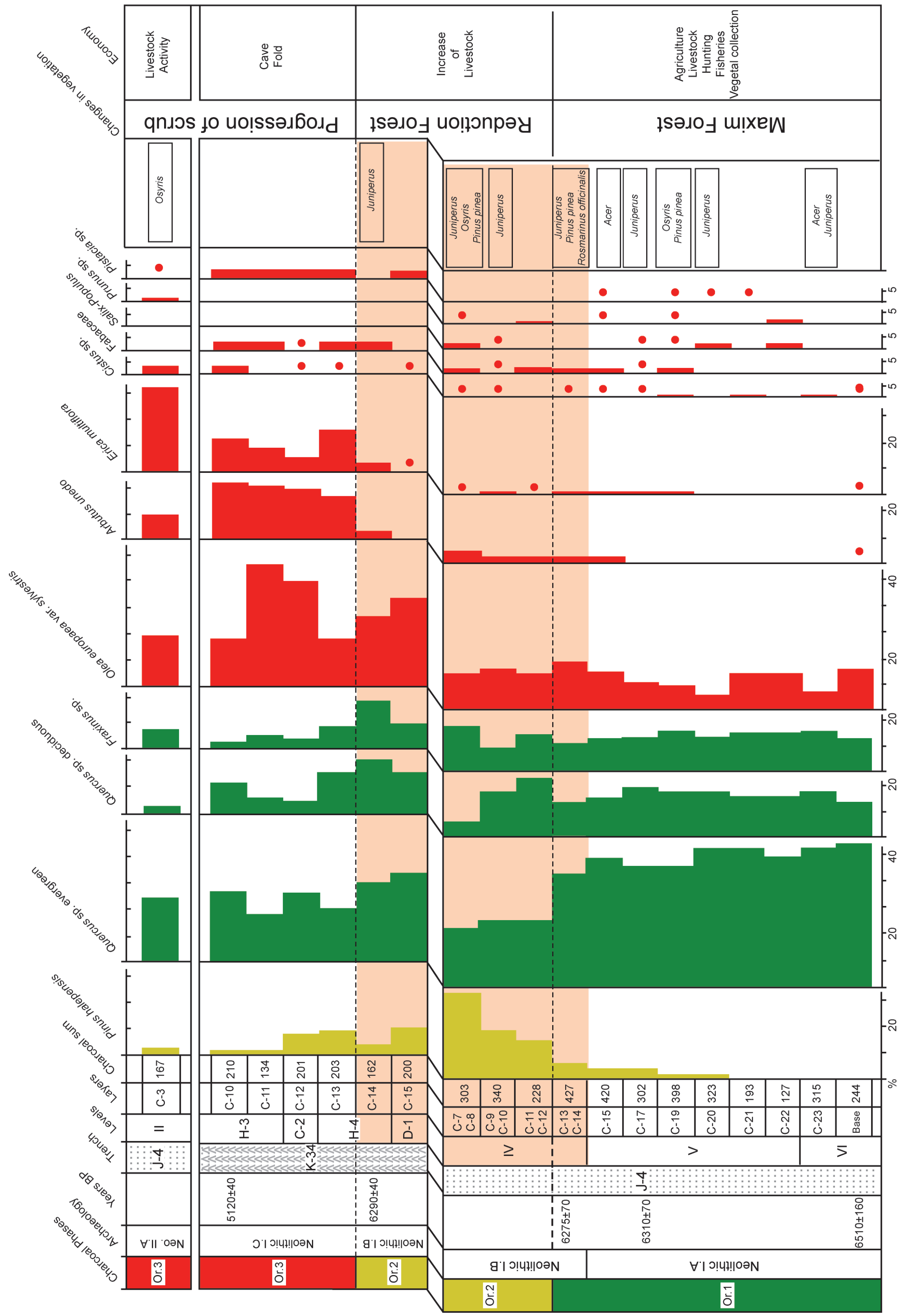

Figure 2. Charcoal diagram from Cova de l'Or in the trench J4 and K-34. The shaded area is synchronous based on material culture and radiocarbon datings

sults suggest the management and use of oaks. The archaeological data provide evidence for a fully-fledged farming economy based on cereal cultivation and animal raising (sheep, goat, pig and cow) supplemented by hunting and gathering. On the basis of the dominant presence of oak woodland it may be suggested that a balanced management of the territory existed. However, palynological data from the cave that show a predominace of herbaceous plants already from the beginning of the Neolithic occupation may clarify this suggestion (Martí *et al*. 1980; Pérez 1980; Dupré 1988; Badal *et al*. 1994).

Phase Or 2. It consists of level IV in sector J-4, the basal part of which was dated to 6275 ± 70 BP and the upper part of level D1 and the lower part of level H-4 in sector K-34. Layer 14 of the latter provided the date 6290 ± 40 BP.

The relevant spectra in the wood charcoal diagram show a clear change indicated by the decrease of *Quercus* remains and the progressive increase of *Pinus halepensis* in sector J-4 and *Olea* in K-34 (Fig. 2). Nevertheless, the remaining taxa maintane similar percentages as in the previous phase. Therefore, continuity of the ecological conditiones may be suggested while herding activities that may be associated with the increase of *Pinus halepensis* and *Olea* increased during the cardial/epicardial phase.

In such a subsistence context human activities caused changes to the natural environment and this would have been the genesis of the rural landscapes. Woodland would have been cleared to create pastures and fields while at the same time communication routes would have been created through tracks and paths (Fig. 3). After several centuries of neolithic presence at Cova de l'Or wood charcoal analysis shows changes in the vegetation and strong competence of Aleppo pine secondary formations *versus* oak woodland. Consolidation of *Olea* could have resulted from the management of the tree for fodder, since it is high quality food for the animals (Badal 1999).

The archaeological finds and the radiocarbon dates place the beginning of these fire levels to the epicardial pottery phase, during the last centuries of the 6th millennium BC, and they provide evidence for a mixed farming economy (agriculture and herding) although there was a tendency towards increased herding.

Figure 3. Reconstruction of landscape at Cova de l'Or in early Neolithic, acording to palaeoecological data

Phase Or 3. It corresponds to dung levels (H4, C2 and H3) of sector K-34. *Arbutus unedo*, *Olea* and other *matorral* plants increase significantly while those taxa that require more humid conditions (riverine plants and *Quercus*) decrease. *Pinus halepensis* remains stable. The change observed in the assemblages of Phase Or 3 is associated with the two lowermost dung levels in trench K-34, H4 and H3. The radiocarbon date obtained from a *Pinus halepensis* wood charcoal fragment from K34, layer 10, is 5120 ± 40 BP, thus placing the observed change to the 5th and early 4th millennium cal BC. Changes in the vegetation would have been the result of a change in the management of the woodland, now oriented towards stockbreeding.

In sector J there is evidence of phase Or 3 only in one layer of level II in which incresed percentage of *Erica multiflora* was documented. This is probably an indirect reflection of the intesified herding activities documented in the thick dung layers of sector K-34.

DISCUSSION

In the eastern part of Iberia, in particular the area of Alicante, during the course of the Neolithic and from de last centuries of the 6th millennium BC onwards, a tendency towards specialization of the productive activities is observed. Certain areas became pastoral, especially the foothills of mountain ranges where most caves are located, while open-air settlements established in lowland valleys were multi-purpose or clearly agricultural habitats. Such evidence is available from the valleys of the Rivers Serpis and Albaida that delimit to the south and north the mountain range where Cova de l'Or is located. Benamer to the south and Camí de Missena in the north provide new evidence of characteristic open-air settlements (Pascual *et al.* 2005; Torregrosa *et al*. 2011).

During the earliest occupation of Cova de l'Or and the other caves in the region by farming groups, the Mediterranenan woodland was dominated by *Quercus* while the presence of secondary plant formations was insignificant (Badal *et al*. 1994; Badal 2009). In the first 400-500 years of neolithic presence in the region the management of the territory would have been balanced probably due to low demographic density, versatility of the environment and equilibrium of productive activities (cultivation-herding; hunting-gathering). It is worth-mentioning that among the other domestic animals sheep and goat were *ab initi*o the most important for the production of meat and milk. In line with this evidence, the study of the handle-spout pottery type present already in cardial contexts prooves the importace of the consumption of milk and dairy products (Martí *et al.* 2009).

The activities carried out in the cave changed pogressively. Starting from phase Or 2 and culminating in phase Or 3 the multi-purpose site became a mainly pastoral one. The study in progress of the faunal remains from sector K documents the changes in the use of the cave along the sequence. Macroscopic study of the faunal remains leads to the hypothesis that the different types of alterations observed on the bones could have been caused by the chemical action of the animal excrements (dung and urine) and the temperatures produced during their fermentation that could have reached the point of combustion. As a result, the cortical part of the bone appears very altered, covered totally or partially by black concretions. This is especially documented in the layers that correspond to phases Or 2 and Or 3. The use of the cave as animal pen is also attested by the presence of isolated ovicaprine deciduous teeth, without roots and very deteriorated, almost exclusively in layers of phase Or

3. These would have been deposited during stabling of the animals in the cave at the time of substitution of the deciduous by permanent teeth. However, stabling would not have been intensive but rather temporal and of small duration. In earlier levels the presence of altered bones in dung layers is very sporadic and only one deciduous teeth was found (layer 20, sector K34) indicating either lesser use of the cave for animal keeping or smaller number of animals limited to the needs of one or few family units living in the cave during Neolithic IA and IB.

Herding activities could have caused the first serious change to the pristine Mediterranean woodland (Badal 2002, 2009). The increase of Aleppo pine observed already in phase Or 2 could have been related to controled burning of parts of the woodland in order to create pastureland. The low mattoral present in phase Or 3 would have been the consequence of such management of the woodland. The dialogue between the natural landscape (cardial contexts) and the anthropogenic landscape (postcardial and epicardial contexts) started at that time when farming intensification caused woodland change documented as well in palynological analysis and in loss of soils evidenced in sedimentological studies (Martí and Juan-Cabanilles 1987; Badal 2002).

The important presence of trees managed for fodder, as it is the case of the oleaster, provides evidence for the pastoral practices in the caves of the Alicante region. High frequency of *Olea* and *Fraxinus* wood charcoal is reported from other caves in the area where dung levels were identified (Badal 1999) and it has been interpreted as the result of the provisioning of leaf and branch fodder. In the sclerophyllous forest *Olea* is the most appropriate species for feeding livestock. In more humid regions relevant evidence from various sites documents the use of ash and other deciduous species for animal fodder (Carrión 2002, 2005; Thiébault 2005; Carrión *et al*. 2006; Delhon *et al*. 2008).

Another important piece of information from the anlaysis of faunal remains is the identification of species of chiroptera, the presence of which is incompatible with human presence at the same place. The majority of such remains is concentrated in layer C2 in sector K. This indicates that during phase Or 3 there were periods when human groups mostly lived in nearby open-air settlements and the cave was not frequently used. Nevertheless, the wood charcoal record does not indicate that reforestation took place. On the contrary regression is observed leading from the prisitne woodland of the beginning of the Neolithic to the xerophytic *matorrales* of the final Neolithic.

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CHANGES IN VEGETATION AND FUEL USE FROM THE NEOLITHIC TO THE MIDDLE AGES IN THE WESTERN CATALAN PLAIN

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***Summary**: This paper presents a synthesis of charcoal analysis data from the West Catalan plain, from the Neolithic to Medieval times. We discuss the changes and trends in the consumption of firewood. Collecting firewood was carried out in an environment characterized by open vegetation, which appears to have been dominating in the area since the Bronze Age. In this environment* Pinus halepensis *has played a fundamental role. On the other hand one can observe a progressive extension of the firewood catchment areas in more recent periods, especially in Roman and medieval times.*

***Key words**: western Catalan plain, forest exploitation, historical vegetation, anthracological synthesis, human activity.*

INTRODUCTION

The western Catalan plain is located in the northeastern Iberian Peninsula. Geologically, it is part of the great morpho-structural unit of the Ebro Basin. Physiographically, this plain corresponds to the sicor territory and it is crisscrossed by Rivers Cinca and Segre and their tributaries. This plain has been a densely populated territory since prehistoric times. The exploitation of forest resources in recent millennia has caused important modifications of the vegetation and the landscape. To characterize this exploitation since the beginning of agricultural production is of great importance in order to infer the relationship of the people who inhabited the plain with their environment.

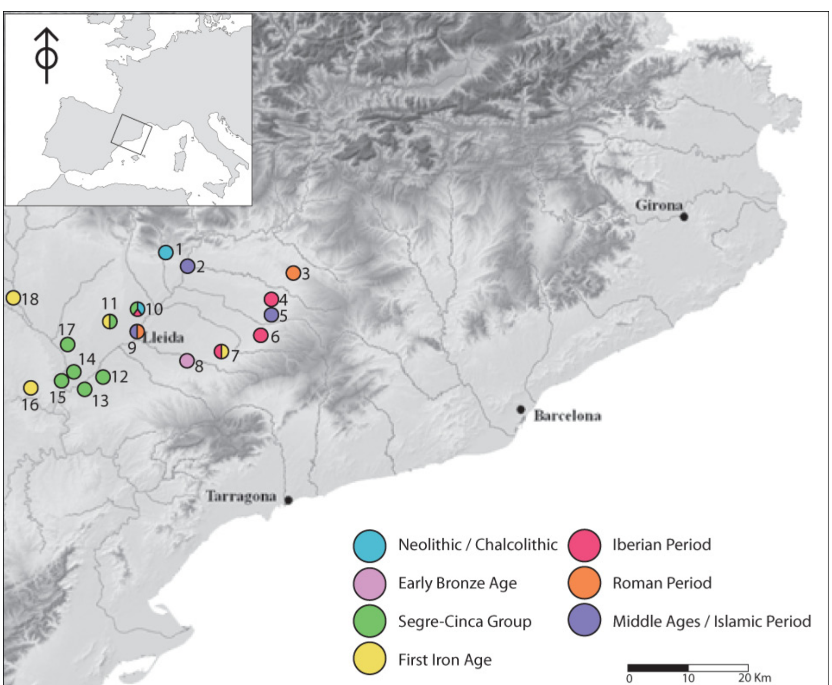
The forest history is the result of environmental variables but also of the interaction between people and their environment. The main objective in this study is to assess the evolution of the forests of the western plain in relation to human societies.

Although there are diverse disciplines that provide important information on this issue, in this case we focus on the study of carbonized wood remains, as they represent the resources of the different environments which were exploited by past societies. Charcoal studies from the area, which have a long tradition, started in 1988. To date, materials from 18 archaeological sites (Fig. 1) of various periods and regions have been analyzed by several specialists, starting with Maria Teresa Ros (1993, 1994-1996, 1995a, 1995b, 1995c), followed by Raquel Piqué and collaborators (Piqué 1998a and b, 2003, 2006, 2008, unpublished a and b; Piqué and Noguera 2000; Piqué and Mensua 2001; Alonso *et al*. 2002; Buxó *et al*. 2004; Martín-Seijo and Piqué 2008; Martín-Seijo and Piqué 2009; Piqué and Vila 2010) and Ethel Allué and Itxaso Euba (2005). However, such studies did not follow a predetermined order within the framework of a specific project.

The reason for the present study is the lack of a synthesis that encompasses all these wood charcoal analyses results and offers the evolution of the landscape in the plain from the Neolithic until the Middle Ages.

DATA AND RESULTS

Published and unpublished data from all these previous studies were collected (Vila 2010). This is a considerable volume of remains, with a total of 14,774 charcoal fragments. Of these, 12,858 fragments from 502 samples have been determined taxonomically (Tables 1 to 6). However, several problems exist in order to make a regional synthesis from anthracological data and interpret the results in a palaeoenvironmental sense. On the one hand, we should keep in mind that the social activity that generated the charcoals and the postdepositional processes are specific to each site. These factors may be partly responsible for the variability, especially in quantitative terms (Piqué 1998c: 7). On the other hand, the differences in the size of the analyzed samples for each site and the methods of recovery of the remains may have also influenced



1. Auvelles (Castelló de Farfanya, La Noguera); 2. Pla d'Almatà (Balaguer, La Noguera); 3. Iesso (Guissona, La Segarra); 4. Missatges (Tàrrega, l'Urgell); 5. Molí del Codina (Tàrrega, l'Urgell); 6. Estinclells (Verdú, l'Urgell); 7. Els Vilars (Arbeca, les Garrigues); 8. Minferri (Juneda, les Garrigues); 9. Ilerda i Medina Larida (Lleida, el Segrià); 10. Roques del Sarró (Torres de Segre, el Segrià); 11. El Vilot de Montagut (Alcarràs, el Segrià); 12. Tossal de Solibernat (Torres de Segre, el Segrià); 13. Genó (Seròs, el Segrià); 14. Cova de Punta Farisa (Alcolea de Cinca, Osca); 15. Masada de Ratón (Candasnos, Osca); 16. Tozal de los Regallos (Candasnos, Huesca); 17. Vincamet (Fraga, Osca); 18. La Codera (Alcolea de Cinca, Osca).

Figure 1. Map of the North East of the Iberian Peninsula. Location of the 18 archaeological sites under study (Drawn up by Jordi Martínez).

the results. Nevertheless, one should keep in mind that the strength of this work lies in the large number of fragments and samples that can correct at least some of these limitations and provide a good overview of the whole.

In order to homogenize the sample a common database was elaborated. In this the nomenclature of various taxa was unified. One reason was to simplify the comparative work. However, we also took into account that is not possible to arrive at certain levels of identification in the case of some species due to the anatomical similarities among them.

The data processing focused, on the one hand, in the analysis of diversity (number of consumed taxa), the analysis of ubiquity (recurrence of use from the number of stratigraphic units in which the use of a taxon is documented) and the analysis of intensity of uses (from the number of remains, or frequencies per taxa). On the other hand, continuity and change in the most representative taxa were evaluated. We considered as representative taxa those that provided more than four hundred pieces of charcoal. The objective was to determine the woods with economic value for each period and evaluate the causes of the differences observed through time.

With the obtained results, we can see that the forested landscape of the western Catalan plain from the Neolithic to the Middle Ages presents a shifting panorama, always directly related to its social management.

With the adoption of agriculture from the Neolithic/Chalcolithic periods, increasingly effective tools (stone axes, adzes, etc.) that allowed more sophisticated logging activities were made. Due to the lack of data from previous periods we cannot affirm that those activities affected the vegetation cover. Still, we can document the most important taxa in the economic sphere. The best represented taxa and the ones that show a higher ubiquity are deciduous *Quercus* (oak) and evergreen *Quercus* (holm oak). This period is represented by two sites, Auvelles (Castelló de Farfanya, la Noguera) and Roques del Sarró (Torres de Segre, Segrià). The differences between the results are considerable. In Auvelles the predominant taxa are deciduous *Quercus* (oak) and evergreen *Quercus* (holm-oak). In contrast, at the Roques del Sarró, deciduous *Quercus* is not represented, whereas *Pistacia lentiscus* (mastic) has certain relevance. With regard to the taxonomic diversity observed among the deposits of this period the most remarkable is the low number of determined taxa, only 11 taxa for the entire period. Although evergreen *Quercus* is represented at both sites, the results show a different landscape during the Neolithic/Chalcolithic in the regions of Noguera (Auvelles) and Segrià (Roques del Sarró). In the northernmost region (La Noguera) fuel was collected in mixed forests of oaks. In contrast at Segrià, located further south, firewood was collected in more open formations, in which shrubland and bushland may have already had some importance.

In the following period (Early Bronze Age, 2700-1650 cal BC), with the emergence of large and scattered villages, the use of a different landscape is documented. This period is represented by a single site, Minferri (Juneda, Garrigues). Both evergreen and deciduous *Quercus* become secondary (Table 1) while *Pinus halepensis* (Aleppo pine) is the dominant taxon, followed by a shrub, *Arbutus unedo* (strawberry tree). This difference from the previous period could be due to the location of the site, much further south than the previous ones. However, we cannot exclude the possibility that a more open landscape had already begun to consolidate around the settlement.

The presence of shrubs is interpreted as a clear sign of the phenomenon of deforestation. However, the shrubs are important in the maquis, which nowadays occupies part of the Mediterranean coastal and interior lowlands. Continental maquis was probably extensive in the territory already during the time of the occupation of Minferri. The taxonomic diversity in the charcoal assemblages is greater than in the previous period. The consumption of a minimum of 23 taxa was determined. However we should remember that the number of fragments and contexts analyzed for this period is higher than for the Neolithic/Chalcolithic.

The vegetation represented in Minferri suggests high population pressure on the environment at the time of the occupation. Greater continuity of the settlement and its bigger size may have had an impact on the environment, forcing the collection of all types of wood, both of trees and shrubs or bushes.

The importance of taxa is similar comparing the number of represented taxa either by ubiquity or amount of remains (Table 1). The taxa follow the same order of importance: *Pinus halepensis*, *Arbutus unedo*, evergreen *Quercus* and *Pistacia lentiscus*.

The population of the Early Bronze Age constituted the elementary substrate on which, in the middle of the 2nd millennium BC, the emergence of new cultural, economic, and social attitudes that characterize the Segre-Cinca Group (GSC) (1650-1250 to 1000-800/750 cal BC) took place. In this period three phases can be distinguished: GSC I (1650-1250 cal BC), GSC II (1250-1000 cal BC) and GSC III (1000-800/750 cal BC) (Alonso *et al*. 1999). Among them there are differences in the exploitation of forest resources (Tables 2 and 3).

In the Segre-Cinca Group I, the species with a higher presence are *Pinus halepensis* and *Pistacia lentiscus*. Most fragments of *Pistacia lentiscus* come from Masada de Raton (Cadasnos, Huesca) and Cueva Punta Farisa (Alcolea de Cinca, Fraga) (Table 2). By contrast *Pinus halepensis* is especially important in Vilot 0 (Alfarràs, Segrià), Masada de Raton, and especially Genó (Seròs, Segrià). The ubiquity of the two species is high in all the archaeological sites. *Pistacia lentiscus* is represented in 64.15% of the samples, whereas *Pinus halepensis* appears in 86.79% of them. Depending on the number of remains the differences between these taxa are reduced (Table 2). Evergreen *Quercus* has a considerable reduction in both the number of fragments as in its ubiquity in relation to the previous period; it is represented only in Genó and, in smaller amounts, in the Roques del Sarró and Vilot 0. Population increase and stronger pressure

	NEOLITHIC/CHALCOLITHIC					EARLY BRONZE AGE		
	Auvelles (Martín i Piqué 2008)	Roques del Sarró (Equip Sarró 2000)	Total			Minferri (Piqué i Mensua 2001)		
Number of samples	49	3				155		
Taxa	Number of fragments		N	%	Ubiq	N	%	Ubiq
Acer sp.	3		3	0,16	1,92	1	0,05	0,65
Alnus sp.						1	0,05	0,65
Arbutus unedo						333	13,22	27,10
Atriplex halimus		4	4	0,21	1,92			
Berberis sp.						1	0,05	0,65
Cistus sp.						14	0,73	4,52
Deciduous *Quercus*	999		999	53,54	28,85	108	5,60	16,77
Erica sp.						1	0,05	0,65
Evergreen *Quercus*	679	12	691	37,03	59,62	276	14,30	35,48
Fabaceae	67		67	3,59	5,77	37	1,92	9,03
Fraxinus sp.	1		1	0,05	1,92	15	0,78	0,65
Globularia						2	0,10	0,65
Lonicera sp.						16	0,83	3,87
Monocotyledoneae						3	0,16	1,29
Olea europaea						2	0,10	0,65
Pinus halepensis	6		6	0,32	1,92	507	26,28	49,03
Pinus sp.						49	2,54	9,03
Pinus type *sylvestris/nigra*	5		5	0,27	1,92	13	0,67	1,94
Pistacia lentiscus		62	62	3,32	5,77	323	16,74	36,13
Pomoideae						13	0,67	3,23
Prunus sp.						73	3,78	5,81
Quercus sp.						18	0,93	4,52
Rhamnus Phillyrea						90	4,66	20,65
Rosmarinus officinalis		25	25	1,34	1,92	22	1,14	7,10
Tamarix sp.		3	3	0,16	1,92	5	0,25	1,94
Ulmus sp.						6	0,31	1,29
Indeterminable	14	1	15	-	-	896	-	-
Indeterminate		2	2	-	-	192	-	-
Cortex				-	-	80	-	-
Heart				-	-	2	-	-
Node				-	-	148	-	-
Total fragments analyzed	1774	109	1883	-	-	3247	-	-
Total fragments identified	1760	106	1866	-	-	1929	-	-

Table 1. Anthracological results in the western Catalan plain from the Neolithic/Chalcolithic to the Early Bronze Age.

on the environment would have probably resulted in deforestation that could have been the cause of the changes observed in the consumption of plant fuel.

In Segre-Cinca Group II, *Pinus halepensis* stands out compared to the other species. This is the case mainly in Tossal de Solibernat (Torres de Segre, Segrià) (535 fragments) and secondly in Vincamet I (Fraga, Huesca) (189 fragments) (Table 3). With regard to ubiquity and number of fragments a similar hierarchy in species is evident; the main species are *Pinus halepensis, Pistacia lentiscus* and *Rosmarinus officinalis* (rosemary).

The Segre-Cinca Group III is represented by two sites: Vincamet (Vincamet phase I) and Vilot de Montagut (Vilot phases I and II). However 96.5% of the identified fragments come from Vilot de Montagut. For the first time, the taxon with the largest number of fragments is a shrub, *Pistacia lentiscus* (Table 3),

	SEGRE-CINCA GROUP I							
	C. Punta Farisa (Ros 1993)	El Vilot 0 (Alonso *et al.* 2002)	Genó (Ros 1994/1996; Maya et al. 1998)	M. Ratón (Ros 1995)	Roques Sarró (Equip Sarró 2000)	Total		
Number of samples	1	1	18	32	1			
Taxa	Number of fragments					N	%	Ubiq.
Acer sp.				2		2	0,13	3,77
Alnus sp.	2	9				11	0,71	3,77
Cistaceae	3	2		12		17	1,10	16,98
Deciduous *Quercus*			31			31	2,01	3,77
Evergreen *Quercus*	10	8	39	56	15	128	8,31	47,17
Fabaceae	11			49		60	3,89	39,62
Fraxinus sp.				2	5	7	0,45	5,66
Juniperus sp.	1	1			1	3	0,19	5,66
Pinus halepensis	41	127	394	136		698	45,30	86,79
Pistacia lentiscus	95	11		190	7	303	19,66	64,15
Pomoideae					1	1	0,06	1,89
Populus sp.	14		32	31		77	5,00	30,19
Quercus cf. *faginea*					2	2	0,13	1,89
Rhamnus/Phillyrea	5			22		27	1,75	24,53
Rosaceae				2		2	0,13	1,89
Rosmarinus officinalis	9	1		85		95	6,16	45,28
Salix sp.		4		16		20	1,30	13,21
Tamarix sp.	11			40		51	0,39	28,30
Ulmus sp.					6	6	3,31	1,89
Indeterminable		4		21	2	27	-	-
Indeterminate	2			17		19	-	-
Total fragments analyzed	204	167	496	681	39	1587	-	-
Total fragments identified	202	163	496	643	37	1541	-	-

Table 2. Anthracological results in the western Catalan plain during the Segre-Cinca Group I.

	SEGRE-CINCA GROUP II					SEGRE-CINCA GROUP III				
	T. Solibernat (Ros 1994/1996)	Vincamet I (Piqué 2003)	Total			Vilot I i II (Alonso *et al.* 2002)	Vincamet II (Piqué 2003)	Total		
Number of samples	1	7				14	4			
Taxa	Number of fragments		N	%	Ubiq.	Number of fragments		N	%	Ubiq.
Acer sp.	1		1	0,10	12,50					
Alnus sp.	7		7	0,72	12,50	13		13	2,84	22,22
Chenopodiaceae						1		1	0,22	5,56
Cistaceae						19		19	4,16	33,33
Deciduous *Quercus*						1		1	0,22	5,56
Evergreen *Quercus*	19	8	27	2,76	37,50	92		92	20,13	66,67
Fabaceae	5	9	14	1,43	25,00					
Fraxinus sp.	2		2	0,20	12,50					
Juniperus sp.	6		6	0,61	12,50	2	9	11	2,41	11,11
Monocotyledoneae		1	1	0,10	12,50					
Pinus halepensis	535	189	724	74,03	75,00	86		86	18,82	61,11
Pistacia lentiscus	48	6	54	5,52	25,00	122		122	26,70	72,22
Populus sp.	19	9	28	2,86	25,00	1		1	0,22	5,56
Prunus sp.						3		3	0,66	11,11
Rhamnus/Phillyrea	2		2	0,20	12,50	2		2	0,44	11,11
Rosaceae/Maloideae						5		5	1,09	11,11
Rosmarinus officinalis	20	23	43	4,40	50,00	84		84	18,38	61,11
Salix sp.	26		26	2,66	12,50	7		7	1,53	27,78
Tamarix sp.		41	41	4,19	37,50	3	7	10	2,19	22,22
Vitis vinifera	2		2	0,20	12,50					
Indeterminable	5	6	11	-	-	106	3	109	-	-
Indeterminate	3	2	5	-	-		1	1	-	-
Total fragments analyzed	700	294	994	-	-	547	20	567	-	-
Total fragments identified	692	286	978	-	-	441	16	457	-	-

Table 3. Anthracological results in the western Catalan plain during the Segre-Cinca Group II and Segre-Cinca Group III.

followed by two trees *Pinus halepensis* and evergreen *Quercus* that already had a significant presence during earlier periods. Also highlighted is the importance of a small shrub, *Rosmarinus officinalis*. The presence

	FIRST IRON AGE						
	El Vilot III (Alonso *et al.* 2002)	**Els Vilars 0 i I** (Ros 1995c)	**La Codera** (Piqué 2008)	**T. Regallos** (Ros 1995b)	Total		
Number of samples	1	17	34	14			
Taxa	Number of fragments				N	%	Ubiq
Alnus sp.	2				2	0,16	1,52
Arbutus unedo		6			6	0,49	4,55
Chenopodiaceae			1		1	0,08	1,52
Cistaceae	3	5	1	1	10	0,82	9,09
Ephedra sp.				2	2	0,16	1,52
Deciduous *Quercus*	2	65			67	5,49	15,15
Erica sp.		3			3	0,25	3,03
Evergreen *Quercus*	19	84	6	98	207	16,95	24,24
Fabaceae	1	3	2		6	0,49	1,52
Juniperus sp.	1				1	0,08	1,52
Labiatae				1	1	0,08	1,52
Pinus halepensis	47	10	28	499	584	47,83	43,94
Pinus type *sylvestris/nigra*	2	6	2		10	0,82	7,58
Pistacia lentiscus	22	49	16		87	7,13	27,27
Populus sp.			1	27	28	2,29	4,55
Prunus sp.	1				1	0,08	1,52
Rhamnus Phillyrea	1	3	7		11	0,90	4,55
Rosaceae/Maloideae	3				3	0,25	1,52
Rosmarinus officinalis	12	23	50	17	102	8,35	36,36
Salix sp.			13		13	1,06	7,58
Tamarix sp.		3	72		75	6,14	24,24
Ulmus sp.	1				1	0,08	1,52
Indeterminable	32	7	11		50	-	-
Indeterminate		4		2	6	-	-
Total fragments analyzed	149	271	210	647	1277	-	-
Total fragments identified	117	260	199	645	1221	-	-

Table 4. Anthracological results in the western Catalan plain during the First Iron Age.

	IBERIAN PERIOD						
	Estinclells (Allué i Euba 2005; Martín i Piqué 2009)	**Els Vilars II i III** (Ros 1995c)	**Missatges** (Piqué i Mensua 2001)	**Roques del Sarró** (Equip Sarró 2000)	Total		
Number of samples	23	18	34	13			
Taxa	Number of fragments				N	%	Ubiq
Acer sp.	1	1	8		10	0,58	8,57
Alnus sp.				23	23	1,34	5,68
Angiospermae	1				1	0,06	1,14
Arbutus unedo	1	7	2		10	0,58	6,82
Buxus sempervirens			27		27	1,57	4,55
Cistaceae		4		1	5	0,29	5,68
Coniferae			2		2	0,12	1,14
Deciduous *Quercus*	479	94	376		949	55,34	61,36
Erica sp.		5			5	0,29	3,41
Evergreen *Quercus*	54	153	9	9	225	13,12	30,68
Fabaceae		2		1	3	0,17	6,82
Ficus carica	2		3		5	0,29	3,41
Fraxinus sp.				34	34	1,98	1,14
Juniperus sp.			1	3	4	0,23	7,95
Pinus halepensis		20		11	31	1,81	4,55
Pinus type *sylvestres/nigra*	1	11	22	30	64	3,73	14,77
Pistacia lentiscus		19		9	28	1,63	10,23
Pomoideae			6	4	10	0,58	9,09
Populus sp.			3	12	15	0,87	6,82
Quercus cf. *faginea*				23	23	1,34	1,14
Rhamnus/Phillyrea				1	1	0,06	4,55
Rosaceae		1			1	0,06	1,14
Rosaceae/Maloideae	1	11			12	0,70	2,27
Rosmarinus officinalis		4	2	6	12	0,70	12,50
Salicaceae	14				14	0,82	1,14
Salix sp.			4	12	16	0,93	3,41
Tamarix sp.	1	3	10		14	0,82	4,55
Tilia sp.			3		3	0,17	1,14
Ulmus sp.	42		66	60	168	9,80	26,14
Vitis vinifera				1	1	0,06	1,14
Indeterminable	4	9	49	9	71	-	-
Indeterminate		8		2	10	-	-
Cortex	2				2	-	-
Total fragments analyzed	603	352	593	251	1799	-	-
Total fragments identified	597	335	544	240	1716	-	-

Table 5. Anthracological results in the western Catalan plain during the Iberian period.

of evergreen *Quercus* increases in relation to the previous period. This may be due to a recovery of the vegetation compared with the GSC II. However, we cannot exclude other possible explanations such as the enlargement of the catchment areas to remote parts in which *Quercus* still had a significant presence and which could have been exploited together with areas around the settlements.

The results for the First Iron Age (800/750-550 cal BC) show certain differences in relation of the GSC III. The best represented species is *Pinus halepensis*, whereas the consumption of *Pistacia lentiscus* that dominated the GSC III assemblage decreases (Table 4). Evergreen *Quercus* and *Rosmarinus officinalis* still have some relevance. The results show that the collection of firewood was carried out in a similar landscape at Tozal de los Regallos, Fortaleza dels Vilars (phases Vilars 0 and Vilars I) and Vilot de Montagut (phase Vilot III), where there was constant presence of *Pinus halepensis*, *Pistacia lentiscus* and evergreen *Quercus*. However, at the site of La Codera (Alcolea de Cinca, Baix Cinca) two shrubs are the predominant taxa: *Tamarix* sp. and *Rosmarinus officinalis*, both in terms of ubiquity and number of remains.

In the Iberian period (550-100 cal BC) forest exploitation in the plain experienced certain changes with respect to the previous period (Table 5). On the one hand, the assemblage shows an increase in the number of consumed taxa; now there are 28 taxa documented, while during the first Iron Age at least 22 were consumed. Another notable change is the considerable increase of deciduous *Quercus*, which together with evergreen *Quercus* are the best represented taxa, both in number of fragments as well as ubiquity. This greater taxonomic diversity and change in the consumed taxa could be the result of a change in catchment areas due to a progressive depletion of forest resources around settlements.

We should also note the growing importance of *Ulmus* sp. (elm), mainly characteristic of riparian woodland, and *Pinus* type *sylvestris/nigra* (pine) that at the present grows in mountainous areas. The presence of these taxa suggests a greater pressure on catchment areas that before were less exploited.

The landscape represented in the sites studied for this period shows some differences. In Estinclells (Verdú, Urgell), Missatges (Tàrrega, Urgell) and Fortalesa dels Vilars the best represented taxa, in both the number of fragments and ubiquity, are deciduous and evergreen *Quercus*. However, at other sites the relative importance of small riparian trees or shrubs is highlighted. This is the case of *Ulmus* sp. which is well represented in Estinclells, Missatges and Roques del Sarró.

During the Roman period, represented by the sites Iesso (Guissona, Segarra) and Ilerda (Lleida, Segrià), the number of consumed taxa increases considerably compared to the previous period (34). For the first time, the exploitation of the wood of fruit trees is observed in the record, which probably reflects the use of pruned branches as firewood. Among others, remains of *Vitis vinifera* (grapevine), *Olea europaea* (olive) and *Prunus* sp. (Table 6) are represented.

In this period shrubs and small trees such as *Ulmus* sp., *Tamarix* sp., *Rosmarinus officinalis*, *Fraxinus* sp. and *Pistacia lentiscus* among others would have been intensively exploited. However the tree taxa are the best represented. The dominant ones are *Pinus halepensis*, *Pinus* type *sylvestris*/*nigra*, deciduous and evergreen *Quercus*. Also remarkable is the presence of *Populus* sp. The Romanization in the western Catalan plain resulted in a significant intensification of the exploitation of arboreal taxa, although there was intensive use of all types of woody resources.

By the Middle Ages, which corresponds to the Islamic occupation, only 24 samples from three sites were analyzed, Medina Larida (Lleida, Segrià), Pla d'Almatà (Balaguer, Noguera) and Molí del Codina (Tarrega, Urgell). However, the large number of represented taxa (31 species) is remarkable (Table 6).

Pinus halepensis is the best represented taxon; however most of the remains come from Medina Larida (645 fragments of 794 in total). The following taxa in importance, depending on the number of remains

	ROMAN PERIOD					MIDDLE AGES/ISLAMIC PERIOD					
	Iesso (Buxó *et al.* 2004)	Ilerda (Piqué 1998a, 1998b; Piqué i Noguera 2000)	Total			Med. Larida (Piqué 1998b)	Molí Codina (Piqué 2006)	Pla D'Almatà (Piqué i Vila 2010)	Total		
Number of samples	7	31				12	1	11			
Taxa	Number of fragments		N	%	Ubiq	Number of fragments			N	%	Ubiq
Abies alba	1		1	0,04	2,63						
Acer sp.	2	13	15	0,67	13,16			3	3	0,38	12,50
Alnus sp.		10	10	0,44	10,53	1			1	0,13	4,17
Arbutus unedo		2	2	0,09	2,63			1	1	0,13	4,17
Betula sp.	21		21	0,93	5,26						
Buxus sempervirens	6	3	9	0,40	13,16			3	3	0,38	8,33
Celtis australis		31	31	1,38	10,53	1			1	0,13	4,17
cf. *Celtis* sp.						1			1	0,13	4,17
Chenopodiaceae		1	1	0,04	2,63						
Chenopodiaceae cf. *salsola*		181	181	8,05	2,63						
Cistus sp.						8			8	1,01	8,33
Corylus avellana	1		1	0,04	2,63						
cf. *Punica granatum*		3	3	0,13	5,26						
Deciduous *Quercus*	141	121	262	11,65	47,37	18	1	10	29	3,65	41,67
Erica sp.								3	3	0,38	8,33
Evergreen *Quercus*	8	136	144	6,41	50,00	65	1	48	114	14,36	62,50
Fabaceae	13	18	31	1,38	10,53	3			3	0,38	8,33
Fagus sp.		1	1	0,04	2,63						
Ficus carica	2	15	17	0,76	10,53	10		1	11	1,39	12,50
Fraxinus sp.	30	2	32	1,42	13,16		1		1	0,13	4,17
Juglans sp.		31	31	1,38	13,16	3	1	4	8	1,01	16,67
Juniperus sp.	1	2	3	0,13	5,26	3	1	2	6	0,76	16,67
Monocotyledoniae						2		5	7	0,88	8,33
Olea europaea		10	10	0,44	10,53	10			10	1,26	33,33
Pinus halepensis	5	399	404	17,97	47,37	258		3	261	32,87	37,50
Pinus sp.		6	6	0,27	7,89	4			4	0,50	4,17
Pinus type *sylvestris/nigra*	118	551	669	29,76	71,05	89	1	15	105	13,22	50,00
Pistacia lentiscus		52	52	2,31	28,95	54			54	6,80	12,50
Pomoideae	3		3	0,13	5,26	11		5	16	2,02	20,83
Populus sp.	4	100	104	4,63	7,89	4	1		5	0,63	8,33
Prunus sp.	1	27	28	1,25	23,68	15	1	23	39	4,91	45,83
Prunus dulcis						3			3	0,38	4,17
Pyrus malus		1	1	0,04	2,63	14			14	1,76	16,67
Rhamnus/Phillyrea		8	8	0,36	10,53	3		2	5	0,63	16,67
Rosaceae/Maloideae		41	41	1,82	13,16	1			1	0,13	4,17
Rosoideae	2		2	0,09	5,26						
Rosmarinus officinalis		59	59	2,62	21,05	2		2	4	0,50	12,50
Salix sp.	6	20	26	1,16	21,05	13		3	16	2,02	16,67
Sorbus sp.						10			10	1,26	16,67
Tamarix sp.		3	3	0,13	7,89	38			38	4,79	33,33
Ulmus sp.	2	31	33	1,47	18,42	1			1	0,13	4,17
Vitis vinifera		3	3	0,13	5,26		1	7	8	1,01	16,67
Indeterminable	3	158	161	-	-	9		5	14	-	-
Indeterminate		32	32	-	-	43			43	-	-
Node		8	8	-	-			4	4	-	-
Cortex		2	2	-	-			1	1	-	-
Total fragments analyzed	370	2081	2451	-	-	697	9	152	858	-	-
Total fragments identified	367	1881	2248	-	-	645	9	140	794	-	-

Table 6. Anthracological results in the western Catalan plain during the Roman period and the Middle Ages/Islamic period.

are evergreen *Quercus* and *Prunus* sp. Furthermore, *Pinus* type *sylvestris/nigra* maintains a high ubiquity in this period.

DISCUSSION

The data obtained show certain continuity in the landscape exploited throughout the period, while we can also observe remarkable differences in the modalities of utilization of resources (Fig. 2).

Except for the Neolitic/Chalcolithic sites, where deciduous *Quercus* and evergreen *Quercus* predominate, the most important aspect of all other periods is the continuity in relation to the species used. From the Early Bronze Age until the Middle Ages *Pinus halepensis* played a major role. Along with it, *Pistacia lentiscus*, *Rosmarinus officinalis* and both *Quercus* (deciduous and evergreen) were constantly present. Their presence together with other taxa as *Cistaceae*, *Rhamnus/Phillyrea* and *Fabaceae*, seems to indicate an open landscape. This open landscape could have been the result of pressure on the environment by the people of the Early Bronze Age (2700-1650 cal BC) and later periods. However, we must also take into account that the continental maquis, now dominant in the area, is characterized by the importance of shrub and its association with *Pinus halepensis*. Therefore, we cannot discard that maquis was already widespread in the area since the Bronze Age. This maquis type landscape was intensively exploited for obtaining fuel. Its

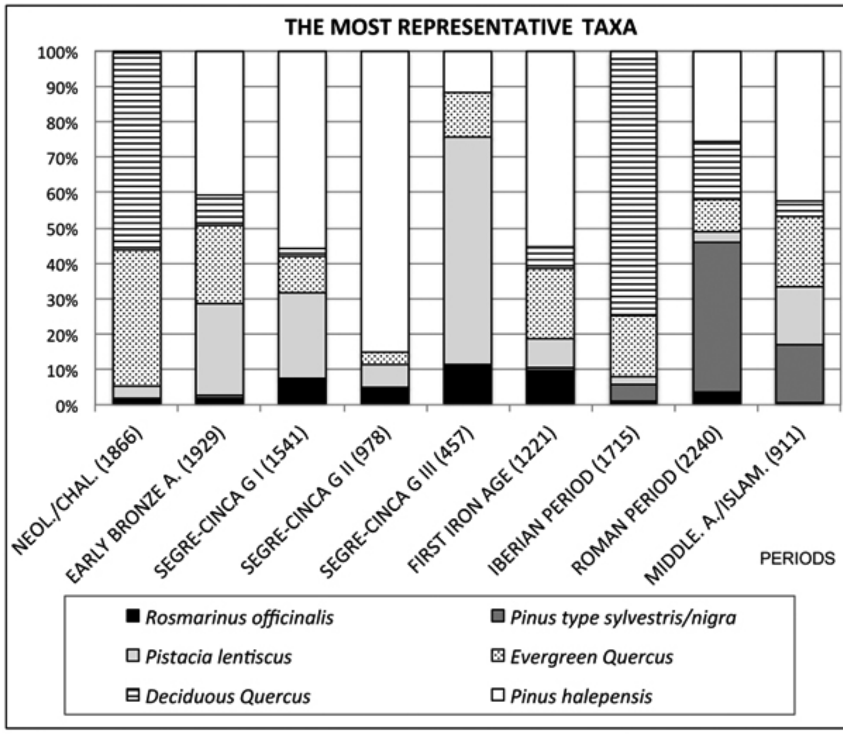


Figure 2. Main taxa from the Neolithic/Chalcolithic to the Middle Ages in the western Catalan plain (in parentheses beside the name of every period, the number of remains is shown).

presence is especially notable during the Segre-Cinca Group and the First Iron Age. In general, since the Early Bronze Age maquis vegetation could have constituted an important source of woody resources for the procurement of fuel.

However, the presence of *Pinus halepensis* fluctuates over time; for example it decreases in the Iberian period, when it is no longer the best represented taxon due to the greater importance of deciduous *Quercus* and *Pinus* type *sylvestris-nigra*. These taxa continue being important in Roman times. We believe that the data reflects the expansion of the catchment areas, probably due to the reduced availability of wood resources in the immediate vicinity of the settlements. It should be kept in mind that, since the Early Bronze Age, the western Catalan plain was occupied by people living in permanent settlements. During the Bronze Age the emergence of large villages with a scattered pattern occured, while in the Segre-Cinca Group a stable settlement pattern linked to stone architecture was intensified. Undoubtedly, continued occupation and proto-urban characteristics would have had significant consequences on the vegetation structure.

Among the most notable differences a highlight is the increasing number of consumed taxa from the Neolithic/Chalcolithic period to the Middle Ages/Islamic period. This increase in the richness of taxa could have been the result of increasing pressure on the environment, which would have resulted in the need to take advantage of every available woody resource for firewood. In this sense, riparian vegetation was especially exploited since the occupation of the Segre-Cinca Group. We also believe that the increased presence of deciduous *Quercus* since Iberian times and *Pinus* type *sylvestris-nigra* during the Roman period could have been the result of the expansion of the catchment areas to middle altitudes, a little further from the flat area where the settlements were located.

CONCLUSIONS

The forest landscape of the plains, from the Neolithic/Chalcolithic to the Middle Ages/Islamic period, presents a changing panorama. During the Neolithic/

Chalcolithic the best represented taxa, both in terms of relative frequency and ubiquity, are deciduous and evergreen *Quercus*.

During the Early Bronze Age (2700-1650 cal BC), with the appearance of large settlements in a scattered pattern, the landscape was different to the above, now dominated by Mediterranean species such as *Pinus halepensis* and evergreen *Quercus*, *Arbutus unedo* and *Pistacia lentiscus*. The presence of shrubs has generally been interpreted as a clear signal of deforestation. However, shrubs are important in maquis type formations, which currently occupy part of the Mediterranean coastal lowlands and interior.

During the Segre-Cinca Group I (1650-1250 cal BC) a stable population associated with stone architecture increased. The predominant species during that period were *Pinus halepensis, Pistacia lentiscus*, and *Rosmarinus officinalis*. During the Segre-Cinca Group II (1250-1000 cal BC) there were no major changes. However, during the Segre-Cinca Group III (1000-800/750 cal. BC), an increase in the presence of evergreen *Quercus* is observed in coincidence with the beginning of a process of concentration of habitats.

During the Iberian period (550-100 cal BC) the use of evergreen and deciduous *Quercus* increased, to the detriment of *Pinus halepensis*. With the Romans the use of a large number of taxa intensified, among which were *Pinus* type *sylvestris*/*nigra*, *Pinus halepensis,* deciduous *Quercus*, evergreen *Quercus,* etc. These changes, in respect to the previous phase might be the result of the enlargement of the catchment areas. The decrease of woody resources in the immediate surroundings of the settlements could be one of the factors that would explain this change.

The vegetation of the western Catalan plain has a distinctly Mediterranean character during prehistoric and recent historic times, with the exception of the Neolithic. Throughout the phases studied degradation of the forest cover is evident. In this sense, we stress the importance of colonizer shrub species in practically all of the studied periods. Changes in the catchment areas represented in these periods could also be another indicator of the degradation. This would have led to the enlargement of the catchment areas to more distant lands, first riparian woodland and secondly forests at higher altitudes.

ACKNOWLEDGEMENTS

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Palaeovegetation and plant-resource management in the district of La Loma (Jaén, Spain) during Recent Prehistory

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***Summary**: The charcoal from two archaeological sites located in the district of La Loma (Jaén, Spain) and dated between the second half of the 4th and the first quarter of the 2nd millennium cal BC was studied. The results document the presence of thermophilous Holm oak woodland with elements indicating a humid environment during the 4th and 3rd millennia. Since the beginning of the 2nd millennium, the tree cover was lost, partially due to aridification of the climate as well as due to human activity in the environment, using fire to open fields for cultivation and pastures for livestock grazing. In the Bronze Age levels, species used for the construction of huts were identified.*

***Key words**: Charcoal analysis, Late Neolithic, Copper Age, Bronze Age, Andalusia.*

SETTING AND BIOGEOGRAPHY

The studied sites are situated in the district of La Loma, in the province of Jaén (Spain), within the River Guadalquivir Depression, which occupies a large part of Andalusia. This district, equidistant between the mountain systems of Sierra Morena to the North, Sierra Mágina to the South and the Sierras of Cazorla-Segura to the East with the West remaining open to oceanic influence, has a slightly elevated relief over the Guadalquivir Valley. In turn, this elevation is bordered by River Guadalimar to the North and Guadalquivir to the South. The landscape is an undulating succession of low hills worked in Tertiary sediments (Fig. 1).

The surroundings of the cities of Ubeda and Baeza belong to the lower mesomediterranean bioclimatic level with a Ti (thermicity index) of 333 and a dry ombroclimate (P 350-600, P=precipitations) (Rivas Martínez 1987). The dominant vegetation series is the Holm Oak (*Quercus rotundifolia*), Paeonio coriaceae-Querceto rotundifoliae S., in its thermophilous faciation with *Pistacia lentiscus* (Rivas Martínez 1987; Valle Tendero 2004). Currently, the area is occupied by olive cultivation with natural vegetation persisting only at isolated points inaccessible to grazing and ploughing. The supramediterranean and oromediterranean levels are found in the mountain massifs of Sierra Mágina and the Sierras of Cazorla-Segura (Fig. 1).

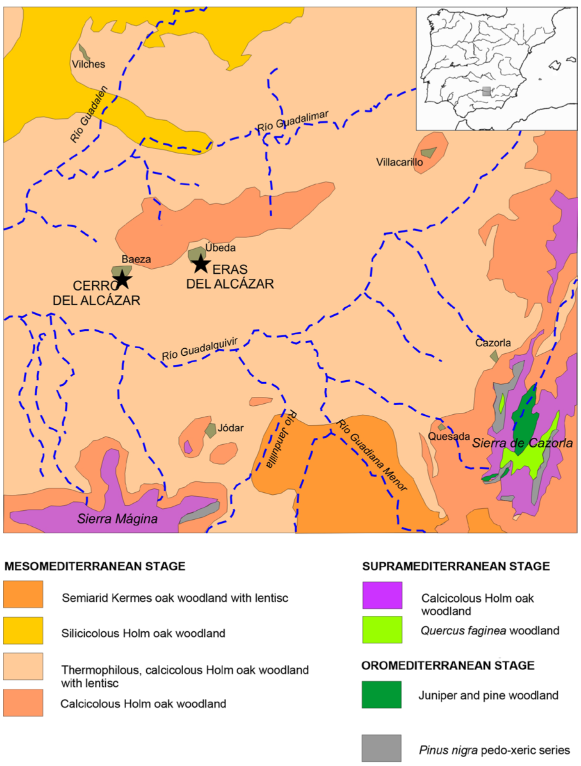

Figure 1. Map showing the location of the settlements and the vegetation of the zone.

THE SITES

The archaeological site of Las Eras del Alcázar is located in the southern part of the city centre of Úbeda, on a spur surrounded by rocky outcrops, slopes and fortified structures that, since prehistoric times, have made it a suitable defensive zone. The extent of the settlement is difficult to estimate due to the scant excavations carried out in the area. However, the evidence from prehistoric levels of the 2nd millennium cal BC found in salvage archaeological work in other parts of the city centre of Úbeda suggests a surface area of more than 6 ha.

Las Eras del Alcázar was dated by 34 ^{14}C dates. The results indicate an uninterrupted sequence from the second quarter of the 4th millennium cal BC to the first quarter of the second millennium BC (Lizcano *et al*. 2009).

For the diagram constructed and the conclusions drawn, the charcoal was grouped according to the chronological-cultural sequence defined for each site. In the Eras del Alcázar of Úbeda, three time periods were defined. The first period, *c*. 3500-2500 BC, dates between the Late Neolithic and the Middle Copper Age and its urban plan is distinguished by circular dwellings excavated in the soil with rammed-earth walls of adobe and plant material. The second period, *c*. 2200-2000 BC, is ascribed to the Late Copper Age, with beaker pottery and free-standing dwellings on the ground. Finally, the third period, *c*. 2000-1700 BC is ascribed to the Bronze Age and the urban pattern changes to rectangular dwellings (Lizcano *et al*. 2009).

Only 11 km away lays Cerro del Alcázar, situated within the city centre of Baeza. This forms a spur on the southern end of the city, surrounded by steep natural slopes that make the site a strategic enclave for the control of the Guadalquivir valley. Radiocarbon dates from the site were obtained from 8 organic samples, 5 of them dated by conventional ^{14}C and three by the AMS technique. The results reveal long occupation from the middle of the 3rd millennium BC until the present, although abandonment levels exist that mark a hiatus corresponding to the 1st millennium BC. Thus, chronological data together with the information gathered through excavation, in particular the construction patterns of the dwellings enabled the determination of 4 broad phases of occupation, which span from 2000 to 1500 cal BC. All four phases present similar characteristics in the construction system of the rooms within rectangular dwellings, and in the materials used for the habitation floors.

Thus, by pooling the data from the two settlements and taking into account the scheme of period divisions proposed by the heads of both archaeological studies, we can define three periods: the first, corresponding to the time-span from the Late Neolithic to the Early/Middle Copper Age (c. 3500-2500 cal BC); the second, situated in the Recent-Beaker Copper Age (c. 2200-2000 cal BC), and the third belonging to the Bronze Age (c. 2000-1500 cal BC), when the settlements were contemporary (Lizcano *et al*. 2009). Both the first two phases were documented in Las Eras del Alcázar (Úbeda).

METHODOLOGY

In Andalusia, the collection of plant samples for bio-archaeological analysis started late, therefore archaeological sampling was undertaken only at certain points or did not take into account the entire volume of sediment processed. This is the case of Las Eras del Alcázar, where samples were collected only at certain points. Although a substantial volume of charcoal was recovered enabling us to evaluate the early phases, for the Bronze Age levels we were able to analyse only 26 charcoal fragments (Fig. 2; Table 1).

In the case of Cerro del Alcázar de Baeza, the charcoal came primarily from manual collection, although a systematic sampling was also carried out, taking a constant volume of sediment (3 to 5 litres), which was increased where necessary. In this way, a total of 309 litres were floated divided among 58 samples; of these, 35 contained charcoal, but only 28 were large enough to be determined. However, carpological remains were recovered in most of the samples (Montes 2011). At this site, in the four construction phases defined for the Bronze Age (Pérez and Lizcano 2003), sufficient charcoal was found only in Phases II and III, while only 12 fragments were analysed for Phase IV and none for Phase I (Fig. 2; Table 1).

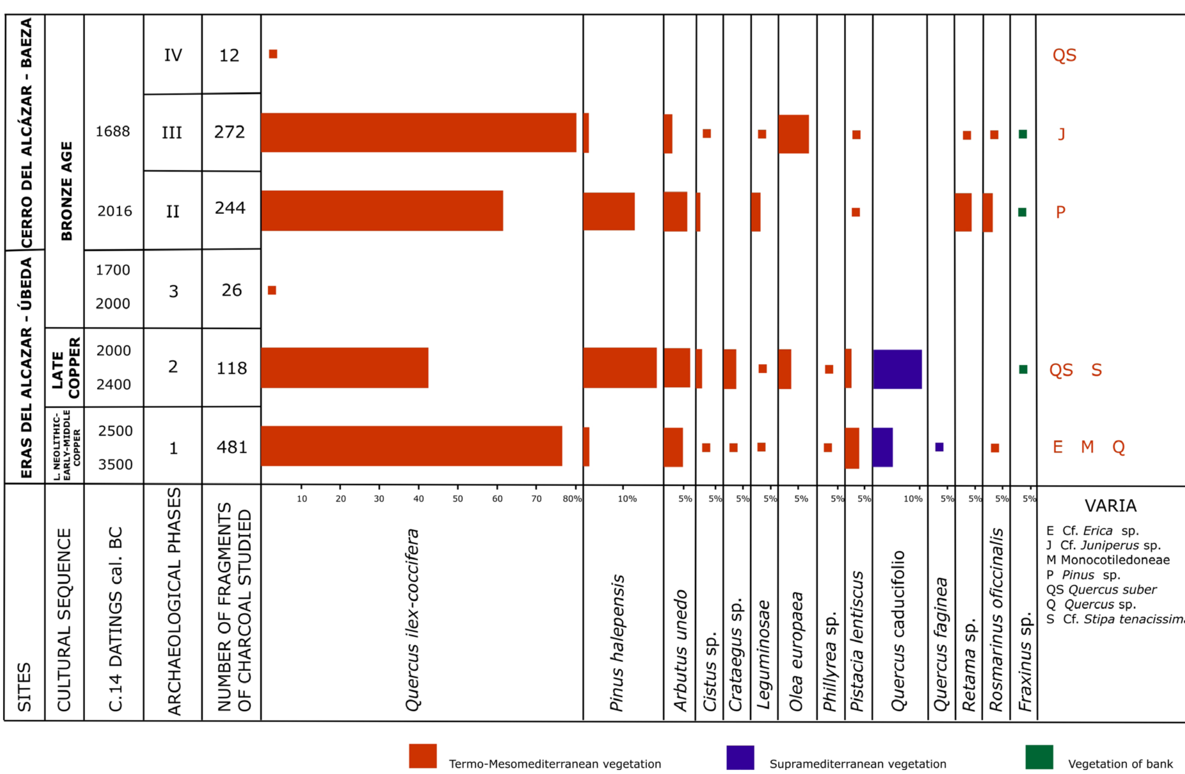

Figure 2. Anthracological diagram of the district of Loma (Jaén, Spain).

SITES	ERAS DEL ALCÁZAR - ÚBEDA					CERRO DEL ALCÁZAR - BAEZA				
PHASES	Phase 1		Phase 2		Phase 3	Phase II		Phase III		Phase IV
TAXA	Nº	%	Nº	%	Nº	Nº	%	Nº	%	Nº
Arbutus unedo	22	4.57	8	6.79		15	6.14	7	2.57	
Cistus sp.	2	0.42	2	1.70		4	1.63	1	0.37	
Crataegus sp.	1	0.21	4	3.38						
Cf. *Erica* sp.	1	0.21								
Fraxinus sp.			1	0.85		1	0.42	1	0.37	
Cf. *Juniperus* sp.								1	0.37	
Leguminosae	3	0.63	1	0.85		7	2.86	1	0.37	
Monocotyledon	1	0.21								
Olea europaea			4	3.38				21	7.72	
Phillyrea sp.	2	0.42	1	0.85						
Pinus halepensis	6	1.24	22	18.64		32	13.11	3	1.1	
Pinus sp.						2	0.84			
Pistacia lentiscus	17	3.53	2	1.70		2	0.84	2	0.74	
Quercus deciduous	26	5.4	15	12.71						
Quercus faginea	4	0.83								
Quercus ilex-coccifera	368	76.5	50	42.37	23	150	61.46	218	80.14	10
Quercus suber			1	0.85						1
Quercus sp.	3	0.63								
Retama sp.						10	4.09	1	0.37	
Rosmarinus officinalis	2	0.42				6	2.45	2	0.74	
Cf. *Stipa tenacissima*			1	0.85						
Indeterminate	3	0.63	2	1.70		2	0.84	3	1.1	
Undeterminable	20	4.15	4	3.38	3	13	5.32	11	4.04	1
TOTAL CHARCOAL	481	100	118	100	26	244	100	272	100	12
TOTAL TAXA	14		13		1	10		11		2

Table 1. Absolute and relative frequencies of the taxa determined in the district of Loma (Jaén, Spain).

RESULTS AND DISCUSSION

PALAEO-ECOLOGICAL RESULTS AND MANAGEMENT OF THE PLANT ENVIRONMENT

The floristic list provided by the analysis of charcoal is composed by 21 taxa. However, if we eliminate the two taxa that can be encompassed by others, namely *Pinus* sp., which could belong to *P. halepensis* and *Quercus* sp., which could belong to deciduous *Quercus*, *Q. ilex-coccifera* or *Q. suber*, the number is reduced to 19. This number is slightly below the number of taxa determined at nearby sites, such as Polideportivo de Martos and Marroquíes Bajos, which have an overall floristic list of 22 taxa. However, the number of taxa identified for each chronological-cultural period varies from 10 to 14 taxa, falling within the range of 12-20 taxa that are found in the different phases of the above-mentioned sites, Peñalosa included (Rodríguez-Ariza 2011).

A closer examination of the floristic list of each of the settlements studied, shows that18 taxa were determined in Eras del Alcázar de Úbeda, and 13 in Cerro de Alcázar de Baeza, denoting a possible loss of floristic diversity. Notable among the taxa that disappeared are deciduous *Quercus* and *Quercus faginea* implying lower environmental moisture, while the disappearance of *Phillyrea* and the decline of *Pistacia lentiscus* would indicate slightly colder conditions. In counterpoint, during the Bronze Age, *Retama* appeared while *Rosmarinus officinalis* slightly increased. These characteristics imply a trend towards aridification that occurred during the Bronze Age and could correspond to the general pattern documented for the Western Mediterranean from the Middle Holocene onwards (Carrión *et al*. 2010).

The anthracological diagram (Fig. 2) reflects the predominance of *Quercus ilex-coccifera* vegetation, with percentages of 40 to 80%. It bears noting that at the levels where *Quercus ilex-coccifera* declines, *Pinus halepensis* augments, although the percentages are far lower (Fig. 2). This trend in the percentages, with a significant increase of *Pinus halepensis* from 1% in the final phase of the Neolithic and the Early Copper Age to 18.64% in the Recent Copper Age may reflect an opening of the plant environment composed of Holm oak woodland for the creation of new cultivated fields. Such activities would have favoured the presence of *Pinus halepensis*. This same pattern would have continued during Phase II of Cerro del Alcázar de Baeza, where deciduous *Quercus* also disappeared, indicating that at the beginning of the Argaric culture, new land continued to be occupied as were the valley floors where these *Quercus* would have found refuge. It is possible that in these zones with rich, moist soils, cultivated areas were established for fava beans. During this time because of the effect of irrigation these crops underwent relative size increases, whereas in the subsequent stage (Recent Copper Age) the seeds were smaller than during the Late Neolithic/Early-Middle Copper Age (Montes 2011) due to the progressive harshening of the climate.

A similar process of abrupt and significant emergence of *P. halepensis* was documented in the Copper Age site of Marroquíes Bajos, practically dating to the same period (Rodríguez-Ariza 2011). This suggests that the area would have undergone successive fires set to eliminate the woody vegetation and to open pastures for the livestock, in such a way that the Aleppo pine, an opportunistic, drought-resistant and heliophilous species, took advantage of the situation and colonized the zone.

However, in the second period of the Bronze Age (Phase III of Cerro del Alcázar de Baeza), all the taxa diminished in percentage, including *P. halepensis*, which remained at 1%, except for the significant advance of the level of *Quercus ilex-coccifera* and *Olea europea*. This possibly indicates the impoverishment of the natural vegetation by the effect of agricultural intensification at this time, in a double sense: on the one hand, with the increase of cultivated species (Montes, 2011) and, on the other, with the possible increase of cultivated surface, as mentioned above. Moreover, harsher climatic conditions are indicated by the disappearance of the most thermophilous species while the size of the cultivated cereal grain progressively diminished (Montes 2011), implying a lower degree of moisture during the Bronze Age. In addition, the increase in the presence of ovicaprine livestock is significant in the last phase of Eras del Alcázar de Úbeda, coinciding with the presence of the pig (Riquelme 2009), thus confirming the progressive disappearance of the Holm oak woodland.

Although the general pattern of floristic evolution coincides with the palynological analysis carried out at these sites (Fuentes *et al.* 2007), there is no agreement concerning the main taxon determined. Based on palynology, the main taxon would have been *Pinus* while charcoal dating pointed to *Quercus ilex-coccifera*. This discrepancy can be reconciled by the fact that palynology reflects mainly the vegetation of the nearby sierras, such as Segura-Cazorla to the East and Sierra Mágina to the South, whereas Loma de Úbeda, situated in the zone immediately below, is open to the winds that deposit the pollen in the surrounding sierras. Moreover, charcoal analysis reflects the vegetation of the surroundings closest to the settlements, introduced by the inhabitants.

USE OF WOOD

At Cerro del Alcázar de Baeza, the existence of several construction phases with fire levels (Pérez and Lizcano 2003) enabled us to retrieve, from tumble, 9 fragments of squared charcoal, with dimensions of approximately 2.5 x 4 cm, identified as *Q. ilex-coccifera*, except for one that belonged to *P. halepensis* (Fig. 3). These fragments may belong to joists that were placed over a framework of beams of *Q. ilex-coccifera*, of which we have identified fragments together with

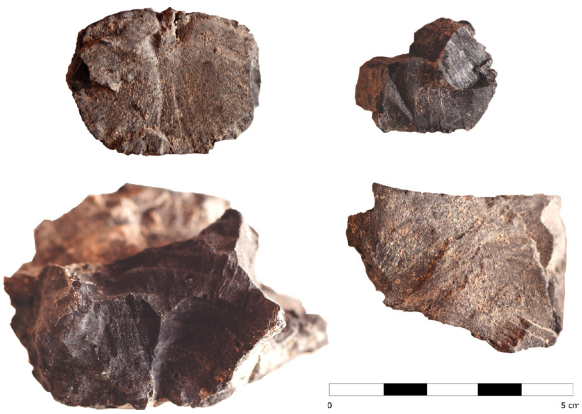

Figure 3. Fragments of squared-off charcoal.

clay from the ceiling or the walls of the huts. In one case, we detected insect bore holes, indicating that this wood, before being burnt had lasted for a long period after being cut.

A sample from Phase II, mainly of fine branches from the collapse of the roof, is composed by *Retama* sp., *Cistus* sp., *Arbutus unedo, Quercus ilex-coccifera*, and Leguminosae. Moreover, in Phase III, another sample of small branches proved to be *Rosmarinus officinalis* and *Arbutus unedo*.

Therefore, we may suggest that the structure of the roofs would have been similar to that of other Argaric settlements of south-eastern Spain (Rodríguez-Ariza 2012), such as Castellón Alto, Fuente Amarga, Loma de la Balunca (Rodríguez-Ariza 1992), El Castillejo de Gador (Rodríguez-Ariza 2001) or Peñalosa (Rodríguez-Ariza 2000), the one closest to the study area. Such roof structure would have been formed by a framework of beams using the above-mentioned species, which would have been connected to posts. Over this framework of beams, smaller rafters would have been placed perpendicularly to support abundant small branches over which a layer of mud would be spread.

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Charcoal analysis in the A750-A75 motorway (Clermont l'Hérault / Saint André de Sangonis - Béziers, Southern France): a case-study in Preventive Archaeology

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Summary*: The drawbacks and advantages of preventive archaeology and the implications for archaeobotanical studies are assessed based on the example of work carried out prior to the construction of the A 750 / A 75 motorway in southern France. Emphasis is given to the most significant charcoal analysis results obtained in sites destined to be rapidly destroyed. They provide a large scale insight on human settlement and land exploitation from the Middle Neolithic to the height of the Roman Empire.*

Key words*: Preventive archaeology, Southern France, Charcoal analysis, Human settlement, Vegetation.*

INTRODUCTION

Rescue Archaeology or Public Archaeology is a British generic expression applied to the work carried out on sites prior to their destruction by modern developments (Bahn 1992). This expression is synonymous with the north-American Salvage Archaeology or Cultural Resource Management and with the French "Fouilles de sauvetage", which was replaced in 2001 by "Fouilles préventives" (preventive archaeology), in an attempt to overturn the drawbacks of traditional rescue archaeology. In Rescue archaeology 'archaeologists run behind the bulldozers' trying to make the best of the unpleasant job of rapidly destroying our history; in Preventive archaeology "archaeologists precede the bulldozers" (Demoule and Landes 2009) safeguarding our history via the excavation, study and publication of uncovered remains.

This is the aim of INRAP (Institut National de Recherches Archéologiques Préventives), which possesses both the infrastructures required for large scale survey / excavation and the will to promote high quality research.

During field work an effort is made to recover as much material as possible to investigate past human communities and their environment. However, our ability to study all the remains recovered from the sediment samples is limited by time and financial resources as work is funded by the developer's budget.

Clear research priorities and sampling strategies must therefore be established in order to obtain reliable datasets. This negative aspect is compensated by the opportunities opened by the work in linear projects such as motorways, railway lines, gas works, which allow us to visualise patterns of human settlement and subsistence adaptation through time and on a regional scale, crossing a large range of ecological habitats.

However, it would be a mistake to restrict the usefulness of linear projects to the actual excavation and recovery of archaeological material. The survey phase is as important, as it opens a large research window to a space devoid of landmarks, allowing us to perceive sites which otherwise would have been overlooked or received much less attention.

The work carried out in 2001 - 2010, prior to the construction of the A 75 - A 750 motorway between Clermont-l'Hérault / Saint André de Sangonis and Béziers (Hérault, Southern France) is a good example of this (Fig. 1).

Based on the assessed importance of remains uncovered during the survey phase ('diagnostique' in French), 26 locations were selected for subsequent major excavation and study, covering the period Neolithic - Middle Ages.

Earth sciences and biological studies undertaken include geoarchaeology, analysis of terrestrial molluscs, zooarchaeology, palynology, analysis of macro remains (wood, charcoal, seeds / fruits), phytoliths, palaeoanthropology.

Concerning charcoal analysis, particular attention was paid to sites / structures where wood charcoal was most likely to occur and thus provide information on ecological, social and economic issues.

A brief summary of the most significant charcoal analysis data from this project are presented here. They provide direct evidence on the composition and exploitation of local woodlands at different periods, thus offering a glimpse of the history of our landscapes.

BIO-GEOGRAPHICAL SETTING

Sites studied are located in an area where the different ecological and cultural influences from the Hérault and the Orb valleys converge (Fig. 1).

In terms of geology, this area of low relief is largely formed by sandy and loamy marls deposited during the Miocene sea transgression (Ambert 1994); In terms of bioclimatology this area is included in the mesomediterranean level which stretches from the coast up to 400m high. Summers are hot and winters are mild with an average annual mean temperature of 14-16°C. Annual rainfall averages 500-600 mm, with heavy rainfall in the autumn. *Quercus ilex*, *Pinus halepensis*, *Pinus pinea* are the major tree species adapted to the drier soils, while *Quercus pubescens* elects more mesophilous conditions. The understorey vegetation comprises shrubby species such as *Pistacia lentiscus*, *Quercus coccifera*, *Viburnum tinus*, *Phillyrea media*, *Rhamnus alaternus*. The riverside vegetation is dominated by *Alnus glutinosa*, *Fraxinus angustifolia*, *Populus alba* and different species of *Salix* (Gaussen *et al*. 1963). Today, this natural vegetation is greatly reduced as a result of human influence and arable land is largely occupied by vineyards.

RESULTS AND DISCUSSION

The most significant information obtained concerns two chronological periods, the Late Neolithic and the Gallo-Roman period:

THE LATE NEOLITHIC PERIOD

Despite the great interest this period has long aroused in the Languedoc region, very few palaeoenvironmental data were available prior to the A 75 – A 750. A first synthesis of these data was presented by Chabal (2003). The discovery of several locations during the survey phase (Puech Haut, Roquessols, Cresses Basses, Barreau de la Deveze Cabrials, Champ Redon, Lagarel, Pirou-Labournas) offered thus a unique op-

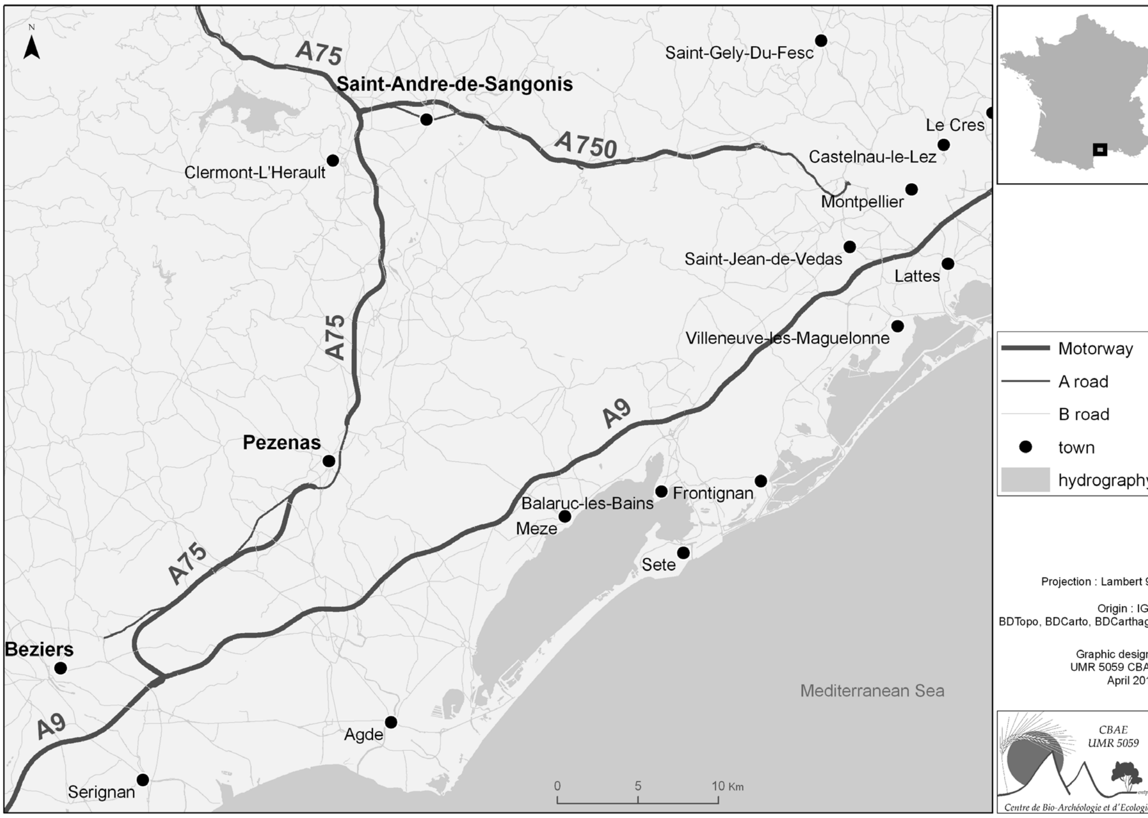

Figure 1. The A 750 - A 75 motorway: Location of study area between Saint André de Sangonis-Pézenas-Béziers (Graphic design: L. Paradis, CBAE).

portunity to enlarge the charcoal data set, despite the fact that habitat layers had disappeared due to erosion leaving only excavated structures (pits) with different morphologies and infills.

The site of Puech Haut stands apart due to the surface of its enclosed space, length of occupation (3 different phases) and the complexity of structures uncovered (Carroza dir. 2005).

The pit concentrations which were particularly dense for the Middle Neolithic (Chasséen), as testified at the site of Le Pirou, tend to occupy smaller surfaces during the Late Neolithic and seem to form small habitation units occupied during short time periods (Loison *et al*. 2008)

Archaeological remains argue for the great level of mobility of these communities rather than a more sedentary way of life. The small amounts of charred plants (charcoal + seeds / fruits) consistently recovered, despite the large scale sampling carried out, seem to support this interpretation. In fact, it is often difficult to assemble a statistically meaningful number of structures and charcoal fragments. In our case, relatively abundant charcoal fragments were recovered only at Puech Haut (Fabre 2005a) and Lagarel (Chabal and Figueiral 2007).

This mobility seems to have entailed significant changes in the landscape. In fact, data assembled so far point to the overall abundance of heliophilous plants (Fig. 2), colonisers of empty spaces, which suggests a long lasting exploitation of the area. This is the case of heathers (*Erica* sp.), Fabaceae and the mastic shrub (*Pistacia lentiscus*). The recurrent presence of this last species, which usually grows on the dry and stony areas of the mediterranean garrigue, is particularly striking. Its presence is not restricted to the A 75-A 750 sites but is also recorded in contemporaneous occupations from nearby areas such as Lespignan (Figueiral 2010). Earlier potential occurrences (*Pistacia* sp.) include the Middle Neolithic sites of Encombres and Les Hermes (Chabal 1999).

This early anthropogenic impact may be linked with the presence and confrontation of "Ferrières" or "Vérazien" populations in this buffer zone.

While a clear pattern seems to be discerned from the Late Neolithic occupations studied, the same can not be said of the Iron Age which must be considered as a key period for the understanding of the Gallo-Roman developments. Data are scarce, limited to sites such as Mas de Pascal (Fabre 2002), and l'Arnoux (Figueiral 2008) including a restricted number of structures. However, they are not without interest as they provide guidelines for future linear projects.

THE GALLO-ROMAN PERIOD

When dealing with this period, linear projects allow a global approach of the rural habitat (including the small and large *villae*, the farms, the "co-operatives", the *vicus*) and the natural landscape. The occupation of the sites studied in the A 75 project covers different aspects of day to day life (and death) during the period from the 1st century BC to the 3rd century AD.

The different ensembles excavated offer different perspectives of how people made use of the land and the plant resources.

The first perspective is offered by the different funerary ensembles - incinerations and inhumations - uncovered. Both burial practices have been practiced in the Languedoc region since the Neolithic, but inhumation seems to have been abandoned for the duration of the Iron Age (Dedet 2004). From the end of the 1st century to the 2nd century AD. cremation and inhumation coexist, until the first practice disappears at some point in the beginning of the 3rd century AD. The reasons for the disappearance of this practice are still unclear (Blaizot 2009).

Charcoal recovered from incinerations (primary cremations and secondary deposits) provide information on the wood used as fuel to cremate the bodies. The presence of wooden objects is more difficult to identify unless recognizable shapes are preserved. In the case of inhumations, the presence of associated fireplaces may offer data on the symbolic aspects of plant use.

In the case of primary deposits the exhaustive sampling of sediments, using a grid to divide the surface into squares, ensures the recovery and precise positioning of a whole range of evidence. In this way, recording of the spatial distribution of plant species is assured, offering us the possibility of reconstructing the layout and functioning of the funerary pyre.

In our case, data have been gathered from rural (Cresses Basses, Renaussas, Soumaltre, Vigne de Bioaux) and peri-urban settings (Peyre Plantade) (Fabre 2004, 2005b; Figueiral *et al.* 2010a).

The diversity of woody plants exploited (minimum of 27 species) suggests the absence, in general, of both particular selection and restrictive rules. Plants identified include arboreal (*Abies sp., Acer* cf. *monspessulanum*, *Cupressus* sp., *Fagus sylvatica*, *Juglans regia*, *Larix decidua* / *Picea abies*, *Olea europaea*, *Pinus* type *halepensis*, *Pinus type sylvestris*, *Prunus* type *dulcis* / *persica*, *Quercus* –deciduous and evergreen–, *Ulmus* cf. *minor*) and shrubby-lianescent taxa (*Acer campestre*, *Buxus sempervirens*, *Cistus* sp., *Clematis* sp., *Cornus* sp. *Erica* sp., *Juniperus* sp., *Pistacia lentiscus*, Rosaceae type *Crataegus*, Rosaceae type *Prunus spinosa*, *Viburnum tinus*, *Vitis vinifera*) (Fig. 3).

However, certain activities linked with the burial ritual may eventually have favoured the sporadic choice of specific species; this seems to be the case of *Cupressus* identified in a fireplace associated with inhumation tombs at Vigne de Bioaux and at Soumaltre. This species is also identified at Rec de Ligno associated with the inhumation of a small child.

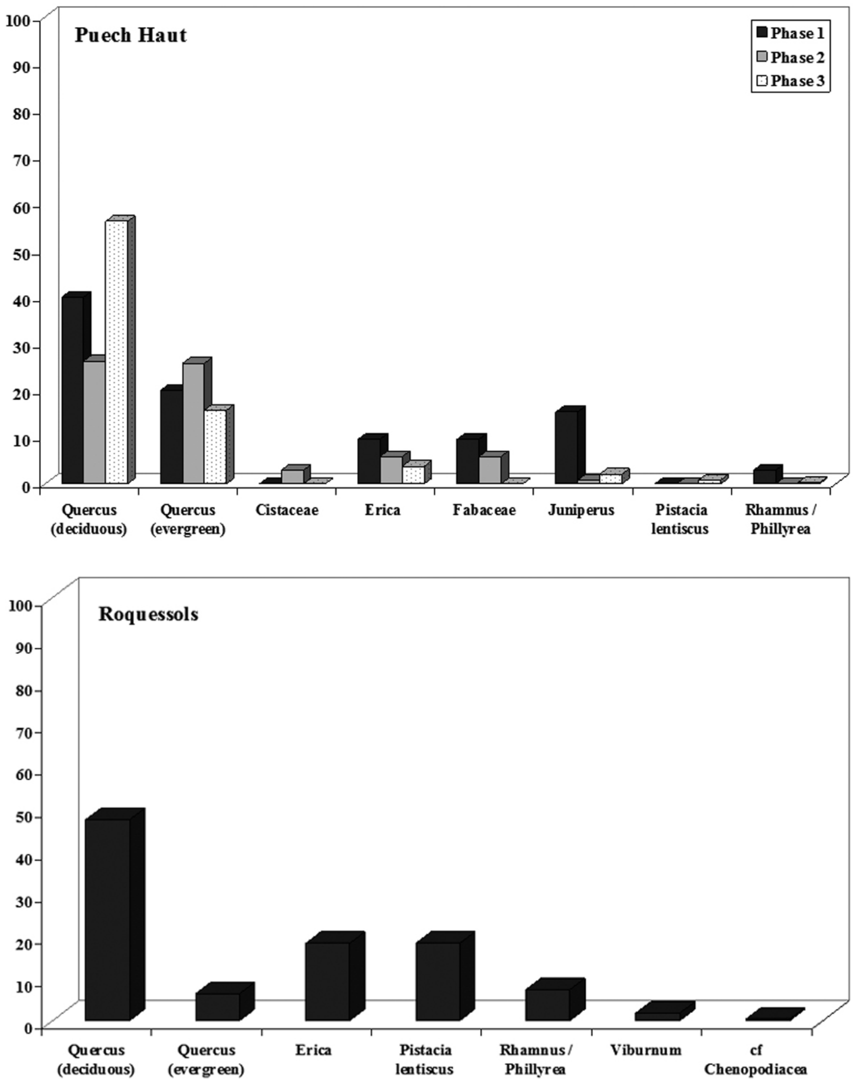

Figure 2. The Late Neolithic is characterized by the abundance of taxa affiliated with open spaces: the example of Puech Haut and Roquessols (relative frequencies).

The use of branches of small calibre may be explained by the technical requirements of the cremation process. The efficiency of the pyre depends on its structure, conceived to maintain the oxygen flow, and on the feeding of the fire to ensure a constant temperature.

The exploitation of the charcoal record from the individual graves, combined with the evidence from fruit / seeds, anthropology and artefacts may still reveal hidden patterns, which are for the moment impossible to recognize.

The second perspective is provided by the study of plantation pits which covered large surfaces (Labournas, Champ Redon, Renaussas, Rec de Ligno). Three main types are distinguished: pits (*alvei*) and trenches (*sulci*) are linked with the cultivation of grapevines while square-shaped pits are associated with orchard areas and fruit trees. While the first type of pits, linked with grapevine cultivation, has been uncovered on a regular basis in this region (Pomarèdes 2005) the same can not be said of the square-shaped orchard pits. As a result, ten on these pits (Champ Redon) were selected to test the type of the information obtained from this kind of structure, and its eventual reliability in terms

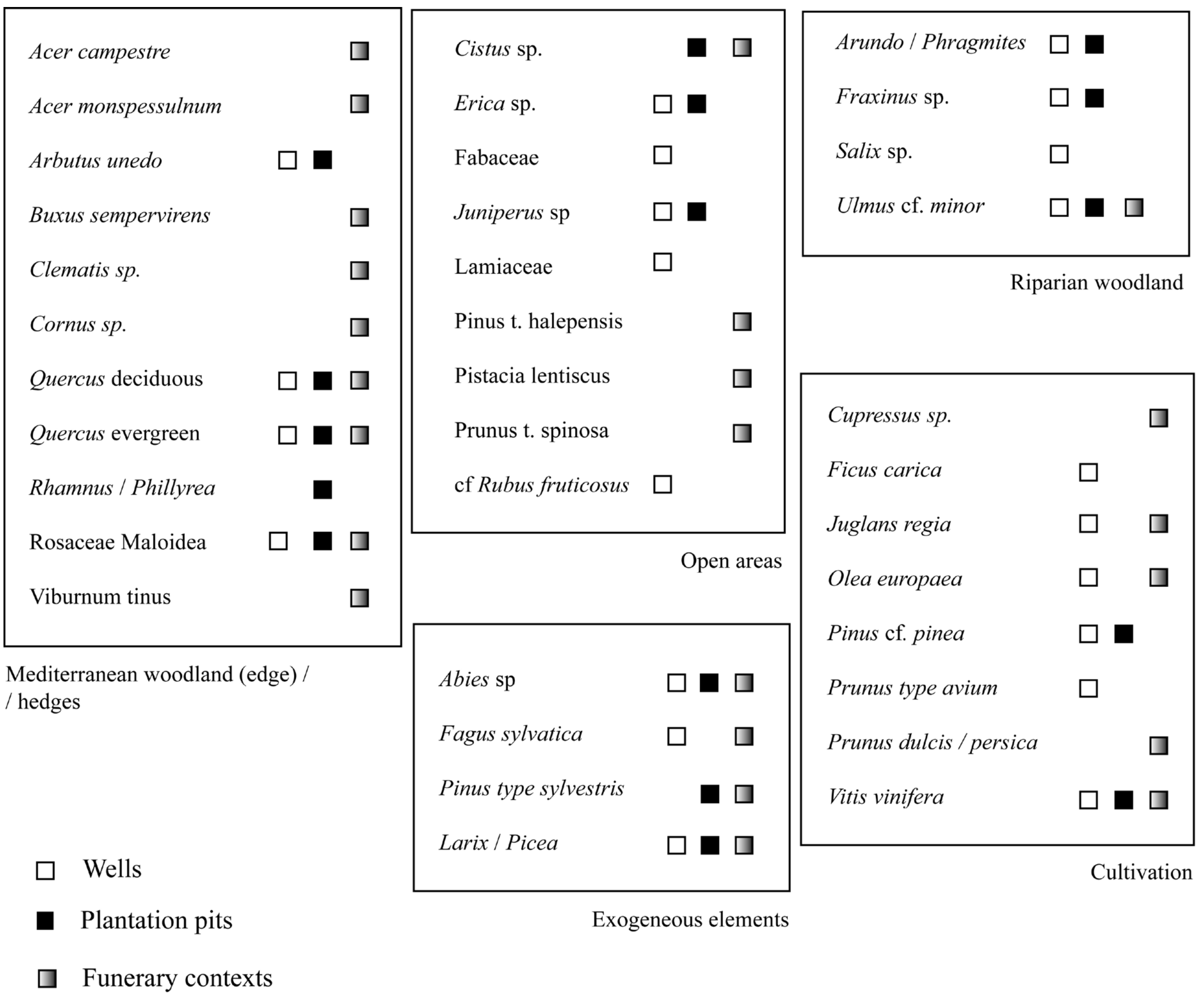

Figure 3. Gallo-roman woody plant resources: three perspectives (Wells, Plantation pits and Funerary ensembles).

of palaeoenvironmental reconstructions.

The excavation of these pits revealed a stratigraphy composed of (1) a lowermost soil level, (2) a "sooty" layer and (3) the root clump surrounded by sediment.

The analysis of the charcoal fragments included in the 'sooty' layer provided unexpected results: the taxonomic diversity recorded, in the whole of the pits, can be considered as remarkable, including sixteen species at least. They include: *Abies* sp., *Arbutus unedo*, *Cistus* sp., *Erica sp.*, *Fraxinus* sp., *Juniperus* sp., *Larix decidua* / *Picea abies*, Monocotyledon, *Pinus* type *sylvestris*, *Pinus pinea* / *halepensis*, *Quercus* (deciduous and evergreen) *Rhamnus alaternus* / *Phillyrea* sp., Rosaceae Maloideae, *Ulmus* cf. *minor* and *Vitis vinifera*. These qualitative results (Fig. 3) are very similar to those usually found when analysing charcoal from domestic contexts. Quantitative results may also be considered as consistent with long-term deposits.

This suggests that the waste from household wood-fuel may have been 'recycled' and used as a fertiliser in agriculture in association with other biological material and pottery fragments. This impression seems to be confirmed by the study of the terrestrial molluscs from three pits (S. Martin in Figueiral *et al*. 2010a) which show that the information obtained from the 'sooty' layers is clearly different from that of the other levels. The higher frequencies of *Cernuella virgata* and *Monacha cantiana* may result from intentional anthropogenic input.

The A 75 project has provided crucial evidence of the role played by arboriculture in the local agrarian economy. However, the recovery of plant material from the interior of these pits does not imply that data obtained will provide information on the actual species planted. Only in the unlikely event of an *in situ* charring would this information be available. It is therefore necessary to get this data in a different way. In our case we can argue that the charcoal recovered in the pits actually suggests two possibilities, *Olea europaeae* and *Juglans regia*, species which were also identified in the funerary ensembles; *Prunus dulcis* or *Prunus persica*, identified in the tombs is also a strong candidate.

The availability and use of plant resources can be approached via a third perspective, which is offered by the study of lined wells, such as those uncovered at Mont Ferrier, Rec de Ligno and Mazeran. Their excavation, which obeys strict safety procedures, was carried out by Jean-Marc Féménias (ARCHEOPUITS) and rewarded us with a great wealth of material and information.

The first well is located in the courtyard of a small *villa* which includes areas dedicated to wine making (Compan 2011) while the second is associated with a funerary and 'ritual' complex in the vicinity of a wine producing establishment (Jung and Bel 2010); the last structure, away from any identifiable buildings, was part of a more complex subterranean hydraulic structure interpreted as a underground irrigation system for the recovery of infiltration water (Haurillon 2011).

The quantity and diversity of plant material vary from one well to the other, comprising fruit / seeds, waterlogged wood and charcoal.

In what concerns wood / charcoal, we consider that while some of the debris might have fallen naturally or been lost accidentally, most of them should result from the use of wells as a rubbish dump. The most relevant wood and charcoal data were obtained in the first well and provide a clear image of the major biotopes exploited by the local population.

The exploitation of wood resources (woodfuel, light and heavy building material, raw material for handcraft activities) targeted several biotopes which are perceived in the wells (Fig. 3):

- The mixed oak woodland and its fringes are represented by *Quercus* (deciduous and evergreen), *Arbutus unedo* and Rosaceae/ Maloideae.

- Heliophilous plants such as *Erica* sp., Fabaceae, *Juniperus* sp., Lamiaceae and *Rubus fruticosu*s would thrive in open, sunny areas such as abandoned agricultural plots.

- Trees / shrubs which usually grow along stream / river banks include *Arundo* / *Phragmites*, *Fraxinus* sp., *Salix* sp. and *Ulmus* cf. *minor*. The abundance of *Arundo donax* / *Phragmites australis* at Mont Ferrier is difficult to explain in terms of local ecology alone and may result from specific activities carried out in the vicinity. Similar results have been obtained in other agrarian sites (Figueiral *et al* 2010a and b).

- Species interpreted as being cultivated locally comprise *Ficus carica*, *Juglans regia*, *Olea europaea* and *Vitis vinifera*. The trilogy already recorded in the plantation pits and in the funerary contexts is once again identified. The status of *Ficus* is more difficult to assert as, it can grow wild in different habitats.

The same problem is felt when dealing with the remaining trees identified, which do not grow at present in the mesomediterranean level. The presence of *Fagus sylvatica*, *Abies* sp., *Larix decidua* / *Picea abies*, already identified in the other contexts, may result both from exchange / trade and from the survival of isolated specimens in favourable and protected lowland locations. This second hypothesis (applied to *Fagus* and *Abies* alone) is supported by the regular identification of these species in sites from the lowlands, all chronologies considered (Chabal 1997; Durand 1998; among others).

CONCLUSIONS

The wealth of information obtained clearly vindicates the central role of preventive archaeology and linear projects in the development of archaeological research in general.

The cross-disciplinary and cross-cultural/ chronological framework outlined by data from the different palaeoenvironmental disciplines clearly draws a complex picture of human occupation and activities. It also allowed us to show the importance of recognizing chrono-cultural disparities in order to understand their influence in the establishment and evolution of vegetal landscapes.

The very open environments documented already during the Late Neolithic invite us to reconsider the impact of anthropogenic disturbance this early in time. While some untouched woodland must have lingered further away from settlements and adjacent exploited areas, it seems possible that intensive land exploitation by middle Neolithic populations may have resulted in the disappearance of large areas of primary arboreal vegetation. This could eventually explain the results obtained for the subsequent cultural period. In southern France, Chasséen populations have been previously identified as agents of important ecological changes (Heinz *et al*. 1993; Heinz and Thiébault 1998; among others).

Data from the Gallo-Roman period helped us clarify the role of small and medium sized agrarian establishments and to identify the diversity of the surrounding environment and of its exploitation.

The "A 75 experience" has also highlighted the importance of a scientific coordination for the paleoenvironmental studies, to provide rapid guidance during field work, to deal with strategic choices in terms of sampling, to assess the potential of remains in terms of research projects, and to ensure that specialists are kept informed of developments.

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Evidence of palaeogeographic constraints on woodlands on the shores of a coastal lagoon during Antiquity: charcoal analysis of the Prés-Bas villa and Le Bourbou (Loupian, Hérault)

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***Summary**: During Antiquity, the mixed oak woodland and the vegetation of the alluvial plain developing on the shores of the Thau lagoon were exploited as a source of wood fuel, as shown by charcoal remains from the villa of Prés-Bas and the pottery workshop of Le Bourbou. Taking into account the local ecology and the vegetation transformations during the second part of the Holocene, charcoal data exemplify the long term opposition between the northern and the southern shores of this lagoon.*

***Key words**: Roman villa, Antiquity, palaeobotany, coastal environment, effects of human activities.*

INTRODUCTION

The purpose of this study is to understand the environmental evolution and exploitation, on a coastal lagoon during Antiquity. This work is based mainly on charcoal analysis carried out at the roman *villa* of Prés-Bas and the nearby pottery workshop of Le Bourbou, located beside the Mediterranean Sea in southern France. The two sites provide complementary information on six centuries of human occupation and can be understood due to a larger archaeological and palaeoenvironmental background, provided by other studies, as cited in the following sections of the article.

Fortunately, the margins of the Thau lagoon, occupied since the early Neolithic, provided abundant archaeological, palaeobotanical and palaeogeographic information. The long term coastal morphological evolution and vegetation history (based on geomorphology, palynology, archaeobotany) are used as reference in an attempt to distinguish the role of physical conditions and human incentive.

GEOGRAPHICAL CONTEXT: A COASTAL LOCATION

The *villa* of Prés-Bas is located at Loupian

(Hérault) (13 m a.s.l.), an area once included in the Roman Narbonnaise (Fig. 1). During Antiquity, the *villa* was situated *c.* 1.2 km from the northern shore of the Thau lagoon, on the Mio-Pliocene plain delimited by the Jurassic limestone substrate of La Gardiole. The site of Le Bourbou – a pottery workshop, a harbour and a small village – was located on the very edge of the lagoon. The absence of a permanent river in the northern coast explains the very slight sedimentary infilling of the lagoon. Only the temporary streams draining the limestone reliefs, away from the lagoon, bring sediments to the northern shore. The very slight strength of these streams explains why Bronze Age sites were found in the lagoon under a very thin layer of sediment.

The Thau lagoon, 5 km large, includes an offshore sand bar, overlying an isthmus, linking two limestone reliefs: the Mont Saint-Clair, at Sète, and the Mont

Figure 1. Location of sites.

Saint-Loup (ancient volcano of Agde). At present, narrow passages link the lagoon to the sea. During the Holocene, the Mont Saint Clair had a continental setting first, becoming an island afterwards as a consequence of rising sea level. Probably a perched lagoon existed temporarily. Finally, the expansion of the offshore bar separated the sea from the actual lagoon, shortly after 7500 BP (Court-Picon *et al*. 2010).

ARCHAEOLOGICAL CONTEXT: A PROSPEROUS GALLO-ROMAN *VILLA*

Middle/Late Bronze Age communities occupied both the northern and the southern shores of the lagoon (Leroy *et al.* 2003) while all known Gallo-roman sites are located on the northern shore.

The excavation of the *villa* of Prés Bas (supervised by Christophe Pellecuer and Iouri Bermond) showed that the main building area occupied a surface of *c.* 1ha, from which only 1/3rd was excavated.

The *villa* was occupied from 50 BC to 600 AD. Built first as a modest farm (phase I: 50 BC/50 AD) it was later transformed into a rich patrician domain (phase II: 50/350 AD) with *thermae* and a courtyard with colonnade. The cellar (315 m^2), with a capacity for 1500 hl provides evidence of an economy based on viticulture. The amphorae for the *villa* were produced by the lagoon at Le Bourbou, active between 50 and 425 AD. The five kilns of the pottery workshop also produced domestic pottery and construction materials, such as tiles. During the 4th century, the *villa* was partially rebuilt as a rural residence (Phase IIIa: 350/375 AD). Under the residential apartments, a complex underground heating system was installed. The thermae complex includes warm / hot chambers and a *piscina* whose walls were heated by hot air transported from the furnace via a system of terracotta pipes. The *pars rustica* was extended. During the 5th century, the *villa* was transformed into a magnificent residence (Phase IIIb and IIIc: 375/6th AD) with rich polychrome mosaic floors (Bermond and Pellecuer 1997; Pellecuer 2000).

CHARCOAL SAMPLING AND DATA

Charcoal was sampled from the domestic deposits of the *villa*, the hypocaust and the pottery kilns by dry sieving (4 mm mesh), to ensure the reliability of data, their paleoenvironmental representativity and the correct identification and interpretation of the area targeted for wood collecting (Chabal 1997).

The paleoenvironmental interpretation is mostly based on the charcoal diagram representing the study of 4600 charcoal fragments from domestic residues sampled in the *villa* (Fig. 2). Further interpretations are based on other contexts, such as the hypocaust deposits of Phase IIIa and the kilns from Le Bourbou.

DIAGRAM RESULTS

Charcoal analysis provided a large plant spectrum with 33 species, at least (Fig. 2).

Evidence of an evergreen oak (*Quercus ilex)* dominated woodland is recorded during all the occupation. Very low frequencies of deciduous oak, most probably *Quercus pubescens*, are recorded. We know by now that the exploitation of the Mediterranean oak forest favours *Quercus ilex*, which resprouts better than *Quercus pubescens* (Chabal 1997). Our results seem to illustrate this type of woodland, exploited by the occupants of the *villa*.

The abundance of *Olea europaea* and the presence of *Cupressus*, *Vitis vinifera, Juglans regia* are particularly noted. The abundance of *Olea* is quite unexpected. In the flatlands of the Languedoc this species usually appears very sporadically. This may indicate good local thermic conditions, as also suggested by palynology (Court-Picon *et al*. 2010). *Cupressus*, probably introduced, is infrequently identified in France. During Antiquity it is mostly present in burial contexts.

Other species, associated with humid conditions (*Fraxinus, Ulmus, Tamarix, Acer*) are little represented. This is quite surprising as even now, when little natural vegetation is left, a fringe of mesophilous vegetation well adapted to the lowlands, is still observed. More precisely, in present-day woodlands, *Fraxinus oxyphylla* and *Ulmus minor* grow near *Quercus ilex* which takes over when topography rises a little.

Key-observations from this diagram can be summarized as follows:

• In a context of Mediterranean oak woodlands, the dominance of evergreen oak is considered as a normal result of wood exploitation.

• The very low representativity of the mesophilous woodlands is however surprising as the *villa* is located at a very low altitude. It is clear that the land was exploited for vine growing and other economic activities. The plain was certainly partly deforested. But these alone can not explain the very low representativity of the exploited alluvial woodlands during this period. Even now, when the area is almost completely deforested, *Ulmus* and *Fraxinus* still survive further west, as residual groves on alluvial soils.

The other contexts studied may provide an explanation for our results, as we will explain next.

CONCENTRATED CHARCOAL FROM THE HEATING SYSTEM (HYPOCAUST)

In the *villa*, data from the underground heating system of two rooms (300/375 AD) reveal the use of diverse species (9 taxa for 540 charcoal fragments) (Fig. 3a): *Quercus* (deciduous), *Quercus coccifera*/*ilex* and *Ulmus* predominate (and not only *Quercus coccifera*/*ilex* as in the domestic fuel). Their frequencies vary slightly according to the 8 sampling areas, i.e. *praefurnium* (furnace) or hypocaust pipes (Fig. 3b).

Do these frequencies result from a representativity chance due to the type of deposit? Indeed we know that charcoal coming from concentrations (instant deposits), very often represent only the last fires (Chabal 1997). Is this the case in these deposits? Frequency of the three main taxa varies very slightly in the different sampling areas of the room 5. A single locus contains almost only *Quercus coccifera/ilex,* in room 1.

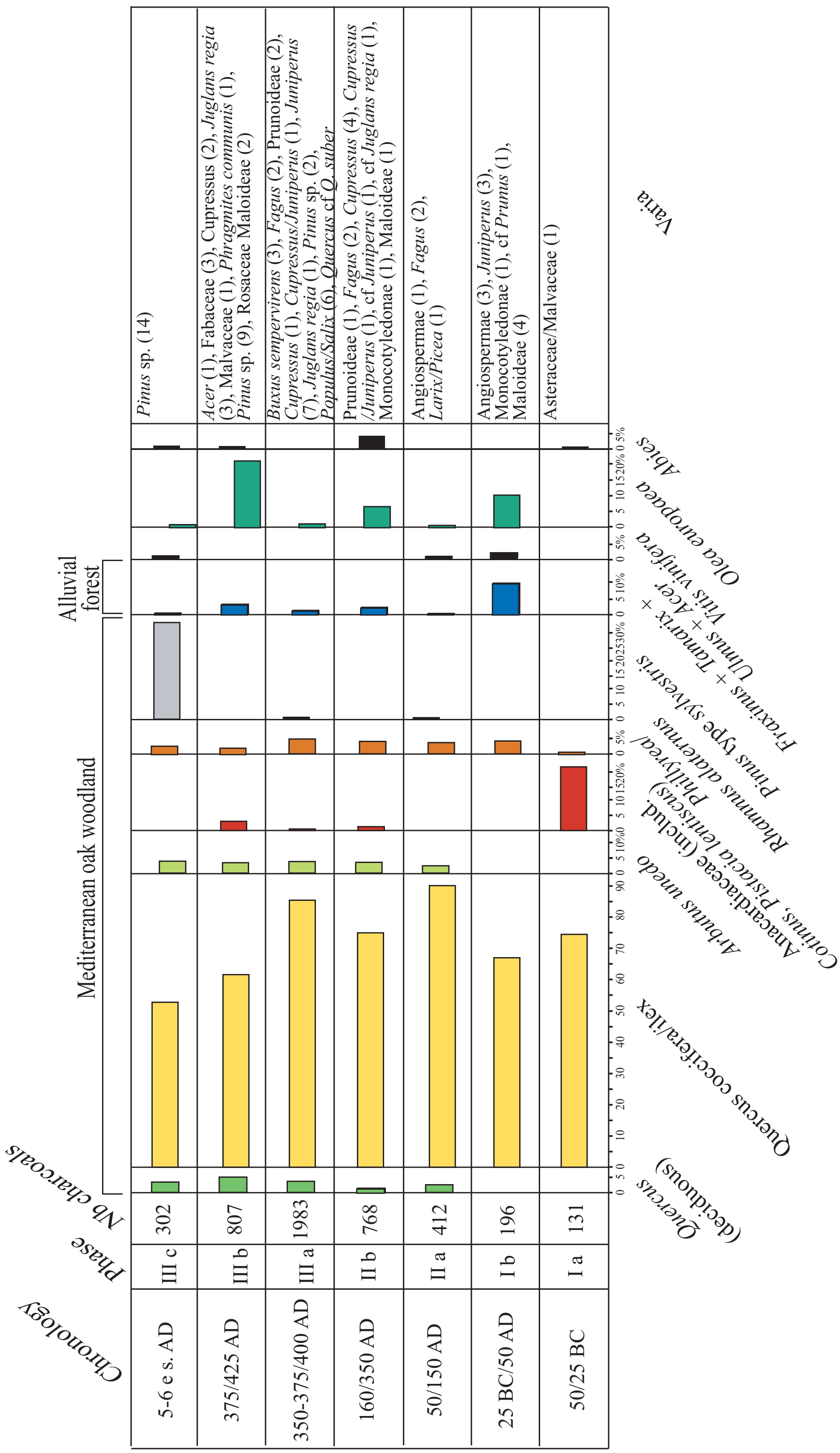

Figure 2. Charcoal analysis diagram of the *villa* of Prés-Bas (Loupian, Hérault).

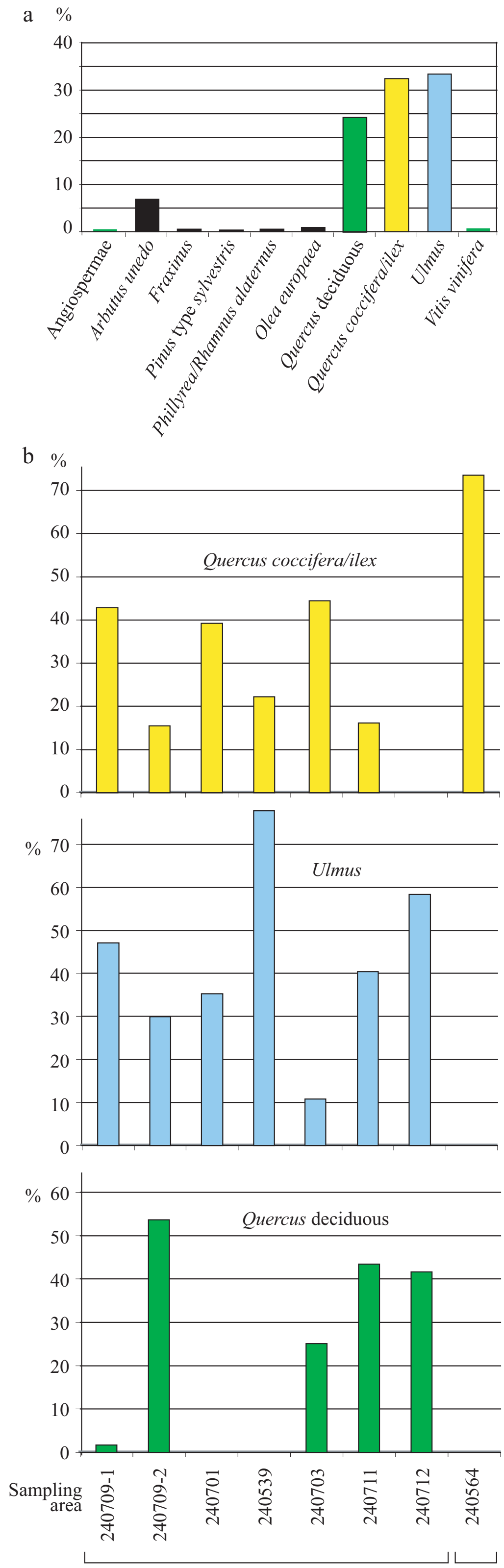

Figure 3. Charcoal analysis of the heating system of the villa, rooms 1 and 5, phase IIIa: 350-375/400 AD): (a) Percentages of the 10 taxa identified (total). (b) Percentages of the 3 main taxa, in 8 sampling areas.

Thereby, results from the hypocaust are very different from those of the domestic fuel, showing that mesophilous woodlands were also well exploited. Two questions should be answered to explain this difference:

• Is the wood used in the heating system subject to selection? Intentional selection appears as an unlikely explanation, as the three main species identified in the hypocaust are hardwoods, with similar behaviour during combustion (Théry-Parisot 2001; Théry-Parisot *et al.* 2010).

• Are different woodland areas exploited for the domestic area and for the heating system? Coppices of holm oak, providing most of the domestic fuelwood, could have been exploited on the hills behind the *villa*, beyond the cultivated areas, and even further away. A more reduced area of ancient woodland could have provided a separate provision of fuelwood for the hypocaust. This mixed or alluvial woodland, older than the oak coppices, could have provided wood of a larger calibre, more appropriate for the slow and continuous heating of the hypocaust. This seems to be the most likely explanation.

THE POTTERY KILNS OF LE BOURBOU

Five pottery kilns, which functioned from 50 to 425 AD, provided a large amount of charcoal fragments. From these, 3500 fragments have been analysed. We must however draw attention to the fact that some samples, collected in nearby deposits, may not belong to the kilns, as they were associated with domestic or metallurgical artefacts. The potters from the Bourbou used 23 species, at least. Fragments of *Quercus coccifera/ilex* and associated species predominate; this result is similar to that obtained in the domestic contexts of the *villa*.

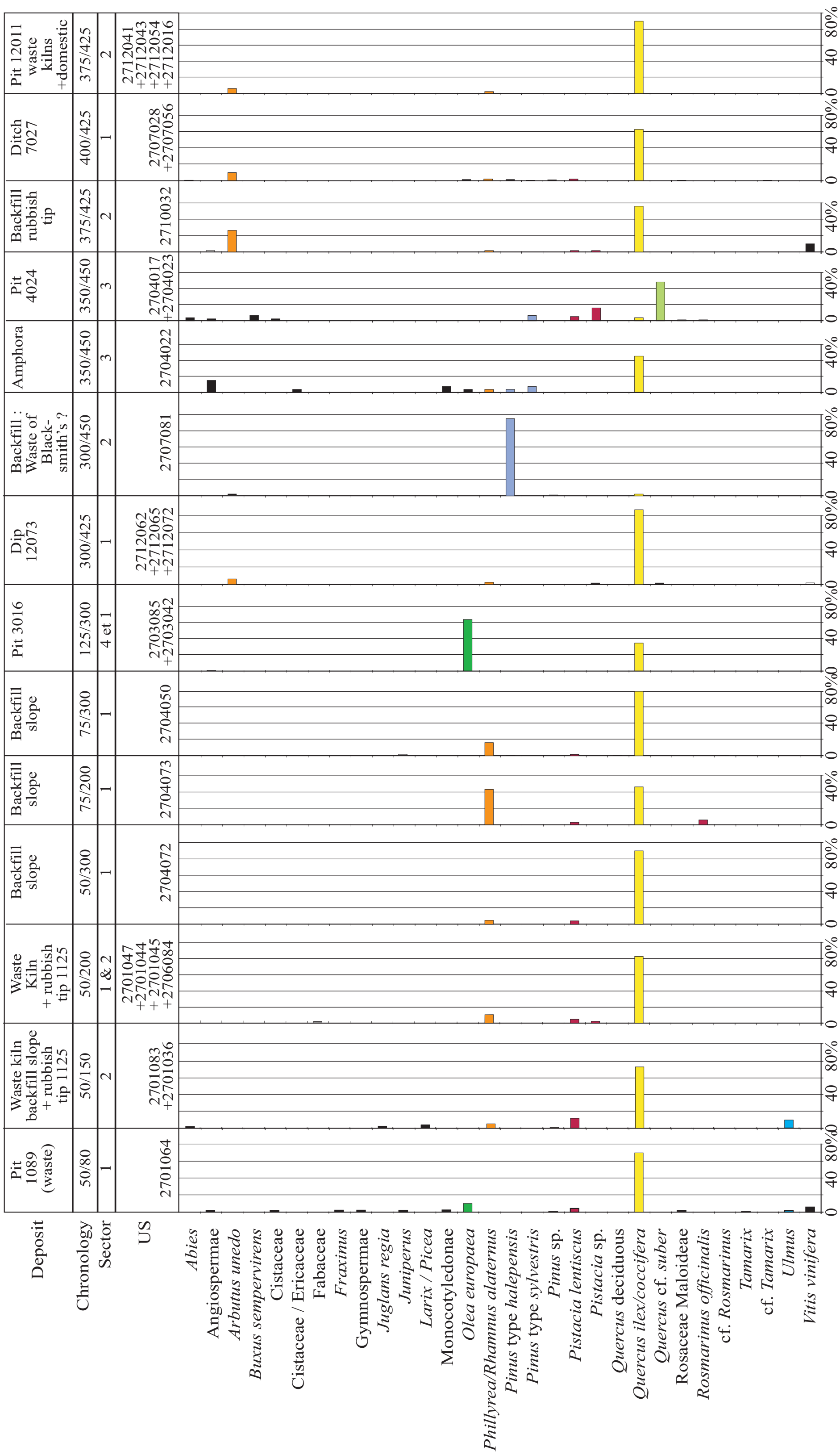

Figure 4. Le Bourbou (pottery kilns): charcoal identification (50 / 425 AD).

The great diversity of species used is not surprising. It has been observed previously in other pottery kilns, such as those of Sallèles d'Aude (Hérault, France) (Chabal 2001). Wood calibre and humidity seem important factors to take into account for this activity, while the species used seems to be of no consequence.

As the deposits are not directly correlated with the phases identified in the *villa*, and the chronological intervals are difficult to match, data are presented as a bar graph, sample by sample, organized by chronological order (Fig. 4). Dominant taxa characterize woodlands rich in *Quercus ilex,* associated with shrubby Mediterranean species such as *Arbutus unedo*, *Phillyrea* or *Rhamnus*, *Pistacia lentiscus*, *Rosmarinus officinalis*. Mesophilous taxa (*Fraxinus*, *Ulmus*, *Juglans regia*…) appear sporadically.

Two anomalies are noticed: the abundance of *Olea europaea* in the pit of one kiln, and of *Pinus* type *halepensis* in the waste from an iron kiln. These frequencies may result from deposit alias. We must however consider that *Olea* and *Pinus* are both rich in flammable compounds; the possibility of a selection based on calorific power must therefore be taken into account, even considering that charcoal is the most adapted fuel for iron smelting.

LONG TERM TRANSFORMATIONS OF THE COASTLINE

Our results seem to indicate that vegetal landscapes from the northern shore have not changed noticeably during the six centuries of human occupation.

Based on the species identified (Holm oak woodlands, cultivated species and plants from the alluvial plain) it appears reasonable to think that the supply area must have included the very near proximity, on the northern shore only.

Quercus coccifera/ilex (probably Holm oak) and associated species are the main components of the fuelwood used both in the *villa* and in the pottery workshop. Coppices of holm oak probably covered the hills behind the *villa.* The wood supply must have been well organized, using all species available without discrimination. Calibre and humidity may have been the factors mainly taken into account.

Inside the *villa*, differences between the domestic areas and the heating system are observed. The observed differences may reflect different supply areas. Deciduous *Quercus* and *Ulmus* could have been the dominant species of ancient alluvial woodlands situated close to the northern shore of the lagoon.

The ecological connotation of this interpretation is supported by our current knowledge of the long term transformations of the coastline.

Geomorphological studies were the first to highlight the complex paleogeographic evolution of this coastal area during the Holocene (Vella and Provansal 2000; Court-Picon *et al.* 2010).

A recent pollen diagram from the southern shore (SETIF) covering the last 7500 years illustrates the Holocene warming (Court-Picon *et al.* 2010). Since the early Neolithic, the stability of the relief (Mont Saint-Clair) favoured the development of a very early Mediterranean thermophilous vegetation, with a continuous curve of *Quercus ilex* and an initial peak of *Phillyrea*, a pioneer species. From the Neolithic to the present, the Mediterranean mixed oak woodland, rapidly becomes dominated by holm oak and xero-thermophilous matorrals. This thermophilous vegetation caraterizes this coastal shore. Unstable environments (sand bar, lagoon banks) and human activities are also perceived.

Other studies, as cited below, include abundant organic macro-remains recovered from the Late Bronze Age dwellings built on the shores of the lagoon, when the sea level was *c.* –2 m a.s.l.

On the southern shore, archaeobotanical data (wood, charcoal, seeds and fruits) from La Fangade show that the majority of the agrarian activities and wood cutting took place in the xero-thermophilous areas, i.e. on the southern shore (lido and Mont Saint-Clair) (Bouby *et al.* 1999; Chabal *et al.* 2010).

On the northern shore, only mesophilous species are recorded when identifying 89 posts from Montpenèdre (*Ulmus*, *Quercus* deciduous, *Populus*, *Fraxinus*, *Salix)*, while data from La Conque identify two contrasting habitats: the alluvial/mesophilous areas with deciduous *Quercus*, *Ulmus*, *Fraxinus*, *Juglans* and the drier areas colonised by *Quercus coccifera/ilex* (Leroy *et al.* 2003). At La Conque, fruits and seeds from alluvial/mesophilous areas were the most represented (Bouby *et al.* 1999; Leroy *et al.* 2003). Thus, in the northern shore, the nearby plant environment is also represented in the archaeobotanical remains.

Based on the information obtained in all these studies, we believe that, during the Bronze Age, very different landscapes existed in the northern and southern shores of the lagoon, as a result of local conditions. On the northern shore, a slight alluvial sedimentation was sufficient to allow a fringe of alluvial forest to settle. On the southern shore, the south-facing thermophilous conditions of Mont Saint-Clair preserved during and after the Bronze Age the holm oak woodlands and the thermophilous vegetation. This complex history can be summarized as follows (Fig. 5):

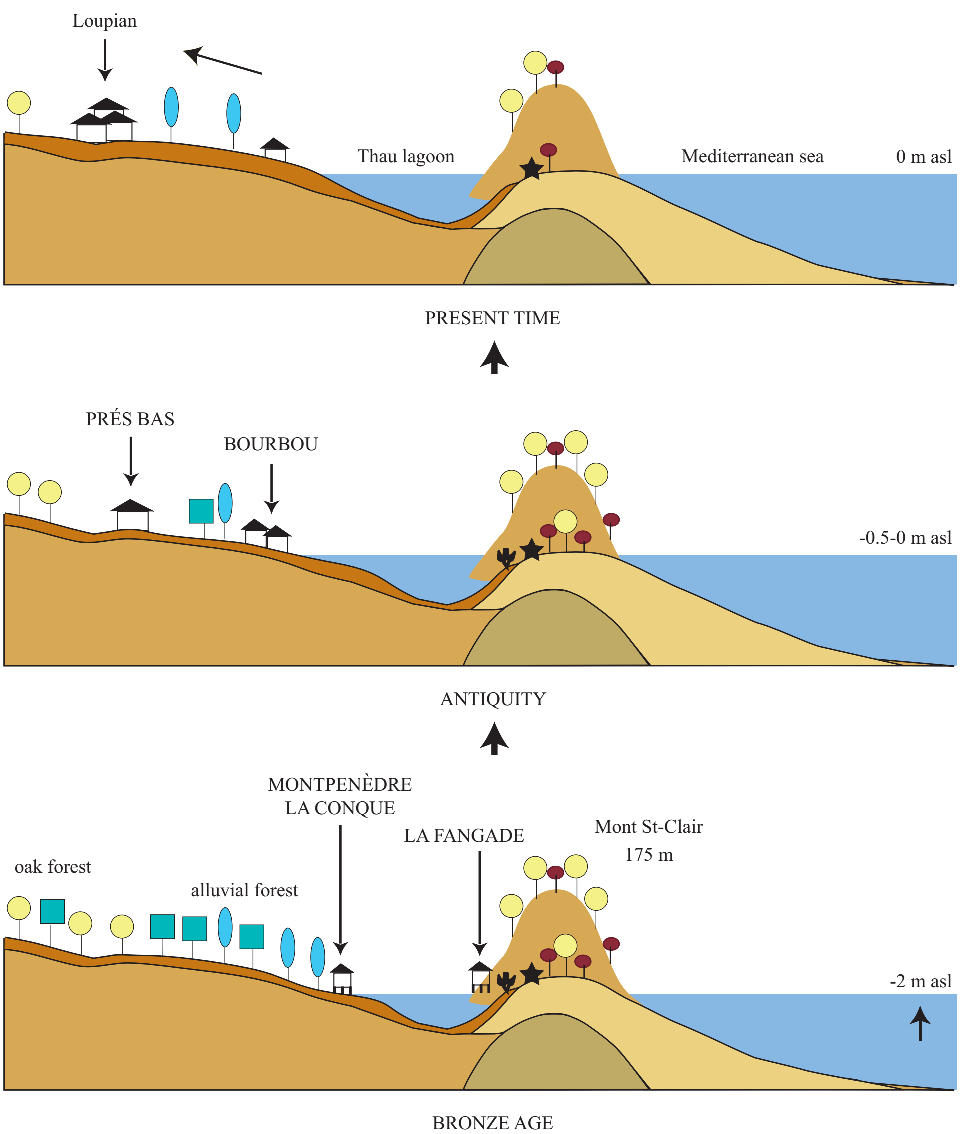

Figure 5. Long term woodland transformations on the shores of the Thau lagoon.

• During the Bronze Age, the rise of sea level slowed down and a fringe of alluvial vegetation developed on the northern shore (but not on the southern shore which is rocky and sandy). This spread of the alluvial vegetation is also recorded in other sites of the Languedoc located in similar settings (Chabal 1997; Cavero and Chabal 2010).

• During Antiquity, the sea level was *c.* 1.5 m higher than during the Bronze Age. As a result, in the northern shore, the alluvial plain may have been partially submerged. The mesophilous forest may also have been cleared for agriculture during the Iron Age. As a result, oak dominated areas may have become the main available woodlands. This would explain the little representativity of mesophilous / hygrophilous species in our two sites. However, they would not have disappeared completely as they are identified in the hypocaust.

In mixed woodlands, the exploitation of wood would rapidly favour *Quercus ilex* over *Quercus pubescens* (Chabal 1997). People living in the *villa* exploited the drier areas of the low hills, as well as the more humid areas / older stands. This was complemented by a more opportunistic supply (pruning of cultivated trees).

• After Antiquity, sedimentation started again, via water runoff and temporary streams. This is why, on the northern shore, we notice at present, a narrow fringe of alluvial vegetation, narrow because the land has not progressed towards the lagoon. Furthermore, in the last decades, the migration of alluvial species towards more inland areas has been noticed, which may suggest that during Antiquity, the lowlands were drier (better drainage) than at present.

CONCLUSIONS

Our perception of local woodlands based on fuel used during Antiquity is in conformity with the ecology characterising the northern shore of the lagoon and its long term evolution. Especially, it reflects the differences noted since the Bronze Age, taking into account the rise of sea level and the alluvial deposits on the northern bank. Based on the species identified (plants from the oak forest, from the alluvial plain, or cultivated species) it appears reasonable to think that the supply area must have included the very near proximity.

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Charcoal analysis at the San Chuis hill fort (Allande, Asturias, Spain)

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***Summary**: The archaeological site of the San Chuis hill fort (Allande, Asturias, Spain) is located in the central part of the western Cantabrian Range. The site was occupied between 920 - 480 cal BC (2870 - 2430 cal BP) and 100 cal BC - 540 cal AD (2050 - 1410 cal BP). Repeated and long-lasting occupation resulted in the overlapping of architectural structures from the first and second Iron Ages and the Roman Period. The study of the wood charcoal remains from these structures allows us to distinguish two groups of wood remains. Those timbers used in the construction of the buildings and those used as firewood.*

***Key words**: Hill fort, Iron Age, Roman period, firewood, timber, woodland exploitation.*

INTRODUCTION AND ARCHAEOLOGICAL BACKGROUND

The San Chuis hill fort (Allande, Asturias, Spain) is located in the western part of the Cantabrian Mountains at an elevation of 780-800 m a.s.l. and 35 km from the coast (Fig. 1). The site is situated between the Eucolino and Submontano bioclimatic levels and within the vegetation series of *Quercus robur* and *Quercus pyrenaica*. Between 600 and 1200 m a.s.l., the average annual rainfall exceeds 1000mm and it is here that *Quercus pyrenaica* woodland is found, including *Corylus avellana*, *Acer campestre*, and *Fraxinus excelsior*. In the clearings, various shrubs of the *Genista*, *Erica*, *Cytisus*, etc. genera are also present (Costa *et al*. 2005).

The hill fort was discovered in 1952 and excavated by Professor Francisco Jordá Cerdá during the 1960's and 1980's, while over the last ten years excavations have continued by one of the authors (Jordá 2009). The sequence covers a long period of time from 920 to 480 cal BC (2870 - 2430 cal BP) and from 100 cal BC to 540 cal AD (2050 - 1410 cal BP) (Fig. 1). The minimum span of this occupation is 1160 years. The chronology of the settlement is finely defined by nine radiocarbon dates (Jordá *et al*. 2002; Marín *et al*.

2008). Three occupation phases were distinguished on the basis of the dates, the stratigraphy, the overlapping structures and the materials recovered. The two earliest phases are associated with indigenous populations and the latest with the Roman reoccupation of the area.

The earliest settlement is located in the upper quarter of the hill fort, where the remains of a timber structure built over the rocky substrate was uncovered. The structure, which was dated to between 890 and 530 cal BC, contained burnt seeds and pottery of the first Iron Age. The following occupation phase was characterized by the construction of circular stone structures in

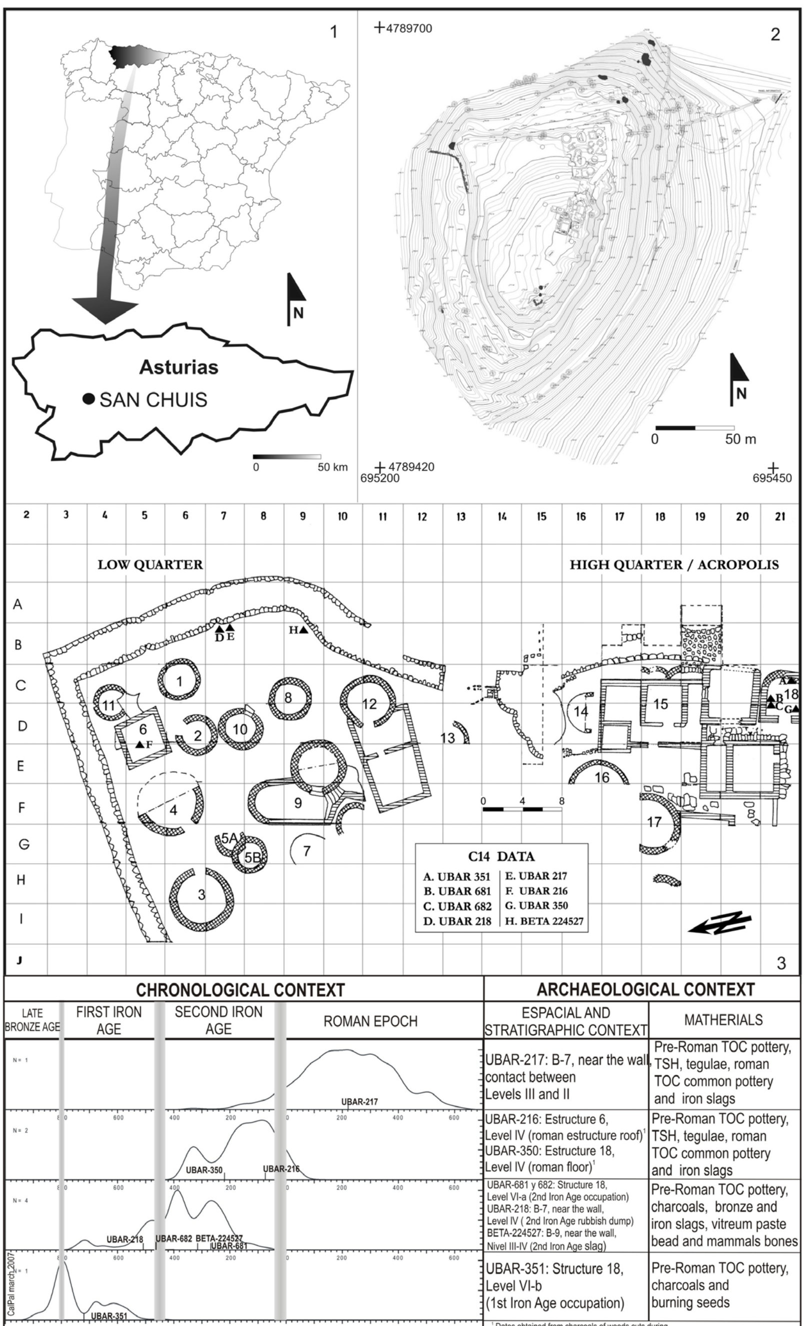


Figure 1. Location and chronological sequence of San Chuis hill fort.

both the upper and lower quarters of the fort, and was dated between 710 and 130 cal BC. Associated with these structures was pottery of the Second Iron Age and remains associated with metallurgical activities. The third occupation phase was dated to the Roman period between 110 cal BC and 530 cal AD. It is characterized by rectangular stone structures, densely built in the upper quarter, either over the previous circular ones or on new foundations. Pre-Roman pottery, *Terra Sigillata Hispanica*, *tegulae*, along with significant quantities of Roman pottery and iron slag was found in this settlement.

The recovery and analysis of wood charcoal samples from San Chuis is significant in the study of Asturian hill forts. There are a small number of other palaeoenvironmental analyses from archaeological sites in the area, including La Campa Torres (Buxó and Echave 2001), Camoca, Moriyón and Olivar (Camino 1999). The new data from San Chuis will enrich our knowledge of the past vegetation and use of timber in these types of hill fort sites.

METHOD AND MATERIALS

The wood charcoal samples presented in this paper were recovered during the excavations of the early 1980's. The aim of their collection was to obtain radiocarbon dates and sampling was therefore restricted to those layers and structures that needed to be dated. Part of the charred material recovered at that time was processed for radiocarbon dating without previously obtaining botanical identification of the wood charcoal remains. The analysis of the rest of the material is presented here, thirty years after its recovery during excavation. For these reasons, the results of the analysis relate only to certain parts of the site, and not to systematic sampling of the whole excavated area.

Wood charcoal samples from the indigenous settlement (level VI) were found at the bottom of circular structures and in a waste pit that correspond to the earliest occupation of the hill fort (UBAR-351: 2600±60 BP). The charred wood remains originate from the clearing out of domestic hearths and they represent firewood collection within the catchment of the site (Table 1).

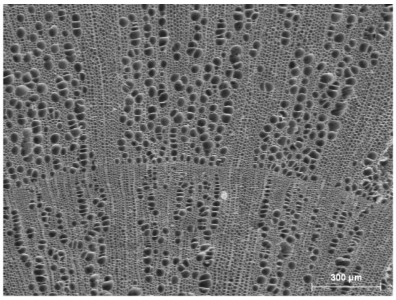
Wood charcoal samples from the Roman period are scarce; with two found scattered in the Roman occupation level IV and one in the collapse layer of an observation tower (level IIIb – UNBAR-216: 2050±50 BP). This latter sample was of construction timber from the tower, which was destroyed by fire and eventually collapsed.

For the taxonomic identification of the specimens we used a Nikon Optiphot-100 dark/bright field incident light microscope with 50-500x magnifications, specialized plant anatomy bibliography and the reference collection of modern charred woods of the Laboratory of the Dept. of Prehistory and Archaeology, University of Valencia, Spain.

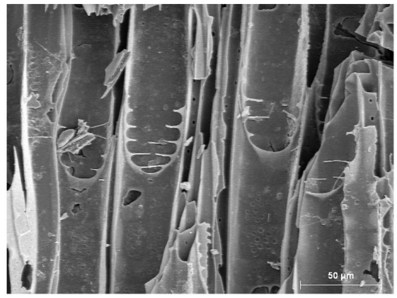
Photography and detailed observation was carried out using a Hitachi S-4100 Field Emission Scanning Electron Microscope and the EMIP 3.0 (Electron Microscope Image Processing) software at the Service for the Support to Experimental Research (SCSIE**),** Universitat de València**.**

Period	Indigenous		Roman	
Level	SC 1, N VI		SC 3, N IV	SC 5-4, N III
Square	C21, D21	C7	B7, E5	D4, D5
Taxa/Context	Feature fill	Landfill	Occupation	Roof collapse
Corylus avellana	1	2		8
Erica sp.			1	107
cf. *Erica* sp.				9
Ficus carica				5
Fraxinus sp.	7			
Fabaceae	6			28
Pinus nigra-sylvestris	2			
Quercus sp. deciduous	22	1	1	90
Rosaceae	3			
Salix sp.	1			
Non-identifiable	1			5
Total	43	3	2	252

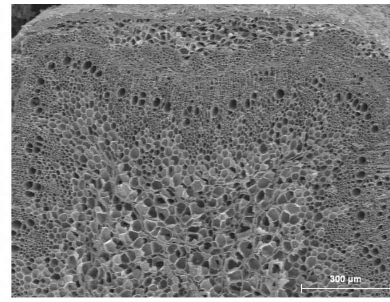
Table 1. Plant taxa identified at San Chuis.



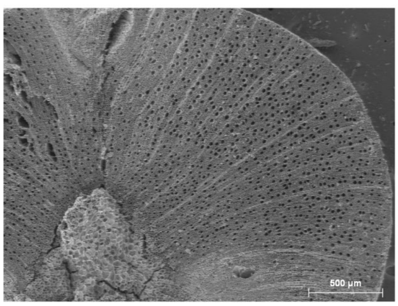
Corylus avellana (cross section X70) from the Roman construction layer



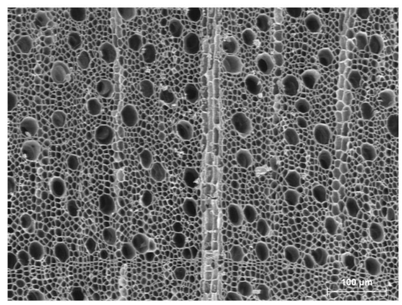
Corylus avellana (tangential section X500) from the Roman construction layer



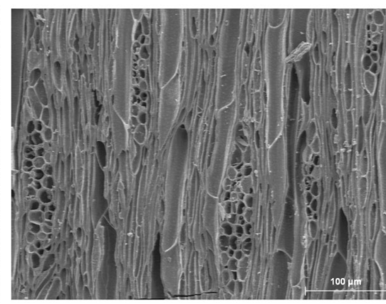
Corylus avellana branche (cross section X90) from the Roman construction layer



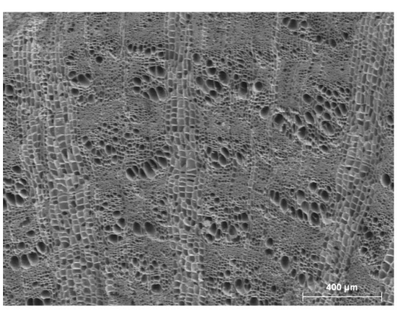
Erica sp. branche (cross section X45) from the Roman construction layer



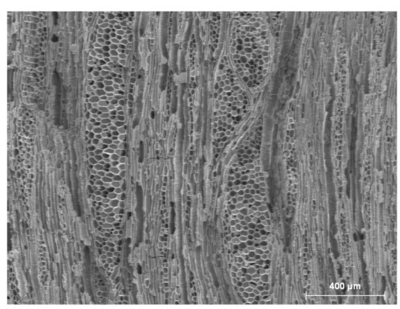
Erica sp. (cross section X180) from the Roman construction layer



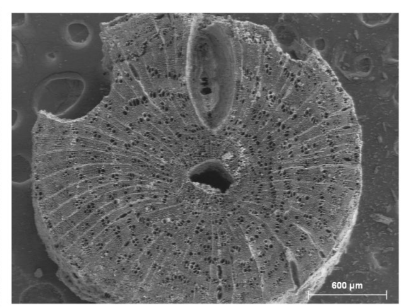
Erica sp. (tangential section X250) from the Roman construction layer



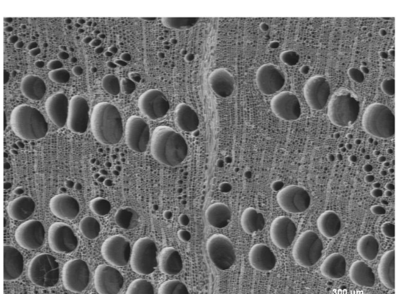
Fabacea (cross section X60) from the Roman construction layer



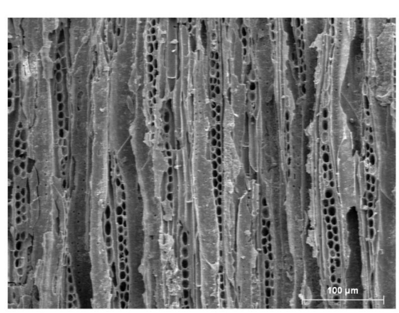
Fabacea (tangential section X60) from the Roman construction layer



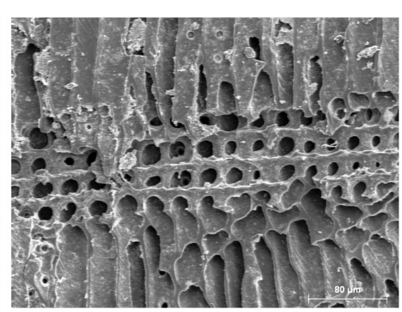
Fabacea branche (cross section X60) from the Roman construction layer



Quercus sp. deciduous (cross section X70) from the Roman construction layer



Rosacea Maloidea (tangential section X250) from the Indigenous feature fill



Pinus nigra-sylvestris (radial section X300) from the Indigenous feature fill

Figure 2. SEM photographies of some plant taxa identified at San Chuis.

DATA AND RESULTS

The following taxa were identified in the indigenous and Roman levels. *Quercus* sp. deciduous type (oak), *Corylus avellana* (hazel tree) and Fabaceae (legume undershrubs). *Pinus nigra and/or P. sylvestris* (black-Scotts pine), *Fraxinus* cf. *excelsior* (ash), Rosaceae (the rose family) and *Salix* sp. (willow) were also identified in the indigenous level. Another two taxa were present in the assemblage from the Roman level, *Erica* sp. (heather), and *Ficus carica* (fig tree) (Table 1; Fig. 2). The material studied can be differentiated as firewood from domestic hearths, and construction timber from the observation tower.

FIREWOOD

The charred firewood remains of the indigenous settlement were collected from different fill layers. The results were not quantified since only 42 fragments belong to these levels. However, the flora recorded and the ecological requirements of the identified taxa reflect the natural vegetation that would have been exploited for firewood. *Quercus* sp. deciduous type woodland would have grown around the hill fort. At present, *Quercus robur* expands from the Cantabrian cordillera to the costal lowlands while *Quercus pyrenaica* grows at higher elevation, usually accompanied by *Corylus avellana* (Costa *et al.* 2005). Given that San Chuis is located at the point of intersection between these two species, we may suggest that mixed deciduous oak woodland with an undestorey of Fabacea and Rosacea would have existed in the area. Riverside vegetation is reflected in the presence of ash and willow.

The conifers are represented by *Pinus*. Although it has been impossible to distinguish the pine species, it is almost certain that cryophilous types are present. Thus, the wood charcoal from level VI may originate from *Pinus sylvestris* or *Pinus nigra*. Both species grow in the coldest bioclimatic zones of the Iberian mountains. *Pinus sylvestris* is more cold-adapted and humidity sensitive than *P. nigra*. Extended *Pinus sylvestris* forests exist in the Pyrenees and the mountains of northern Iberia. *P. nigra* is restricted to the eastern mountains from the Pyrenees to Andalucía and does not reach Asturias.

During the Roman occupation some of the indigenous structures were reused (with the addition of rectangular walls) and new ones were built. From the habitation floors of these structures there are only two wood charcoal fragments, documenting the presence of *Erica* sp. and *Quercus* sp. deciduous type.

TIMBER

Level III corresponds to the collapse of walls and stone structures of the 2nd century AD. The wood charcoal associated with the observation tower of the Roman period, dated to 2050±50 BP (UBAR-216) was analyzed, provided evidence for the plant species used for the construction of the walls and roof.

200 wood charcoal fragments were collected from the remains of the roof while only 52 fragments belong to the collapsed walls. *Erica* sp., Fabaceae and *Quercus* sp. deciduous type wood was selected for the construction of the roof. *Erica* is the taxon mostly used, followed by *Quercus*. For the construction of the walls *Corylus avellana, Erica* sp., *Ficus carica* and *Quercus* sp. deciduous type were used. In Figure 3 the proportion of the different taxa used in the construction of the roof and walls is presented.

The morphology of the wood charcoal allows us to distinguish two categories of wooden structural elements. Large caliber trunks would have formed the structure of the tower. Squared surfaces were present in some charcoal samples but due to the high degree of fragmentation it was difficult to count with precision the annual growth rings and estimate the minimum age of the trees used. All the larger structural elements were identified as *Quercus* sp. deciduous. The second category includes small diameter branches that in many cases preserved bark. This allowed us to calculate the diameter of the branches and to determine the caliber of those selected for the roof.

The diameter of 100 branches from the roof was measured. The column charts in Figure 4 show the percentages for each taxon, together with the distribution of the taxa in different diameter categories (<5; 5-10; 11-15 and >15 mm). Selection of *Erica*, Fabaceae and *Quercus* branches with diameters between 5 and 10 mm is indicated. However, the diameters of *Erica* branches are more variable and this may be due to the indiscriminate use of all the branches of plants of this genus since they are adequate for roofing material.

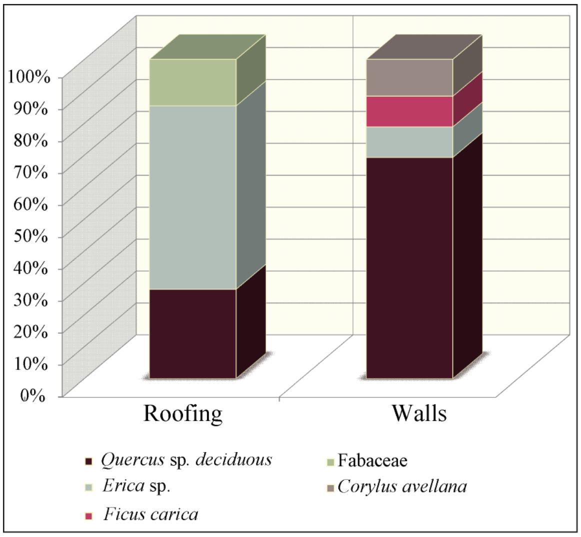


Figure 3. Plant taxa identified in the construction debris of the Roman tower at San Chuis.

Preservation of the bark on many branches allowed us to estimate the cutting season. This information was obtained by observing the characteristics of the last annual growth ring in relation to the bark. The presence of latewood in the last annual ring indicates that the branch was cut during the least favorable season for plant growth, which is after the summer. When earlywood starts to form this indicates that the cutting season was in spring.

The growth of the last annual ring was observed in 41 branches. Figure 5 shows that the wood was predominantly cut when earlywood was forming during the most favorable season for tree growth, the spring. Only *Corylus* was cut when latewood was forming. The branches of Fabaceae were all cut in the favorable season as was also the case for *Quercus* with only one exception (Fig. 5).

The work of Vitruvius provides evidence of the high degree of knowledge concerning the different mechanical qualities of wood in each season. When rigid wood was required this had to be cut at the beginning of the autumn while in spring the wood would be more porous, fragile and flexible due to the presence of substances associated with the growth of new leaves and fruit (Adam 1984: 91). Therefore, the cutting season would have been adapted to the wood

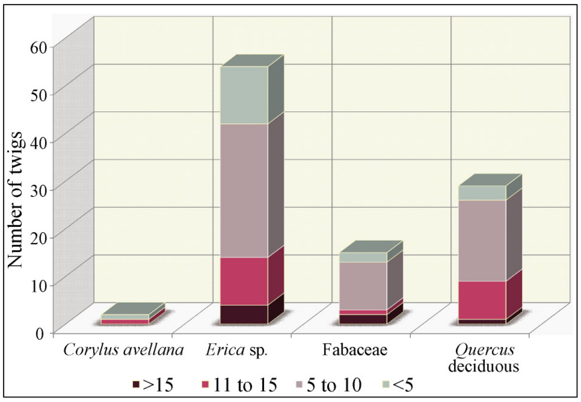


Figure 4. Proportions of various diameter branches of different taxa used for the construction of the Roman tower roof.

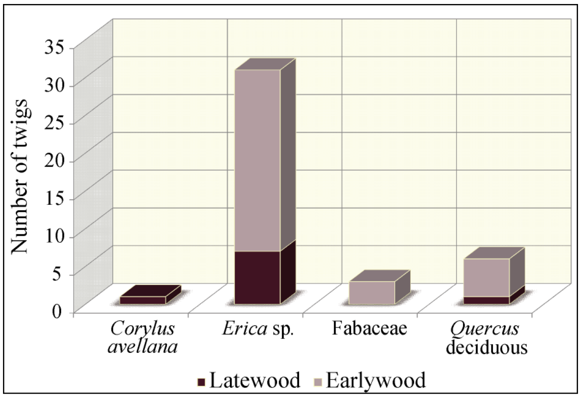


Figure 5. Felling season of the branches used for the construction of the Roman tower roof.

qualities required for different uses.

The sample from San Chuis, although small, indicates that spring was the main cutting season and to a lesser degree others. This would have been deliberately geared to obtaining timbers of variable flexibility or for storage, as construction requires planning and early procurement of raw materials.

DISCUSSION

The results of the wood charcoal analyses from the San Chuis hill fort have provided a snapshot of the flora of Asturias during the Iron Age. They include woody plants used for fuel by the indigenous population and the timber selected for the construction of the Roman observation tower. The results are limited though, since the samples derive from early archaeological work where systematic sampling was not common. However, some interesting results have been provided by the analysis of this small number of wood charcoal samples.

The flora associated with the indigenous settlement indicates that thermo-climatic characteristics then were similar to those prevailing today in the study area. The same plant taxa form the present woodlands in the region although the signs of human impact on the vegetation are more intense. The presence of *Pinus sylvestris* and/or *Pinus nigra* indicates cooler conditions.

The Alto de la Espina (Salas, Oviedo) peat bog which is located at 650 m a.s.l. and close to the San Chuis hill fort has provided a pollen diagram. The wood charcoal results from the fort can be compared with the palynological evidence in order to further develop our regional understanding. According to the pollen diagram the vegetation during the Iron Age was dominated by deciduous *Quercus* sp. and *Corylus avellana*. The most abundant undershrubs belonged to *Erica*, *Calluna* and *Cytisus* (Lopez Merino 2009; Carrión *et al.* 2012). According to López Merino, evidence for human impact on the vegetation can be seen in the increase of *matorral* species, cereal pollen and *Plantago.* The flora identified in the levels of the indigenous settlement at San Chuis is in line with the pollen results. Moreover, at San Chuis we identified specimens of *Pinus sylvetris* and/or *P. nigra* that could have originated from the coldest parts of the region.

From the Roman occupation, only wood charcoal remains from construction timber were available for analysis. Therefore, it is not possible to make inferences as to the natural vegetation of the area since the material was intentionally selected for specific uses. However, we may suggest that the timber used was procured from the local woodland and this is supported by the pollen data from Alto de la Espina, with vegetation characteristics similar to the previous period, i.e. *Quercus* and *Corylus avellana*. The intensification of mining activities during the Roman occupation can be detected in the pollen record by the increase of Cerealia, *Castanea sativa* and *Junglans* (Lopez Merino 2009; Carrión *et al*. 2012).

The wood charcoal remains from the Roman levels at San Chuis provide information about the timbers used in the construction and the criteria for their selection in relation to their function. For structural elements used to support heavy loads, deciduous oak (*Quercus*) lumber was selected. For roof coverings or the wattle structure of walls, *matorral* species were used since these provided twigs and branches of adequate caliber that could be used without thinning. It is for this reason that many branches preserve bark while the majority are of a standard diameter (5-10 mm charred). Similar construction techniques were documented at other sites such as O Castelo (As Laias, Ourense) or Noville (Mugardos, Coruña) (Carrión 2005). In terms of cutting season, the results are similar at all sites, with wood harvested all year long although preferably towards spring.

Woodworking marks were not observed on the timbers from the observation tower at San Chuis due to the high degree of fragmentation of the charcoal. The exception are the *Quercus* poles or beams, on some of which intentional squaring was observed. These timbers would have formed part of the wall or roof framework. The use of deciduous oak timber in Roman architecture is documented in the *Opus craticium* technique and the wattle. However, we do not have enough evidence to suggest which of these techniques would have been used in the tower.

The branches used for the wattle structure of the walls or for the roof were not prepared in any way. The majority preserve bark and probably only had a transversal cut depending on the desired length. At San Chuis most of the twigs were cut in spring while at other sites there is no clear tendency towards one season or another. Vitruvius writes "timber should be felled between early autumn and the time when Favonius begins to blow. For in spring all trees become pregnant, and they are all employing their natural vigour in the production of leaves and of the fruits that return every year. The requirements of that season render them empty and swollen and so they are weak and feeble because of their looseness of texture. (Vitr. 2.9). It is possible that there was some planning concerning the provison of timber for woodworking and carpentry. Wood would have been cut during the year in order to season before being used for construction. However, the predominance of branches cut in the spring may indicate that flexible and easy to bend materials were needed for the wattle structure of walls and roofs.

CONCLUSIONS

Analysis of the wood charcoal from the San Chuis hill fort has suggested the following:

- A variety of species were used for firewood in domestic hearths in the indigenous settlement, except for *Erica*. Deciduous oak woodland around the site would have included mountain pines, heather, legume undershrub and some riverine taxa (ash and willow).

- For the construction of the Roman tower, heather was mainly used as roofing material, with deciduous oak timbers for the structure, along with some use of *Corylus avellana*, Fabaceae and *Ficus caria*.

-The wood used in the construction shows morphological characteristics which allow us to define two types of timber use. Large oak beams and then twigs or small diameter branches of various taxa, oak included.

- Bark preservation on some twigs shows that the wood used for the construction was mainly cut in the most favorable season for growing and obtaining the best mechanical qualities. However, a small percentage of wood collected during less favorable seasons may suggest either that construction activities were quite long-lasting, or that the collected wood was stored for some time. Alternatively these characteristics may reflect periodic maintenance of roofs and walls.

ACKNOWLEDGEMENTS

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Shaping wood: Woodworking during the Iron Age and Roman period in the northwest of the Iberian Peninsula

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***Summary**: This article discusses several timber structures, wooden objects and manufacturing waste recovered from settlements and specialized production sites during the Iron Age and the Roman period in northwest Iberia. These archaeobotanical remains were preserved directly by carbonization, waterlogging and occasionally mineralization, as well as indirectly by impressions on clay. The study of these artifacts and structures allows us to characterize forestry practice, technical process of woodworking (sequence of actions, techniques and gestures), household equipment and architecture.*

***Key words**: Woodworking, carpentry, charcoal and wood analysis, forestry practice, household equipment, architecture, Iron Age, Roman Period, Northwest Iberian Peninsula.*

INTRODUCTION

This article discusses both wooden artifacts and wooden structures from Iron Age and Roman sites in the northwest of the Iberian Peninsula. The study of these pieces provides a greater understanding of how this raw material was used for woodworking. While the preservation of these types of objects and structures is rare in archaeological contexts, wood was used in many different ways in the day-to-day life of past societies: domestic, artisanal and ritual tools, weapons, structures, logboats, ships, carts, etc. (Coles *et al*. 1978; Earwood 1993; Figueiral 1996; Pugsley 2003; Bosch *et al*. 2006; Pillonel 2007; Ulrich 2007; Carrión and Rosser 2010).

Although wood, like most organic substances, rapidly perishes in temperate climates once it is buried, wooden remains can survive in waterlogged conditions, or can be preserved by carbonization, mineralization or even survive, indirectly, as impressions in clay. In the assemblages studied, whole items were most commonly preserved by water or humidity saturation, along the margins of rivers or *rías*. However, the most ubiquitous type of preservation (for fragments of items) was through carbonization as a result of burning events, where structural timbers and wooden objects were fire-affected, or in hearths, where wooden objects were occasionally burned as fuel. Preservation by mineralization was rare in the assemblages. Even less frequent were the examples of impressions of branches on clay, which provide indirect evidence for construction in wood.

There are many references in the specialized literature about woodworking and carpentry (including structures and objects) in Iron Age settlements and Roman sites (García-Rollán 1971; López-Cuevillas and Lorenzo 1986; Silva 1986; Orero 1988; Alves *et al*. 1988-89; Carballo 2002; Carrión 2005; Martín-Seijo 2006; Alves and Rieth 2007; Vigo 2007; Martín-Seijo 2008; Carrión and Rosser 2010, Martín-Seijo and Carballo 2010; Rey *et al*. 2011). The sites considered in this study (Fig. 1) are eleven fortified settlements (*castros*) occupied during the Iron Age - Zoñán, Neixón Grande, Alto do Castro, Castrolandín, Castrovite, Montealegre, Nabás, Punta do Muiño, Coto do Mosteiro, O Castelo and Castromao-, along with two habitation sites, a *vicus* (Caldas), a *villa* (Noville), and a marine saltern (Areal), dating to the Roman period.

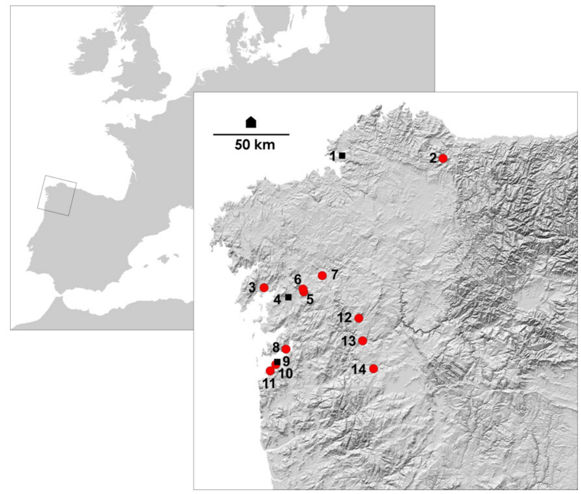

Figure 1. Location of the sites (Iron Age in red, Roman in black). 1. Noville, 2. Zoñán, 3. Neixón Grande, 4. Caldas, 5. Alto do Castro, 6. Castrolandín, 7. Castrovite, 8. Montealegre, 9. Areal, 10. Punta do Muiño, 11. Nabás, 12. Coto do Mosteiro, 13. O Castelo, 14. Castromao.

MATERIAL AND METHODS

At the macroscopic level, the technological study of the wooden artifacts consisted first in the morphometric analysis of the object: overall description, graphic recording and measuring. Indirect evidence of wooden constructions, such as clay impressions of wattle and daub structures (Cubero 1996; Nava and Fernández 2001; Gómez 2008), was also analyzed. The diameter of each impression was measured using a digital caliper. The different stages of the *chaîne opératoire* or operational sequence were then described: raw material procurement, blank and product preparation and final product. This concept considers a production process as a sequence of actions influenced by technical possibilities and personal and cultural choices (Skibo and Schiffer 2008).

During the microscopic study the samples were first identified taxonomically, according to the specific anatomical patterns on the three sections of wood (cross, tangential and radial). Several dendrological and taphonomic characteristics of the samples were also registered: part of the plant, presence of tyloses, minimum diameter, number of annual rings, season of cutting and alterations related to the taphonomic processes (fragmentation, erosion, biological action, etc.) (Crone and Barber 1981; Morgan 1988; Théry-Parisot 2001; Marguerie and Hunot 2007; Martín-Seijo and Carballo 2010).

RESULTS AND DISCUSSION

IRON AGE WOODWORKING

The charcoal assemblages recovered from the hillforts (*castros*), ranging in date from the 8th century BC to the 1st century AD, provide information about different stages of the *chaîne opératoire* of woodworking. Most of the fragments or pieces studied were final products of building material or domestic objects. It was only in Castrolandín (Cuntis, Pontevedra) that it was possible to identify a carpenter's workshop by the presence of manufacturing waste and fragments of finished objects or structures.

Oak (*Quercus* sp. deciduous) was the most common and ubiquitous taxon identified in wooden manufacture during the Iron Age, used as elements of building structures (planks, beams, wedges, laths, etc.), and for many different kinds of objects (handles and agricultural implements). Other taxa identified in lower percentages were *Corylus avellana*, Fabaceae, *Quercus* sp. evergreen, *Arbutus unedo*, *Erica* sp., *Alnus* sp., *Fraxinus* sp., Rosaceae/Maloideae, *Prunus* sp. and *Salix/Populus*. All the species identified were hardwoods and probably were available in the surroundings of the settlements.

All the information related to timber, roofing and wattle from the Iron Age samples came from burning episodes which resulted in deposits with a high concentration of carbonized organic remains. Main structural elements, such as beams and posts, were made of oak (*Quercus* sp. deciduous). In Alto do Castro (Cuntis, Pontevedra) a fire event dated to between the 5th and 4th centuries BC preserved an oak beam. At Neixón Grande (Boiro, A Coruña), from a context of similar date, a carbonized oak fence-post was found.

In Nabás (Nigrán, Pontevedra) a burning episode that affected several buildings of the settlement was identified. Wood-charcoal from this fire event was dated between the 2nd century BC and the 1st century AD. Several planks were dismantled and burned, before the construction collapsed. The results (Fig. 2) show that the taxa used for timber were mainly *Quercus* sp. including deciduous and evergreen species; other taxa, such as *Corylus avellana*, *Alnus* sp. and *Salix/Populus* probably formed part of wattle walls, while the roofing material came from Fabaceae. Other species were identified sporadically.

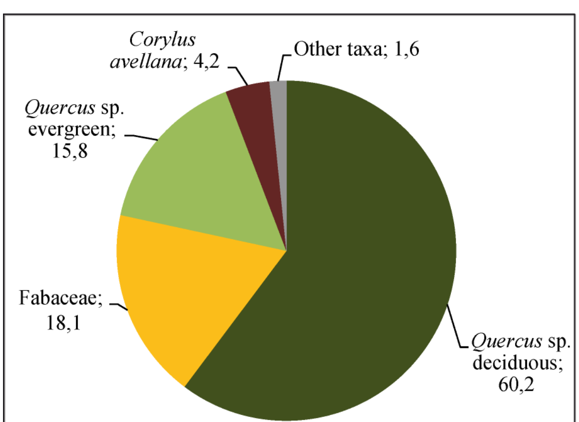

Figure 2. Percentages of identified taxa in the burning event of Nabás.

The assemblages recovered in Castrovite (A Estrada, Pontevedra) were related to several fire epi-

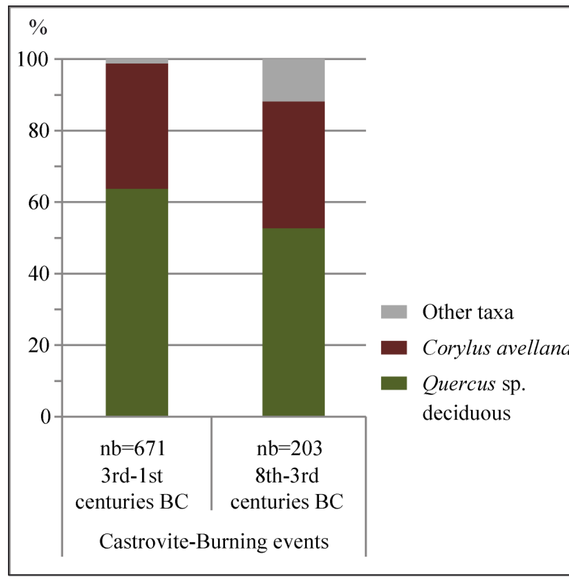

Figure 3. Taxa identified in the burning layers of Castrovite.

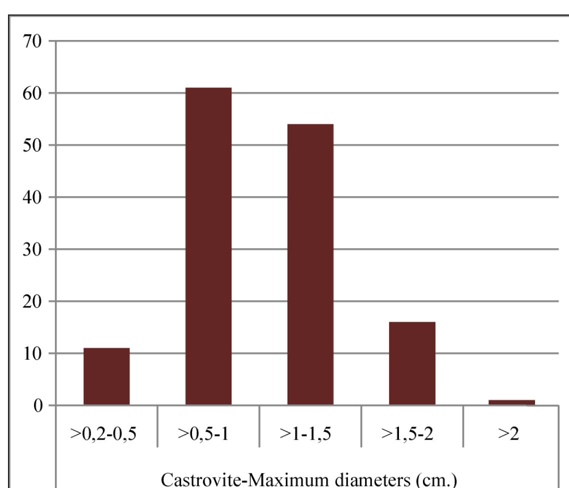

Figure 4. Maximum diameters of the hazel branches found at Castrovite.

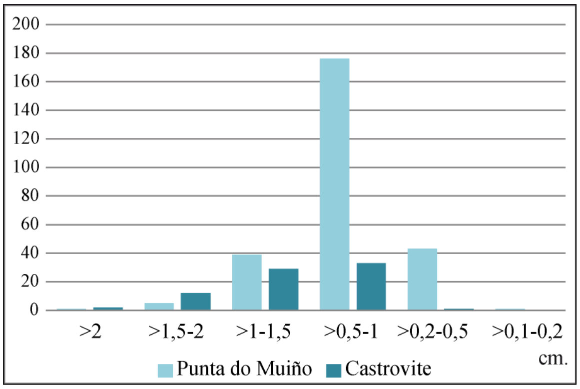

Figure 5. Maximum diameters of the impressions on clay found at Punta do Muiño and Castrovite.

sodes dated to between the 8th and the 3rd centuries BC and between the 2nd and the 1st centuries BC (Rey *et al*. 2011). In these deposits, high percentages of oak (*Quercus* sp. deciduous) were identified, including some well preserved planks, laths and wedges (Fig. 3).

Several wattle hurdle structures for cereal storage were also identified from these contexts. They were made of hazel twigs with maximum diameters of 0.5 -2 cm (Fig. 4), with the majority ranging from 0.9 to 1.6cm (Martín-Seijo and Carballo 2010). The hazel twigs were aged between 1 and 8 years (*nb* = 77). However, as growth rings are completely preserved only in the base of the trunk or base of the branch (Morgan 1988), the age could only be approximately estimated due to the fragmentary nature of the charcoal and subsequent difficulty in identifying what part of the branch they belonged to. The cutting season was predominantly during the autumn.

This pattern is also observed in O Castelo (Cenlle, Ourense), where several assemblages of branches (*nb*=75) of *Arbutus unedo, Erica* sp., Fabaceae, *Quercus suber* and *Salix* sp, most of them between 0.5 to 1 cm diameter, were identified. In this case, branches were cut throughout the year, which may be evidence of repairs of the roofing and wall structures.

The presence of wattle and daub structures in the Iron Age settlements is quite common, as is shown by the presence of small diameter, flexible twig assemblages in many sites. Their presence is also indicated at Punta do Muiño (Vigo, Pontevedra), O Castelo and Castrovite, through indirect archaeobotanical evidence as clay impressions. Measurement of the maximum diameters of these impressions showed the prevalence of branches ranging between 0.5 and 2 cm (Fig. 5).

Site	Description	Species
Castromao	Handle*	*Quercus* sp. deciduous
Neixón Grande	Handle*	*Quercus* sp. deciduous
Castrolandín	Handle	*Alnus* sp.
Montealegre	Handle	*Corylus avellana*
Zoñán	Bowl/scoop	*Fraxinus* sp.
Castrolandín	Bowl/scoop	*Alnus* sp.
Castrolandín	Bowl?	*Alnus* sp.
Nabás	Box	*Quercus suber*
Coto do Mosteiro	Hook	*Quercus* sp. deciduous
Nabás	Indeterminate	*Quercus* sp. deciduous
Alto do Castro	Indeterminate	*Alnus* sp.
Castrolandín	Waste	*Ilex aquifolium*

Table 1. Wooden objects recovered in 'castros' (*preserved by mineralization).

During the Iron Age wood was used for construction timbers as well as raw material for the manufacture of many domestic and artisanal objects, agricultural implements, weapons, etc. *Quercus* sp. deciduous, *Alnus* sp., *Corylus avellana, Quercus suber* and *Fraxinus* sp. wood was used for the manufacture of the eleven wooden objects studied (Table 1) while the manufacturing waste belongs to *Quercus* sp. deciduous and *Ilex aquifolium*.

Handles of tools and weapons were the most common wooden pieces found at the *castros*. These are likely to have been part of metal tools used in different activities and were made of *Quercus* sp. deciduous and *Corylus avellana*. These species were probably selected for their wood qualities - hardness and toughness for oak and elasticity for hazel. All of them were fragmented, two preserved by mineralization and the rest by carbonization.

Several fragments of wooden containers were

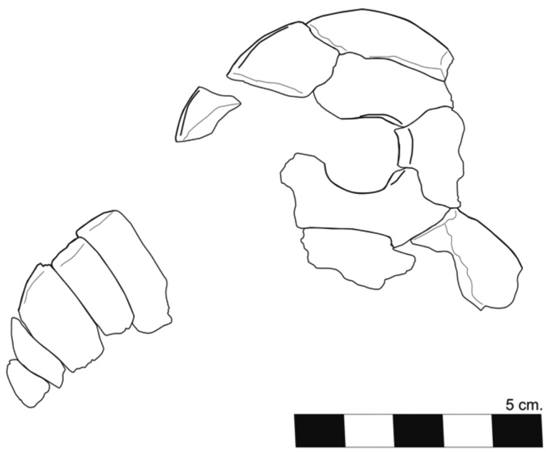

Figure 6. Handle of an indeterminate object found at Alto do Castro.

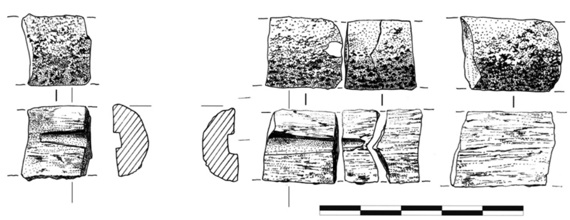

Figure 7. Manufacturing waste probably related with the use of a lathe.

identified: five of them were made of *Alnus* sp. and one of *Fraxinus* sp. The vessels found preserved the handholds and could be described as bowls or scoops. In Nabás several fragments, probably from a box, of cork (*Quercus suber)* were recovered, in association with seeds of *Panicum miliaceum*. An indeterminate object with a handle was also made of *Alnus* sp. (Fig. 6).

Few tool-marks are preserved with sufficient clarity to determine the kind of tool used. In several pieces cutmarks were identifiable. Other tool-marks include the presence of a cylindrical perforation in one piece of *Quercus* sp. deciduous from Castrovite dating to between the 4th and 2nd centuries BC, which could be related to the use of a bow drill. Manufacturing waste of *Ilex aquifolium* was probably related with the use of a lathe in a context dated between the 1st and 2nd centuries AD (Fig. 7).

ROMAN WOODWORKING

The samples recovered from the Roman sites presented a greater taxonomic variability, probably due to the nature of preservation of the wooden remains, mostly from waterlogged contexts (Areal and Caldas), with the remainder preserved by carbonization (Noville). Several waterlogged objects could not be identified because they were treated prior to sampling or because the samples were too degraded to identify the species.

In the marine saltern of Areal (Vigo, Pontevedra) many structural timbers survived in their original position in a context dating to between the 1st and 3rd centuries AD. The posts and planks which delimited the salt evaporation pond were made of *Quercus* sp. deciduous (*nb*=270), *Alnus* sp. (*nb*=7) and *Castanea sativa* (*nb*=5) (Fig. 10). In this case we could register the process by which timbers were obtained (also called conversion). The posts/planks were obtained by radial and longitudinal splitting and presented different morphologies (Fig. 8).

The posts which delimited the channel associated with the evaporation pond (Fig. 9) were made of *Cas-*

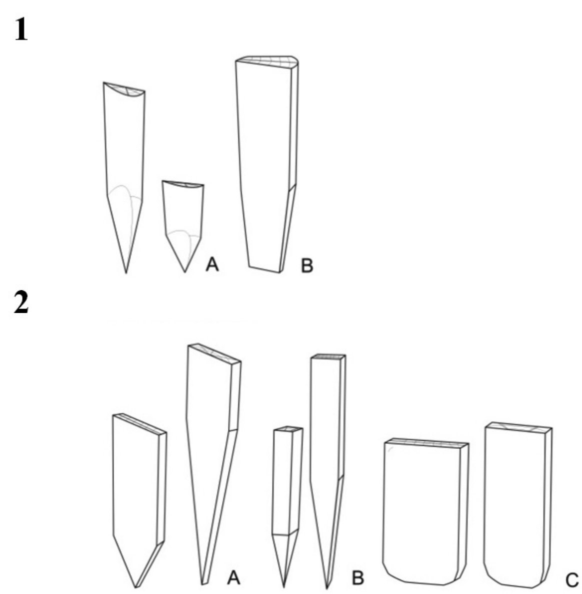

Figure 8. Posts and planks obtained by (1) radial and (2) longitudinal tangential splitting.

tanea sativa (*nb*=26), *Quercus* sp. deciduous (*nb*=21) and *Q*. sp.evergreen (*n*=1), and the wattle hurdle was also made of *Quercus* sp. deciduous (*nb*=26), *Castanea sativa* (*nb*=26) and *Frangula alnus* (*nb*=1) twigs. The diameters of these twigs were between 0.3 and 4 cm, although the predominant range was from 1 to 2 cm. The number of annual rings idenfied was from 1 to 6, the predominant range was 2-3 annual rings. The cutting season was varied. Other structural elements, such as stakes or wedges, were made of *Quercus* sp. deciduous.

Figure 9. Wattle structure of the channel associated with the evaporation pond at Areal.

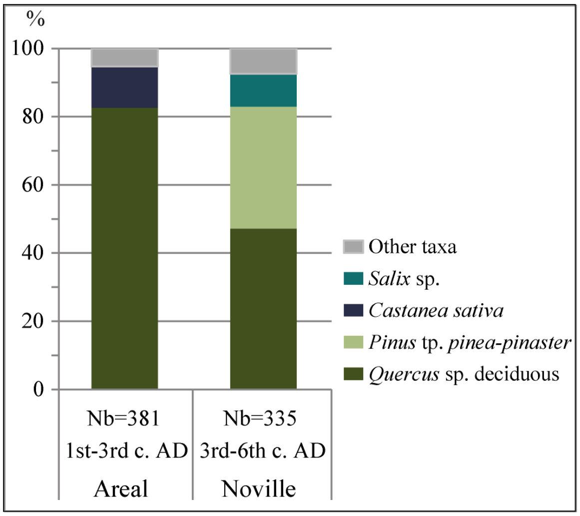

Figure 10. Taxa identified at Areal (waterlogging) and Noville (carbonization).

At the villa of Noville (Mugardos, A Coruña) a rich assemblage of wood-charcoal was recovered from a fire-affected layer. The species most used in construction were *Quercus* sp. deciduous and *Pinus pinea-pinaster* (more likely the second), but *Alnus* sp., *Corylus avellana, Fraxinus* cf. *F. excelsior*, Fabaceae and *Salix* sp. are also present (Fig. 10). The wood is highly fragmented, but it seems to originate from large-diameter elements; an exception are some small-diameter willow woods, a species highly valued for the elasticity of its twigs, which most likely formed part of a network of wattle and daub structures.

In archaeological contexts dating to between the 3rd and 5th centuries AD manufacturing waste (chips) and objects related to construction (posts, stakes, nails, plugs, wedges, planks, strips and a joinery piece), fishing (net weight and floats, corks, awls, spatula) and other activities (tray, bowl/scoop, top, etc.) were identified. The species represented in the manufacturing waste were *Quercus* sp. deciduous, *Castanea sativa, Salix/Populus, Fraxinus* sp., *Juglans regia* and Rosaceae/Maloideae. The elements related to wooden frames were made of *Quercus* sp. deciduous and evergreen, *Castanea sativa, Salix/Populus, Prunus* sp., *Pinus* tp. *pinea/pinaster* and *Pinus* tp. *sylvestris/nigra*.

Site	Description	Species
Areal	3 Awls	-
Areal	Spatula	-
Areal	Bowl/Scoop	*Fraxinus* sp.
Areal	Tray	-
Areal	2 Corks	*Quercus suber*
Areal	Top	-
Areal	Net weight	*Quercus* sp. deciduous
Areal	2 Net floats	*Quercus suber*
Areal	Indeterminate	*Castanea sativa*

Table 2. Wooden objects from Areal.

The wooden objects related to fishing and other activities were made of *Quercus suber*, *Castanea sativa*, *Fraxinus* sp. and *Quercus* sp. deciduous (Table 2).

At Caldas de Reis (Pontevedra) a wooden beam of *Quercus* was preserved associated with a level of collapse dated to between the 3rd and 4th centuries AD.

CONCLUSIONS

The analysis of these assemblages provides information on the use of wood during the Iron Age and the Roman period in the northwest of the Iberian Peninsula (Table 3). Romanization probably affected the three pillars of all craft production - raw materials, technology and social contexts (Feugère 2011; Tisserand 2011) – in different ways. Further analysis of the innovation and spread of woodworking techniques would require the investigation of a greater number of artifacts and structures.

These data show the wide range of uses to which wood was put by these communities while the wooden artifacts and timber structures provide an insight into contemporary domestic life. Although in the past many tools and household equipment would have been of wood, little is known about the use of this material due to problems of preservation on most sites. Species were selected for their physical and mechanical properties responding to the requirements of the end object in question, e.g. high quality trunks for structural elements, flexible branches for frameworks, or fine-grained wood for more finely worked objects.

The wooden frameworks indicate the presence of forestry management practices related to the production of large, straight and flexible branches. The observation of the cutting season through the presence of bark on the branches indicates that felling took place during various seasons. Ethnographic examples indicate that branches for frameworks are used when still green because of their great flexibility; but the structures could have also been repaired in various seasons of the year. The presence of *Corylus avellana, Salix/Populus* and *Castanea sativa* branches with a diameter between 1.5-2 cm, as well as the clay impressions of branches, was related to wattle hurdles and wattle and daub structures during the Iron Age and the Roman period.

Taxa/Manufactures	**Iron Age**		**Roman**	
	Timber	**Tools**	**Timber**	**Tools**
Quercus sp. deciduous	*	*	*	*
Fraxinus sp.	*	*	*	*
Alnus sp.	*	*	*	
Corylus avellana	*	*	*	
Quercus suber	*	*		*
Fabaceae	*		*	
Frangula alnus	*		*	
Rosaceae/Maloideae	*		*	
Salix/Populus	*		*	
Quercus sp. evergreen	*		*	
Arbutus unedo	*			
Erica sp.	*			
Prunus sp.	*			
Ilex aquifolium		*		
Castanea sativa			*	*
Juglans regia			*	
Laurus nobilis			*	
Pinus tp. *pinea/pinaster*			*	
Pinus tp. *sylvestris/nigra*			*	

Table 3. Taxa identified in wooden manufactures from Iron Age and Roman sites.

The timber requirements were met by local resources since the identified taxa were characteristic of the landscapes of Northwest Iberia during the Iron Age and Roman period and there is no evidence for the use of "exotic" wood. The widespread use of the maritime pine at Noville can probably be attributed to the plantation of these species by the Romans for wood exploitation.

ACKNOWLEDGEMENTS

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YOLANDA CARRIÓN MARCO[1], JAIME VIVES-FERRÁNDIZ SÁNCHEZ[2], GUILLERMO TORTAJADA COMECHE[2], HELENA BONET ROSADO[2]

The role of wood and fire in a ritual context in an Iberian *oppidum*: La Bastida de les Alcusses (Moixent, Valencia, Spain)

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***Summary**: Fieldwork carried out in 2010 and 2011 at the Iberian oppidum of La Bastida de les Alcusses revealed the existence, underneath the floor of the main gate, of a layer with abundant wood-charcoal and metal objects. Both the typology of the objects, their treatment and their stratigraphic-spatial situation suggest that this is a ritual deposition related to the re-foundation of the main enclosure of the site. Among the timber remains two species have been identified (Aleppo pine and holm oak) and they might be interpreted as lumber pieces of a previous gate that were consciously burnt with iron weapons, rivets and nails.*

***Key words**: Iron Age, Iberian* oppidum*, timber, gate, ritual/foundational context.*

INTRODUCTION

La Bastida de les Alcusses is an Iberian settlement occupied from the end of the 5th century BC to the middle of the 4th century BC. It is located on a ridge in the Serra Grossa Mountains and it is strategically situated at the intersection of two natural routes leading from the interior to the coastland. La Bastida is interpreted as an *oppidum* or fortified central place (see Bonet and Vives-Ferrándiz 2011 for details). The *oppidum* is a crucial part of the settlement pattern throughout the Iron Age in Iberia (Bonet and Mata 2001; Ruiz Rodríguez 2007). Integrated in its immediate environment and in the context of the political economy it constitutes the highest range of the hierarchy in the settlement pattern which, in this area, is formed by a number of *oppida* as centres of small regional territories.

The settlement covered four hectares and was surrounded by a walled enclosure that followed the contours of the hilltop (Fig 1). This wall is some four metres wide. There are four gates: three located to the western area (South, West and North gates) and one to the eastern area (East gate). In its final phase of occupation there were only three towers (two between the West and South gate and another larger one by the East

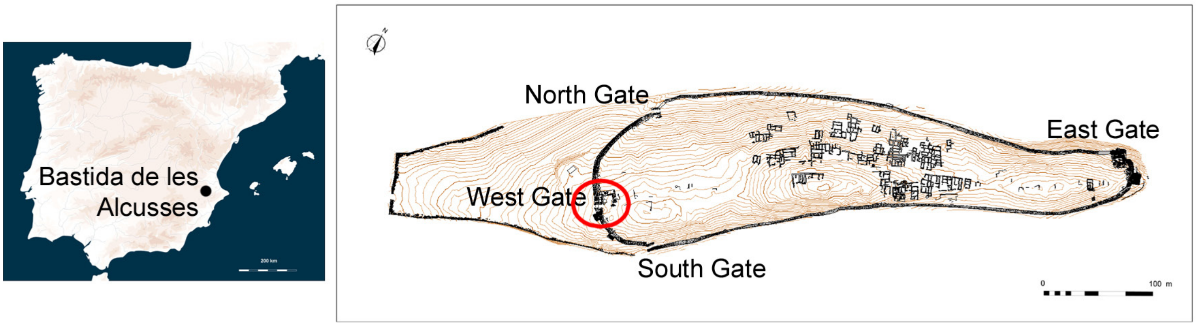


Figure 1. General layout of the *oppidum* of La Bastida de les Alcusses, and location of the West Gate.

gate), probably because the site was under structuring before being definitely destroyed and abandoned.

A central street and a walkway organised and distributed the circulation of people and goods around the site, as these were wide enough to allow the circulation of carts. A number of smaller streets were laid out perpendicular to the main streets. The urban layout of the settlement was structured in large multi-room buildings organised in blocks of different size and internal organisation. La Bastida engaged in a wide range of economic activities, from production to exchange. Not only do agricultural tools and evidence for craft activities extensively occur in the site, but also long distance exchanges between the inhabitants of La Bastida with other Mediterranean areas like Greece, Italy or the Straits of Gibraltar have been documented. An important feature for the interpretation of this site as a political center is the identification of a storage house located in the center of the site where surplus production –mainly grain–was stored and controlled by the elite groups ruling the settlement.

La Bastida was abandoned around the third quarter of the 4th century BC following a violent episode with other Iberian groups of the area. The extensive excavations carried out by the Museum of Prehistory in Valencia since 1928 and the fact that its inhabitants abandoned the settlement in a rush and left a number of daily life implements there make this site the best example for understanding the internal organisation of an Iberian *oppidum* during the 5th and 4th centuries BC.

THE EXCAVATION IN THE WEST GATE

The excavation seasons in 2010 and 2011 took place in the West gate, interpreted as the main gate of the *oppidum*. This gate has two phases of construction: the later phase was excavated in 1998 and 2000 and it was dated to the middle of the 4th century BC. An earlier gate, dated to the first half of the 4th century BC, was excavated in 2010 and 2011.

A number of charred objects were found on the paved floor of this first gate (Fig. 2). They were all recorded in two stratigraphic units, SU 1054 and 1066. A preliminary inventory of the recovered objects lists iron objects, pottery and other finds together with a number of burnt wooden remains.

Among the iron items, there are nails and pieces for assembling wooden objects and five sets of Iberian weapons, each of them including a falcata sword, shield, spear and *soliferreum* –a type of javelin made of iron (Fig. 3). All these weapons made up to the typical panoply of a high rank warrior of the 4th century BC. Pottery vessels –among them a red-figure Greek krater– and other organic materials such as seeds –cereals and olives– and animal bones were also recovered. It is important to note that these objects were part of a ritual performance and for this reason the weapons should not be considered as remnants of a conflict but ritualized objects instead. In fact they were ritually bent, following the typical treatment of weapons deposited as grave goods, although the present contexts are not tombs (Bonet and Vives-Ferrándiz 2011: 240). It is worth noting that fire played a key role in the performance of this ritual. In this paper we present the results of the analysis of the charred wood in this context.

MATERIAL AND METHOD

In the above-described stratigraphic units (SU 1054 and 1066), 33 pieces of wood of varied morphology and size were analysed (Fig. 2). The wood was in a fragile state of conservation as it was very fragmented and, in some cases, only partially burned, which had resulted in the complete degradation of the non-charred parts. During fieldwork, drawing and measurement of every single piece was undertaken, according to their *in situ* location on the floor of the gate.

The analysis of the wood remains included the following observations: botanical identification; reconstruction of their original morphology from the reconstruction of a whole section of the object and the identification of traces of woodworking; assessment of the minimum diameter of the timber (the fragments were large enough to obtain this information with a template of circles); assessment of the cutting season from the presence of bark; and analysis of wood decay caused by xylophages.

Botanical identification of charcoal was carried out at the Laboratory of Prehistory and Archaeology of the University of Valencia, under a dark/bright field metallurgical microscope, with 50X to 1000X magnifications. The samples were compared with specialized plant anatomy literature and a reference collection of modern charred woods.

The following wood anatomy features were observed under low magnification through a binocular lens (20 to 50 X):

- Tree-ring bending, which can show the part of the tree where the sample comes from (Hunot 2000: 12; Marguerie and Hunot 2007) (Fig. 4).
- Presence of the pith and/or the bark: by this means we can measure the complete radius of the wood, and discover the felling season depending on the bark position in the early or latewood.
- Presence of fungi and xylophagous insects that gives rise to an interesting discussion about the state of the collected wood (dead, green, altered, etc) (Théry-Parisot 2001).
- Woodworking has been documented from polished, shaped or squared surfaces, etc.

When a higher magnification was needed, detailed observation was carried out with a Hitachi S-4100 Field Emission Scanning Electron Microscope at the University of Valencia Service Support to Experimental Research (SCSIE). Photographs were taken using

Figure 2. Picture showing the charred wood associated to the ritual deposition of iron objetcs in the West Gate.

Figure 3. Set of iron weapons, rivets and nails documented in the West Gate.

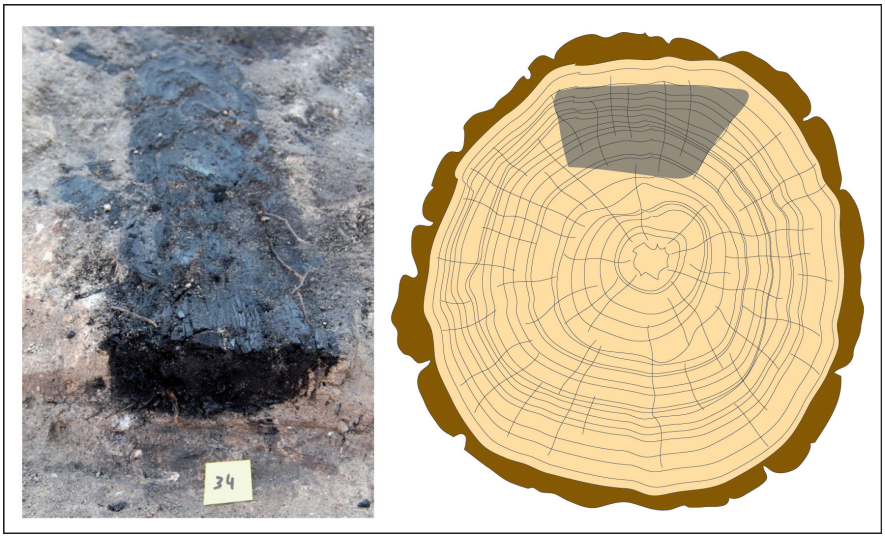


Figure 4. Section analysis of one of the wooden pieces.

the software EMIP 3.0 (Electron Microscope Image Processing).

RESULTS OF THE WOOD ANALYSIS

WOOD-CHARCOAL FROM THE WEST GATE

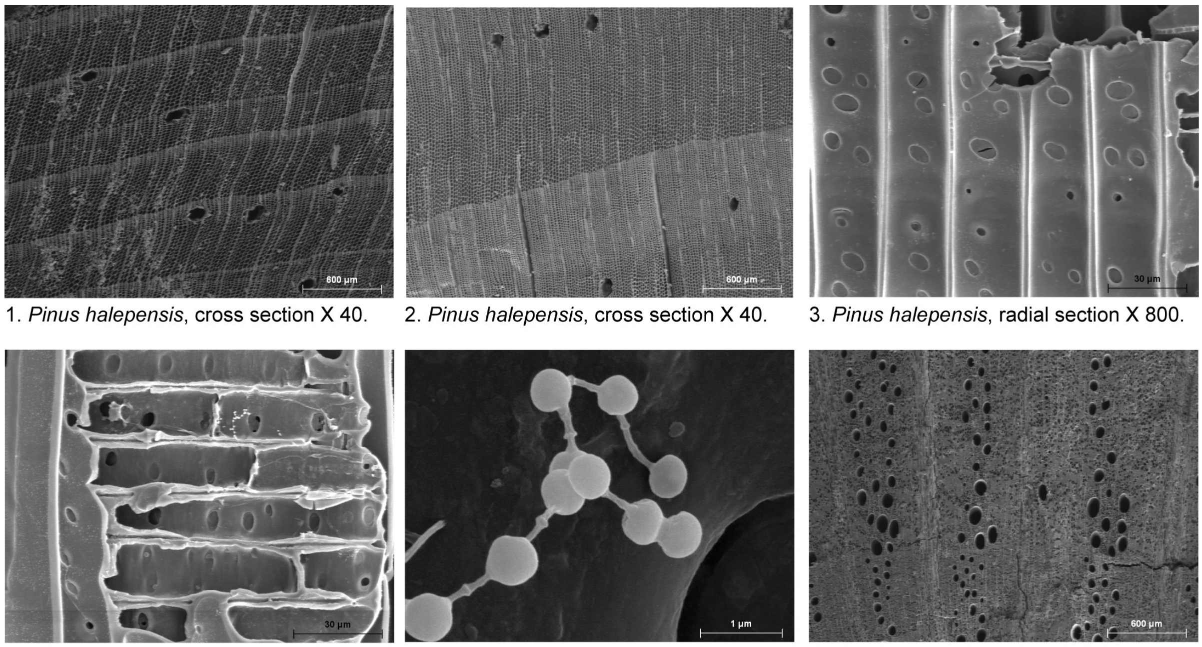
Two taxa were recorded: almost all fragments belong to Aleppo pine (*Pinus halepensis*) while only two are of kermes/holm oak (*Quercus* sp. evergreen) (Fig. 5). These taxa are not specific to this context as they have been also documented in construction and fuel remains in fireplaces (Pérez Jordà *et al*. 2011).

The qualities of the wood of these species make them suitable for construction purposes. The Aleppo pine can generate straight trunks if it grows in good conditions, its wood is very tough but at the same time strong and easily worked and it does not break with nails and other metal rivets. The holm oak wood is hard and compact, suitable for woodworking, but the slow growth and the short and highly branched trunk make this wood less profitable than pine. Moreover, the wide availability of these species in the Mediterranean area is well-known thanks to various palaeobotanical analysis carried out in other Iron Age sites (e.g. Dupré and Renault-Miskovsky 1981; Grau 1990; Bonet and Mata 2002; Mata *et al*. 2010).

As mentioned in the previous section, the way wood was exploited and the role it played in the daily life of the settlement, constitute two additional lines of analysis that were undertaken beyond the botanical identification of the wood.

Regarding the shape of the timber we can state that some of the pieces were squared (9 pieces), but other branches maintained their natural morphology including the bark. We were not able to confirm if they ever formed part of a wooden structure (e.g. timber joists or beams) or if they had been used specifically as fuel during the ritual. In this sense, the identification of the cutting season (on the basis of the presence of bark), was possible in 8 pieces only. Interestingly, all of them showed a rather uniform pattern, one which suggests that wood was cut during an unfavorable season for plant growth, i.e. from the beginning of the summer to the winter. This homogeneity might indicate that the set of branches represents a specific, one-time occurrence.

It was also possible to measure the exact diameter of branches that conserve their bark. They were quite varied, ranging between 11.6 and 2.3 cm, but the vast majority were 5 cm or less. Regarding the pieces which did not preserve their whole radius, the mini-



1. *Pinus halepensis*, cross section X 40. 2. *Pinus halepensis*, cross section X 40. 3. *Pinus halepensis*, radial section X 800.

4. *Pinus halepensis*, radial section X 900. 5. Microorganism on *P. halepensis* radial section, X 25000. 6. *Quercus* evergreen, cross section X 40.

Figure 5. Plant species identified in the West Gate.

mum diameter was estimated between 11 and 15 cm.

The wood had a significant microorganism attack pattern (fungal hyphae and ducts of xylophages) (Fig. 5: photo 5; Fig. 6); this alteration was more visible on larger timbers, whereas the branches were apparently less altered. This could be related to the fact that two kinds of wood were burnt in this context: on the one hand, wooden structures and/or objects contaminated during their lifetime, and on the other hand, wood that was cut and used specifically as fuel for burning during the ritual performance. However, this hypothesis remains to be confirmed in a subsequent stage of this study.

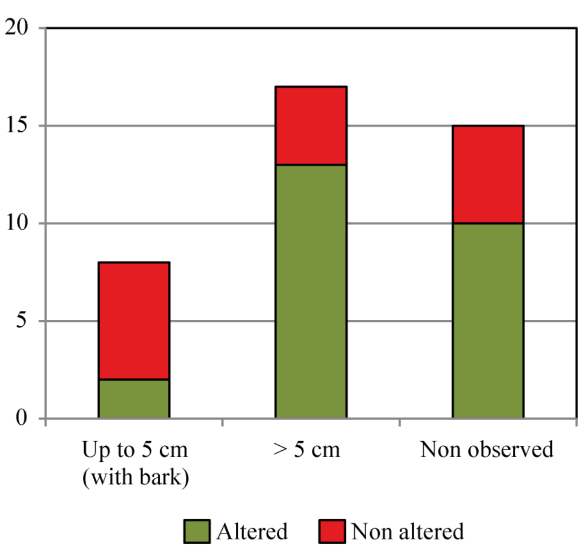


Figure 6. Frequency of altered wood (microorganism attack pattern) in relation to the caliber of the timber.

WOOD-CHARCOAL IN OTHER CONTEXTS OF LA BASTIDA

At La Bastida, wood-charcoal remains are systematically present in stratigraphic units of occupation and abandonment. The list of species identified allows usto infer different uses of wood in the settlement.

Some of the wood would have been used as fuel for hearths, ovens and furnaces, which required a constant supply of large quantities of wood. Apart from domestic fires e.g. hearths and ovens, one of the activities that requires a constant supply of wood is metallurgy (Pérez Jordà *et al.* 2011). Metal production (bronze, iron, lead, silver) is well-attested at La Bastida suggesting that smiths and craftsmen lived at the site. For this purpose tree species were used while the use of bushes was sporadic.

The taxa identified in the contexts of dumps suggest that a large variety of plant species were collected for their use as fuel (Fig. 7). These taxa were available in the vicinity, mainly kermes/holm oak, Aleppo pine, *Prunus* and olive-oleaster. The very occasional occurrence of maritime pine is explained by the existence of siliceous outcrops suitable for the development of this species at the piedmont of the Serra Grossa, some two kilometres away from the site.

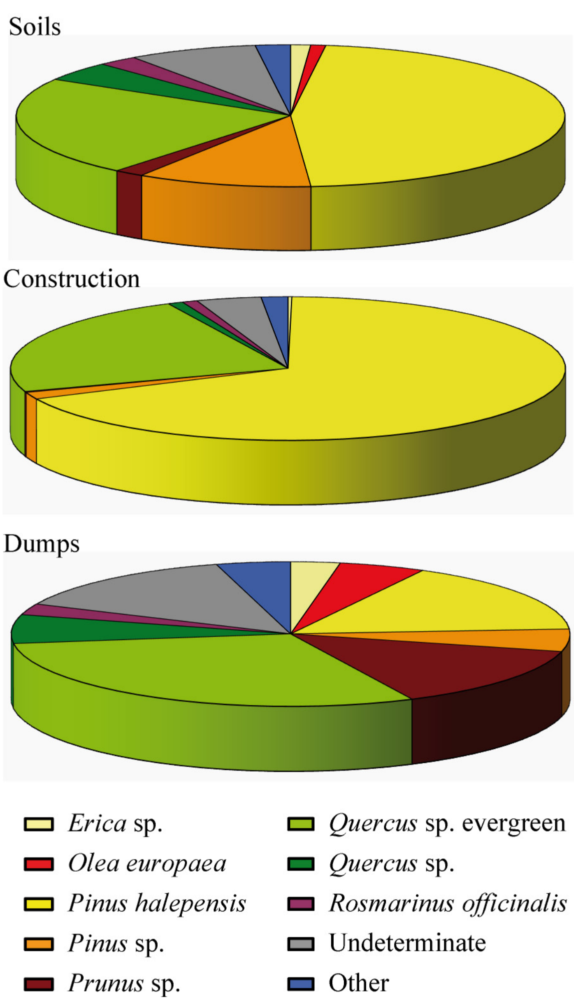


Figure 7. Plant species identified in other contexts of La Bastida de les Alcusses.

Furthermore, the stratigraphic units likely to yield remains of wooden structures are collapse layers and layers on top of the floors of buildings. In collapse layers, small calibre twigs belonging to the lattice of the roof were rarely documented. Heather and rosemary twigs were probably used for this purpose. Their presence is indirectly documented in the imprints on mudbricks from walls and on fragments of mud from roofs. Differential preservation, which causes the smaller elements to disperse or completely turn to ashes by the action of fire, is a likely explanation for the fact that these remains are rarely preserved.

Timber is especially abundant in the stratigraphic units documented in the gates. In all four gates it appears concentrated and associated to several iron objects interpreted as rivets for the door planks. The predominance in these contexts of pine and, secondly, of oak, allows us to suggest a systematic use of these species for woodworking and carpentry (Fig. 7).

Nevertheless, analysis of non-carbonised wood remains adhered to one of the rivets of the doors from the East Gate revealed an unexpected result. The wood used for the elaboration of the planks of the door was willow/poplar (*Salix-Populus*). These species are very rare in other contexts of La Bastida, thus indicating the selection of this wood specifically for the elaboration of the door. The fact that pine and oak charcoal were also recovered on the floor of this gate suggests that this wood may belong to other construction elements or furniture that burnt out while fire did not affect the wood of the door planks, which decayed naturally.

DISCUSSION AND CONCLUSIONS

In this paper we have dealt with wood charcoal recovered in a ritual deposit at the West gate of the Iron Age Iberian *oppidum* of La Bastida de les Alcusses. The ritual involved the deposition and cremation of weapons, pottery, foodstuffs, a number of iron nails and rivets and wooden pieces. We suggest that the latter belong to planks of doors and probably to other structural elements of the gate that were taken to pieces before being cremated *in situ*.

Almost all the timber recovered belongs to Aleppo pine and it may have been part of the wooden planks that made up the doors of the gate. This is precisely the most frequent species in other contexts of the settlement (Fig. 7), maybe for its qualities as construction timber and because it is widely available in the surroundings. Aleppo pine was also present in stratigraphic units interpreted as collapsed walls and roofs in gates and houses, which in turn suggests that it was used for different purposes (beams, joists) and in a variety of contexts.

No specific plant species was selected to set fire to the items placed on the floor of the gate. However, the presence of "natural" wood (i.e. not manufactured) represents either the collection of firewood for this purpose, or that this would have been part of beams or joists that were used with the bark.

Despite the sampling strategy, which selected and isolated charcoal remains associated to objects from other wooden structures, no samples have been clearly identified as weaponry parts (e.g. handles or hilts). In other contexts of La Bastida as well as in other Iberian sites the use of high-quality woods for making handles and wooden tools has been documented (Carrión and Rosser 2010; Pérez Jordà *et al.* 2011), but in the case of the West gate no other species apart from pine and holm oak have been identified.

The similarity of this ritual with the elite funerary practice is remarkable, especially regarding the fact that weapons were ritually killed –bent– like the way they were treated before being deposited in tombs (Quesada 1997). Equally important is the role that fire played in this ritual, as it did in the cremation of corpses. However, because there are no human remains in this context whatsoever a different explanation needs to be given to these findings.

We state that the association of door elements and weapons is meaningful for an understanding of this ritual. The fact that several sets of personal –and inalienable– weapons were ritually killed and carefully deposited together with fragments of the doors, nails and rivets suggests that all these items belong to the same ritual. Because the performance of the ritual is clearly connected to the construction of a new gate, a walled enclosure and new towers, it can be interpreted in terms of an elite warrior memorial following the re-foundation of the public space and defensive structures in the *oppidum*.

The ongoing study of the rest of the materials will help to better understand the characteristics of this unique context.

ACKNOWLEDGEMENTS

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Charcoal analysis of a burnt building at the Iron Age site of Los Morrones I, Cortes de Arenoso, Castellón, Spain

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Summary: *In the excavations of the year 2007 at the Iron Age settlement of Los Morrones I (Cortes de Arenoso), three habitation areas affected by fire were documented, providing plenty of charred wood remains. Since these woods might have been part of building structures, they may supply data about their use in construction during that period.*

Key words: *Iron Age, settlement, building structures, charcoal analysis.*

INTRODUCTION

The farm of Los Morrones I located within the city limits of Cortes de Arenoso to the northeast of the province of Castellón, is a large archaeological area where four settlements have been found, proving the long occupation of this space situated in the high plateau of Alto Mijares (Fig. 1).

Habitation in the area started in the second millennium and went on to the Romanization. Among all settlements, the best preserved was the one dating to the Old Iron Age, called Los Morrones I. Therefore, we decided to initiate a series of interventions with highly

Figure 1. Archaeological site Los Morrones I.

satisfactory results (Barrachina 2004-2005).

The results of the first three archaeological campaigns uncovered a group of rooms which might have been part of the same house. All the structures are concentrated on the top of the hill, apparently without extending on the steep slopes.

DATA AND RESULTS

During the 2009 campaign, an entire room was excavated (Room 2 –Fig. 2) and so were parts of the other two (Rooms 1 and 3). In all of the rooms, it was possible to document elements that showed the effect of fire on structures not made in stone. All of the rooms provided abundant remains of charred wood, although in Room 1 they were smaller and scattered. Since those remains were part of building elements, they can put forward data related to the use of timber as building material during that period.

Figure 2. Los Morrones I. Room 2.

104 samples containing timber remnants were obtained from the room structures. More precisely, the samples come from Stratigraphic Units (SU) 1017, 1025, 1026, 1027, 1028, 1029 and 1032. They were retrieved manually and each item was marked individually (Buxó and Piqué dirs. 2003).

A reflection optical microscope was used for the anatomical analysis of one or various charcoal fragments from each sample. By these means it was possible to observe the microscopic characteristics of the wood elements, which are usually different depending on the species (Jaquiot 1955; Jaquiot 1973; Schweingruber 1978; García *et al.* 1996). Microscopic analysis and comparison with modern charred plants, allowed us to identify three taxa: *Pinus nigra-Pinus sylvestris, Quercus* sp. deciduous, *Quercus* sp. evergreen (Table 1, Fig. 3, 4, 5).

After the botanical identification the data were correlated with the stratigraphic information (stratigraphic units):

UE 1017. 4 samples were collected from Room 1. All of them were identified as *Pinus nigra-Pinus sylvestris*.

UE 1025. 64 samples were collected from Room 2. The following results were obtained:

- *Quercus* sp. deciduous in 64.1% of the samples.
- *Pinus nigra-Pinus sylvestris* in 31.3% of the samples.
- *Quercus* sp. deciduous along with *Pinus nigra-Pinus sylvestris* in 3% of the samples.

	ROOM 1	ROOM 2		ROOM 3			
S.U.	1017	1025	1029	1026	1027	1028	1032
Pinus nigra-Pinus sylvestris	4	20	3		1	3	8
Quercus sp. deciduous		41		1		7	9
Quercus sp. deciduous/ *Quercus* sp. evergreen		1					
Quercus sp. deciduous/ *Pinus nigra-Pinus sylvestris*		2			1	2	1
TOTAL SAMPLES	4	64	3	1	2	12	18

Table 1. Los Morrones I. Qualitative and quantitative results.

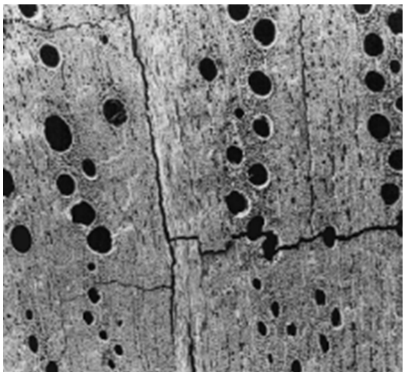

Figure 3. *Quercus* sp. evergreen, transversal section, x40.

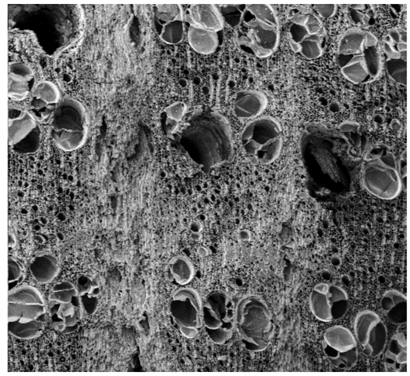

Figure 4. *Quercus* sp. deciduous, transversal section, x80.

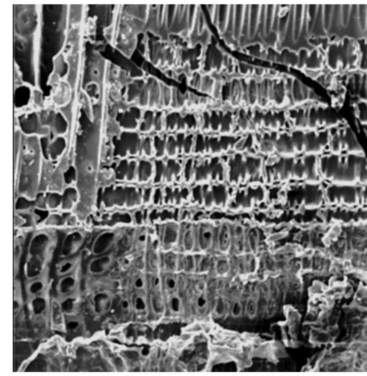

Figure 5. *Pinus nigra-Pinus sylvestris*, radial section, x 400.

-*Quercus* sp. deciduous along with *Quercus* sp. evergreen *in* 1.6% of the samples.

UE 1026. One sample collected from Room 3 was identified as *Quercus* sp. deciduous.

UE 1027. Two more samples, 1A and 1B, were collected from Room 3. Sample 1A was identified as *Quercus* sp. deciduous and *Pinus nigra-Pinus sylvestris;* sample 1B was *Pinus nigra-Pinus sylvestris.*

UE 1028. 12 samples were collected from Room 3. Samples 5, 11, 12, 13, 18, 28 and 29 were identified as *Quercus* sp. deciduous. Samples 26, 27 and 64 were identified as *Pinus nigra-Pinus sylvestris.* Both taxa were identified in samples 14 and 44.

UE 1029. All three samples collected from Room 2 were identified as *Pinus nigra-Pinus sylvestris.*

UE 1032. 18 samples were collected from Room 3. Samples 63, 65, 66-69, 71, 75B, and 76 were identified as *Quercus* sp. deciduou*s*. Samples 70, 72, 73, 75A, 75C, 78, 86 and 87 were identified as *Pinus nigra-Pinus sylvestris.* Both taxa were identified in sample 74.

Examination of the distribution of the identified taxa in relation to each room (Fig. 6) led us to the following observations:

1. The significant presence of *Quercus* sp. deciduous charcoal and *Pinus nigra-Pinus sylvestris*, shows that the construction timber was the material mainly used, for elements such as poles, beams, roof, floorboards, doors, stairs, furniture, etc., which might have been part of the rooms.

2. Findings in Room 1 differ from the other rooms, since the only taxon represented is *Pinus nigra-Pinus sylvestris*.

3. It seems clear that the samples where several taxa were found would be the result of a mixture of charcoal of diverse nature caused by the process of fire and subsequent formation of the archaeological record.

4. The presence of *Quercus* sp. evergreen, which was identified only in Room 2 is scarce.

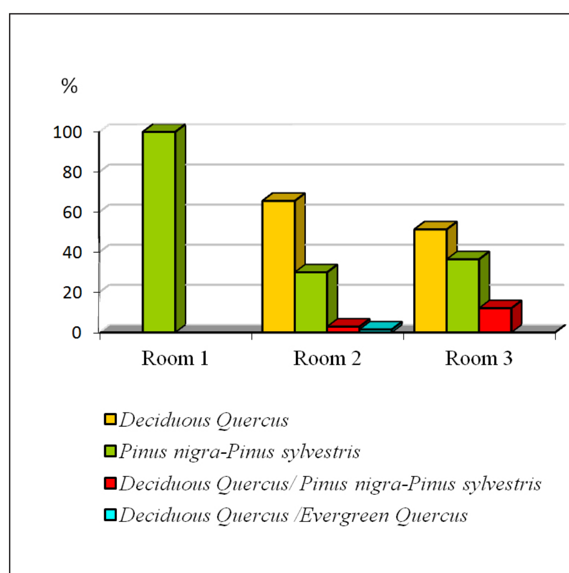

Figure 6. *Los Morrones I. Taxa identified in relation to each room*.

DISCUSSION

The settlement of Los Morrones I is situated on top of a hill at about 1146 m above sea level, in the municipality of Cortes de Arenoso, in the natural region of Alto Mijares. The site is included in the maestracense chorological sector, under the influence of the following bioclimatic levels (Roselló 1994; Peris *et al.* 1996):

- Superior Mesomediterranean. It is located to the south of Cortes de Arenoso. Evergreen oaks are predominant, although the valley bottoms are covered by deciduous oaks.

- Supramediterranean. It is located to the north of Cortes de Arenoso, where extensive *Pinus nigra* forests grow. At the lower levels, they mingle with evergreen oaks.

- Oromediterranean. It is located at the top of Las Cruces peak (1710 m above sea level). *Pinus sylvestris* dominates there.

These vegetation types would have already been exploited by the inhabitants of Los Morrones I in the Iron Age. This we can infer from the three taxa identified in this study, since they would have been retrieved precisely from those forests. However, the extension of these formations cannot be determined through this analysis due to the provenance of the samples; these were concentrated samples associated with building structures that provide ethnological data, but not environmental data at a quantitative level (Chabal 1991; Grau 1991). What seems to be evident is that deciduous oak, pine and evergreen oak woods were selected for a specific purpose. Their particular use is unknown so far, although they could correspond to poles, beams, roof, buttresses, lintels, stairs, etc., which collapsed on the floor level during fire.

Other archaeological sites dated to the same period, such as Castellet de Bernabé (Llíria, Valencia) and Puntal dels Llops (Olocau, Valencia), have revealed remains from the roof which show a main structure made with beams and tie-beams, and a secondary one made with various reeds and branches. Poles and other wooden structures have been documented as well. However, given that these two sites are situated in the termomediterranean bioclimatic level, the timber used is different from that used at Los Morrones I (Grau 1991).

At the settlement of Los Villares (Caudete de las Fuentes, Valencia), located in the mesomediterranean bioclimatic level, a set of structures forming a series of departments lined up throughout perpendicular streets in a complex urban planning was documented. A fire episode which affected most part of the departments, provided, in some areas, charred wood remains that were part of the building materials that made up the structure of those buildings. In this case the woods mainly used were Austrian pine and evergreen oak, although deciduous oak, strawberry tree, leguminous plants and ash tree were also represented (De Haro 2002).

In the province of Castellón a fire level has been documented at the site of La Morranda (Ballestar). Plaster remnants and charred branches have been retrieved from area 3, some of them not yet completely consumed, woody debris still being visible. There were also documented three big wooden fragments with north-south orientation, in parallel with the wall, which might have been part of the longitudinal beams of the roof (Flors and Marcos 1998). Unfortunately, those charcoal remains have not been analyzed yet and, therefore, we do not know what kind of wood was used in those particular buildings.

CONCLUSIONS

At the archaeological site of Los Morrones I, three rooms affected by fire have been documented, providing charcoal remains of *Quercus* sp. deciduous, *Pinus nigra-Pinus sylvestris,* and evergreen *Quercus*, which were part of building structures. *Quercus* sp. deciduous and *Pinus nigra-Pinus sylvestris* were mainly used as timber as well as evergreen *Quercus* but to a lesser extent. The woods were extracted from areas near the site: *Pinus nigra-Pinus sylvestris* from the north of Cortes de Arenoso and *Quercus* sp. deciduous and evergreen *Quercus* from the hillsides and the valley bottoms to the south. The extension of the excavated areas, including Room 3, it is likely to provide new data that may complement those presented here. we should bear in mind that the present study is only a first approximation of the analysis of carbonized remains from the site.

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Forest resource management during Roman and Medieval cave occupations in the Northwest of the Iberian Peninsula: Cova do Xato and Cova Eirós (Galicia, Spain)

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***Summary**: References to the existence of historic remains in NW Iberian caves are frequent. However, archaeological research tends to focus on the search for evidence of older occupations, with little attention given to these historic levels. The aim of this article is to present the results of archaeobotanical analysis (charcoal analysis and carpology) from two caves in the eastern mountains of the province of Lugo – Cova do Xato and Cova Eirós – to determine the management of forest resources by the different communities living in them.*

***Key words**: Forest management, Roman, Medieval cave occupations, charcoal analysis, carpological analysis, Northwest Iberia.*

INTRODUCTION

In recent decades, archaeological surveys carried out in the eastern mountain ranges of NW Iberia (the only area with limestone formations in this region) led to the discovery of several Paleolithic sites. However, late prehistoric and historic levels were also identified, showing the evolution of the role and functionality of the karstic systems for human communities (De Lombera 2011). The present article focuses on the archaeobotanical results obtained from the Roman and Medieval occupations of Cova do Xato (Folgoso do Courel, Lugo) and Cova Eirós (Triacastela, Lugo).

Cova do Xato is located at an altitude of 1080 m a.s.l. in the northwestern sector of the O Courel mountain range (Noceda), part of the Cándama Limestone Geological Formation. The entrance to the cave is 3.5 m wide and 4m high, with the gallery extending back for a distance of 45 m. At the entrance to the cave, a hearth with associated bones (several of them burnt) and potsherds was discovered in Test Pit 2. The presence of a fragment of *Terra Sigillata* enabled the dating of this occupation to the 4^{th} - 5^{th} century AD (Fábregas Valcarce *et al.* 2008). The scarcity of archaeological remains, linked to a single occupation layer, suggests sporadic use of the cave. This could be related to either the Late Roman settlement in the Courel area associated with auriferous exploitations, or to the activities of hermits in these regions prior to the constitution of monastic communities in the 10th century AD; the latter hypothesis suggested by the isolated location of the site, the scarcity of archaeological remains and the existence of other Galician parallels (Fernández *et al.* 1993).

Cova Eirós, also related to the Cándama Formation, was occupied at a later period. The cave is located on the N-NW slope of Monte Penedo, 780 m a.s.l., and 25 m above a stream. The entrance to the cave is 2m high and 3.5 m wide for the first 18 m, after which it narrows to form a deep gallery. During archaeological fieldwork several anthropic structures were identified in the entrance area (Rodríguez *et al*. 2011) (Fig. 2).

Two pits (UA1, UA2) of 1m diameter and 1.1-1.3m deep were cut into Pleistocene layers, and contained bones, charcoals, seeds and potsherds. The mixing of this assemblage and the lack of stratigraphic coherence suggest that these pits were refilled on a number of occasions after they had fallen out of use. Radiocarbon dating of a nearby hearth (UA 6) produced a date of 1040 ± 30 BP (949-1032 cal. AD -2s- Beta-308578), although morphological analysis of the pottery assemblage suggests a long period of use of the cave, with vessel forms dating from the 10-11th to the 15th centuries AD (FábregasValcarce *et al*. 2009, in press). A cobbled surface, which consisted of limestone blocks and quartzite cobbles, surrounded the pits highlighting the significance of this central space. Among these structures, several domestic faunal remains were recovered (pigs, cows and ovicaprids), some of them with clear cutmarks.

Cova do Xato and Cova Eirós are located in the environs of the O Courel Sierra in the Northwest of the Iberian Peninsula (Fig. 1). The flora shows various phytogeographical characteristics, which reflect the transitional position of this mountain range, between

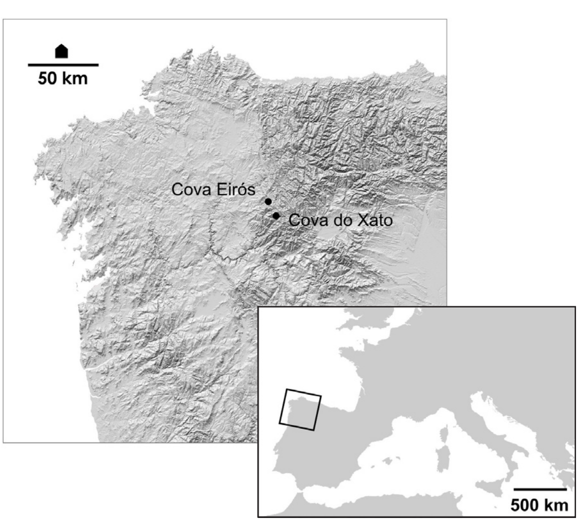

Figure 1. Cova do Xato and Cova Eirós in NW Iberia.

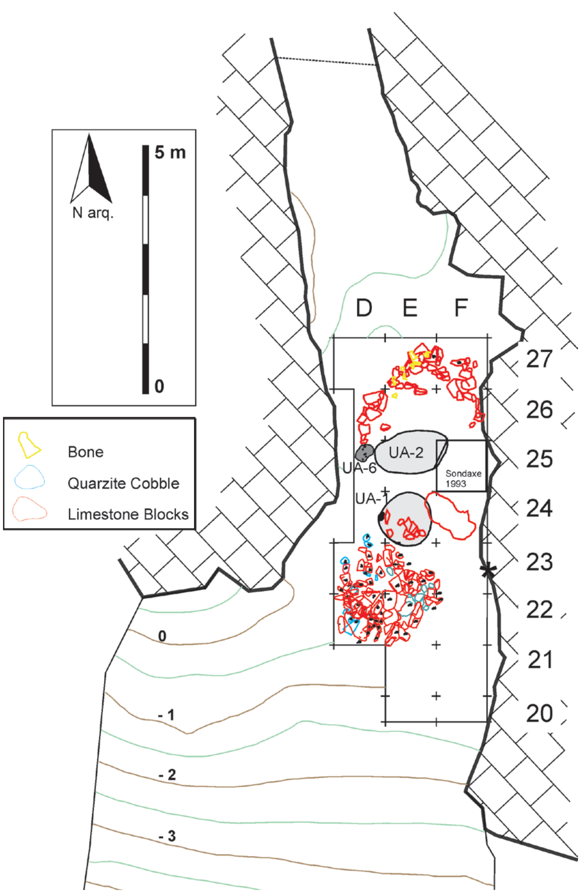

Figure 2. Location of the medieval structures at the entrance of Cova Eirós.

Eurosiberian-type deciduous forests belonging to the phytosociological class *Querco-Fagetea*, as well as Mediterranean-type perennial vegetation composed mainly of *Quercus ilex* (Santos *et al*. 2000). The environmental conditions in this area from the 4th to the 11th centuries AD were conditioned by the *Roman Warm Period* (250 cal. BC-450 cal. AD), followed by a cold episode (450-950 cal. AD) and, finally, by the *Medieval Warm Period* (950-1400 cal. AD) (Desprat *et al*. 2003; Sánchez-Goñi 2006). Recorded in the peat bogs of the Xistral Mountains, several episodes of deforestation took place during the medieval period, dating to between 610-740 AD, 740-1040 AD and 1080-1570 AD (Mighall *et al.* 2006). These episodes were probably related to the opening up of new crop fields, and to the high demand for wood for construction, woodworking, and fuel for artisanal activities.

MATERIALS AND METHODS

A similar sampling strategy was employed at both Cova de Xato and Cova Eirós. The largest pieces of charcoal were collected by hand to avoid fragmentation, while soil samples from the features were processed and floated in the laboratory using 2, 1 and 0.5mm meshes. Fruits and seeds were identified under a stereomicroscope, using an actual reference collection, and were counted, distinguishing between entire plant remains and fragments. Charcoal fragments and seeds were identified under a microscope using various atlases (Schweingruber 1990; Hather 2000; Vernet *et al.* 2001; Schoch *et al.* 2004; Jacomet 2006) and an actual reference collection. Dendrological features were also recorded during the analysis (ring curvature, presence of tyloses, cracks, vitrification, callous, etc.).

At Cova do Xato, 146 fragments from one sample (19.5 l of sediment) recovered from a hearth were analyzed. At Cova Eirós, 5 samples were recovered and 10*l* of soil from pit UA1 were floated, in total 105 fragments analyzed.

COVA DO XATO			
Taxa	MO-10	Total	
		Nb.	%
Quercus sp deciduous	98	98	66.7
Fabaceae	15	15	10.2
Fraxinus sp.	14	14	9.5
Corylus avellana	11	11	7.5
Salix/Populus	2	2	1.4
Rosaceae/Maloideae	2	2	1.4
Prunus sp.	2	2	1.4
Ulmus sp.	1	1	0.7
Arbutus unedo	1	1	0.7
Indeterminable	1	1	0.7
TOTAL TAXA	9	9	100
TOTAL FRAGMENTS	146	146	100

Table 1. Taxa identified during charcoal analysis at Cova do Xato.

DATA AND RESULTS

The results from **Cova do Xato** indicate the presence of 9 different taxa (Table 1). The most significant taxon, according to its percentage representation, is *Quercus* sp. deciduous. Other taxa are present in low percentages, among which Fabaceae, ash (*Fraxinus* sp.) and hazel (*Corylus avellana*) are the most abundant. The identified taxa belong to different biota, indicating the exploitation of different environments. Most of the taxa identified could be related to mixed deciduous forest; this is the case of oak (*Quercus* sp. deciduous), and bushes that grow in the clearings or along the edges of forests, such as hazel tree (*Corylus avellana*), pomes type (Rosaceae/Maloideae) and prunus type (*Prunus* sp.). Strawberry tree (*Arbutus unedo*), a termophillous shrub, was also identified. The scrubland formations are represented by the presence of Fabaceae. Some of the other taxa, such as *Fraxinus* sp., *Salix/Populus* and *Ulmus* sp. with greater water needs, probably grew close to rivers or other water courses.

The results of charcoal analysis are comparable to those obtained from pollen samples collected from different stratigraphic contexts at Cova de Xato (Expósito *pers. comm*.). Two samples from levels 2b and 2d are contemporary with the Roman occupation. In both samples, arboreal pollen (AP) prevails over non-arboreal (NAP) (between 60-80%). *Corylus avellana* in particular, stands out, accounting for 80% of the total when only the AP is taken into account. It is followed, in lesser proportions, by *Quercus* sp. deciduous, *Betula*, *Quercus ilex/coccifera*, cf. *Juniperus*, *Pinus* sp. and *Alnus*. Cistaceae was the only shrub identified (Expósito *pers. comm.*). The high values of *Corylus avellana* and the negative results of several samples could be related to taphonomic processes affecting the conservation of pollen grains. It is probable that hazel is over-represented in the pollen assemblage of Cova de Xato.

The number of carpological remains identified was restricted, with only 4 individual examples of *Triticum aestivum/durum* found, each of which presented a high degree of degradation of the internal and external surface.

At **Cova Eirós** 11 different taxa were identified (Table 2). The main taxa, in relation to their percentage representation, are *Salix/Populus*, birch (*Betula* sp.), oak (*Quercus* sp. deciduous) and pomes (Rosaceae/Maloideae). Most of the taxa identified such as *Salix/Populus*, *Betula* sp., *Ulmus* sp. and *Fraxinus* sp., are species with high hydric requirements associated with riverine woodlands. In this case, the percentage representation of the mixed deciduous forest is lower than at Cova de Xato. Other taxa identified were oak (*Quercus* sp. deciduous), pomes type (Rosaceae/Maloideae), hazel (*Corylus avellana*) and plum tree/blackthorn (*Prunus domestica/spinosa*). The termophillous shrub, *Arbutus unedo*, was also identified. The presence of chestnut (*Castanea sativa*) probably relates to the cultivation of this tree, which witnessed a great expansion during the medieval period.

The palynological data reveals that forest clearance in the Courel Sierra resulted in an increase of *Betula*, although sites cleared of oak were mostly occupied by grasses and moorland plants (Santos *et al.* 2000: 630). Widespread forest clearance of the area dated to the 10th century was recognised at the Sanabria Marsh (Santos *et al*. 2000).

One of the fire-affected fragments was a handle of a wooden container (Fig. 3), broken and reused as opportunistic firewood. This object was made from carving a trunk of *Betula* sp. While most of the vessels and containers from this period were made of wood, conservation of this kind of wooden object is unusual in this area (Morris 2000).

At both sites the presence of moderately curved rings is predominant in the fragments observed: 44.5% in Cova do Xato and 67.54% in Cova Eirós. Alterations of the anatomical structure of the wood included radial cracks, vitrification and galleries of xylophagous insects. At Cova do Xato radial cracks were identified in fragments of *Quercus* sp. deciduous (19.2%), *Fraxinus* sp. (0.7%), and *Ulmus* sp. (0.7%). Vitrification and galleries of xylophagous insects were only observed occasionally in *Quercus* sp. deciduous. At Cova Eirós galleries of xylophagous insects

COVA EIRÓS				
Taxa	MO-01	MO-08	Total	
			Nb.	%
Salix/Populus		29	29	27.6
Betula sp.	2	20	22	20.9
Quercus sp. deciduous		15	15	14.2
Rosaceae/Maloideae		15	15	14.2
Ulmus sp.		7	7	6.6
Fraxinus sp.		6	6	5.7
Fabaceae	2	2	4	3.8
Castanea sativa		3	3	2.8
Corylus avellana		2	2	1.9
Prunus domestica/spinosa		1	1	0.9
Arbutus unedo	1		1	0.9
TOTAL TAXA	3	10	11	100
TOTAL FRAGMENTS	5	100	105	100

Table 2. Taxa identified during charcoal analysis in Cova Eirós.

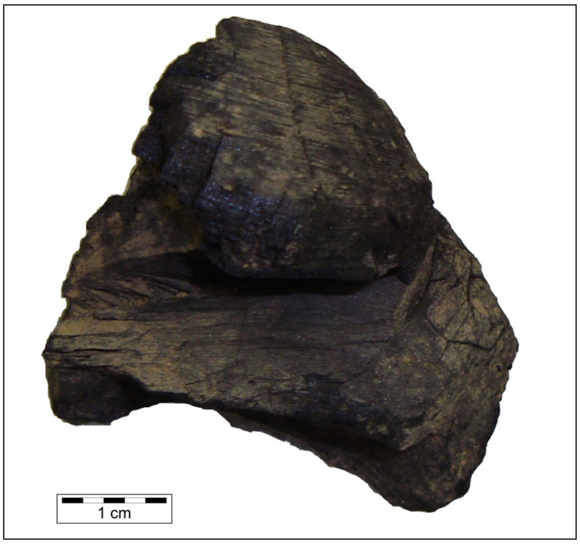

Figure 3. Handle of wooden container (*Betula* sp.).

were identified in 2.9% of the fragments, and affected only *Quercus* sp. deciduous and *Rosaceae/Maloideae*. The presence of radial cracks (5.7%) and vitrification (1.9%) was sporadic, the former affecting *Quercus* sp. deciduous, Rosaceae/Maloideae and *Ulmus* sp., the latter affecting only *Quercus* sp. deciduous.

Carpological analysis of sediment from pit UA1 reveals a combination of cultivation and plant collection strategies (Table 3). The absence of ruderal vegetation and vegetation associated with cultivation indicates the presence of agricultural products free from impurities, arising from the final processing stage prior to consumption. Several cereal taxa stand out, in particular naked wheat (*Triticum aestivum/durum*) and emmer (*Triticum dicoccum)*. According to the measurement of various morphometric indices based on the criteria established by Jacomet (2006), spelt (*Triticum* cf *spelta*) is also possibly identified. Barley (*Hordeum vulgare*) is very rare, with only one seed recovered.

COVA EIRÓS. CARPOLOGY		
Taxa	Nb.	Fragments
Corylus avellana		65
Hordeum vulgare	1	
Linum sp.	30 ml*	
Triticum sp.	25	29
Triticum aestivum/durum	43	5
Triticum dicoccum	34	1
Triticum cf *spelta*	2	
Indeterminate		17
TOTAL	108	130

Table 3. Seeds identified in the medieval settlement at Cova Eirós. (*seeds of *Linum* sp. are aggregated and expressed in terms of volume).

Another identified crop is flax (*Linum* sp), which was usually destined for non-dietary purposes. According to Herbig and Maier (2011) flax seeds of smaller size tend to be used for the extraction of their fibre for textile production, while larger seeds are exploited for their oil. The dimensions of the flax seeds (n=7) from Cova Eirós range from 3.16–3.51 mm in length, and 1.65–1.92 mm in width, which correspond to those of seeds exploited for their fibre.

Among the remains various fragments of *Corylus avellana* were found, indicating a probable seasonal dietary exploitation of this taxon. Refitting of the fragmented achenes was undertaken, although the complexity of the assembly of various fractures and the small size of the fragments made the process difficult. It was only possible to securely refit two pairs of remains, resulting in the identification of 63 minimum number of individuals, which is very close to the total of fragments (n=65). To refine this data only the fragments of the basal part of the pericarp (n=10) were counted (Fig. 4), giving a final maximum number of individuals of 9 hazelnuts.

Indeterminate fragments and those attributed to the genus *Triticum* sp. correspond to very degraded and deformed remains, which made it impossible to assign a more precise determination.

DISCUSSION

The archaeobotanical record reflects the relationship established between communities and their envi-

Figure 4. Fragmented pericarp base of hazelnut (*Corylus avellana*).

ronment, which determined the exploitation of forest resources in the past. This activity was conditioned by such issues as availability and proximity, but also by social and economic factors (settlement type, duration of occupation, group size, technological development, etc.). The occupation of caves was unusual during the Roman and medieval periods. The choice of these places for settlement could have been motivated by different factors: short-term occupations could reflect the use of the cave as a refuge during periods of instability, as a hermitage or, as in the case of Cova Eirós, as a fold for livestock. Diachronic occupation is evidenced at Cova Eirós, where the cave was used for cereal storage inside pits. In both cases the caves were probably occupied by small groups.

The taxa identified show a diversified catchment area, from valley floors, to mountain slopes, to the banks of rivers or other water courses during the Roman occupation of Cova do Xato. During the occupation of Cova Eirós, from the 10th to the 15th century, the presence in charcoal analysis of taxa related to mixed deciduous forest was lesser than in the preceding period. The decrease of these taxa in parallel with the increased presence of riverine woodland taxa could be related to the deforestation of the valleys associated with the opening of new crop fields (Guitián 2001), and the maintenance of trees in the environs of rivers and water courses. The high representation of a pioneer species such as *Betula* also strengthens the hypothesis of forest clearance during this period (Santos *et al.* 2000). Several taxa of cereals and flax identified at Cova Eirós would indicate the economical exploitation of these fields by communities located in the vicinity. The presence of chestnut at Cova Eirós is also interesting, as it could be related to the spread of *Castanea* during the medieval period in the Northwest of the Iberian Peninsula.

CONCLUSIONS

The archaeobotanical analyses of Cova do Xato and Cova Eirós provide data about the management of forest resources related to complementary activities of the rural economic system by small groups. Both caves were occupied during warm periods - Cova do Xato at the end of the *Roman Warm Period* and Cova Eirós at the start of the *Medieval Warm Period*. Charcoal analysis reveals the degradation of forest cover during the medieval period, as shown at Cova Eirós. The presence of *Castanea* is closely tied to human activity. Chestnut cultivation took place in Western Europe from the early medieval period onwards, and flourished in the later medieval period (11th-16th centuries), when it became an essential source of both food and timber in Galicia and Northern Portugal (Conedera *et al*. 2004; Conedera and Krebs 2008).

The extent of the area excavated at **Cova do Xato** was not sufficient to obtain a clear view of the characteristics of the occupation of this site. The presence of charred cereals and *Terra Sigillata* could indicate the existence of stable occupation of this settlement, although the only structure identified was a hearth. The strategy of firewood collection evidenced at this site was influenced primarily by the availability in proximity to the cave, as indicated by the palynological analysis, but also by the properties of the wood. Species such as *Quercus* sp. deciduous or Fabaceae, were selected due to their combustion-resistant characteristics and consequent production of long-lasting embers, and were combined with some faster burning ones (e.g. *Salix/Populus, Corylus avellana*) to produce abundant flames.

At **Cova Eirós**, as well as at Cova do Xato, firewood was collected in the surroundings of the settlement: near riverbanks, in the valley areas and at the foot of the mountains or scrub areas. It was also an opportunistic consumption of different types of firewood, which could have been collected when fetching water or harvesting wild fruits (hazelnuts). The presence of two pits and the predominance of storage vessels indicate that the medieval occupation was mainly related to the storage of agricultural products rather than to shelter or habitation, though some domestic activities did occur on the site. It can be considered as evidence for the progressive human settlement of the eastern ranges of NW Iberia from the 9th century onwards.

ACKNOWLEDGEMENTS

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MARIA LITYŃSKA-ZAJĄC

Forest plant remains from the Late Pre-Roman and Roman Iron Age in Poland

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***Summary**: The history of forests is presented on the basis of macroscopic remains (charcoal, seed and fruit) of trees and bushes coming from different archaeological sites such as settlements and cemeteries and various features (burials, hearths, pits, among others) found on the territory of Poland. Plant material is dated to the Late Pre-Roman, Early Roman and Late Roman periods, from the 2nd century B.C. to the ca. mid 5th century A.D. The frequency of remains suggest that the most common or the most often exploited forest communities were mixed forests with a domination of oak (*Quercus *sp). and Scots pine (*Pinus sylvestris*).*

***Key words**: charcoal, forest, palaeoenvironment, Roman Period, Poland.*

INTRODUCTION

The questions formulated in this article deal with the history of forest communities in Poland. The analysis is based on the remains of trees and shrubs coming from 46 archaeological sites, dating back to the Late Pre-Roman (phases A1-A3), Early and Young Roman (previously called Early Roman; phases B-C1) and Late Roman (phases C2-D) periods (Fig. 1). These periods encompass the time span from the 2nd century B.C. to approximately the mid 5th century A.D. Materials from the following cultures have been studied –Late Pre-Roman: Przeworsk Culture and Tyniec Group; Early Roman: Przeworsk, Puchow and Wielbark Cultures, Tyniec Group and West Balt circle; Late Roman: Wielbark and Przeworsk Cultures, West Balt circle and Dębczyno Group. The results were evaluated in the context of plant remains from the Roman period (Lityńska-Zając 1997) and were also supplemented by more recent archaeobotanical studies (Lityńska-Zając 2001; Pirożnikow 2002; Tomczyńska 2002; Wasylikowa, *et al*. 2008). The aim of this paper is to present species and genera of trees and bushes found at several archaeological sites located in different regions of Poland (Fig. 1). Another goal of the present work is to evaluate and discuss the changes that took place in the forests during prehistoric periods. A part of these investigations has been published elsewhere (Lityńska-Zając 2011).

A large abundance of charcoals was found among the plant remains gathered from Roman archaeological sites. This paper presents the results of macroscopic analyses of plant remains collected from different archaeological sites such as settlements and cemeteries as well as various kinds of features including burials, hearths and pits, among others.

RESULTS

The remains of trees and shrubs from the Late Pre-Roman and the Roman Iron Age are mostly charcoals, charred and uncharred seeds and fruits, as well as imprints in burnt clay of leaves and seeds. A total of 53 taxa were identified including 35 species, 11 identifications to the genus and one to the family level. Qualitative and quantitative contents from different chronological periods are shown in Tables 1-3. Two methods were employed for the evaluation and interpretation of the results. The first method was based on the abundance, which means the number of specimens present for each culture. The second one consisted of determining the frequency of taxa found at each archaeological site. Most of the data concern the Late Roman Iron Age. Species or genera were grouped according to their occurrence in present-day forests communities based on studies conducted by W. Matuszkiewicz (2001), J. M. Matuszkiewicz (2005) and K. Zarzycki, *et al*. (2002). A similar type of analysis was employed to discuss the changes that took place in forest flora during prehistoric times.

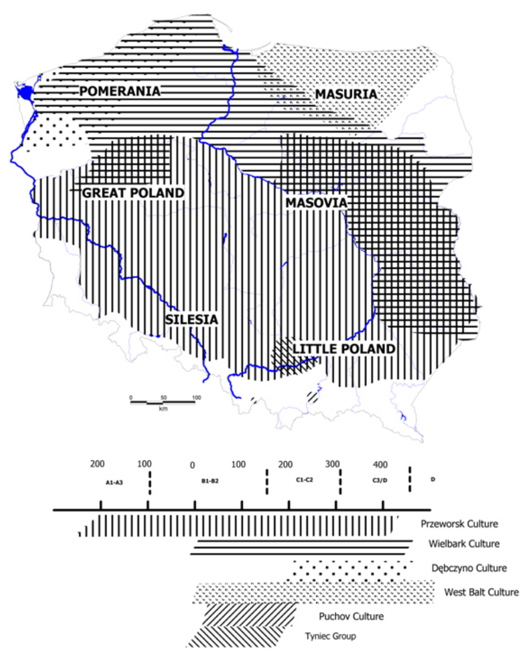

Figure 1. Schematic spatial and chronological ranges of the Late Pre-Roman and Roman Iron Age cultures (according to Kaczanowski, Kozłowski 1998).

Charcoals from the Late Pre-Roman Iron Age were found at 4 sites belonging to the Przeworsk culture. The most common species present at 2 of the sites were oak (*Quercus* sp.), Scots pine (*Pinus sylvestris*), European beech (*Fagus sylvatica*) and ash (*Fraxinus excelsior*) (Table 1). The most abundant taxon found in all of the sites was oak (*Quercus* sp.), which was followed by poplar (*Populus* sp.) or willow (*Salix* sp.). In addition, elm (*Ulmus* sp.) and European beech (*Fagus sylvatica*) were found in lesser amounts. Other taxa such as *Fraxinus excelsior,* Rosaceae indet. and Coniferae indet. were represented in a limited number of specimens. An imprint of *Salix* leaf was present at one site belonging to the Tyniec Group. In general,

Name of taxa	Late Pre Roman Iron Age	
	Number of fragments	Number of sites
Quercus sp.	1410	2
Populus sp. or *Salix* sp.	608	1
Ulmus sp.	594	1
Fagus sylvatica	469	1
Pinus sylvestris	294	2
Fraxinus excelsior	8	2
Rosaceae indet.	6	1
Coniferae indet.	P	1
Salix sp.	1xl	1

Table 1. Number of charcoal fragments from the Late Pre-Roman Iron Age. Explanation: p – number of charcoal fragments is not given, xl – imprint of leaf.

macroscopic plant remains from the Late Pre-Roman period were very scarce and only appeared in the Little Poland region (Fig. 1).

From the Early Roman Period, six species and ten genera of trees and shrubs were identified among charcoals. Furthermore, five species were found among fruits and seeds. A total of 122 specimens of charred wood from two sites were classified as Rosaceae (Table 2). In the list of trees and shrubs, a diversity of taxa is observed among the remains of trees and shrubs. However, only two taxa, namely oak (*Quercus* sp.) and Scots pine (*Pinus sylvestris*), clearly predominated in the charcoal assemblages. They were also more ubiquitous since they were found at six of the sites. In contrast, European beech (*Fagus sylvatica*) and hornbeam (*Carpinus betulus*) were less frequent and they appeared only at two of the sites. Plant remains from this chronological unit were found at sites belonging to various cultures, namely Przeworsk, Puchov, Wielbark and the West Balt circle, which occupied different historic-geographical regions of Poland (Fig. 1).

Remains of trees and shrubs from the Late Roman Period were indentified at 33 sites (Table 3). Among macroscopic plant remains, the charcoals were more frequent. *Rubus* and *Sambucus* were found in the form of fruits, while different species of *Salix* genera (*Salix alba, S. caprea, S. fragilis* and *S. vininalis*) were preserved as imprints of leaves. Charcoals and other kinds of plant remains from this period represent different cultures and locations (Fig. 1). In addition, sites that are characterized for having undefined cultural contexts were located only in the Carpathians Mountains.

The taxa that were more frequently found include: Scots pine (*Pinus sylvestris*) (25 sites), oak (*Quercus* sp.) (16 sites) and hornbeam (*Carpinus betulus*) (14 sites). As far as the number of fragments is concerned, the most abundant were, birch, followed by Scots pine and hornbeam. The remains of *Betula* and *Carpinus betulus* were mainly found on sites belonging to

Nameof taxa	Cultures					Early Roman Age	
	Przeworsk; N=5		Puchov; N=1	West Balt circle; N=1	Wielbark; N=1	Number of	
	specimens	sites	Number of specimens			specimens	sites
Quercus sp.	2866	3	9	4	3	2882	6
Pinus sylvestris	786	4	2	2		790	6
Fagus sylvatica	394	1	2			396	2
Carpinus betulus	204, 1f	2				204,1f	2
Ulmus sp.	184	1	2			186	2
Rosaceae indet.	122	2				122	2
Abies alba	65	1				65	1
Populus sp.	52	1				52	1
Corylus avellana	41, 5f	2	1f			41, 6f	3
Tilia sp.	31	2	5			36	3
Betula sp.	27	1	2f			27, 2f	2
Populus sp. or *Salix* sp.	12	1	2	2		16	3
Fraxinus excelsior	12	2				12	2
Alnus sp.	9	1				9	1
Ulmus leavis	4f	1				4f	1
Salix sp.	3	1				3	1
Picea sp. or *Larix* sp.	1	1	1			2	2
Coniferae indet.			1			1	1
Sambucus nigra	1s	1				1s	1
Rubus sp.	1s	1				1s	1

Table 2. Number of charcoals, fruit and leaf trees from the Early and Young Roman Iron Age. Explanation: f – fruit, s – seed.

Name of taxa	Cultures									Late Roman Age	
	Przeworsk; N=14		Wielbark; N=2		Dębczyno; N=1	West Balt circle; N=12		Culture ?; N=4		Number of	
	specimens	sites	specimens	sites	specimens	specimens	sites	specimens	sites	specimens	sites
Quercus sp.	3438	10			23	771	2	48	3	4280	16
Betula sp.	86	4	2560	2	1	226,p,7f	3			2873, p, 7f	10
Pinus sylvestris	878, p, 11s	9	308	2	1	204, p	11	8	2	1399, p, 11s	25
Quercus robur	p, 1xl	2	680	1		p	8			680, p, 1xl	11
Quercus petraea			471	1		p	1			471, p	2
Carpinus betulus	14	3	356	1		21, p, 2f	10			391, p, 2f	14
Picea sp. or *Larix* sp.								313	4	313	4
Fagus sylvatica	104	3			7	141, p	6	39	3	291, p	13
Fraxinus excelsior	57	3	199	1				4	1	260	5
Ulmus sp.	41	3				127	1	5	1	173	5
Alnus sp.	155	3				1f	1	4	1	159, 1f	5
Juniperus communis			1	1		p	4	134	3	135, p	8
Picea abies			134	2		p, 1s	6			134, p, 1s	8
Tilia sp.	99	3			4					103	4
Acer sp.	29	2				44	1	12	2	85	5
Corylus avellana	6f	2				70,p,2f	2	13, 86f	4	83, p, 92f	8
Populus sp.	3	2				76	1			79	3
Populus sp. or *Salix* sp.	49	4				28	1			77	5
Abies alba	5	1						57	3	62	4
Rosaceae indet.	39	3				4	1	16	2	59	6
Alnus glutinosa	38uchf	1				p, 5s	4			38uchf, p, 5s	5
Coniferae indet.	6	4				2	1	28	4	36	9
Alnus glutinosa	38uchf	1				p, 5s	4			38uchf, p, 5s	5
Salix sp.	1, xl	2				26	1			27, xl	3
Acer campestre			26	2		p	1			26, p	3
Rubus idaeus						22s	4			22s	4
Betula pendula or *B. pubescens*						16uchf	1			16uchf	1
Taxus baccata	p	1	12	1		p	1	2	1	14, p	4
Euonymus sp.								10	1	10	1
cf. *Quercus* sp.								8	1	8	1
Staphylea pinnata			7s	1						7s	1
Rubus ceasius	2s	1				1s	1			3s	2
Ulmus scabra			2	1		p	1			2, p	2
Betula humilis						p	3			2	3
Juglans regia			1	1						1	1
Rubus sp.	1xs, 1s	2								1xs, 1s	2
Rubus t. *plicatus*	1s	1								1s	1
Sambucus sp.	1xs	1								1xs	1
Betula pendula	p	1				p, 1 s	5			p, 1s	6
Malus sylvestris	1s	1				p	1			p, 1s	2
Acer platanoides						p	3			p	3
Acer pseudoplatanus						p	1			p	1
Betula pubescens						p	2			p	2
Larix decidous						p	3			p	3
Populus tremula						p	2			p	2
Rhamnus cathartica						p	1			p	1
Tilia cordata						p	3			p	3
Ulmus campestris						p	1			p	1
Ulmus leavis						p	2			p	2
Salix alba	xl	1								xl	1
S. caprea	xl	1								xl	1
S. fragilis	xl	1								xl	1
S. vininalis	xl	1								xl	1

Table 3. Number of charcoals, fruits, seeds and leaf trees from the Late Roman Iron Age. Explanation: p – number of charcoal fragments is not given, f – fruit, s – seed, xl – imprint of leaf, ; state of preservation: uch - uncharred.

the Wielbark culture. Some very small specimens of charcoal coming from 8 sites were merely classified as coniferous trees. The presence of European beech (*Fagus sylvatica*) constitutes the most important finding from the sites that formed part of the West Balt circle. They are situated beyond the present-day limit of its eastern limit range. *Fagus sylvatica* is a species that developed relatively late in Polish forest communities. According to the palynological data, its widest expansion barely took place in the Iron Age. Isopollen maps, from 2000-1500 BP, show small values of pollen grain belonging to this species in the north-eastern part of the country (Latałowa *et al.* 2004). Moreover, in this chronological unit, other interesting taxa were commonly found including walnut *Juglans regia* and bladder nut *Staphylea pinnata.* They were discovered at the Wielbark Culture site located in Pruszcz Gdański (North Poland). Walnut shell and seeds of bladder nut were elements of jewelry such as pendants and necklaces discovered in graves (Latałowa 1994). These two species probably did not grow at that time in the vicinity of the site. *Juglans regia* was probably cultivated since the Early Medieval period in the territory of Poland (Jarosińska 1994).

DISCUSSION AND CONCLUSIONS

Archaeobotanical sites containing remains of trees and shrubs were mainly located in Little Poland and in Masuria, while the knowledge about other regions is limited. The majority of plant macro-remains come from the Late Roman Period. In contrast, the plant material coming from the Pre-Roman Iron Age was scarce. Among trees and shrubs described herein, a large diversity of taxa can be noticed. There was a clear dominance of several trees, such as Scots pine (*Pinus sylvestris*) and oak (*Quercus*).

The results of the anthracological analysis are in agreement with the palynological data (Dybova-Jachowicz and Sadowska eds. 2003) and isopollen maps (Ralska-Jasiewiczowa ed. 2004). It is observed that trees preserved in archaeological charcoals were found within their ranges indicated by the pollen analysis. However, there are also certain differences in the development of vegetation during the Roman period in several geobotanical regions.

A reconstruction of forest may indicate a type of plant communities that developed in the vicinity of settlements. Numerous finds of pine and oak in nearly all geobotanical regions and chronological units suggest that coniferous mixed forest occupied large areas during the Roman period. In the Masurian region (north-east Poland), numerous pine remains confirm the occurrence of humid coniferous mixed forests similar to those found today in northern Poland. Among other genera of trees and shrubs found in charcoal assemblages, the following ones were capable of growing in forest habitats located on airy ground: maple (*Acer* sp.), birch (*Betula* sp.), ash (*Fraxinus excelsior*), linden (*Tilia* sp.), hornbeam (*Carpinus betulus*), hazel (*Corylus avellana*) and spindle tree (*Euonymus* bushes). In addition, remains of wood come from marshy swamps in which poplar (*Populus*), elm (*Ulmus)*, ash (*Fraxinus excelsior*) and willow (*Salix*) commonly grow. These last taxa occurred more often during the Late Roman period. This may indicate that in this period the exploitation of the forests growing in the proximity of river valleys was greater. When comparing with earlier periods, it can be stated that this was probably due to dry climate conditions. Furthermore, some trees are present only in certain regions. For example, spruce (*Picea abies*) is typically found on the Little Poland plateau, while fir (*Abies alba*) appears only in the Carpathians. This indicates regional differentiation in prehistoric forest communities.

The analysis of species composition indicates the presence of plants coming from different forest communities, suggesting the permanent use of these habitats by human groups.

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Optimal use of the date palm (*Phoenix dactylifera* L.) during Antiquity: Anatomical identification of plant remains from Madâ'in Sâlih (Saudi Arabia)

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Summary: *Ethnographic observations, literary sources and plant remains underline the usefulness of the date palm products and by-products, from at least the Bronze Age until today. Recent anatomical works on modern palms enable us to identify various genera of palms and the different parts of these plants: stem, petiole and lamina. Practical application of these anatomical studies is applied for the first time at the archaeological site of Madâ'in Sâlih (Saudi Arabia) where charred plants have been found in domestic contexts dating from at least the 2nd century B.C. until the 7th century A.D. Date palm (*Phoenix dactylifera *L.) dominates the assemblage. Petiole and midrib remains are more often testified than stem fragments. These results are discussed in terms of plant use and fuel economy.*

Key words: *Palm anatomy,* Phoenix dactylifera *L., date palm use, fuel management. Madâ'in Sâlih.*

INTRODUCTION

Since Prehistory the date palm, *Phoenix dactylifera* L., has played an important role in the subsistence economies of the hot deserts of the Middle East and North Africa. The earliest evidence for the consumption of date fruits comes from the Persian Gulf area and goes back to the late 6th and early 5th millennium B.C. (Beech and Shepherd 2001; Beech 2003; Tengberg 2003b, 2012). These early finds of date stones may either correspond to fruits collected from the wild or result from an early cultivation of date palms (Nesbitt 2005: 83). In any case, date palm cultivation seems to have developed essentially in the Bronze Age, that is from the early 3rd millennium B.C., in different regions of the Middle East, where archaeological sites provide large quantities of both seeds and stem fragments (Potts 2002; Tengberg 2003a and b, 2012; Boivin and Fuller 2009; Méry and Tengberg 2009; Zohary *et al.* 2012). The diploid date palm is a perennial and dioecious plant adapted to arid environments that necessitates special propagation, cultivation and management techniques (Battesti 2005: 133–151; Chao and Krueger 2007). At least since the Bronze Age, and until the present day, the date palm constitutes the main species of the particular oasis agrosystems that concentrate agricultural production in environments of great aridity. Besides producing highly nutritious fruits, the date palm offers a protective shade allowing cereals, pulses and vegetables to be grown on the ground level (Battesti 2005: 35–95).

DIFFERENT USES OF THE DATE PALM

Ethnographic observations show that even though the fruits of the date palm, used for food and fodder, constitute the main produce of the species, many other products are traditionally obtained from its different parts (Figs. 1 and 2): the straight, cylindrical stem, or trunk, can grow to a height of over 20 m and is appreciated as a construction element. Split into halves

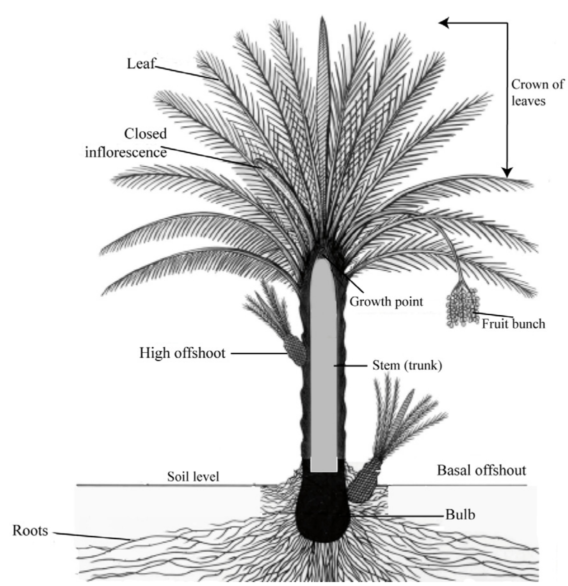


Figure 1. Schematic representation of date palm (*Phoenix dactylifera*) structure (after Munier 1973: 25).

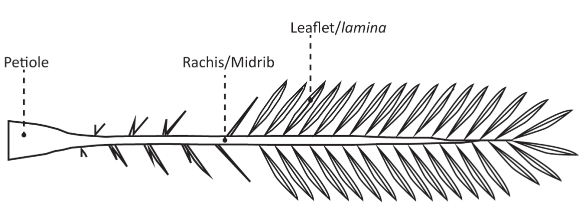


Figure 2. Schematic drawings of a date palm leaf (after Munier 1973: 28).

or quarters it is used for beams or posts (Figs. 3 and 4). It also serves as a support pillar for wells and other structures, and as a brace for slanting date palms in danger of collapse. Sections of the trunk can be partially hollowed out and used as mortars, or split into halves, as cattle troughs. Omani beekeepers used to stack palm trunk cylinders, sealed at either end by clay and ash plugs, and use them as hives. The fan-shaped leaves are useful for the covering of roofs (Fig. 4) and huts and can be lashed together to form panels that are used in the construction of dwellings and livestock pens. Basketry and ropes are produced from the leaflets. The fibres that develop around the leaf basis – the *fibrillum* – are made into cordage and used as padding for mattresses, pillows, camel saddles, *etc*. The woody petioles and midribs are transformed into furniture, small fishing boats or other works of carpentry. After the harvest, the cluster remains – without the fruits – serve as brooms. Finally, edible elements others than fruits are known: date seeds can be used as feed for livestock, the sap constitutes a refreshing beverage, the pith of the palms can be made into date palm flour and the palm hearts – i.e. the growing point of the crown – is an appreciated dish (Munier 1973; Richardson and Dorr 2003; Chao and Krueger 2007).

The usefulness of the date palm is also related to ancient texts. Cuneiform writings cite many of the uses described above, among them frequently quoted works of basketry. Date palm beams appear in the list of materials used for ship-building (Landsberger 1967: 7, 40). Palm hearts are among the items presented to the goddess Ba-u as gifts on her yearly wedding festival (Landsberger 1967: 13). In a famous poetic dispute between the date palm and the tamarisk tree, the earliest version of which dates to the Old Babylonian period (early 2nd millennium B.C.), the date palm argues for its superiority based on the usefulness of its different parts: "*The king eats from my dish, from* [*my*] *goblet* […] *From my plate. The warriors eat from my bread-basket* […]. *The baker takes up flour. I am a weaver, [beating up] the threads. I clothe the troops* […] *of the god. I am the chief exorcist and renovate*

Figure 3. Beginning of the splitting of a date palm trunk for architectural purposes (Makran, Pakistan, © M. Tengberg).

Figure 4. Covering system made of half date palm trunk, tamarix beams and date palm midribs (Al-'Ula, Saudi Arabia, © C. Bouchaud).

Figure 5. Bread oven supplied with date palm petioles and midribs (Kerman, Iran, © M. Tengberg).

Figure 6. Date palm ashes used as fertilizer (Adam, Oman, © M. Tengberg).

the temple. [*I am*] *indeed an aristocrat* […]. *I certainly have no rival*" (Lambert 1960, 152-154). In later texts, Theophrastus also notes that the leaves are useful for basket making whereas its "wood" has a loose, fibrous and spongy structure (Theophrastus, *Historia plantarum* IV. 2.11). These characteristics made the trunk solid and elastic, well adapted to architectural works (*H. P.* V. 3. 6; V. 6. 1). Pliny the Elder refers to the strength of the cordage made with the leaves (*Historia naturalis* XVI. 37. 1) and notes several medicinal and cosmetic usages (*H.N.* XIII. 51. 1; XIII. 53. 1).

The use of the ligneous parts of the palm for fuel is not often mentioned in the ethnographic literature, maybe because it represents a common secondary use, that does not seem to be worth mentioning. We can read that clusters and spathes are traditionally employed as domestic fuel (Munier 1973: 181) or that surplus date-palm material is used as fuel for the firing of pottery and the boiling of dates (Richardson and Dorr 2003). In Iraq at the beginning of the 20th century, the chief use of the leaf bases was for fuel while the fruit bundles and the fibres around the leaf basis were secondarily used as an inferior fuel (Dowson 1921; Landsberger 1967: 18, 19, 23). Our personal observations in present palm groves of the Middle East highlight that trunks and fronds are generally burnt. In southeastern Iran, bread ovens are fuelled with petioles and midribs (Fig. 5). In Oman, even the ashes from the burnt date palm leaf midribs find a secondary use as they are spread out on the soil in the date palm gardens as a fertilizer (Fig. 6). Ancient cuneiform texts provide informative remarks on the use of palms for fuel. For example, economic texts related to the temple administration of the city of Uruk in southern Mesopotamia indicate that the production of fuel from date palm fronds had become a centralised industry out of the retail delivery of by-products, accompanying the yield of dates through the gardeners or little entrepreneurs (Landsberger 1967: 49–50). The only data found among the classical literature comes from Theophrastus, who, even though he does not designate a specific part of the date palm, maintains that the species produce a very unpleasant smell when burnt (*H. P.* V. 9. 5).

ARCHAEOLOGICAL IDENTIFICATION

Besides seeds, desiccated and charred elements of ground and vascular tissues of date palm are commonly found in archaeological sites of the Middle East and correspond to a use either as construction elements or fuel. In some cases, when the preservation conditions are favourable, their original use can be known. Thus several date palm beams found in Near Eastern sites highlight theirs architectural uses, such as the carbonised stem fragments found in levels dated to the Ubaid 4 period (4700-4200 BC) in Tell el'Oueili (Iraq) (Neef 1991), in the Bronze Age houses of Tell Bderi in Northeast Syria (Engel 1993) or in the great city of Susa during the Iron Age (Miller 1981). Remains of a couple of date palm columns, that were thought to have been covered with sheet copper, were discovered flanking the entrance to an Early Dynastic III temple at Tell al-'Ubaid (Woolley and Hall 1927: 115-116). A similar device is thought to have been used a few centuries later in front of a temple at Nippur dated to the Ur III period (2100-2000 BC) even though the identification is uncertain (McCown and Haines 1967: 10). The soft parts of the palm leaves are rarely preserved in archaeological contexts. One example of this exceptional preservation is the discovery of ropes and baskets made from palm leaves in 'En Rahel (Negev desert) during the Antiquity. These items were probably involved in trade activities (Shamir 1999: 101-109). In others cases, baskets and mats have frequently left impressions on floors and mud bricks.

The identification of the plant parts – and thus the original use – of the majority of palm charcoal, remains problematic though mainly due to two factors. First, ground parenchyma and fibrovascular bundles of taxa belonging to the palm family present similar anatomical structures – characterised by a lack of secondary growth –and confusions may exist (Tomlinson *et al.* 2011), above all when the preservation is not good. Indeed, we know that several other palm species were used in the Old World, as for example the desert palm (*Nannorrhops ritchieana* (Griff.) Aitch.) used for a protohistoric net in Baluchistan (Thomas *et al.* 2012), or the doum palm (*Hyphaene thebaica* L.) that had similar uses to the date palm (Theophrastus, *H. P.* IV. 2.11). The second reason for the difficulty of interpretation is that until now, palm remains were identified taxonomically without considering if they came from the palm stem or from the woody leaf base, i.e. petiole and midrib (Figs. 1 and 2). Yet, the differentiation is important in order to understand practices of date palm exploitation and management of date palm gardens in the past.

In this paper we propose a method for distinguishing between the different parts of the palms on the basis of morpho-anatomy, taking into account the four palm genera that are endemic to the Middle East: *Nannorrhops*, *Phoenix, Chamaerops* and *Hyphaene*. The method is then applied to charred plant material from Madâ'in Sâlih, a Nabataean site located in

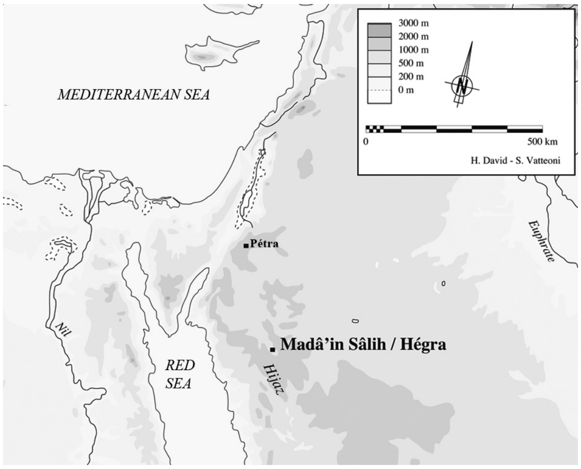


Figure 7. Location of Madâ'in Sâlih/Hegra in Northwestern Saudi Arabia.

northwestern Saudi Arabia (Fig. 7) in order to confirm the identification of the palm remains and to see what parts of the plant are found in the archaeobotanical assemblages. The results are interpreted in terms of plant use and fuel economy.

METHODS

THE ANATOMICAL STUDY

The anatomical study allows recognising anatomical characters in order to differentiate between the two woody vegetative parts (stem and petiole-midrib). The main descriptors that discriminate these elements are based on the structure of the fibrovascular bundles (Tomlinson 1961; Tomlinson *et al.* 2011). These are made of a fibrous part adjacent to the phloem (with possible different shapes), and a vascular part. The vascular part consists of the phloem and the xylem with some paravascular parenchyma. The fibrovascular bundles of a stem usually have a well developed fibrous part adjacent to the phloem (or dorsal cap) whereas in the petiole the fibres are less abundant (Fig. 8). On the contrary, the phloem is more developed in the petiole. The fibrous part adjacent to the xylem (ventral cap) is always well developed in the petiole, and it is sometimes found in the stem vascular bundles of some genera. Thus the vascular bundles of the petiole are almost enclosed in a fibrous sheath except at the level of the metaxylem.

From the stem (Tomlinson 1961, Tomlinson *et al.* 2011; Thomas 2011a and b) and the petiole (Tomlinson 1961) anatomical descriptors, discrimination between some genera is possible (Fig. 9). This analysis (Thomas 2011a) was based upon the observation of 114 species in 81 genera (4 specimens of 3 species of *Phoenix*, 6 specimens of 2 species of *Hyphaene*, 1 specimen of *Nannorrhops*, 5 specimens of *Chamaerops*). In *Nannorrhops* genus, fibrous bundles are found in the stem. A fibrous part adjacent to the xylem is sometimes developed and the vascular part consists of two vessel elements. The shape of the fibrous dorsal cap is Vaginata to Lunaria. In *Phoenix*, no fibrous bundles are found in the stem. The fibrous part adjacent to the xylem is well developed but not always visible. The vascular part consists of two vessel elements. The ground parenchyma is compact and the shape of the fibrous part is Vaginata. The vascular part of *Chamaerops* is made of four vessel elements and fibrous bundles are present. The shape of the fibrous part is Reniforma to Lunaria. The fibrovascular bundles of *Hyphaene* have two vessel elements and a Reniforma fibrous part. The ground parenchyma is compact (Thomas 2011a and b).

THE ARCHAEOLOGICAL SITE AND THE ARCHAEOBOTANICAL MATERIAL

Madâ'in Sâlih, the antique site of *Hegra*, is located in a wide desert plain surrounded by mountains (Fig. 10). Arid conditions (± 50 mm of mean annual precipitation, Sanlaville 2010) are attenuated by mountain runoff that supplies subterranean groundwater, allowing irrigated agricultural activities (Nehmé *et al.* 2006; Courbon 2008). Today, the natural vegetation is composed mainly by open thorn shrublands of the *Haloxylon salicornicum* (Moq.) Bunge ex Boiss. community and scattered trees of *Acacia tortilis* ssp. *tortilis* (Forssk.) Hayne, *A. tortilis* ssp. *raddiana* (Savi) Brenan

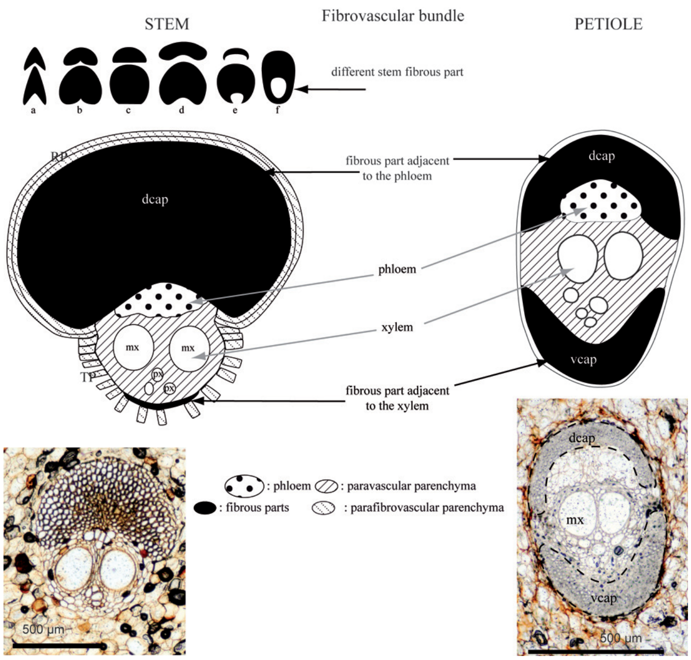


Figure 8. Anatomical differences between stem and petiole (schemes and photographs, left: *Hyphaene*, Right: *Phoenix*). A fibrovascular bundle (fvb) is made of a fibrous part and a vascular part which contains metaphloem and metaxylem elements with paravascular parenchyma. The stem fvb presented here has a Reniforma fibrous part (other types of fibrous parts adjacent to the phloem are encountered in palms: a. Sagittata, b. Cordata, c. Complanata, d. Reniforma, e. Lunaria, f. Vaginata). dcap: fibrous part external to the phloem (ex-fibrous dorsal cap); mx: metaxylem; px: protoxylem; RP: radiating parenchyma; TP: tabular parenchyma; vcap: fibrous part external to the xylem (ex-fibrous ventral cap). Modified from Thomas (2011a).

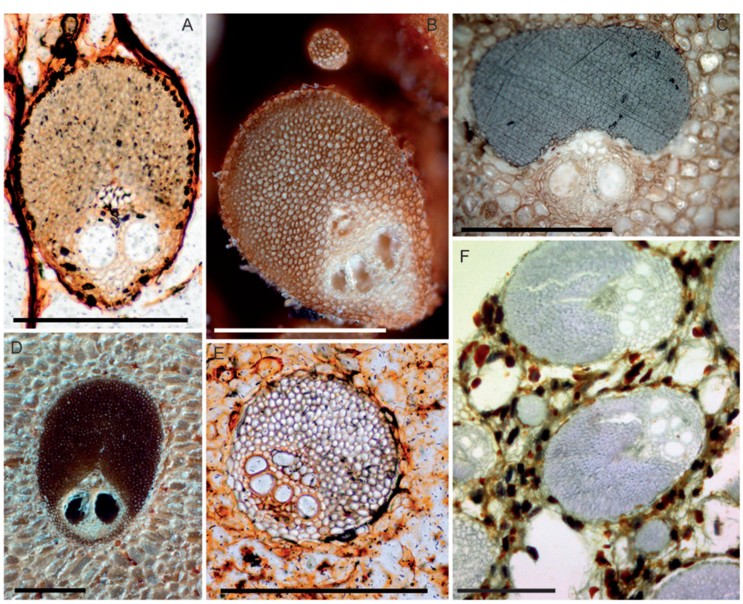


Figure 9. Transverse sections of stem fibrovascular bundles (fvb). A, B. *Nannorrhops ritchieana* with Reniforma to Lunaria fibrous part and with an isolated fibrous bundle. C. *Hyphaene thebaica*, without fibrous part adjacent to the xylem and with a Reniforma fibrous part. D. *Phoenix dactylifera* with a Vaginata (to Lunaria) fibrous part (fibres cells are all around the fvb). E, F. *Chamaerops humilis* with Lunaria to Reniforma fibrous part, 4 metaxylem elements and with a well developed fibrous bundles. All these genera have spheroid and compact ground parenchyma but in *Chamaerops* and *Nannorrhops* cells are sometimes collapsed and are difficult to observe. Scale bar: 500 µm.

and *Tamarix aphylla* (L.) Karst. growing along wadis.

The Madâ'in Sâlih archaeological project started in 2001 with a five-year survey project directed by J.-M. Dentzer (University of Paris 1) and L. Nehmé (CNRS). From 2008, the surveys were followed by a French-Saudi Arabian archaeological and restoration mission directed by L. Nehmé, D. al-Thali (Saudi Commision for Tourism and Antiquities) and F. Villeneuve (University of Paris 1). These recent works show that the town of Madâ'in Sâlih was occupied from the 4^{th}-3^{rd} centuries BC to the beginning of the 7^{th} century AD After a first phase of occupation of which little is known (Nehmé *et al.* 2011: 28-31), the site constituted the southern limit of the Nabataean kingdom between the 2nd century BC and the end of the 1st century AD During that time, it was an important site on the 'Incense road' leading from southern Arabia to the Nabataean capital Petra, in Jordan (Nehmé and Villeneuve 1999). Then, from the 2nd century AD, the city belonged to the Roman imperial province of Arabia. The site was still inhabited during the 4th-6th centuries AD but was abandoned around the beginning of the Islamic era in the 7th century AD.

Four main sectors have been recognized at the site: a residential area (Fig. 10), located in the middle of the town and surrounded by a mud brick wall, has revealed dense domestic activities during all periods of occupation. Within and around the residential area, monumental tombs cut into the sandstone cliffs were used during Nabataean and Roman periods. Many rock-cut monuments—mostly niches with betyls, altars and basins— and inscriptions characterised cultic areas. Finally, agricultural land has been defined by the areas that could potentially be irrigated from the 132 wells dug mainly during the Nabataean period (Courbon 2008; Nehmé *et al.* 2009, 2010a and b, 2011).

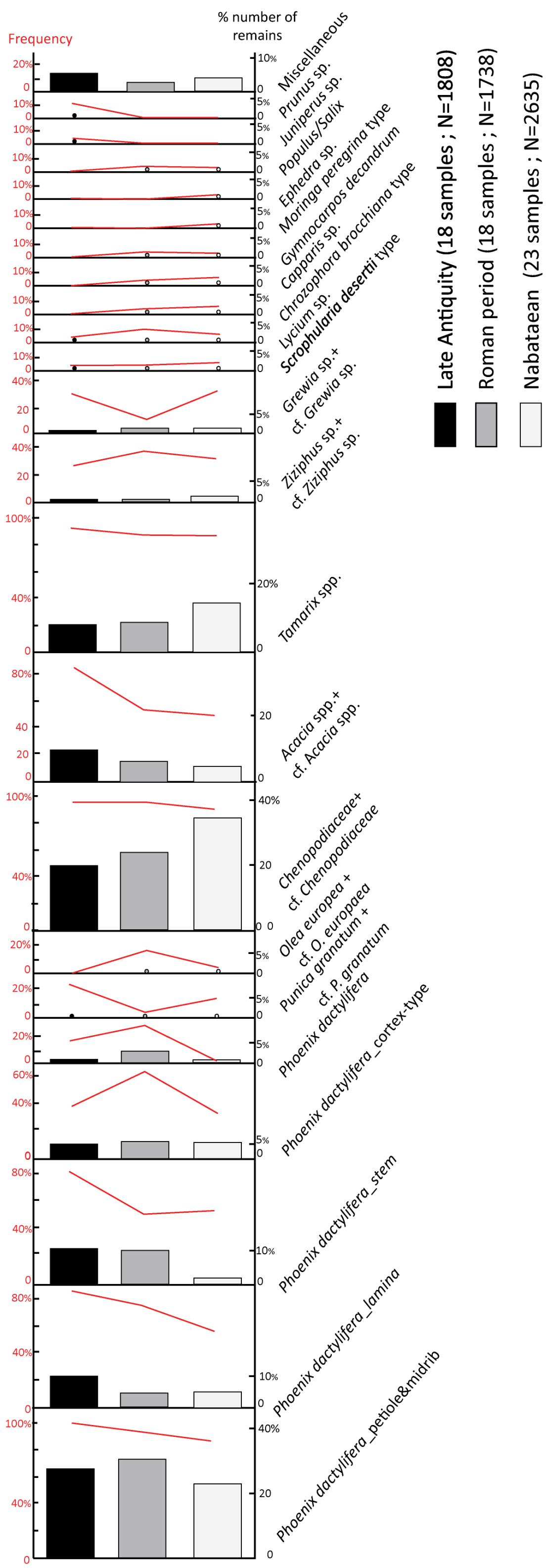
In view of seed and charcoal studies, 1215.5 liters (118 samples) of sediment were collected from domestic layers in the residential area – mainly fireplaces and refuses – and processed by flotation using a 0.5 mm mesh. The quantitative results presented in the article correspond to the charcoal analysis based on 6181 fragments (59 samples) identified by using reflected light microscopes in the archaeobotanical laboratories of the UMR 7041, Nanterre and UMR 7209, National Museum of Natural History, Paris (France).

RESULTS AND DISCUSSION

Date palm dominates the seed assemblages. The presence of numerous other cultivated plants in form of carbonised seeds and wood suggest that these plants were most likely cultivated in a traditional irrigated oasis agrosystem. Date palm was the main crop, whereas fruit trees such as olive (*Olea europaea* L.), pomegranate (*Punica granatum* L.), grape (*Vitis vinifera* L.), fig (*Ficus carica* L.), annual crops as naked wheat (*Triticum aestivum*/*durum* L.), hulled barley (*Hordeum vulgare* L.), lentil (*Lens culinaris* Medik.), pea (*Pisum sativum* L.), common vetch (*Vicia sativa* L.) and textile plants, cotton (*Gossypium* sp.), were secondary products (Bouchaud 2010, 2011, in press; Bouchaud *et al.* 2011).

At least eighteen taxa were identified by charcoal analysis (Fig. 11). From a qualitative point of view, most of them represent the collection of wood from natural plant formations. Various desert plant species attest to the great biodiversity of the Madâ'in Sâlih plain during Antiquity characterised by the influences of the Sudanian (*Acacia* spp., *Calotropis procera* – apple of Sodom – *Capparis* sp. – caper plant –, *Chro-*

Figure 10. View of the plain of Madâ'in Sâlih (westward) and the Harrat plateau. The residential area is located between the two sandstone mounds in the foreground (© C. Bouchaud)



zophora brocchiana type, *Moringa peregrina* type – ben tree –*Ziziphus* sp.) and Saharo-Arabian floras (*Chenopodiaceae*, *Gymnocarpos decandrum*, *Scrophularia desertii* type, *Tamarix* spp.). The dominant taxa are acacias, tamarisks and shrubs from the goosefoot or *Chenopodiaceae* family (in which *Haloxylon salicornicum* type is recognized).

The *Palmae* family is well represented. The observation of specific anatomical criteria has allowed concluding that the only palm species present at the site is the date palm, *Phoenix dactylifera*. The charred remains of this species reach between 30% and 50% of the total of ligneous fragments observed per period (Fig. 11). These results confirm the existence of a palm grove during all the periods of occupation of the site. One old saying describes the date palm as growing with "its feet in the water and its head in the fire" (Munier 1973: 51). The arid climate and the presence of the groundwater in the plain constitute ideal conditions for the growth of the plant.

Anatomical distinctions have been applied in order to distinguish the presence of the different parts of the date palm (Fig. 12). The remains of petioles and midribs dominate the palm assemblages (Fig. 11), attaining between 22% and 30% of the total amount of charcoal observed. They are present in 80% to 100% of the archaeological contexts. Lamina fragments are also identified (5% to 11% of the total amount; 50% to 82% of frequency), indicating that whole leaves were put into the fire and not only the woody parts. Their fragility to fire may interfere in their representation. Stem fragments appear to a less extent, cumulating between 2% and 10% of the total, and are present in at least half of the samples. Some remains, regularly attested, are characterised by irregular fibrovascular bundles (smaller or bigger with numerous protoxylem elements), very often tangentially compressed,

Figure 11. Charcoal diagram of Madâ'in Sâlih. Nabataean (1st c. BC – 1st c. AD), Roman (2nd-3rd c. AD) and Late Antique (4th-7th c. AD) periods, residential area. Histograms show the percentage of each taxon per period. Red lines show the frequency of each taxon per period. Undeterminable fragments are not included.

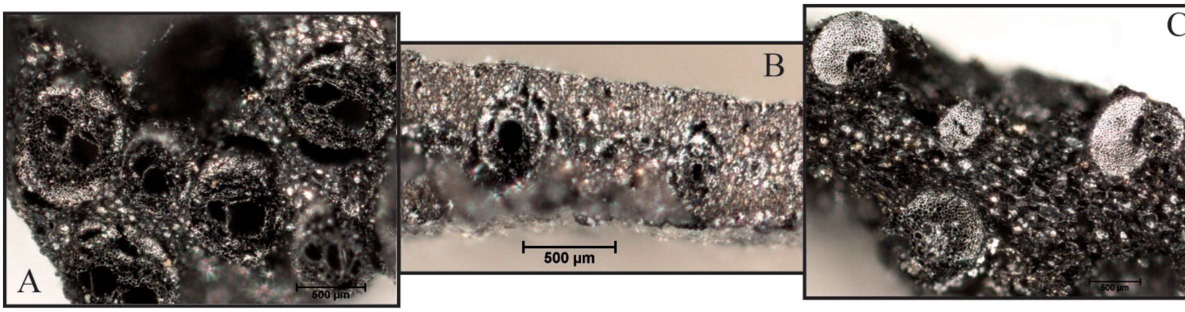


Figure 12. Transverse sections of archaeological date palm fibrovascular bundles (fvb). A) Petiole fvb (Locus MS10250); B) Lamina fvb (Locus MS10216); C) Stem fvb (Locus MS10250).

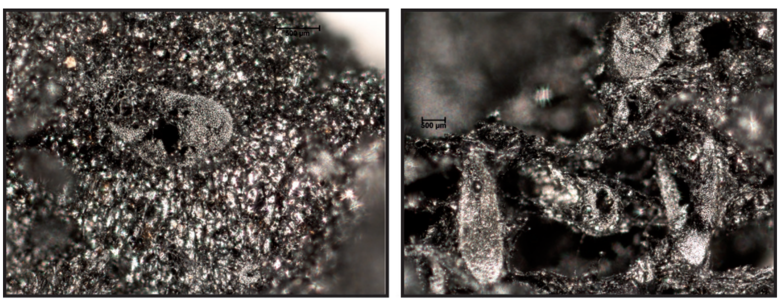


Figure 13. Transverse sections of archaeological date palm fibrovascular bundles of the stem cortex (Left: Locus MS25094; Right: Locus MS25105).

Figure 14. Traditional pruning in a palm grove (left) and the residues after pruning (right) (Adam oasis, Sultanate of Oman, © R. Thomas).

Figure 15. Nabataeo-Roman oven after excavation in the residential area (Sector 20000). Charcoals were deposited in the bottom of the structure (© Madâ'in Sâlih Archaeological Mission).

with parenchyma cells in irregular tangential bands. This peculiar anatomy is characteristic of the cortex (and the outer part of the central cylinder) (Fig. 13). The sample-by-sample examination show that stem remains are dominant in only six archaeological contexts; two fireplaces, one bread oven (*taboun*) and three occupation layers.

As charred date palm remains were found in residential and domestic contexts, we postulate that they represent in majority fuel residues. Most of them are associated with food plants, suggesting culinary purposes, but others function, such as heating for small handicraft activities, lighting, *etc.* are also possible. The predominance of leaf remains in the archaeobotanical assemblages of Madâ'in Sâlih is not surprising. Indeed, leaves usually constitute a readily available fuel source. This is explained by the regular cutting, or pruning, of older leaves that wither after three to seven years, in order to maintain the vigour of the tree and enhance fruit production (Fig. 14). Pruning also facilitates climbing up the tree during the artificial pollination or the harvest of fruits. These practices are well known from ethnobotanical observations and also from classical literary sources such as Theophrastus (*H. P.* II. 6. 4) and Pliny the elder (*N. H.* XII. 7. 2).

Today, in industrial palm groves, the cutting is generally made after the harvest. In the arid and semi-arid regions, where firewood is scarce, the cutting works are often practiced little by little according to needs (as fuel, building material, *etc.*) (Munier 1973: 136–137). It can be assumed that this was also the case in the oasis of Madâ'in Sâlih. The use of palm leaves as fuel could also result from the burning of construction material, for example roof coverings, after a traditional building fell into ruin, but such a secondary use is difficult to detect in our material.

Charred fragments of date palm stems are much less common than the leaf remains. Indeed, whole date palms are less likely to be cut as the plant is useful as such and would not be used for fuel unless old and no longer producing fruits. Also texts and ethnographic observations do not show the common use of the fibrous stem as fuel. A particular use of the stem is noticed in the samples of Madâ'in Sâlih. The excavation of an oven dated to the 2^{nd}-3^{rd} centuries A.D. revealed the presence of a great amount of charred material in the bottom part of the structure (Fig. 15).

Charcoal analysis underlines the strong presence of date palm stem fragments whereas the leaf remains are almost absent (Table 1).

This may suggest the occasional burning of a whole tree or the re-use as fuel of construction elements. As leaves are not found, we rather look for the

Locus 20026 (oven, 90 liters) - 2nd-3rd c. A. D.

SEED ANALYSIS	N	%
CULTIVATED CEREALS		
Hordeum vulgare vêtu, grain	7	0,30
H. vulgare hulled, rachis	66	2,84
Triticum aetivum/durum, grain	20	0,86
Rachis	69	2,97
Glume base	1	0,04
Cerealia, grain	20	0,86
Rachis	52	2,24
Stem/node	697	**29,98**
Root	53	2,28
CULTIVATED PULSES		
Lens culinaris, seed	2	0,09
indeterminate *Fabaceae*, seed	1	0,04
CULTIVATED WOODY PLANTS		
Phoenix dactylifera, whole seed	129	5,55
fragmented seed	1159	**49,85**
Perianth	7	0,30
Pericarp	4	0,17
Olea europea, fragmented endocarp	2	0,09
Punica granatum, seed	6	0,26
Vitis vinifera, seed	1	0,04
TEXTILE PLANTS		
Gossypium sp., graine	1	0,04
WEEDS		
Asperula/Galium, mericarp	1	0,04
Boraginaceae, nutlet	1	0,04
Centaurea sp., achene	1	0,04
Fumaria sp., seed	2	0,09
DESERTIC PLANTS		
Citrullus colocynthis, seed	7	0,30
Ziziphus sp., fruit	1	0,04
OTHERS		
Undetermined seeds	15	0,65
ovi-carpids coproliths	61	
Rodent coproliths	17	
Camel coproliths	1	
Total seeds	**2325**	

CHARCOAL ANALYSIS	N	%
CULTIVATED PLANT		
Phoenix dactylifera _petiole	2	0,17
Phoenix dactylifera _stem	412	**35,18**
Phoenix dactylifera _cortex-type	300	**25,62**
DESERTIC PLANT		0,00
Acacia sp.	2	0,17
cf. *Acacia*	1	0,09
Chenopodiaceae	30	2,56
cf. *Grewia* sp.	1	0,09
Lycium sp.	1	0,09
Tamarix sp.	3	0,26
OTHERS		0,00
Undetermined little branchs	128	10,93
Monocots	61	5,21
Undetermined	230	19,64
Total charcoals	**1171**	

Table 1. Seed and charcoal analysis of the sample from the oven.

second option. Rachis and stems fragments of cereals and broken date seeds probably represent one or several fuel provisions coming from the residues after the processing and/or the consumption of the crops. Besides the use or re-use of by-products of the cultivated spaces, desert plants provide also a fuel supply. We do not exclude that some of the identified elements correspond to their disposal in the oven and not their intentional use (Reddy 1998). This could be the case, for example, of the scarce elements of grape seed and olive stones that may represent food rejections after consumption near the oven.

CONCLUSION

The present study attempts to underline the scientific potential offered by the modern anatomical characterisation of palm stems and petioles and its practical application in archaeological contexts. Well-defined archaeological layers compared with ethnographic and literary sources shed light on agricultural practices and fuel management. Dates are a main income source and staple food for local populations in many countries in which they are cultivated, and have played significant roles in the economy, society, and environment. During the Antiquity and Late-Antiquity in Madâ'in Sâlih, date palm leaves constituted a privileged source of firewood compared both to stems of the same species and to other ligneous taxa. The preference for this fuel is probably much related to its availability as a by-product from date palm cultivation. More generally, fuel management seems clearly linked with the possibilities offered by the oasis and the spontaneous resources coming from the natural environment. This opportunistic behaviour was probably conditioned by a real organisation of the repartition of the resources, among which the date palm by-products had an important place.

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The use of wooden linings in the archaic wells of Fratte (Salerno-Italy)

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***Summary**: Recent archaeological investigations in the archaic settlement (6th-5th centuries BC) of Fratte (Salerno – Italy) reveal a complex system of groundwater exploitation by wells. Thanks to the specific environmental conditions it was possible to retrieve many fragments of cypress wood, some of which were found on the sides of the well shafts. Integration of ethnographic studies with wood technology has shown that this wood was used to line the well shafts at the sandy/clayey levels.*

***Key words**: Cypress wood boards, archaic age settlement (6^{th}-5^{th} BC), ethnographic comparisons, well lining.*

THE ARCHAEOLOGICAL CONTEXT

The settlement of Fratte lies on the hill of Scigliato (71 m a.s.l.) north-east of Salerno (Campania, Italy), in a favourable topographical position above the course of the river Irno (Fig. 1).

On the heights of Scigliato, thanks to the tuffaceous nature of the soil, it is possible to extract from the subsoil stone that is both easy to work and resistant and can be used in construction (Santo in press).

The subsoil of this area also yielded high quality clay for production of ceramics an activity amply documented by the presence of kilns and associated structures, identified during excavations conducted in the area (Gambardella 1997; Pontrandolfo 2011; Serritella 2011).

The presence of a subterranean aquifer feeding watercourses even in periods of drought, ensured water in abundance for both domestic and productive uses (Orrico 2008).

In general, the wealth of natural resources in the subsoil, the presence of perennial springs that supplied a dense network of streams and the strategic position in an area of transit all facilitated the quick settlement of the area around the ancient village of Fratte (Pontrandolfo 2011).

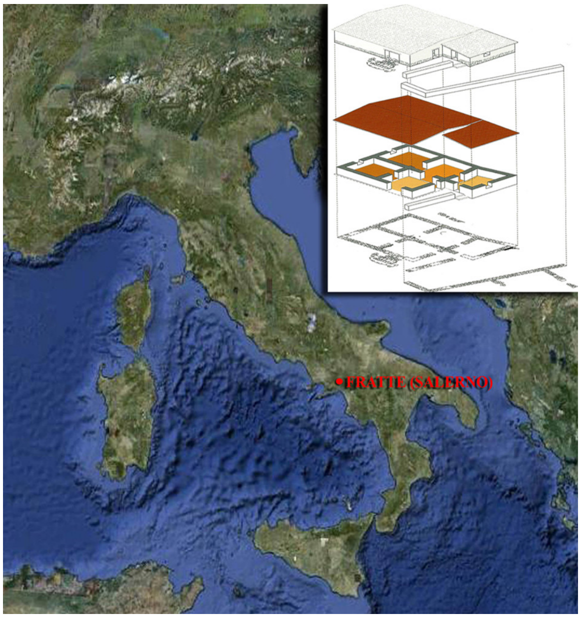

Figure 1. Fratte settlement location and hypothetical reconstruction of a Republican age building (Santoriello 2011, modified).

In the 6th century BC the geomorphological and hydrographic characteristics of the hill of Scigliato attracted Etruscan settlers, probably from *Amina*, today Pontecagnano. They moved into the valley of the river Irno, founding a city near its mouth, believed to be *Marcina* mentioned by Strabon that in the 5th and 4th centuries BC it was occupied by the Samnites (Napoli 1965; Cosimato 1996).

In the 3rd century BC the city was finally conquered by the Romans after their victory in the Samnite wars (Santoriello 2011).

THE WELL SYSTEM

The archaeological investigations identified the presence of a complex water supply system based on a number of wells drawing from a large aquifer. Distributed over the entire plain, on the heights of Scigliato were ten wells with vertical shafts and at least five ponors leading to sub-horizontal underground tunnels. There was also a system of man-made tunnels, probably used for mining or quarrying, the entrance to which was identified on the western slopes of the hill.

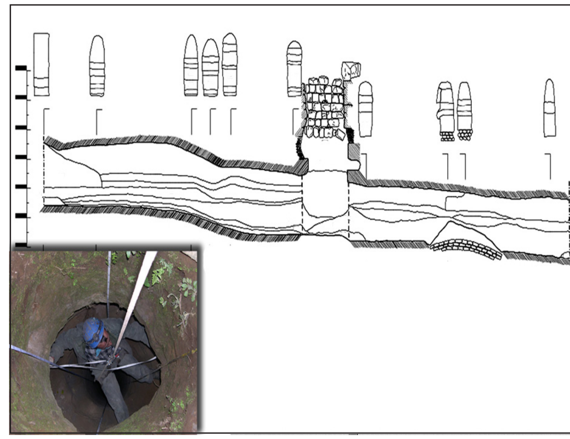

Figure 2. Relief of part of the Fratte hydrological system and picture of one of the wells during the excavation.

These wells and tunnels were mostly dug during the archaic period (6th-5th centuries BC), corresponding to what the archaeological evidence indicates is the most ancient phase of the Etruscan settlement.

Although the ten wells are spread over a large area and are characterised by a wide range of depths, they all draw from the same aquifer (Orrico 2008; Scelza 2009) (Fig. 2). All the well shafts are circular in shape with diameters of between 1.20 m and 0.95 m. They were excavated mainly in the solid layer of grey tufa, down to the softer clayey levels below, which were more than 16 m deep in some cases.

The structures investigated in Fratte are part of a highly complex system which, given our current knowledge, does not appear to have any immediate parallels with other sites in Campania or southern Italy (Orrico 2008).

DATA AND RESULTS

The archaeological excavation focused on the levels of sediment that had accumulated inside the well shafts, enabling the composition of the finds to be studied in relation to the dynamics of their abandonment (Orrico 2008; Danza and Scafuro 2009; Pontrandolfo and Santoriello 2009; Citera 2011; Scafuro 2011).

The different levels of material in the well shafts yielded archaic ceramics and numerous archaeobotanical remains, both carbonised and waterlogged. Non-combusted plant remains were sampled from the clayey levels at the bottom of the wells (Fig. 3).

Given the potentially dangerous conditions during the excavation, safety considerations prevented us from adopting a more precise sampling strategy. Nevertheless, 14 wood fragments from Well 6 and 12 from Well 9 were retrieved, all of them reddish in colour with yellowish concretions arising from sulphurous infiltrations that are believed to have already contaminated the aquifer in ancient times.

Xylotomic analysis performed at the Laboratory of Archaeobotany and Palaeoecology of the University of the Salento identified these fragments as cypress wood (*Cupressus* sp.). The fragments are mainly rectangular in shape with an average size of 20 cm by 10 cm by 1.5 cm (Fig. 4).

Judging by the shape and size of the finds, it seems that they are flat boards, some of which were discovered flat against the wall of the well shaft with the longer edge vertical. On one of the boards was a hole about 0.5 cm in diameter, possibly a mark left by a pointed tool used to shape it.

DISCUSSION

The exceptional nature of this type of discovery is shown by the absence of clear parallels with the water supply systems of other ancient contexts that are geographically and chronologically comparable.

The discovery of fragments and wooden objects in wells has generally been interpreted as the result of material accidentally falling into the well or attributed to post-depositional dynamics (Coccolini and Folieri 1980; Kooistra and Hessing 1989; Forbes 1993; Marlière 2002; Blair and Hall 2003; Rossi 2004; Wilson 2008).

The cypress boards discovered in the wells of the Etruscan-Samnite settlement of Fratte seem to have been used to line and stabilise the vertical surfaces of the well shaft, particularly at the levels characterised by soft clayey sediment near the bottom.

Ethnographic parallels with this technique of reinforcing and containing the walls of well shafts at levels characterised by sediment that is clayey and/or sandy and therefore poorly cohesive are seen above all

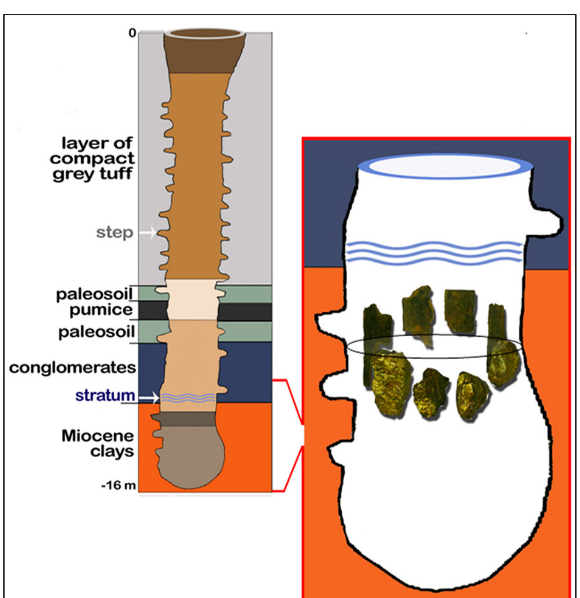

Figure 3. Radial section of Well 9.

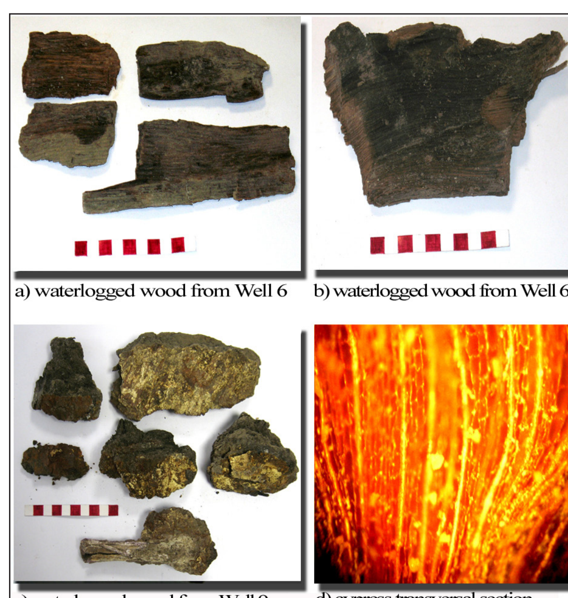

Figure 4. Fragments recovered and their xylotomic analysis.

Figure 5. Wood employment in a hand drilled well in Zambia (Sutton 2002).

in traditional contexts.

Particularly interesting examples of this are to be found in Niger and Zambia (Sutton 2002; Danert 2006), where wells excavated in sandy sediments are lined with wood selected from the local vegetation to prevent the collapse of the walls.

A common alternative to this technique is the recycling of artefacts of various kinds, including wooden ones that have been damaged, for example the remains of canoes mixed with ceramic fragments.

In both cases, locally available trees are used but those considered most resistant to damp are preferred (Fig. 5).

Further information emerges from a study conducted in 1917 in the Oasis of Dakhla in the Libyan desert (Harding King 1917). It describes a series of wells of varying chronology from the Roman period onwards, in which the same construction technique seems to emerge. The well shafts are quadrangular or circular in cross section and are on average 100 m deep, in order to get below the clayey levels and reach the aquifer, which occupies a hard layer of white sandstone. Near the surface, where the well shafts are carved out of unstable sandy sediment, the walls were reinforced by lining them with boards made from palm tree wood to a depth of about 2 m.

CONCLUSIONS

Archaeological research in the Etruscan settlement of Fratte has highlighted the use of water supply systems drawing on underground aquifers by means of wells. The discovery of wooden fragments in contact with the sides of the well shafts shows that the walls of the wells were lined at levels where the sediments were most unstable.

Xylotomical analysis of the fragments retrieved from inside the wells has shown they were all made of cypress wood. Cypress was chosen for lining the wells because of its chemical and physical properties, which make it resistant to ageing, damp and attack by lignivorous insects (Villavecchia and Eigenmann 1973; Giordano 1999; Frigione and Mairo 2006).

The presence of this *taxon* alone in the wells does not reflect the taxonomical richness of this area during the 6th and 5th centuries BC (Colaianni, in press) but selection based on ancient knowledge of cypress's distinctive resistance to decay in damp conditions.

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The last firewood of a late ancient limekiln in Egnatia (SE Italy)

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Summary: *During a recent excavation campaign in Egnatia (south-eastern Italy) a lime-kiln was discovered. It was totally sealed and its original load was still inside. This circumstance, which is rarely seen in archaeological investigations, made it possible to study how these structures work. Anthracological and taphonomic analyses, together with analyses of the charcoals' dimensions, enabled us to determine the composition of the fuel used and to suggest that it included wood that had originally been used as timber for construction and was subsequently discarded.*

Key words: *limekiln, anthracological analyses, Late Antiquity, management of wood fuel, southeastern Italy.*

INTRODUCTION

The fuel used in specialised heating structures (baths, furnaces, limekilns, etc.) has only rarely been the object of systematic anthracological analysis designed to highlight choices based on the characteristics of the fuel itself and its availability in terms of the presence of certain plant species in the natural vegetation of the surrounding area.

A further consideration is linked to aspects of archaeological conservation and the conversion – or successive conversions – of a structure to new uses. The discovery of one such structure, a limekiln near the Bishop's Basilica in Egnatia (Fig. 1), still sealed and preserved with both its fuel and limestone, enabled us to analyse in detail how the structure functioned and was used.

GEOGRAPHICAL AND VEGETATIONAL BACKGROUND

The site is located on the Adriatic coast of Puglia, on the boundary between the ancient regions of Messapia and Peucetia (Fig. 2), not far from the modern town of Fasano. The site is in the coastal section of the Murgia hills, which from an altitude of 500 metres descend towards the Adriatic sea via a series of Pleistocene terraces.

Currently the area of Egnatia is characterised by broad morphological and micro-climatic variability, reflected in the high variability of trees and plants, which can be summarised as belonging to three zones. Firstly there is a coastal strip characterised by species that are adapted to conditions of salinity, or live in sandy soils and rocks. The main elements of this herbaceous and shrub vegetation are the Golden samphire (*Inula crithmoides* L.), the european searocket (*Cakile maritima* Scop.), the common glasswort (*Salicornia europaea* L.) and the caper (*Capparis spinosa* L.). Also found in the coastal strip are evergreen shrubs such as the common juniper (*Juniperus communis* L.), mastic (*Pistacia lentiscus* L.) and Phillyrea (*Phillyrea latifolia* L.) which tend to grow on the slopes around Fasano. The second ecozone is that of the low plains. Here the terrain is extensively used for the cultivation of olive trees, with the presence of fig trees (*Ficus carica* L.), carobs (*Ceratonia siliqua* L.) and vegetables. The third ecozone in the area is that of the plateau. Once subject to intense deforestation, today it is characterised by maquis and numerous orchards and vineyards. Common trees here include the Holm-oak (*Quercus ilex* L.), wild olive (*Olea europaea* var. *sylvestris*), sage-leaved rock rose (*Cistus salvifolius* L.), strawberry tree (*Arbutus unedo* L.), mediterranean buckthorn (*Rhamnus alaternus* L.), spanish broom (*Spartium junceum* L.), downy oak (*Quercus pubescens* Willd.) and macedonian oak (*Quercus trojana* Webb.).

Figure 1. Aereal view of Egnatia.

Figure 2. Position of Egnatia regarding the ancient regions.

The current vegetation of the area around Fasano is thus the result of centuries of human activity that have shaped the terrain by limiting the wild vegetation to small patches of macedonian oak and Holm-oak and areas where the maquis has degraded to the level of garigue (Macchia and Vita 1973; Gigante and Girolamo 2008).

HISTORICAL AND ARCHAEOLOGICAL CONTEXT

The geographical characteristics of this area probably favoured the birth of numerous villages during the Bronze Age: some of these, such as Egnatia, evolved towards proto-urban and urban forms. Its position therefore facilitated a long-lasting human presence, from the Bronze Age (15th to 11th centuries BC) to the medieval period (11th-13th centuries AD). This site played a key role in the commerce passing through the Mediterranean Basin and the hinterland of Puglia from the Roman period to Late Antiquity (Cassano *et al.* 2008a and b; Fioriello 2008).

Recent excavations have brought to light a series of structures used for production that can be interpreted in relation to the rebuilding and reorganisation of Egnatia that followed the earthquake of 365 AD. During this phase, some public buildings such as the baths saw a change of use towards productive activities (for example making lime). The discovery of numerous limekilns highlights the vitality of the settlement even during the late ancient period, from the late 4th to the early 6th centuries AD (Cassano and Fioriello 2009).

LIMEKILNS IN ARCHAEOLOGICAL STUDIES AND ETHNOGRAFIC COMPARISONS

To date, few studies of ancient limekilns in Italy have been conducted. Those that have, tend to focus above all on their evolution or on the reconstruction of their various phases (Gelichi and Novara 1990; Fontana 1995; Baragli 1998; Petrella 2007). In addition, most of the studies are of medieval structures (Saguì 1986; Gatto 2003). Where the type of fuel has also been studied, the data seem to indicate use of local resources available in the immediate vicinity of the site (Solter 1970; Jackson *et al.* 1973; Dix 1982). Thus whether they used woodland species (e.g. *Fraxinus excelsior* or *Ostrya carpinifolia*), maquis or shrubs depends on the phyto-geographical characteristics of the area.

In the absence of a large body of studies of ancient limekilns, ethnographic studies conducted both in Italy and elsewhere (Tunisia, Greece) of kilns in use until the twentieth century (Adam 1994; De Guio 1995; De Guio and Bressan 2000) are particularly important. These studies help fill in the gaps in our knowledge concerning the choice of fuel. Indeed, against expectations, what emerges is the widespread use not only of small branches, such as bunches of olive and almond twigs, but also in some areas of wheat straw, cherry, peach and olive stones, pine cones and grass (Adam 1994; Bandini *et al*. 1999; Balenzano and Moresi 2004).

Historical sources do not provide much information on the fuel used. The first writer to dedicate a large part of his work to lime production techniques was Cato, who, in about 160 BC, when building with blocks bound with mortar was becoming more widespread, described the construction of a limekiln in detail (*De Agricultura*, XXXVIII). In his *De Architectura* (II, 5: 1-3), Vitruvius dedicates only a few lines to the production of lime while Pliny the Elder limits himself to replicating the words of Cato on what type of stone produces the best quality lime (*Naturalis Historia*, XXXVI 53: 174). Like his predecessors, Palladio, in his *Opus Agriculturae* I, X, 3, focuses on the type of stone to be used in lime-making. It is only in Diderot and D'Alembert's *Enciclopédie* that we find a reference to the use of tree heath as a fuel for the production of lime.

DATA AND RESULTS

Interesting clues concerning the selection of fuel for limekilns emerge from the furnace (4th - 6th centuries) discovered in Egnatia (Fig. 3). This limekiln was found with its original load: pieces of limestone derived from the structure elements of the nearby baths and charcoal from the oven's last firing.

The furnace is in the shape of a truncated cone, with a diameter of about 3 metres. At its base are some holes, probably used for removing ashes. The Egnatia

Figure 3. Lime kiln found in the area to the south of the basilica.

limekiln may be said to belong to the so-called "pit" type (Fig. 4).

In Figure 3 a conduit for the supply of fuel and limestone to the furnace is visible in the upper part of the furnace.

This study is based on the analysis of 143 charcoals. The identification was performed studying the three main anatomical planes, transversal, tangential and radial, by means of a reflected-light microscope and comparison with atlas of wood anatomy (Schweingruber 1990) and reference collections. The anthracological analyses highlighted the use of four taxa: *Fraxinus* sp., *Olea europaea*, *Pistacia lentiscus* and Rosaceae/Maloideae of the *Pyrus/Sorbus* type (Fig. 5). *Pyrus/Sorbus* was also recognised as a fuel in the baths complex of the Roman imperial epoch, specifically in the hypocaust of the *tepidarium*, highlighting a continuity of use of the same trees from the imperial epoch until the late ancient period (Fiorentino and Stellati in press).

In terms of size, the charcoals recovered are of two categories: small (<1 cm) and large (>7 cm). The larger charcoals, in a fair state of conservation, slightly vitrified and with radial cracks, account for most of the assemblage.

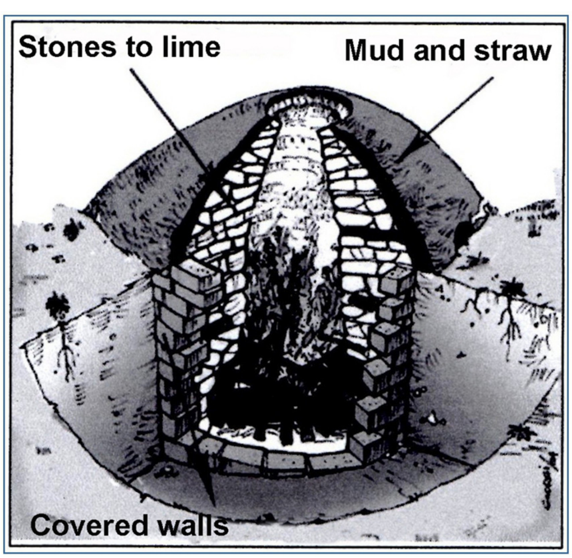

Figure 4. Example of a "pit type" kiln (Petrella 2007, modified).

The quantitative differences between the two size categories of the charcoals may be due to the combustion itself, which was more destructive of the smaller branches. The larger charcoals, quantified in 104 fragments on the total, were found to be exclusively *Fraxinus* sp., while the smaller fragments belong to the other species identified (Table 1, Fig. 6).

DISCUSSION AND CONCLUSION

The specific anthracological assemblage identified in this study allows us to make a few observations. Ethnographic studies have shown that limekilns often used shrubs, olive stones and almond shells, which were more likely to keep the flame alive (Adam 1994; Balenzano and Moresi 2004) and sometimes when specific arboreal taxa are used (e.g. *Fraxinus excelsior*, *Ostrya carpinifolia* or *Castanea sativa*) this choice is closely linked to the phyto-geographical characteristics of the surroundings (Bandini *et al*. 1999). Ethnoarchaeological analyses of dismissed contexts show how all building materials are subject to reuse, especially timber, often chosen as fuel (Kramer 1979, 1982; Fiorentino *et al.* in press).

The investigations of the limekiln of Egnatia allow us to assume the use as fuel of the local vegetation (*Olea europaea* and *Pistacia lentiscus)* and also the likely exploitation of reused wooden material derived from dismissed buildings. This hypothesis is based on some considerations: the concentration and size

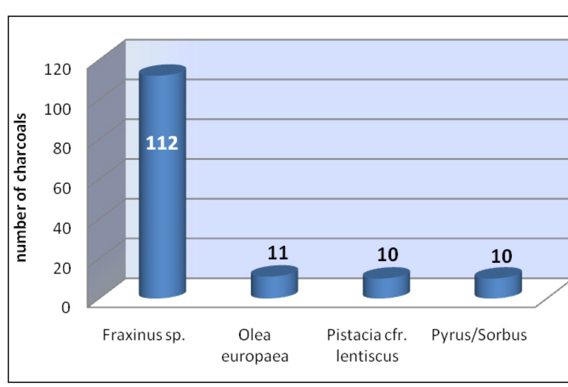

Figure 5. Anthracological diagram.

TAXA	Size of charcoals		TOT.
	> 7 cm	< 1 cm	
Fraxinus sp.	104	7	112
Olea europaea	-	11	11
Pistacia cf. *lentiscus*	-	10	10
Pyrus/Sorbus	-	10	10

Table 1. Dimensional range of charcoals for each identified taxon.

Figure 6. The two main dimensional categories of charcoals found in the archaeobotanical assemblage.

of ash tree charcoals seem to be compatible with the use of construction timber; furthermore, it is important to consider that in this period Egnazia underwent a phase of reorganization and deep urban transformation. As ascertained during excavations, the numerous limekils, that prove this building fervour, exploited architectural fragments and blocks from abandoned buildings, both in their structure and as load. All this brings to establish a tendency towards the use of all the available material: limestones and probably the wooden structures of dismissed buildings.

Timbers derived from ash trees were exploited as fuel to maintain the temperature in the kiln during the firing, and other *taxa* were used as kindling to create a flame able to reach the pieces of limestone placed above. The evidence thus points to the use of resources available in the immediate vicinity: old construction timbers and plants growing near the site. Their joined use allows obtaining the best result in terms of heat and duration.

The particular type of fuel used (old construction timbers) and the position of the limekiln near the narthex of the church suggest that its purpose was linked to the expansion of the Basilica at the end of the 5th century.

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WOOD FOR FUEL IN ROMAN HYPOCAUST BATHS: NEW DATA FROM THE LATE-ROMAN VILLA OF FARAGOLA (SE ITALY)

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***Summary**: Archaeological excavations at the villa of Faragola brought back to light a complex system of hypocaust baths dated to the Late-Roman period. This finding, which represents one of the most important thermal complexes in southern Italy, offered the possibility to correlate the traditional study of the architectural characteristics with the analysis of charcoal remains. The results of radiocarbon dating define the chronological pattern of use, while anthracological analysis reveals an intentional pattern of wood exploitation.*

***Key words**: Fuel, charcoal, hypocaust baths, Late-Roman, villa, South-Italy.*

INTRODUCTION

Traces of hypocausts are widespread all across the Roman Empire, but whereas the structure of these systems has been widely documented and several analyses were carried out to identify the way it worked, very little is known about the wood used as fuel (McParland *et al*. 2009).

Archaeological excavations at the *villa* of Faragola brought back to light a complex system of hypocaust baths dated to the Late-Roman period. This finding, which represents one of the most important thermal complexes in southern Italy, offered the possibility to correlate the traditional study of the architectural characteristics with the analysis of charcoal remains.

The hypocaust, which in Greek means 'fire underneath', provides the heat for the warm (*tepidaria*) and hot rooms (*caldaria*). The principle of such a system is that furnaces are needed either to provide direct heat from burning (exhaust gases), or to heat water and generate steam. Furnaces (*praefurnia*) were placed near *caldaria*, which had the floor popped up by cylindrical supports, made of brick and limestone, called *pilae*. By covering the ground along the hypocaust system, flue gas arose from charcoal and/or wood burnt in a furnace (*praefurnium*), which also provided heating of the bath (Fig. 1). The water was heated in copper or bronze tanks above the furnace combustion chamber. Hot flue gas would also heat up the water in the pool through *chimneys* placed at the corners of the room, which provided flue gas flow. Together with heating through the ground, many baths were also heated through the walls by structural elements referred to as *tubuli*, which were usually made of brick (Basaran and Ilken 1998**).**

Despite the great importance of fuel in such structures, little is known about the species used to fire Roman hypocaust furnaces.

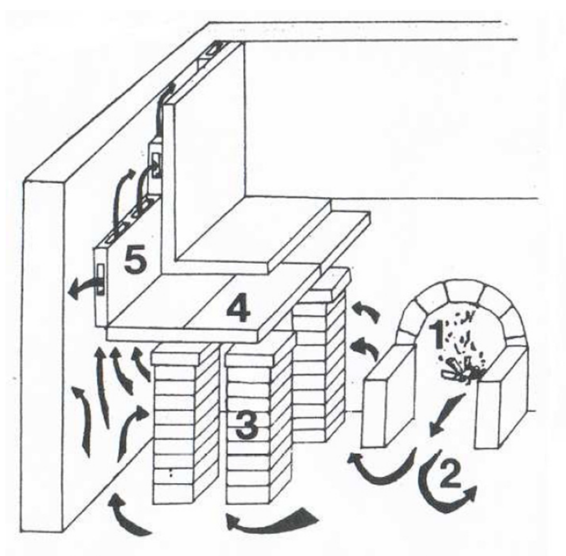

Figure 1. Schematic representation of an hypocaust bath: 1) furnace, 2) exhausted gas, 3) *pilae*, 4) floor, 5) *tubuli*. (Adam 1999).

It is often stated that the fuel to feed the hypocaust would have been wood (Yegül 1992), a hard wood (Blyth 1999). However, it is also suggested that charcoal might have been used as it would have been easier to generate more heat (Rook 1978, 1992, 1993).

The anthracological analyses of the Faragola charcoal remains provide information on the selection of wood and the impact of the thermal system on the local environment.

CONTEXT OF STUDY

ECOLOGICAL FEATURES

The *villa* of Faragola is located in the northeastern part of the Apulia region (SE Italy) in a strategic position in a plain close to the Carapelle stream, a natural resource of fresh water, and the Subapennines wooded hills.

The site also benefits from the proximity to different environments such as the broad plain of Tavoliere to the west, the Gargano promontory to the north and the Murgian plateau to the south.

Each of these areas is characterized by a specific morphology which influences the average temperature and rainfall and has remarkable effects on the natural vegetal cover (see Table 1).

Five different eco-zones coexist in north Apulia. The first homogenous climatic area includes the highest part of the Gargano promontory and of the Subap-

AREA	WINTER TEMPERATURE (°C)	AVERAGE RAINFALL (mm)	ALTITUDE (m a.s.l.)	TYPE OF VEGETATION
A.1	>7	900-1000	1000-800	*Fagus sylvatica*, *Carpinus betulus*
A.2		800	800-700	*Quercus cerris*, *Carpinus betulus*, *Carpinus orientalis*, *Cornus sanguinea*, *Rosa canina*, *Hedera helix*, *Crataegus monogyna*
B	7-14	700	700-600	*Quercus pubescens*, *Quercus cerris*, *Eunomius europaeus*, *Corylus avellana*, *Acer campestris*
C		600-500	600-400	*Quercus pubescens*, *Paliurus spinachristi*, *Prunus spinosa*, *Pyrus amygdaliformis*, *Rosa sempervires*, *Phillyrea latifolia*, *Pistacia lentiscus*, *Smilax aspera*
D	14-16	500-400	400-150	*Quercus ilex*, *Pinus halepensis*, *Pistacia lentiscus*, *Myrtus communis*, *Olea europaea*
E	<16	400-350	150-0	Cereal field, orchards and residues of riverine species (*Populus alba*, *Ulmus minor*, *Fraxinus excelsior*) on the bank of streams.

Table 1. List of the wooded areas of North Apulia distinguished according to winter temperature, annual average rainfall and altitude.

pennines, where, due to continentality, *Quercus cerris* woodlands predominate, whilst under particular topo-climatic conditions, *Fagus sylvatica* woodlands prevail.

The second homogenous climatic area occupies the whole north-western part of Murge and the north-eastern sides of the Subappennines up to elevations between 700 and 600 meters. It is influenced by the north-eastern geographic sector and by the Appennine chain and displays a high continentality with a sub-montane mesophyllic vegetation, dominated by *Q. pubescens*, ascribable to *Quercion pubescentii-petreae*.

The third eco-zone shows similarities with the second one, but developing at lower altitude includes elements of the thermofilic woodland such as *Pistacia lentiscus* and *Phyllirea latifolia*.

The fourth homogenous climatic area corresponds to the wide plain of the Gargano promontory at elevations of 150 to 400 meters. The vegetation is characterized by *Quercus ilex* L. which, near the coast, is replaced by *Pinus halepensis* and by thermophilic sclerophylls of the Mediterranean bush (Macchia *et al.* 2000).

The last area, which corresponds to the Tavoliere plain, is almost completely deforested and scattered exemplars of *Populus alba*, *Ulmus minor* and *Fraxinus excelsior* survived in proximity of the banks of seasonal streams and rivers (Fig. 2; Table 1).

THE HISTORICAL SETTING

The site of Faragola has been excavated since 2001 by the University of Foggia and a complex system of archaeological evidence was brought to light. The archaeological remains include an Iron Age tribal settlement (4^{th}-3^{rd} century BC), a villa farm of the Early-Roman period (1^{st} BC-3^{rd} century AD), a large Late Roman villa (4^{th}-6^{th} century AD), and an Early Medieval village (7^{th}-8^{th} century AD) (Volpe 2006). However, the Late Roman residence is by far the most important site in the area (Fig. 3). Only a part of the *villa* estate has been investigated (about 1200 square meters), but this has already led to the discovery of an elaborate thermal bath-house that extends over a vast area of more than 1000 square metres.

This complex was built on the southern-western part of the *villa*, according to the pattern followed in almost all baths built by the Romans in order to maximize the benefit of the solar heating (Eschebach 1979).

The oldest part (3^{rd}-4^{th} cent AD) included the cold bathroom (*frigidarium*) (A. 19), with pools filled with cold water called *natatio* (A. 20, 31, 23, 29 and the heated area, made up by the two *tepidaria* (A. 18, 25), the huge *caldarium* (A. 21-22-23) and two *sudationes* (A. 57a-57b), heated rooms used for massages and rest. Close to the *caldarium* was the furnace (A. 36)

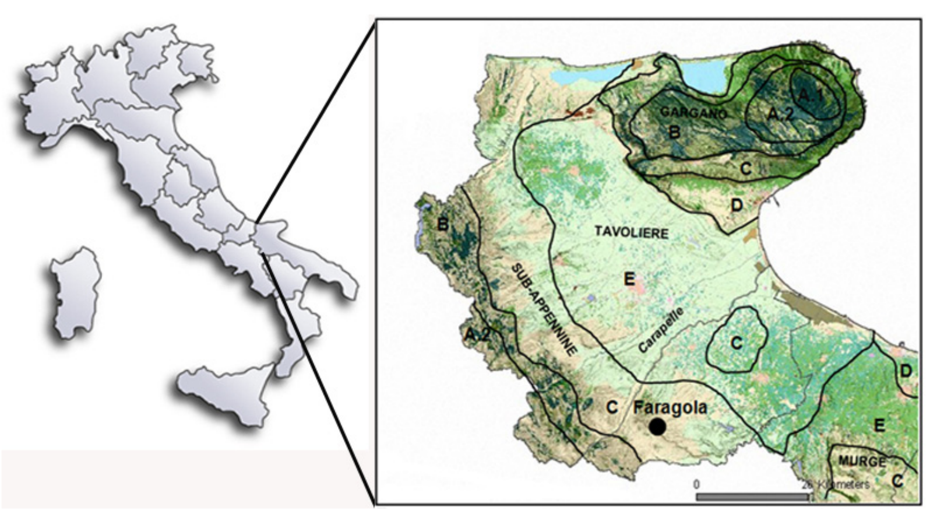

Figure 2. The geographical context with the distribution of the woodland cover.

needed to heat the entire system.

North-west of this complex, a smaller bath was built in the 5th century AD. Remains of this *balneum* are the *caldarium* (A. 40), the *tepidarium* (A. 41) and the two heated pools (A. 43, 44) located on the side of this room.

Two furnaces (A. 48-52), probably not in use at the same time, heated this small bath (Volpe *et al.* 2009).

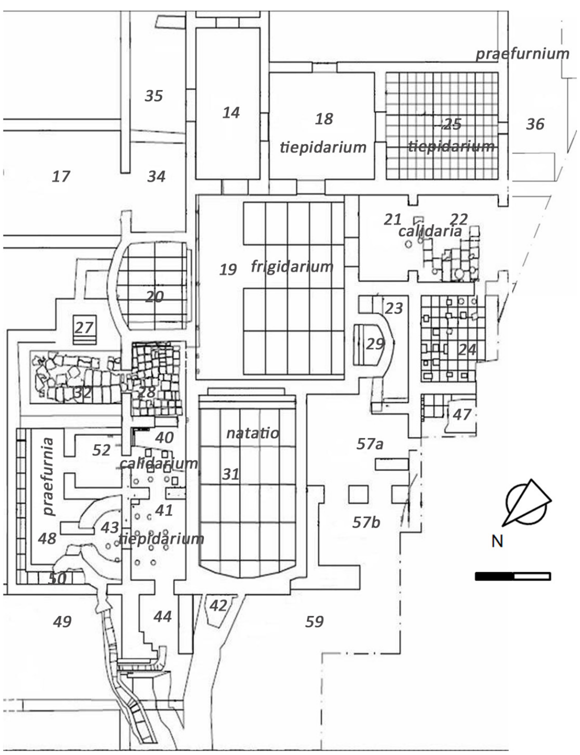

Figure 3. Topographic map of the termae of Faragola.

MATERIAL AND METHODS

Soil samples were collected from the three furnaces (A. 36, 48, 52) located, respectively, in the southern and the northern part of the thermal complex.

Sampling was carried out in different ways according to the context investigated in each occasion.

Charcoal and ashes, dispersed in the strata, were collected randomly from the bottom of furnaces A.36 and A.48, while the deposit of furnace A. 52 was subjected to a more accurate analysis.

In this specific context, half of the deposit had been previously removed uncovering a section that ran longitudinally to the furnace itself.

Preliminary observations made on the bare section revealed a complex sequence of greyish and brownish layers, which were interpreted as the attempts to keep the furnace clean and in use by creating new floors.

Micro-layers distinguished on the section were excavated in extension in order to understand how the furnace worked and, eventually, if there had been any change in the fuel selection along time.

Once the sediment of the three furnaces had been collected and labelled, it was wet sieved to separate bio-archaeological remains from the soil matrix using sieves of 5 and 1 mm mesh.

Charcoals were sorted from other remains, while branches and angled fragments were separated from the round-shaped charcoals. The diameter of the branches was measured, while the dimension of the other fragments was estimated by comparing each of them with a standard of 6 cm^3.

The anatomical features of each charcoal were analysed using the Nikon microscope (Eclipse ME600) available at the Laboratory of Archaeobotany and Palaeoecology of the University of Salento. Atlases (Greguss 1955, 1959; Fahn *et al.* 1990; Schweingruber 1990) and the reference collection of the mediterranean arboreal vegetation were used to get accurate taxonomical identifications.

Finally, four short-lived branches, two from A.52, and one from A. 36 and A. 48 were selected and dated using the Accelerator Mass Spectrometer (AMS).

RESULTS

The amount of soil sampled in the three contexts corresponded to three hundred and twenty-one litres of sediment.

Two hundred and twenty-eight litres come from

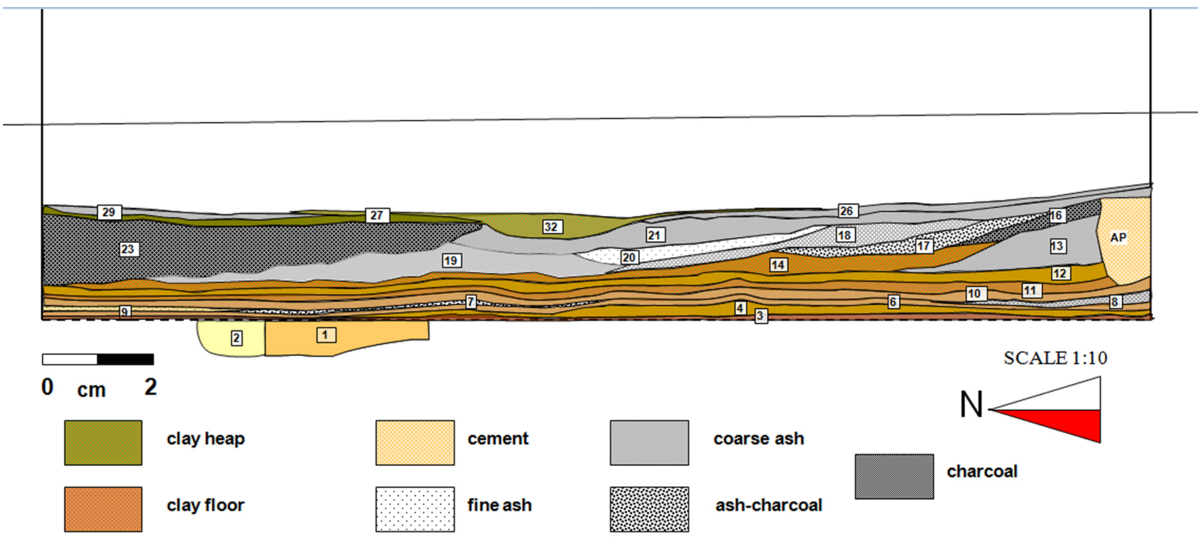

Figure 4. Section of furnace A.52. Layers of charcoal, ash, clay and cement are distinguished by different colors (see the legend).

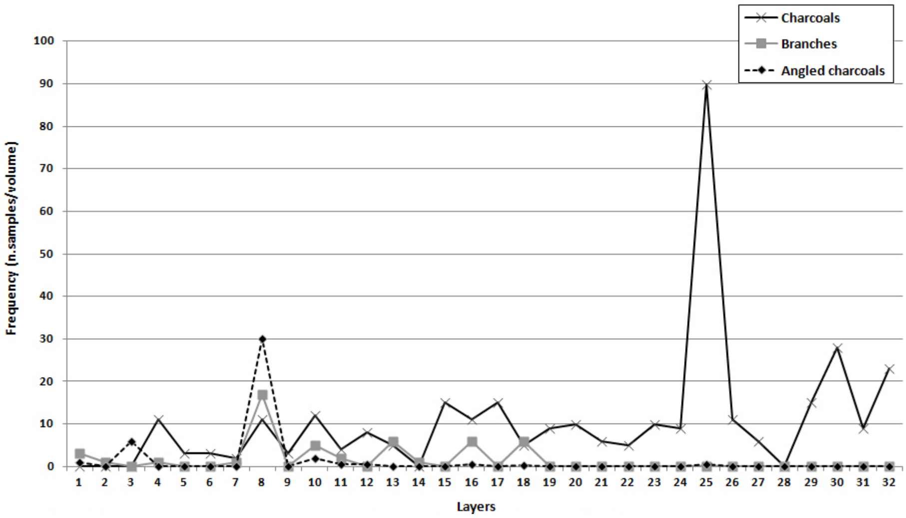

Figure 5. Frequency of charcoal, branches and angled branches in furnace A.52.

the deposit of furnace A.52 where the microstratigraphical excavation led to the recording of thirty-two micro-layers. Twenty-three of these layers were visible on the section, while the other nine were discovered during the excavation of the entire deposit. (Fig. 4).

The greyish layers were residues of fuel, while the brownish were identified as clay floors, cement or heaps of clay and dismissed pottery.

Charcoals were found in twenty-seven of the thirty-two layers and, for the same volume of soil, they were far more frequent in black-greyish strata than in clay-like layers (Table 2; Fig. 5).

The number of branches and angled charcoals bigger than 6 cm^3 increases in the black-ashy layers, and thus proved, beyond any doubt, that these strata were made by fuel residues.

LAYER	COMPONENT	TYPE OF LAYER	RADIOCARBON DATE (CAL. AD)	*Quercus cf. ilex*	*Pistacia lentiscus*	*Rhamnus/Phillyrea*	*Quercus* cf. *pubescens*	*Acer* cf. *campestris*	*Ulmus* cf. *minor*	*Fraxinus* sp.	*Populus\Salix*	*Olea europaea*	*Punica granatum*	*Sorbus* sp.	*Prunus* sp.	TOTAL CHARCOALS	VOLUME (LT)	FREQUENCY (N. CHARCOALS/LT.)
4	clay	floor		1	8	0	4	0	0	0	0	0	0	10	0	23	2	11
5	clay	pit		0	5	0	16	0	0	0	2	0	0	0	1	24	8	3
6	clay	floor		1	6	3	18	0	0	0	5	2	0	0	1	36	10.5	3
7	ash/charcoal	fuel waste		3	4	0	22	0	0	0	2	0	1	2	0	34	13.5	2
8	ash/charcoal	fuel waste	130-420	0	9	4	29	0	0	0	0	5	0	0	0	47	4	11
9	cement	floor		0	4	1	6	0	0	0	0	1	0	0	0	12	4	3
10	clay	floor		0	5	1	46	0	0	0	0	0	2	3	1	58	4.5	12
11	clay	heap		1	2	1	29	1	2	0	0	0	0	2	0	38	8.5	4
12	clay	floor		0	2	3	19	0	0	0	0	0	0	0	0	24	3	8
13	ash/charcoal	fuel waste		0	4	19	42	0	1	0	0	0	0	0	5	71	13	5
14	clay	floor-heap		0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
15	charcoal	fuel waste		4	26	1	61	0	2	0	0	0	0	0	0	94	6	15
16	charcoal	fuel waste		0	1	5	38	0	0	0	0	0	1	0	1	46	4	11
17	ash/charcoal	fuel waste		13	34	7	25	0	11	0	0	0	0	0	2	92	6	15
18	ash/charcoal	fuel waste		0	0	2	21	0	0	0	0	0	0	1	0	24	4.5	5
19	ash/charcoal	fuel waste		9	9	0	52	0	1	1	0	0	0	0	0	72	8	9
20	ash/charcoal	fuel waste		0	8	0	12	0	0	0	0	0	0	0	0	20	2	10
21	ash/charcoal	fuel waste		0	9	3	49	2	0	0	0	1	0	1	0	65	10	6
22	clay	heap		7	55	1	88	0	0	0	0	0	0	0	1	152	27	5
23	ash/charcoal	fuel waste		6	48	2	129	2	7	0	0	0	0	0	0	194	18	10
24	ash/charcoal	fuel waste		4	29	9	72	5	2	1	1	0	0	3	1	127	13	9
25	charcoal	fuel waste		0	3	0	33	0	0	0	0	0	0	0	0	36	0.4	90
26	ash/charcoal	fuel waste	230-420	2	9	1	40	0	1	0	0	1	3	1	0	58	5	11
27	clay	heap		12	38	9	132	5	0	0	2	0	3	1	1	203	30	6
28	clay	heap		0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
29	ash/charcoal	fuel waste		12	14	5	60	0	0	0	0	0	3	0	0	94	6	15
30	charcoal	fuel waste		0	10	1	29	3	0	1	39	0	0	1	0	84	3	28
31	clay	heap		0	11	7	18	1	4	1	1	0	3	0	0	46	5	9
32	clay	heap		0	23	8	32	2	0	1	0	1	3	1	0	71	3	23
Totals				43	249	46	682	20	14	4	43	3	15	8	3	1845	227.9	

Table 2. Arboreal species found in furnace A.52. The findings are divided according to layers, each of which has been characterized on the base of specific physical features (component) and function (type of layer). Layers 1-2-3 were not included because they did not contain any charcoal remains Calibrated radiocarbon date is added when available. Volume of soil is provided as well as frequency, which is calculated as the ratio between the number of charcoals and the volume of soil for each layers.

THE ANTHRACOLOGICAL ANALYSES OF THE FURNACES

On the whole, 2137 charcoals were identified, more than half of these specimens were of *Quercus* cf. *pubescens* (1233 fr.), while one quarter of the remaining were of *Pistacia lentiscus* (495 fr.). Less were the remains of *Rhamnus/Phillyrea* (137 fr.), *Quercus* cf. *ilex* (75 fr.), and *Populus/Salix* (57 fr.), and even scarcer were those of *Sorbus* sp. (32 fr.), *Ulmus* cf. *minor* (31 fr.), *Acer* cf. *campestris* (21 fr.), *Punica granatum* (20 fr.), *Olea europaea* (15 fr.), *Prunus* sp. (14 fr.) and *Fraxinus* sp. (7 fr.).

The number of taxa varied according to the context of finding: four taxa in the southernmost furnace (A.36), seven and thirteen in the northernmost *praefurnia* (A.48, 52). As expected, the variability raised as the number of identified charcoals increased (Table 3).

THE RADIOCARBON DATING

One young branch of *Quercus* cf. *pubescens* was sorted from the findings recovered in furnace A. 36. Sample LTL4383A provided a date in calendar years between the 1st and the 3rd centuries AD. Comparison with stylistic dating elements of the mosaic of room A.14, allowed reducing this time range and precisely dating this nucleus to the 3rd centuries AD.

Much older are the dates obtained from the other two furnaces. The two branches of *Quercus* cf. *pubescens* picked from upper and basal layers (LTL4382A-LTL4381A) of A.52 dated the use of this furnace between the 2nd and the 5th centuries AD. Architectural evidence limits the use to the 5th century AD.

The last radiocarbon measurement, obtained from a young branch of *Pistacia* cf. *lentiscus* sampled from furnace A.48 (LTL4380A) dated this part of the complex to the 5th-6th centuries AD (Fig. 6)

DISCUSSION

The study of the fuel used in the *termae* represents only a part of the anthracological investigation which has been carried out at the site of Faragola since 2003.

The data collected from the Late Roman villa, and the Early Medieval settlement which spread over its ruins, provided information on the vegetal cover, the catchment basins and the way in which man had exploited the natural resources between the 2nd and the

CONTEXT	RADIOCARBON AGE (CAL. AD)	Thermo-mediterranean woodland			Meso-mediterranean woodland		Riverine forest			Orchards						
		Quercus cf. *ilex*	*Rhamnus/Phillyrea*	*Pistacia lentiscus*	*Quercs* cf. *pubescens*	*Acer* cf. *campestris*	*Ulmus* cf. *minor*	*Fraxinus* sp.	*Populus\Salix*	*Olea europaea*	*Punica granatum*	*Sorbus* sp.	*Prunus* sp.	TOTAL	VOLUME	FREQUENCY (N. CHARCOALS/LT.)
A. 36	70-230	-	5	6	37	-	-	-	-	-	-	2	-	50	30	1,6
A. 52	130-420*	75	93	376	1122	21	31	5	52	11	19	26	14	1845	228	8
A. 48	380-540	-	39	113	74	-	-	2	5	4	1	4	-	242	63	3
Total		75	137	495	1233	21	31	7	57	15	20	32	14	2137	321	

Table 3. List of the plants found in the three furnaces separated on the base of their ecological provenience. *The range is obtained from two measurements LTL4381A-LTL4382A.

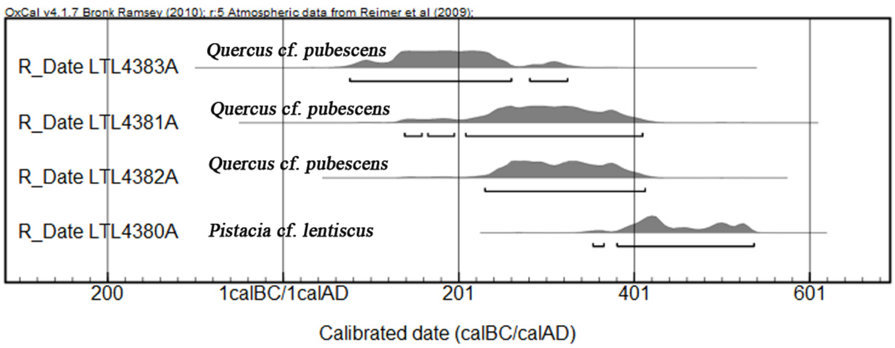

Figure 6. Calibrated curves of the four dated samples: LTL4383A (furnace A.36); LTL4381A and LTL4382A (furnace A.52); LTL4380A (furnace A.48).

7th centuries AD (Caracuta and Fiorentino 2009; Caracuta 2011).

Three catchment basins were identified: the coppice on the hill-top, the thermophilous woodland in the sunny valleys and the riparian vegetation along the local streams. Residues of olives and fruit trees, found scattered in the Late-Roman contexts, suggest that wood was collected also from orchards where pruning made available young branches.

Fuel used in the hypocaust baths would have been procured especially from the first area, where *Quercus* cf. *pubescens* would have grown. Partially exploited was also the thermophilous woodland where *Pistacia lentiscus*, *Rhamnus/Phillyrea* and *Quercus* cf. *ilex* were collected. Scarcely represented is the riparian vegetation, even though branches of *Populus*/*Salix* are relatively abundant in furnace A. 52.

It is worth noting, that this kind of remains are found exclusively in the basal (1-12) and uppermost layers (24-32) of furnace A.52,

Populus/*Salix* is not the only species that was found mainly in such layers, evidence of fruit-trees, such as *Punica granatum*, and *Olea europaea* are limited to these strata as well.

One possible explanation could be that fuel selection would have changed during time within the same context: more species were used during the first phase (L.1-12), but then the selection of fuel became more specialised as the number of species decreases (L. 13-23), until it increased again (L. 24-32) (Fig. 7).

The reasons of such changes are still unclear, but remains of *Populus*/*Salix*, *Punica granatum* and *Olea europaea* were also found in furnace A.48, confirming the importance of such species as fuel at least in the last phase of the thermal complex (5th-6th centuries AD) (Fig. 8).

CONCLUSION

The analysis of charcoals found in three furnaces at the site of Faragola provides the first evidence of fuel selection in a Late Roman *termae* of Southern Italy and is one of the few such attempts in the Mediterranean world (Baldson 1969).

The antracological investigation, coupled with microstratigraphical excavation and radiocarbon dating, open new perspectives in the study of thermal furnaces pointing out differences in the selection of fuel and the exploitation of wood.

Local woodlands were widely exploited: the coppice provided *Quercus* cf. *pubescens* but also, in sunnier spots, *Pistacia lenstiscus* and *Rhamnus*/*Phillyrea*.

The proximity to the Carapelle stream made riverine vegetation easily available, while the remains of fruit-trees suggest that even orchards were close to the site.

The highest variety of species was found in the furnace A.52, dated to the 5th century AD, which, in addition, showed changes in fuel selection through time. The presence of *Populus/Salix*, *Olea europaea* and *Punica granatum* seems to reflect some kind of choice, since these species are recorded only in certain layers of furnace A.52 and in furnace A.48, whilst they are absent from furnace A.36. However the evidence coming from A.48 and A.36 is too scarce to suggest that *Populus/Salix*, *Olea europaea* and *Punica granatum* became part of the fuel only since the 5th century AD. Indeed, their absence in the oldest furnace A. 36 could be due to a bias in the data instead of being representative of a real situation.

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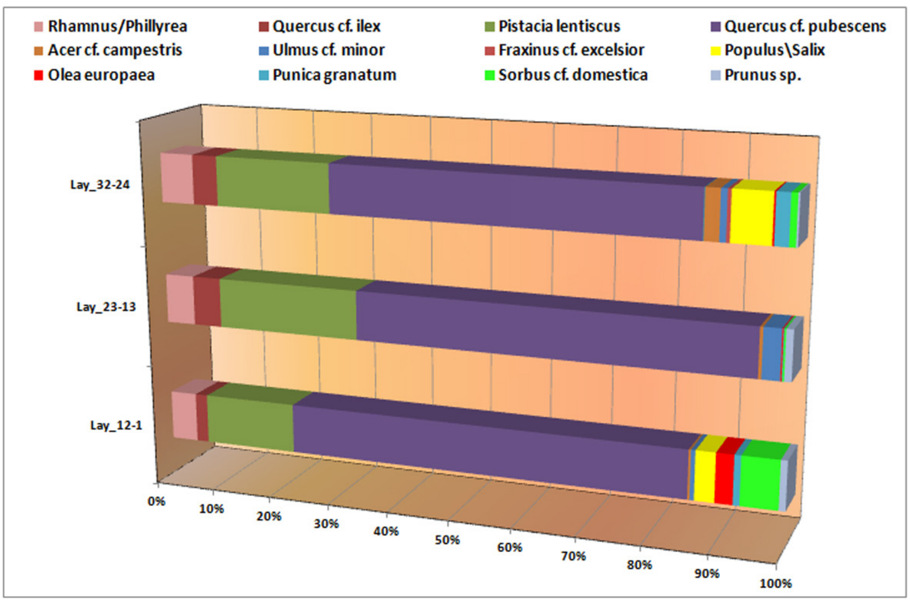

Figure 7. Comparison between the anthracological assemblages (%) of the three categories of layers of furnace A.52.

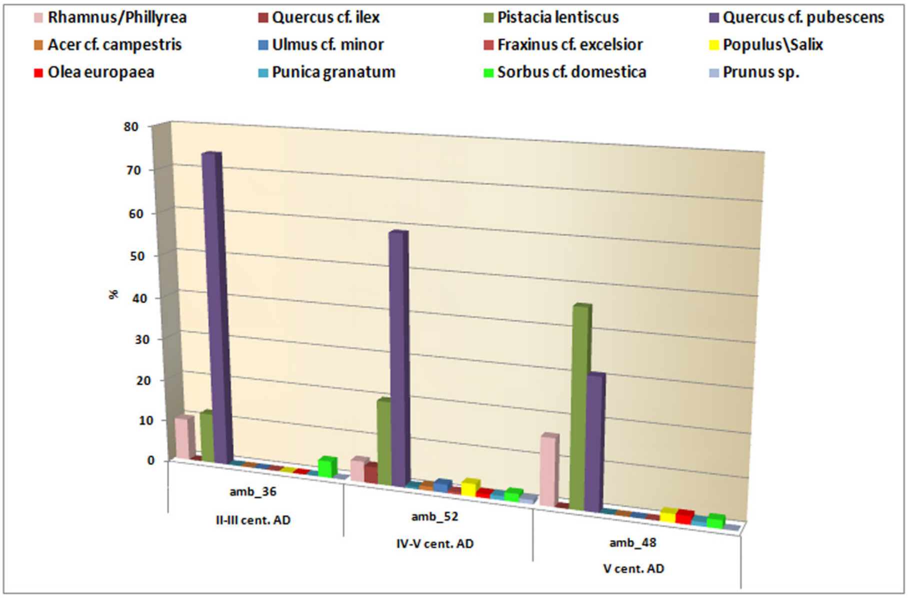

Figure 8. Arboreal species found in the three furnace: comparison of percentages.

the University of Foggia, DISCUM Department.

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Brick in the wall: an archaeobotanical approach to the analysis of dry stone structures (Puglia – Italy)

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***Summary**: Dry stone constructions are a common occurrence in many Mediterranean landscapes. One of these structures known as* Paretone dei Greci *(Taranto, Southern Italy), was subject to an archaeological investigation. Soil and sediment material within this wall, as well as those above and below it, were sampled and processed for archaeobotanical studies. In this manner it was possible to understand its building technique as well as to provide a chronological context for it. Through anthracological analysis it was possible to insert the* Paretone *within the surrounding agricultural landscape, thus better highlighting its function in relation to the history of the territory.*

***Key words**: Dry stone wall, Archaeobotany, Middle Ages, Southern Italy.*

INTRODUCTION

In central-southern Puglia, the dry stone building technique is used for linear and boundary structures (walls of various dimensions) and for individual structures such as buildings used for temporary, seasonal, intermittent or permanent habitation (shelters, huts etc.). It is also used to create random or structured piles of stones (*specchie*, *cairns*, *tumuli*) (Ambrosi 1990). Their ubiquitous presence in the region has prompted landscape archaeologists to seek special instruments with which to perform a thorough reading of this rich source of data. Indeed, it is precisely their frequency – together with their function as the "skeleton" of the anthropised landscape – that makes the systematic study of dry stone structures crucial to our overall knowledge of the history of the environment, of the landscape and the region.

In Puglia, the dry stone walls are mostly of two types. On the one hand there is the dense web of low walls that mark the boundaries between fields. The other type is relatively rare; much taller and thicker, they are known locally as *paretoni* or *limitoni* (the suffix indicating their large size) and in some cases stretch for many kilometres. While the former are to be studied precisely because of their ubiquity, the exceptional nature of the *paretoni* raises specific questions regarding their origin and function.

This study aims to analyse an exemplary case of the latter type of structure, by means of a field study that began in 2005 of the so-called *paretone di Sava*, in the province of Taranto (Stranieri *et al.* 2009). The *paretone* has been identified by local historians as part of the possible fortified frontier between the Byzantine and Lombard areas of influence, the territory having been a bone of contention between the two powers from the late 7th to late 9th centuries. The myth of "the Greek dyke" seems however to have been formed in the 19th century (Stranieri 2000) and does not seem to be borne out by field data, hence the need to establish the structure's true historic nature.

Generally speaking, the survey techniques used by archaeologists for this type of artefact are descriptive. Only rarely has there been a thoroughgoing stratigraphic survey of the terrain to establish the context. This study also sought to assess the potential utility of an archaeobotanical study of these dry-stone constructions. Their specific informative potential is based on the following considerations: 1) They rest on top of long stretches of palaeo-soil, which has thus not been affected by ploughing; 2) they themselves constitute long stretches of organic sediment; 3) they represent ecological – and ultimately archaeological – "niches" or rather "corridors". On the basis of these results it is possible to propose a diachronic model of the evolution of an agricultural landscape, to be integrated with data on the dynamics of settlement.

THEORETICAL BACKGROUND

This study, part of a wider research project, focuses on the history of the environment and on the evolution of the medieval agrarian landscapes of central and southern Puglia. This project looks at various aspects of the landscape (cf. Sereni 1962; Aston 1985, Caldo 1987; Cambi and Terrenato 1994; Chouquer 2000) such as the structural and interrelated components of a system (Raynaud 2003), some of which have long been amenable to an archaeological reading while others remain obscure due to a lack of suitable survey techniques. In consideration of this varied legibility, archaeology has tended to rely on settlements, projecting on to the surrounding agrarian landscape an image derived from data gathered in tiny portions of space that are –often erroneously and with no regard to nuance– referred to as "sites".

In a systemic and holistic framework however (Fiorentino 2004), a suitable characterisation of the agrarian structures would take account of their regional and administrative aspects and their relationship to the road network, the size and ownership of landholdings, palaeovegetation, use of the soil, crop systems and management of uncultivated areas, so as to cover the entire economic system including agriculture. This could be used to complement or modify interpretations that derive from research into settlements, especially when such research is not based on a satisfactory series of data, as is still the case with the early-medieval northern Salento. Indeed, the two types of evidence mutually depend on each other, to the point that the transformations observed in the one may be considered a reflection of those occurring in the other. Knowledge of the history of the fields, pastures and woods (the "living space" and the "places of work") makes it easier to understand the dynamics of settlement, even when little is known about the settlements themselves.

When the landscape begins to be thought of as an enormous archaeological tableau, readable not just from above but also from within (by means of archaeological excavation), then *all* the evidence necessarily enters the field of archaeology and its transformations can be read as the expression of environmental, economic and social dynamics. In this way, spaces that were not settled –and even spaces that were not cultivated– cease to be considered "marginal" and are therefore studied fully –not merely in search of certain "anomalies" that may be considered evidence of abandoned settlements. In such an archaeology of agrarian systems, each element of the landscape –whether still functional, no longer functional or fossilised– must therefore be studied and explained before being inserted in a chronological perspective (Chouquer 1996; Raynaud 2003). As well as knowledge of these components, it can also provide new elements for the archaeology of settlements and the history of technology, thus completing the picture in terms of material culture.

Within this tradition of studies and in the wake of the pioneering work of Richard Hodges in the United Kingdom (cf. Hodges 1991), Italy has also seen the development of an archaeology of agrarian and rural property delimitation, by means of rows of stones, ditches, hedges and dry stone walls. The historical development of such delimitation is manifested in the contemporary landscape –with its distinctive geometrical forms, dimensions and physical appearance. It reflects territorial boundaries, the limits of large feudal and ecclesiastical estates, the patchwork of smallholdings and the road network, all stratified in a "collapsed chronology" of thousands of years of human influence on the landscape.

THE CASE STUDY

The *paretone* studied here is situated in the municipality of Sava, 31 km east of Taranto and 15 km north of the Ionian Sea (Fig. 1). It is cited in archive sources from the 15th century onwards. In addition, a trove of coins was discovered by chance in 1953 (Pichierri 1976), in a stretch of the *paretone* that is no longer extant. The trove was composed of an unknown number of silver carlini gigliati, datable to the reign of Robert I of Anjou (1309-1343).

In its current state, the *paretone* of Sava is about 1.3 km long but only the central stretch of about 700 m is still in a good state of conservation. It consists of two parallel walls with fill between them, and is on average about 4 m thick. It is oriented along a north-south axis and the height varies between 1 and 3 m (Fig. 2).

It is made up of small, medium and large stones from the surrounding fields, which are characterised by numerous outcrops of Altamura (Cretaceous) limestone. Along its east side are numerous ramps up to the top, as well as basic shelters incorporated into the structure of the wall. Such structures are entirely absent from the west side. Again on the east side of

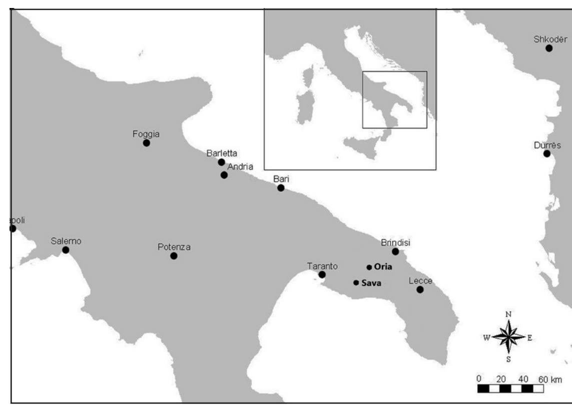

Figure 1. Site location.

Figure 2. The *paretone* of Sava.

the *paretone* are rectangular and semicircular niches, whose functional and chronological interpretation remains problematic. What is certain is that the east side appears to have been the object of greater attention than the other side. To the south and north of this central stretch the *paretone* has a less structured appearance; where the wall is built on a calcarenite substrate (Gravina Calcarenite) (cf. Stranieri and Napolitano 2009), long stretches of it have been invaded by a tall, Mediterranean maquis-type hedge. The boundary marked by the wall continues in a northerly direction in the form of a country lane and rows of stones marking the edges of fields for a total length of roughly 4.3 km.

METHODS

In choosing which stretch of the *paretone* to excavate we selected a point where a country lane cuts across it, enabling us to make use of an existing cross section. This part of the structure was also characterised by an interesting difference in height between the two outer walls, which is also seen in the DTM. Stratigraphic assays were conducted in an area 3x8 m that was perpendicular to the structure and included its terminal segment, which was entirely dismantled. In addition, two other assays of 1x2 m were conducted adjacent to the wall, one on each side (Fig. 3). The wall was stratigraphically surveyed in cross section, disassembled and then rebuilt as before.

Figure 3. The *paretone* being excavated.

Systematic archaeobotanical sampling was conducted for each stratigraphic unit. A grid with one-metre squares was imposed on the entire area subject to stratigraphic assays and a 5-litre sample of earth was taken from each of them.

After taxonomic classification, a sample was ^{14}C-dated with high resolution mass spectrometry at the CeDaD - University of the Salento, thus providing an absolute dating.

Lastly, reconnaissance of the current vegetation was conducted on the wall and the area immediately surrounding it.

DATA AND RESULTS

The excavation of the structure highlighted a complex archaeological stratigraphy (Fig. 4) and some interesting anthracological data.

The substrate on which the two external sides and the fill between them were built up (SUs 17, 27, 29, 34, 35) is characterized by the overwhelming presence of *Erica* sp. In addition, SU 35 yielded 82 fragments belonging to a ceramic cooking pot, probably of local manufacture. Though highly degraded, these fragments do not exhibit traces of fluitation and may thus be considered primary deposits. The only diagnostic element of the pot is the bottom with umbo, which bears similarities with ceramics from excavations conducted in the province of Lecce datable to the 7th to 8th centuries.

The most ancient phase of construction is a level made up of two rows of medium to large stones bound with earth and placed directly on the agrarian palaeosoil. In its conserved state, this arrangement is about 3.5 m thick and does not exceed 0.45 m in height. The first row (SU 20) yielded only charcoals of *Erica* sp. The second row, broadly similar to the first in structural terms, is characterised by the presence of *Quercus ilex* L. (Fig. 5 cf. “I structural phase”). From the time it was built, this linear structure functioned as a “dike”

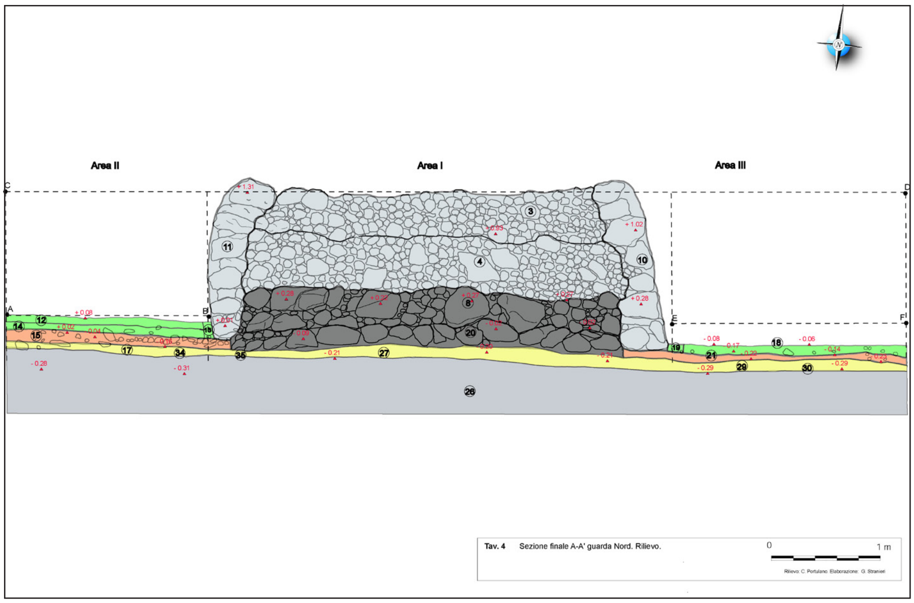

Figure 4. Final section of the *Paretone dei Greci*.

that blocked the eastward movement of colluvium. SUs 15-21, corresponding to these colluvial deposits, were radiocarbon dated to 670-880 cal. AD. They are characterized by the same species found in the earlier phase with the conspicuous addition of *Olea europaea* L. (Fig. 5 cf. "post I structural phase").

The second row of large stones was covered by a layer of fill, roughly one metre thick, made up of stones of small and medium dimensions (SUs 3-4-10-11). The fill is contained on either side by the two outer walls, which are made of medium to large stones and lean inwards in order to enhance stability. The two outer walls show numerous traces of repairs and reinforcement. For example, below the outer wall on the west side (SU 14) a fragment of etched polychrome ceramics was discovered, datable by its decorative motif to the 16th century. The discovery provides a *terminus post quem* for this later building work. The soil beneath the two outer walls (SU 13- 14- 18-19) yielded anthracological remains of *Olea europaea* L., *Erica* sp., *Myrtus communis* L., *Cistus* sp., *Ostrya carpinifolia* Scop., *Sambucus* sp., *Prunoideae* and *Pomoideae* (Fig. 5 cf. "post II structural phase"). The fill (SU 3-4) contained a large quantity of fictile and vitreous fragments, all from modern times.

Currently the area surrounding the *paretone* is mainly used for olive groves. In the immediate vicinity, and often inside its less well-conserved stretches, there are specimens of *Quercus ilex* L., *Punica granatum* L., *Phillyrea* sp., *Myrtus communis* L., *Galium* sp., *Ruscus aculeatus* L., *Crataegus monogyna* Jacq., *Erica* sp., *Calycotome spinosa* (L.) Link, *Rubus fruticosus* L., *Prunus* sp., *Cydonia oblonga* Mill., *Pistacia lentiscus* L., *Asparagus acutifolius* L.

DISCUSSION AND CONCLUSIONS

The *paretone* today appears to be the result of a single effort of construction. The building techniques and the characteristics of the fill as derived from the archaeological survey do not however entirely clarify its origins and lead rather to two distinct hypotheses. The first is that it was built in a single operation during the early Middle Ages and was perhaps restored at certain points in subsequent periods, as indicated by the presence of ceramics datable to the 16th century discovered below the outer wall on the west side. The second is that there were at least two major and distinct structural interventions, possibly separated by a period of use and/or decay of the structure. What is certain however is that at least the original core of the structure was already present in the 7th to 9th centuries.

The second issue is the function of this imposing structure. In the absence of documentary sources or clear diagnostic elements, the archaeobotanical approach enabled us to assess changes in the use of the land surrounding it following its construction. However, the proposed approach also entails a reflection on the dynamics of taphonomy in the area of deposition. Due to its inherent design features, this type of structure initially constitutes an "open" basin of deposition: the interstices and gaps between one stone and another allow the passage of sediment and of macro and micro remains of anthropic, animal or plant origin. In time, these spaces fill up, limiting the processes of post-depositional removal. Thus the structure eventually becomes a "closed" basin of deposition. Therefore, from a diachronic perspective, the wall can also be described as "temporarily open", the processes of input and removal of material ending either when the basin is full or when it is sealed off by the construction of new, adjacent structures.

The absence of any thermally altered elements near the structure indicates that the charcoal remains entered the context and then settled as a result of depositional and post-depositional processes driven by physical and biological agents. Their basin of origin cannot be far from their place of discovery, because, after a comprehensive visual examination, the charcoals show little sign of rounding. Consequently, since the charcoals are not the result of a single event or process, they indirectly provide information on the evolution of the palaeovegetation of the area. The type and relative chronological horizon of the artefacts and ecofacts discovered in the *paretone* (dated to a period from the 7th century to the sub-contemporary period) have also confirmed the validity of considering this type of structure as a "container of information" re-

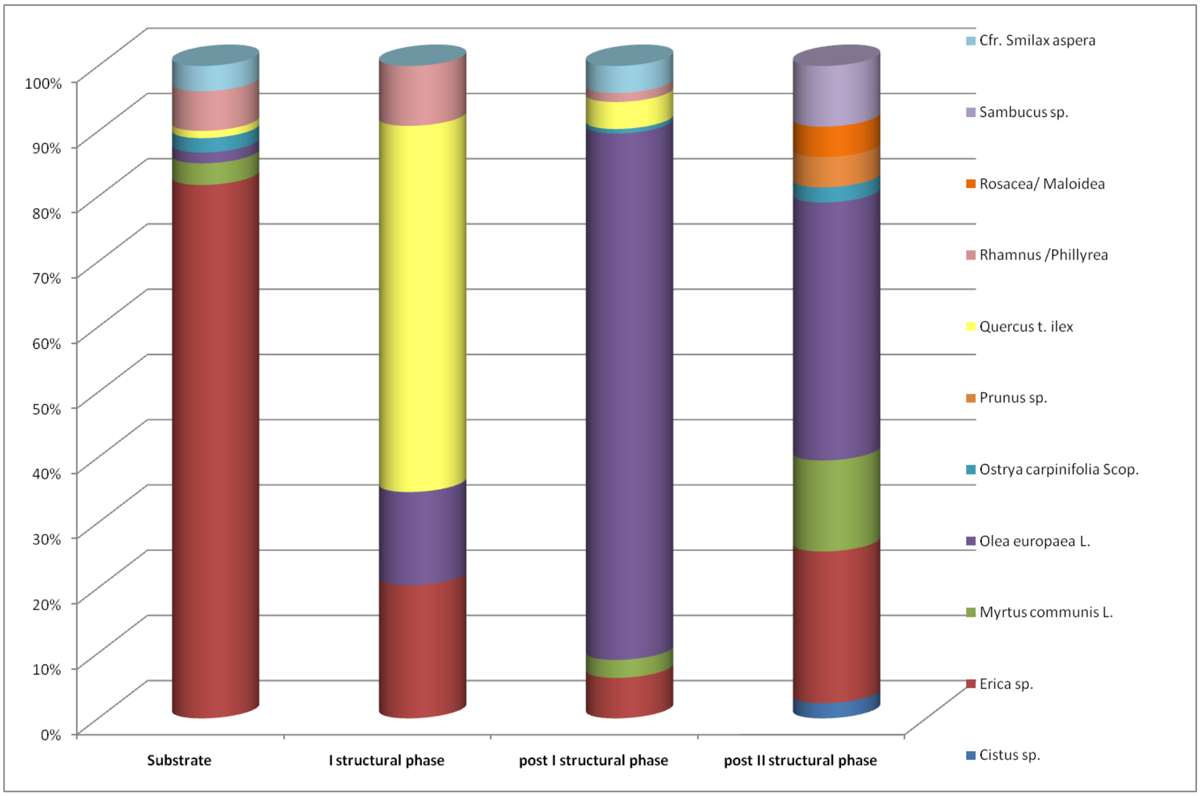

Figure 5. Results of the anthracological analysis (Total fragments: 460).

garding the evolution of the surrounding area.

Thus, the phase preceding the building of the structure is characterized by a landscape of low scrub vegetation, while the first construction phase is linked to a vegetational stage moving towards a mature forest. After this phase (7th to 9th centuries), the landscape around the *paretone* changed and was probably characterized by olive groves. This was probably not an isolated development but rather was linked to a reorganisation of space and agricultural resources throughout the Salento peninsula. Analyses of pollen conducted near the Alimini Lakes (Di Rita and Magri 2009) indicate an increase in the cultivation of olives in this period and archaeobotanical analyses of the abandoned village of Apigliano seem to confirm pre-eminent role of this resource (Arthur *et al.* 2012). Finally, the soil beneath the outer walls, corresponding to the second stage of construction, contains not only olive, but also plum and apple charcoals, indicating that the landscape had evolved again as a result of increased human exploitation. The results of the anthracological analyses thus seem to provide little backing for a defensive or military interpretation of the structure. Indeed, if that had been the case, it would probably not have been necessary to modify the use of the terrain, for example by planting olive groves. The *paretone* is believed to have originally constituted a field or property boundary which may, in the late Middle Ages, have also become an administrative boundary. In the points where the *paretone* has undergone partial collapse, it has become fossilised due to its colonisation by Mediterranean maquis-type vegetation.

In conclusion, the additional information provided by the archaeobotanical investigation of a dry-stone structure has allowed it to be viewed in the context of its original vegetation. This has provided material for deepening our understanding of the history and function of the artefact and its relationship to the landscape. The importance of the result is enhanced by the consideration that the *paretone* of Sava is situated in a landscape where the nature of the soil and the depth of the aquifers –unreachable by traditional techniques– make the area unsuitable for settlement. In some periods, such areas play only a minor role in human settlement patterns while in periods of greater demographic and agrarian pressure, they are used as arable land after exhaustive removal of the stones, which are piled up in walls and other structures.

Thus, despite the absence of data on the history of settlement, the knowledge provided by the stratigraphic analysis of this structure and of the surrounding landscape indicates tendencies in terms of demographic pressure and the use of the soil in a given area, phase by phase, over a long period. In the second place, it is legitimate to assume that a better knowledge of the organisation of the agrarian landscape and the use of the soil in successive historical periods will also help to fill the remaining gaps concerning certain phases of the history of settlement, especially the early Middle Ages. Indeed, in a systemic framework, the characterization of the fields, pastures and woods (the “living space” and “places of work”) –by means of studies of this kind– enhances our understanding of the dynamics of settlement, even when the settlements themselves remain obscure due to a lack of diagnostic materials and/or adequate research programmes. Furthermore, the archaeological characterisation of rural settlement patterns and the transformations of the agrarian landscape in the area considered here can improve our understanding of the spatial, regional, economic and cultural dynamics of the northern Salento in the 7th to 9th centuries. This in turn may shed light on the whether –as has been argued– this area constituted a frontier region between the Byzantine empire and Lombard duchy of Benevento.

The study of the dry-stone walls of central and southern Puglia in accordance with the methods outlined here has thus proved to be a valid approach. It has produced a new series of data that opens up new hypotheses and illustrates patterns in a research context, which for the early Middle Ages had appeared somewhat paralysed due to the lack of data on the history of settlement. When such data become available, providing a diachronic vision of settlement, the archaeology of the agrarian structures will provide a useful bridge between self-contained approaches to diachronic settlement patterns, uninfluenced by other themes (Brogiolo 1995: 239), and a broader, geo-historic overview of the region.

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An anthracological approach to understanding Late Classic period cultural collapse in Mesoamerica's northwestern frontier

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Summary: *For over 50 years, researchers have suggested that increased regional rainfall over the highland deserts of Mesoamerica's northwestern frontier zone during the Classic period (AD 200-900) allowed for the colonization of the zone by farming groups who originated from Central and/or West Mexico. A severe and prolonged drought is hypothesized to have later provoked the abandonment of the region by these sedentary populations by AD 900. However, very little research has been carried out in the zone to detect evidence of this proposed climate change. I present results from the first systematic study of wood charcoal from the northwestern frontier, comparing the data from three Classic period ceremonial centers that span the region's north-south gradient of intensifying aridity. The results indicate that the strongest evidence of environmental degradation is found in the south (where average annual rainfall is the highest), while the sites located farther north (with lower annual rainfall) demonstrate more stable use of wood resources. These findings suggest that anthropogenic impact played a more significant role in regional abandonment than climate change, and that the current models of the process of the collapse in the northwestern frontier may need to be reconsidered.*

Key words: *Mesoamerica, anthracology, wood charcoal, forest management, human impact.*

INTRODUCTION

Scholars have proposed that the development and later collapse of sedentary agricultural societies in the northwestern frontier of Mesoamerica was driven by regional climate change (Palerm and Wolf 1957; Armillas 1964, 1969). The occupation of the zone spanned the Classic period (AD 250-900), with the peak of population growth focused in the period AD 600-800 (Fig. 1).

This period of demographic growth is hypothesized to be characterized by a significant increase in annual precipitation caused by a rise in global sea surface temperatures (culminating in the Medieval Warm Period) and the northward shift of subtropical high pressure zones in the northern hemisphere (Armillas 1964: 77-79; Gunn and Adams 1981: 96). This climate change expanded fertile grassland zones and reduced the semi-arid steppe in the frontier region, enticing Mesoamerican farmers from Central and West Mexico to settle farther north. Later, a decrease in global temperatures (linked to the Little Ice Age) led to drought conditions over northern Mexico and provoked the expansion of semi-arid steppe, poorly adapted to maize farming, toward the south. After a regional collapse around AD 900, the area did not see large-scale sedentary settlements again until the arrival of the Spanish in the early 1500's.

Despite the apparent logic to this model of linked climatic and cultural change, later research demonstrated a number of difficulties. One principal problem lay in the chronology of events. It has only been since the 1990's that systematic programs of radiocarbon dating have been carried out on multiple, well-controlled contexts at frontier sites (Trombold 1990; Nelson 1997; Lelgemann 2000). These dates indicate the sites were primarily founded around AD 500 and that they were abandoned at the latest by AD 900. Earlier generations of archaeologists had believed that the frontier settlements were founded closer to AD 600 and were not abandoned until at least AD 1200. The more accurate dating suddenly pushed the sequence of settlement and abandonment of the northwestern frontier zone back *before* either of the global climate changes that had been proposed as triggering factors (Fig. 2).

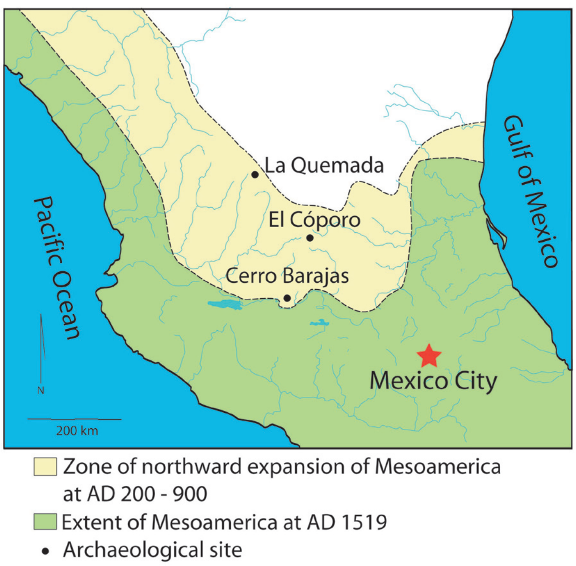

Figure 1. Map of the northern frontier zone of Mesoamerica with the locations of archaeological sites discussed.

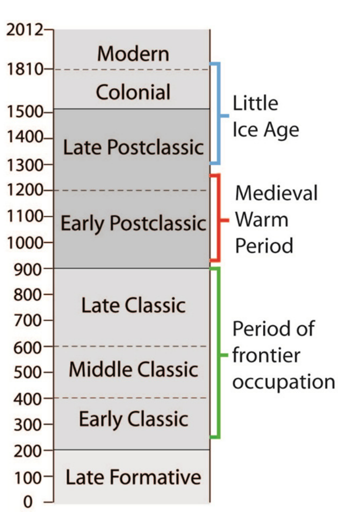

Figure 2. Chronology of the occupation of the Mesoamerican northwestern frontier compared with global climate changes.

Furthermore, the lack of systematic paleoenvironmental studies carried out in the northwestern frontier zone itself makes it difficult to assess how global climate changes manifested at the regional scale, and also how human land-use strategies and responses to climate factors affected local landscape evolution. In fact, the few studies that have been carried out in the region *do not* support the idea of environmental stress provoking social collapse. Instead, they indicate that the Classic and Postclassic periods were climatically stable, and that the greatest disturbance to the environment (producing the landscapes that are visible today) are the product of Colonial and Historic land-use practices that began in the 16th century (Brown 1992; Frederick 1995; Trombold and Isarde-Alcántara 2005; Elliott *et al.* 2010).

Thus, some important questions that remain unanswered are 1) did the environment of the frontier zone change through time? 2) How spatially homogenous were these changes? and 3) does the occurrence and the pace of environmental change correlate with cultural changes in the Classic period settlements? To begin to address these questions, I present the first study of wood charcoal for the region, focusing on three Classic period archaeological settlements that span the north-south axis of the frontier zone.

BACKGROUND AND ENVIRONMENT

The Mesoamerican northwestern frontier zone is an expanse of roughly 100,000 km^2 whose southern boundary follows the course of the Río Lerma-Santiago. Annual precipitation averages 700-800 mm along the southern margin, which is characterized by grassland and sub-tropical forested patches in low lying areas, transitioning into pine and oak forest in mountainous zones (Armillas 1964: 63; Labat 1995). This southern edge also marks the modern limit for non-irrigated maize agriculture, and it was an area of cultural division in the 16^{th} century, with groups of sedentary farmers to the south and mobile societies in the arid north (Armillas 1964: 65). As one moves northwest toward the Sierra Madre Occidental, rainfall decreases to 450 mm annually, and the landscape transitions to semi-arid steppe and desert vegetation (e.g., cactus, acacia, mesquite).

CERRO BARAJAS

Cerro Barajas is the southernmost of the three communities presented in this study. It is located in southwest Guanajuato in the Bajío region, a lowland zone of valleys, plains, and rolling hills between 1600 and 1800 m a.s.l. that surround the course of the Río Lerma-Santiago. The Bajío is one of the most important agricultural centers of modern Mexico. Uncultivated areas of the zone are marked by acacia and cacti. The region was fairly densely settled in the Classic period, with several other similarly sized ceremonial centers (*e.g.,* Peralta, Plazuelas, Zaragoza) located within a few kilometers of Cerro Barajas (Fernández Villanueva 2004; Cárdenas 2007; Castañeda 2007).

Cerro Barajas is a volcanic massif located just north of the Río Lerma and characterized by more than 20 prehispanic settlements that date to the Epiclassic period (Pereira *et al*. 2005). Los Nogales is the largest and most monumental of the ceremonial centers on the massif. All of the sites were abandoned by AD 900, following a phase in which fortifications were added to many of the larger sites. Nevertheless, there is no evidence of violence or warfare associated with the abandonment of Cerro Barajas.

EL CÓPORO

El Cóporo is located in the Ocampo Valley of Guanajuato, approximately 120 km northeast of Cerro Barajas, in the foothills of the Sierra Santa Barbara, at 2200 m a.s.l. (Torreblanca Padilla 2007). This monumental center is fairly isolated, being much larger than other contemporary sites in the valley, which are villages and hamlets. The valley's vegetation is characterized by cacti, yucca, mesquite, acacia, and other leguminous trees and shrubs. The average annual rainfall is 485 mm. The Sierra Santa Barbara, which rises to an elevation of 2650 m a.s.l. to the east, is marked by pine, oak, and madroño (*Arbutus xalapensis*).

The archaeological site consists of several complexes of domestic and ceremonial architecture located on the valley floor, as well as in hilltop positions that mark the interface of the mountains and the Ocampo valley. The Gotas complex, on the valley floor, contains a monumental hall of columns similar to that of Los Nogales at Cerro Barajas and the ceremonial precinct at La Quemada (see below). The peak of occupation occurred between AD 600 and 800, and the site was unoccupied by AD 1000.

LA QUEMADA

La Quemada is the northernmost site. It is located in the Malpaso Valley of southern Zacatecas, 250 km northwest of Cerro Barajas and 180 km northwest of El Cóporo. La Quemada is larger than the other contemporaneous sites in the valley by several orders of magnitude, and like El Cóporo, represents an isolated ceremonial center. The floor of the Malpaso Valley is 1950 m asl and sits in the foothills of the Sierra Madre Occidental. It has an average annual rainfall of 400 mm and is marked by nopal cactus, yucca, acacia, and some mesquite. Although Colonial period documents attest to the presence of pine and oak in the valley, none are observed today. The closest existing pine-oak forest is in the Sierra Fría, approximately 25 km to the southeast. Studies of the settlement pattern formed by the more than 250 contemporaneous village and hamlet sites in the valley indicate access to rivers and seasonal streams was of paramount importance (Elliott 2005).

La Quemada was the valley's principal prehispanic ceremonial center, covering 50 ha. It consists of more than 50 terraces constructed atop a small mountain (Nelson 1995). The ceremonial precinct contains a hall of columns that is one of the largest in Mesoamerica. The site was founded by AD 550 and the peak of occupation occurred between AD 600 and 800 (Nelson 1997). The site was no longer permanently occupied by AD 900.

Habitat type	Taxa	La Quemada	El Cóporo	Cerro Barajas
High elevation forest (> 2,500 m asl)	*Pinus* spp. *Quercus* spp.	X X	X X	X X
Riparian forest	Salicaceae *Salix* spp *Populus* spp.	X	X	
Disturbed woodland or sub-tropical deciduous forest	Fabaceae (Mimosoideae) *Acacia* spp. *Mimosa* spp. *Prosopis laevigata* *Lysiloma* sp. *Senna* sp.	X	X	X
Agricultural refuse	*Zea mays*	X	X	
Open/cleared zone	*Agave/Yucca?*			X

Table 1. A list of the wood charcoal taxa recovered in the archaeological samples and the assumed habitat type each is interpreted to represent. Their presence at each site is noted in the corresponding column with an "X". The Fabaceae charcoal recovered belongs to the Mimosoideae sub-family, but for the moment it is not possible to make more precise identifications.

METHODS

Ten-liter sediment samples were collected systematically from every excavation level of three stratified midden deposits (La Quemada) or stratified trash deposits used as fill in monumental architecture (Cerro Barajas and El Cóporo). Samples at La Quemada and El Cóporo were floted using a combination of manual and machine assisted techniques. Samples at Cerro Barajas were floted manually.

The taxa recovered in the archaeological samples are listed in Table 1, along with the assumed habitat type that they represent.

The Fabaceae genera that occur around the sites today are typically associated with "sub-tropical deciduous forest". While this woodland type is often presented as a natural vegetation community, the prevailing opinion among botanists in the region is that it is in fact the result of anthropogenic degradation of primary forest (Labat 1995). It was difficult to distinguish between *Salix* and *Populus*, thus no distinction is made between these two riparian genera.

In total, 1,792 fragments of wood charcoal were identified using a reflected light binocular microscope at magnifications of 100x – 400x. Charred wood references and published photographs of wood anatomy were used in the identifications. The modern wood samples were collected at Cerro Barajas and vouchered by the Herbarium of the Universidad Nacional Autonoma de México. Botanical survey and mapping was also carried out at Cerro Barajas to identify communities of trees and shrubs and their associations with altitude and land-use (Elliott in preparation), complementing earlier work in the Bajío region by Labat (1995).

DATA AND RESULTS

891 pieces of wood were analyzed from 11 flotation samples excavated from the patio of a monumental elite residence at the site of Los Nogales (Fig. 3). The sediment excavated comes from stratified trash deposits used as architectural fill over the course of the patio's construction and various remodeling episodes. Wood is present from a pine-oak zone and secondary, disturbed woodland. Fabaceae is present in all samples while pine and oak are present in eight of the 11 samples. By counts, pine-oak and disturbed woodland zones are present in the assemblage almost equally (34% pine-oak, 30% Fabaceae). A high percentage of monocotyledon remains were also recovered (27%

of the total assemblage). These consist of many large fragments that indicate a plant with flat, broad leaves, such as yucca or agave. These remains are predominantly found in levels that are associated with burning of the structure, and likely represent material used to construct the roof.

Those samples that can be assigned to early, middle, and late phases of construction (Nogales, Early Barajas, and Late Barajas) indicate important changes in the use of wood. A sudden decrease in pine and oak is correlated with a strong increase of Fabaceae in the late phase, which suggests over-exploitation of the local forest and subsequent colonization by woody taxa that thrive in disturbed environments. This pattern coincides with the period of peak population growth and construction at Cerro Barajas.

520 pieces of wood were analyzed from eight flotation samples excavated from the interior patio of the monumental Hall of Columns in the Gotas Complex at El Cóporo (Fig. 4). The fill for this patio was deposited over time and came from various trash deposits, presenting a well-stratified pattern that is confirmed by radiocarbon dating. Wood resources are present from pine-oak forest, riparian, and open grassland/desert zones that may have included cultivated fields. The taxa observed include *Pinus*, *Quercus*, *Salix/Populus*, Fabaceae, and *Zea mays*. Pine and oak are present in all samples, while Fabaceae is present in only two. The pine-oak forest also dominates the assemblage in counts (74%). This finding is notable because there is no pine or oak visible around the site currently, indicating that either the site's inhabitants traveled long distances to obtain this wood, or that significant landscape change has occurred since the site's abandonment. Fabaceae shrubs and small trees dominate the modern landscape.

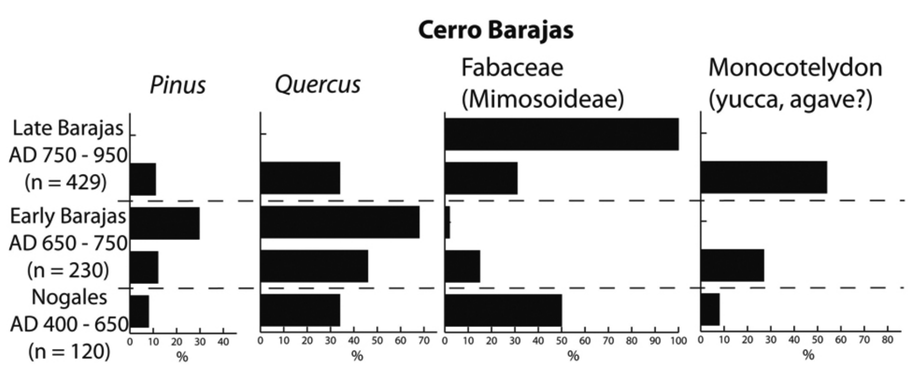

Figure 3. Proportions of wood charcoal recovered from stratified architectural fill in Patio A3 of the Nogales complex at Cerro Barajas.

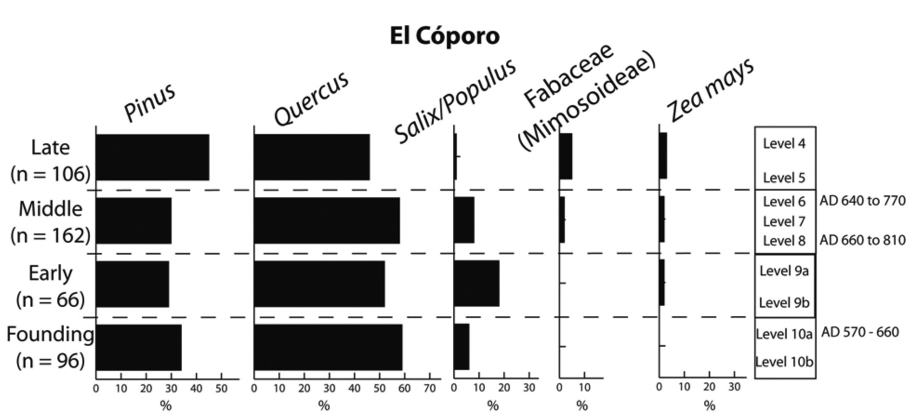

Figure 4. Proportions of wood charcoal recovered from stratified architectural fill in the Gotas Complex at El Cóporo.

The levels of the Hall of Columns can be divided into founding, early, middle, and late phases that span the period AD 550-800. The overall pattern indicates stable patterns of wood use, until the late period, when pine, oak, and riparian taxa decrease, and a slight increase in Fabaceae is detected. A chi-square test indicates these changes occur at a statistically significant level (Table 2). Nevertheless, these changes are more subtle than those observed at Cerro Barajas.

Taxa	Middle	Late
Pinus	48(58)	48(38)
Quercus	94 (86.4)	49(56.6)
Salix/Populus	13(8.46)	1(5.54)
Fabaceae (Mimosoideae)	4 (5.44)	5(3.56)
Zea mays	3(3.63)	3(2.37)

Table 2. A chi-square test of changes in wood taxa frequencies between the Middle and Late period at El Cóporo. Observed frequencies are listed first, and expected frequencies are in parentheses. X2 = 13.4, df = 4, p = 0.009.

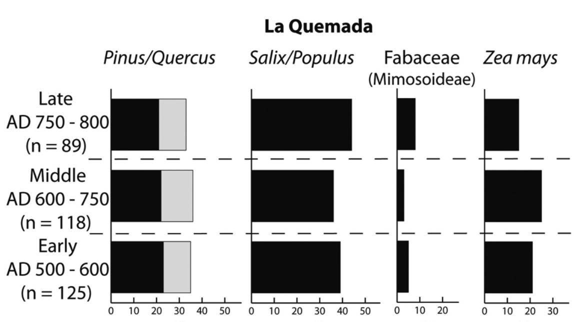

Figure 5. Proportions of wood charcoal recovered from three stratified middens at La Quemada.

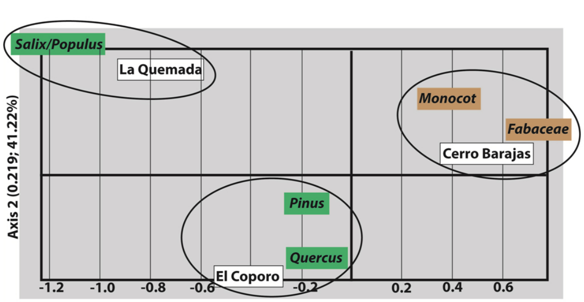

Figure 6. Correspondence analysis of wood taxa recovered at all sites. Taxa associated with anthropogenic disturbance and/or dry climatic conditions (in brown) cluster with Cerro Barajas, while high altitude forest and riparian vegetation (in green) are more closely associated with La Quemada and El Cóporo.

381 pieces of wood from 50 flotation samples were analyzed from three well-stratified and radiocarbon dated middens at La Quemada (Fig. 5). The results indicate that the inhabitants of the site had access to trees from a variety of ecological settings that include pine-oak forest, a riparian zone, and open areas that appear to have included agricultural fields. The taxa recovered include *Pinus*, *Quercus*, *Salix/Populus*, Fabaceae, and *Zea mays*.

At La Quemada, riparian and pine-oak forests are the most significant sources of wood used. There are no significant changes through time in the proportions of wood used from the pine-oak, riparian, and open/agricultural zones.

A correspondance analysis of the charcoal data from all three sites more clearly illustrates the similarities between the two northern sites (La Quemada and El Cóporo), and their distinction from the more southern site (Cerro Barajas) (Fig. 6). Riparian taxa are most closely associated with La Quemada, and high-elevation pine-oak forest is clearly associated with El Cóporo. In contrast, Cerro Barajas is most closely related to monocotyledons and Fabaceae, taxa that tend to be linked to semi-arid conditions and/or anthropogenic disturbance of soils.

DISCUSSION AND CONCLUSIONS

The results indicate that the environment of each of the three archaeological zones has changed significantly at some point subsequent to the Late Classic period. The higher elevation pine-oak forests have contracted and forested patches that are well adapted to dry and/or disturbed conditions have increased. However, these changes are not uniform through time or space. They are likely the result of anthropogenic impacts, which in some cases began in the Prehispanic period, and later intensified in the Colonial, historic, and modern periods. The evidence for stress in wood resources at Cerro Barajas and El Cóporo correlates with the later phase of occupation (the period of most intense demographic growth). In contrast, La Quemada exhibits a stable pattern of wood use that is independently supported by data from Elliott *et al.*'s (2010) study of alluvial sediments in the same valley, which indicates that little climatic change has occurred over the last 2000 years, but that significant landscape degradation followed the introduction of mining and livestock by the Spanish in the 16th century.

The evidence for landscape change across the frontier zone is negatively correlated with the degree of aridity. The strongest evidence for wood resource stress comes from Cerro Barajas, the zone with the highest annual rainfall. La Quemada shows long-term stability, despite its significantly lower annual precipitation. El Cóporo appears to follow a more intermediary pattern, with some evidence of wood resource stress, but much less marked than that for Cerro Barajas.

I suggest that a possible explanation for this pattern is stronger demographic pressure on resources at the more southerly sites toward the end of the Classic period. Cerro Barajas is comparable in scale to La Quemada and El Cóporo, but the density of large centers overall is much higher in the Bajío region than it is in the northern reaches of the frontier zone. Cerro Barajas coexisted within a few kilometers with a number of neighboring monumental Classic period centers. In contrast, in the more semi-arid north, large centers such as El Cóporo and La Quemada are isolated, resulting in much lower settlement densities, and lower resource demands.

However, I would argue that the differences observed in the wood charcoal assemblages are not due simply to population pressure alone. I propose that contrasting perceptions of the availability of wood resources also contributed to the divergent patterns detected. Although each of these northwestern frontier communities were situated in ecologically fragile zones, the southern settlement with higher annual rainfall (Barajas) may have appeared more abundant in wood resources, thus attracting a higher density of people and the founding of large centers with intense wood resource needs (demonstrated by the regional settlement pattern), resulting in greater anthropogenic impact in the long-term. In contrast, drier (and more unpredictable?) climate conditions farther north at El Cóporo and La Quemada may have made these populations more cognizant of the necessity for the management of wood resources, and coupled with a lower settlement density, resulted in a more stable pattern of resource use over the long-term. A similar pattern has been documented between the Mimbres Valley of western New Mexico and the more arid Eastern Mimbres zone (Hegmon *et al*. 2006).

If the observed contrasts in wood use strategies and settlement density are indeed products of differing environmental conditions, it still remains to be explained why these frontier centers (and others like them across the region) all collapsed at essentially the same moment in time, despite some successfully developing sustainable strategies of resource management. The findings presented here indicate that the factors surrounding the regional collapse are complex and merit a more detailed explanation than simple environmental change. The social, economic, and political connections among these sites deserve further investigation (as well as the addition of data from other contemporary sites) to better understand how their developmental trajectories affected one another and what the long-term consequences of their interactions were at the regional scale. In addition, off-site paleoenvironmental reconstructions, focused on a variety of environmental proxies, should be carried out near multiple Classic period centers in the northwestern frontier (such as Elliott *et al.*'s 2010 analysis near La Quemada). These studies would provide a complement to the charcoal studies and improve our understanding of the accuracy of anthracological data to reflect episodes of landscape change or stability across a region where this method has not previously been applied.

What can be concluded for the moment from the charcoal data is that models of frontier abandonment that assume climate change was the primary cause and that a process of collapse originated on the north edge of the frontier and then spread to the south may require revision. Instead, they raise the possibility that cultural collapse originated in the *southern* edge of the frontier due to anthropogenic degradation and then spread to sites farther north. The collapse of large sites like Cerro Barajas, which sit along major corridors for the movement of people, goods, and ideas, between Central and West Mexico and regions farther north, would likely have severed key lines of communication with the Mesoamerican core for communities such as El Cóporo and La Quemada. This process might therefore be more accurately visualized as a cultural "implosion" that began in the south and whose socio-political-economic "shockwaves" traveled quickly northward.

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EXPLOITATION OF FUELWOOD IN GASTEIZ (BASQUE COUNTRY, NORTHERN IBERIA) DURING THE MIDDLE AGES (700-1200 AD)

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***Summary**: The excavation of medieval contexts linked to the restoration works carried out in the cathedral of Vitoria-Gasteiz has allowed to recover different archaeobotanical assemblages that help us understand past agrarian practices and human exploitation of woodlands. Here we summarize the results of the wood charcoal analysis from samples dated* c. *700-1200 AD.* Quercus *subg.* Quercus*,* Fagus sylvatica *and Rosaceae would have been the main fuels used in domestic activities with* Fagus *increasing through time. In contexts related to metallurgy,* Prunus *and Pomoideae were the most abundant taxa.*

***Key words**: Woodland, Middle Ages,* Quercus*,* Fagus*, metallurgy.*

INTRODUCTION

The village of Gasteiz (named Vitoria in 1181 through the Fuero given by the King of Navarre Sancho VI the Wise) was settled permanently at least from the end of the 7th century or early 8th century AD. It has a strategic location in the centre of the “Llanada alavesa” plateau, a crossroads between the Meseta, the Ebro Basin, the Western Pyrenees and the Atlantic Valleys of northern Iberia.

During the past years the Santa María Cathedral of Vitoria-Gasteiz (Basque Country, Spain) and the area around it have been involved in a well-known excavation and restoration project (www.catedralvitoria.com) (Fig. 1). The analysis of different types of bioarchaeological material has been fundamental in this project in order to shed light on past landscapes and on the economy and subsistence in Gasteiz during the Middle Ages (Azkarate and Solaun 2009). The excavated contexts have been sampled for plant macroremains, faunal remains and pollen.

Here we present the results of the analyses of wood charcoal ascribed to the time from the 8th to the 12th century AD, a period for which written records for this area are particularly scarce. The aim of this work is: 1) to identify the charred wood preserved in different types of contexts, 2) to offer new information that may help us understand the past vegetal landscape around the site, 3) to know the selection and exploitation of woodland resources by the inhabitants of the village, and 4) to assess the existence of woodland management practices during this period.

Figure 1. General view of the excavated medieval contexts in the exterior of the present cathedral of Santa María (Vitoria-Gasteiz, Basque Country).

MATERIAL AND METHODS

The results presented in this paper were obtained from the analysis of materials from the excavation of the immediate area around the present Santa María Cathedral in Vitoria-Gasteiz. A systematic sampling strategy was carried out in order to study stratigraphic units with different functions: metallurgical and general ones -which we interpret as most probably domestic-. Sampling for macro-remains was carried out on-site during the excavation. The excavated sediment was processed with a Siraf-type flotation machine as described by De Moulins (1996). The floating and suspendable fractions were collected in a sieve with a mesh size of 250 µm. The sunken residue was collected in a 1 mm mesh and was also examined. The samples were sorted under a low-power, reflected-light microscope. For wood charcoal, 44 samples were analysed with an average of 40 l of sediment per sample being processed through flotation.

The total number of fragments as we show in Table 1, results from summing different samples ascribed to the same chronology on the basis of the maximum resolution possible obtained during the excavation and the post-excavation study. Five chronological groups were defined: 1) from the 8th century AD to the first half of the 10th century AD, 2) second half of the 10th century AD, 3) first half of the 11th century AD, 4) second half of the 11th century AD, and 5) 12th century AD. Grouping of samples was carried out with the following criteria: a) all the combined samples clearly originated from the same chronological group, b) samples were only retrieved from stratigraphically very reliable areas, and c) wood charcoal in these samples was scattered in the sediment, it was not concentrated charcoal or charcoal from hearths.

When possible, a minimum of 100 fragments was identified for each chronological group. However, the number of fragments analysed is higher for the earlier centuries (8th-10th) due to context availability which is smaller in later periods. For the most recent group (12th century AD) only 45 fragments were available. Notwithstanding the limitations derived from this low number, we decided to include it due to the coherence that the results showed with the rest of the sequence. Regarding context provenience, in this text we present: 1) scattered wood charcoal from general contexts, which we assume most probably derives from domestic fuel, and 2) wood charcoal from stratigraphic units where primary iron metallurgy was attested by the directors of the excavation (8th and 9th centuries AD only).

Fragments bigger than 4 mm were identified and the samples included both, the flot and the charcoal collected from the residue. Identification of wood charcoal was carried out using epi-illuminated light microscopy, with reference to Schweingruber (1978 and 1990) and to our own reference collections of modern woods from Western Europe.

RESULTS

PLANT MACROREMAINS OTHER THAN WOOD (700-1200 AD)

Carpological remains identified in these samples help us understand the characteristics of medieval agriculture in Gasteiz. The main crops were free-threshing wheats (*Triticum aestivum /T. durum*), hulled barley (*Hordeum vulgare vulgare*) and millets (*Panicum miliaceum* and particularly *Setaria italica*). Rye (*Secale cereale*) became significant only from the 12th century AD. As a general rule, naked wheat increased through time whereas the importance of barley decreased. Regarding the legumes, we retrieved some taxa that are very appreciated in human subsistence such as the lentil (*Lens culinaris*), faba bean (*Vicia faba*) and pea (*Pisum sativum*), and some others that have traditionally been used as fodder in the region although we should stress that they may also be used as human food; these are bitter vetch (*Vicia ervilia*), common vetch (*Vicia sativa*) and grass peas (*Lathyrus sativus / L. cicera*). Regarding flax (*Linum usitatissimum*), its cultivation was important in the earlier phases but the taxon disappears from the samples of the 11th and 12th centuries AD. Summarizing the results of the carpological remains from Gasteiz, we may suggest that from the 8th to the 12th centuries AD agriculture was based on the cultivation of cereals complemented with several pulses and, in the early moments, flax. The presence of fruit trees is limited or at least seeds from fruits were not preserved in these contexts.

WOOD CHARCOAL FROM GENERAL CONTEXTS (700-1200 AD)

The charcoal analysis from general medieval contexts of Santa María Catedral was carried out by identifying 1498 scattered wood fragments > 4 mm. The results are shown in Table 1 and in Figure 2.

The fragments identified at the site correspond to different taxa (Fig. 3): the conifers are represented by

	VIII -IX -X	**2nd 1/2 X**	**1st 1/2 XI**	**2nd 1/2 XI**	**XII**
Acer tp. *campestre*	2		3	2	1
Acer sp.		4	1		
Cornus sanguinea			4		
Corylus avellana	4	4	4		4
Fagus sylvatica	68	106	35	50	26
Fraxinus sp.	9	3	17		
cf. *Juglans*	1				
Pinus sp.	1				
Pomoideae	120	87	21		1
Prunus tp. *avium*			8		
Prunus sp.	94	40	2	1	2
cf. *Prunus*	1				
Quercus subg. *Quercus*	418	205	73	47	11
Rhamnus	2	1			
Rosaceae		9			
Salix sp.	1				
TOTAL	**721**	**459**	**168**	**100**	**45**
Indet.	4			1	

Table 1. Number of fragments identified in medieval contexts from Gasteiz. Contexts with metallurgical evidences are excluded (n=1498).

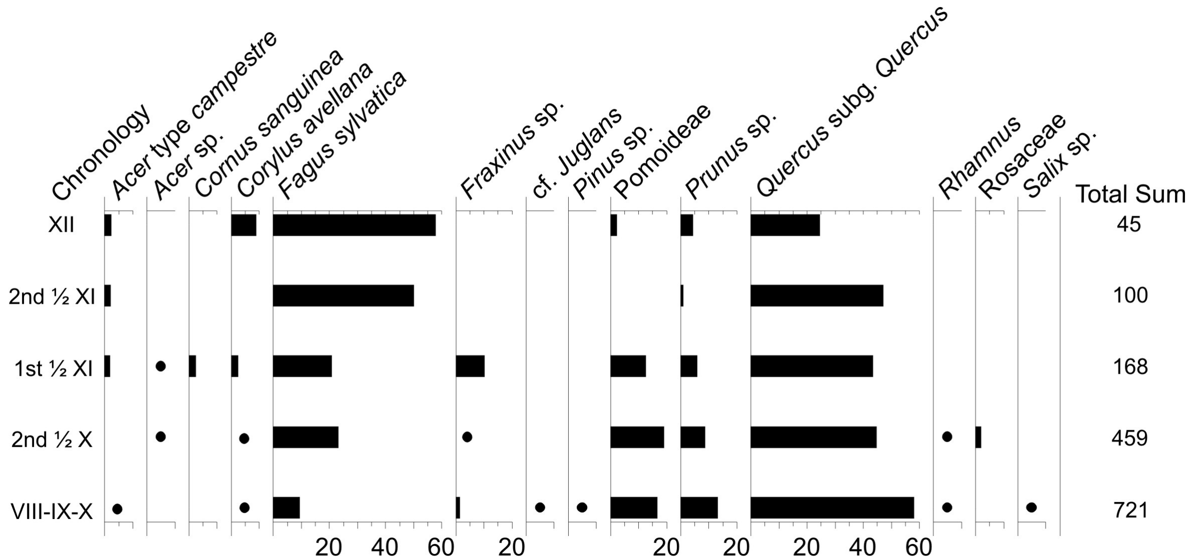

Figure 2. Wood charcoal diagram from general medieval contexts not linked to metallurgy from Gasteiz (n=1493; indet not included).

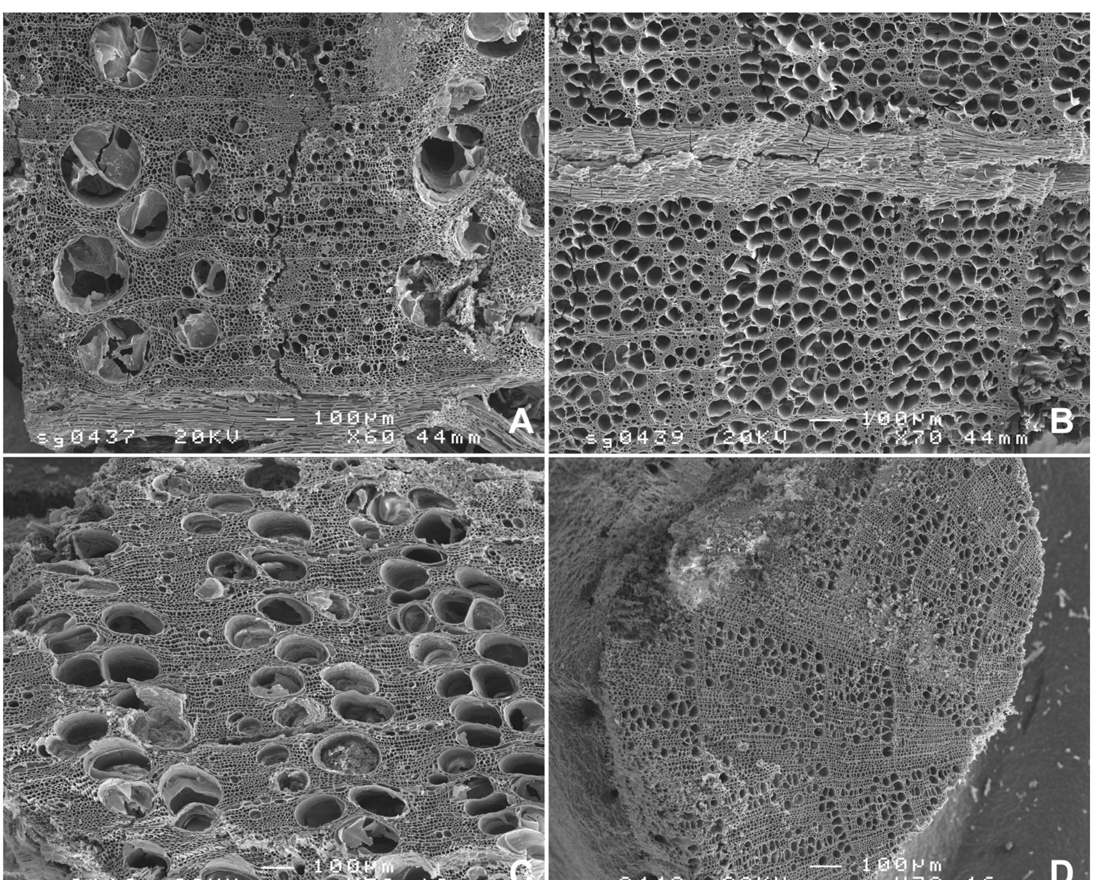

Figure 3. Some of the main taxa identified in medieval wood charcoal assemblages from Gasteiz. A: *Quercus* subgenous *Quercus* (TS); B: *Fagus sylvatica* (TS) ; C: *Fraxinus* sp. (TS); D: *Corylus avellana* (TS).

a single fragment of pine (*Pinus* sp.); the angiosperms include *Acer* and *Acer* tp. *campestre* (maple), *Cornus sanguinea* (dogwood), *Corylus avellana* (hazel), *Fagus sylvatica* (beech), *Fraxinus* (ash), cf. *Juglans* (walnut), *Quercus* subg. *Quercus* (deciduous and semideciduous oaks), *Rhamnus* (buckthorn), Rosaceae, *Salix* (willow) and *Ulmus* (elm). Five fragments (0.3%) could not be identified due to preservation problems.

As we can see in Table 1, there is a higher diversity of taxa during the 8th-10th centuries, even more so if we include the samples from metallurgical activities presented in Table 2 (*Pinus, Acer, Cornus, Corylus, Fagus, Fraxinus*, Rosacae, *Quercus* subg. *Quercus*, *Quercus ilex/Q.coccifera, Salix, Ulmus, Rhamnus* and most probably *Juglans*). However, we must also consider that more fragments were identified from these earlier centuries; therefore minor taxa were more likely to appear. According to our results, during this early period the most important fuel in the village was deciduous *Quercus* wood followed by Rosaceae (which here includes *Prunus*, Pomoideae and Rosaceae) and *Fagus sylvatica*. *Quercus* wood was particularly important in Gasteiz from the 8th to the first half of the 10th century. Leaving aside the fuel used in metallurgy, it sums up 58% of the fragments identified during this period. Beech wood increased through time and eventually became the most important fuel during the second half of the 11th century and during the 12th century (Fig. 2). Although we must bear in mind that the number of fragments analysed for these last periods is lower, the results may reflect a major trend. The rest of the fuels have a minor representation with the exception of *Fraxinus* during the first half of the 11th century and *Corylus avellana* during the 12th (both close to 10%).

Gasteiz, SMC Metallurgical contexts 8th -9th century	
Acer tp. *campestre*	7
Cornus sanguinea	5
Corylus avellana	2
Fagus sylvatica	28
Fraxinus sp.	3
Pomoideae	136
Prunus sp .	109
Quercus subg . *Quercus*	60
Quercus ilex/coccifera	3
Rosaceae	1
Salix sp .	1
Ulmus sp.	2
TOTAL	**357**
Indet .	14

Table 2. Number of fragments identified in contexts from Gasteiz where metallurgical activity was attested (8th and 9th centuries; n=357).

WOOD CHARCOAL FROM CONTEXTS LINKED WITH IRON METALLURGY (8TH AND 9TH CENTURIES AD)

Sixteen samples from five different contexts associated with the primary reduction of iron ore were detected in the earliest occupation of Gasteiz (8th and 9th centuries AD). Table 2 summarizes the results from the wood charcoal retrieved in them (371 scattered fragments > 4 mm). Rosaceae wood (*Prunus* and Pomoideae) is the most important fuel here (almost 70% of the total) followed by deciduous oaks (18%) and *Fagus sylvatica* (8%) (Fig. 4). Other woods such as *Acer*, *Cornus*, *Corylus*, *Fraxinus*, *Salix* and *Ulmus* are present in percentages lower than 2%. Some fragments could not be identified due to anatomical distortion, vitrification and preservation problems (14 fragments, 3.7%).

DISCUSSION

THE OAK – BEECH DYNAMICS IN GASTEIZ

If we exclude the samples related to metallurgical activity, we can stress the general importance of *Quercus* wood and progressively of *Fagus* which

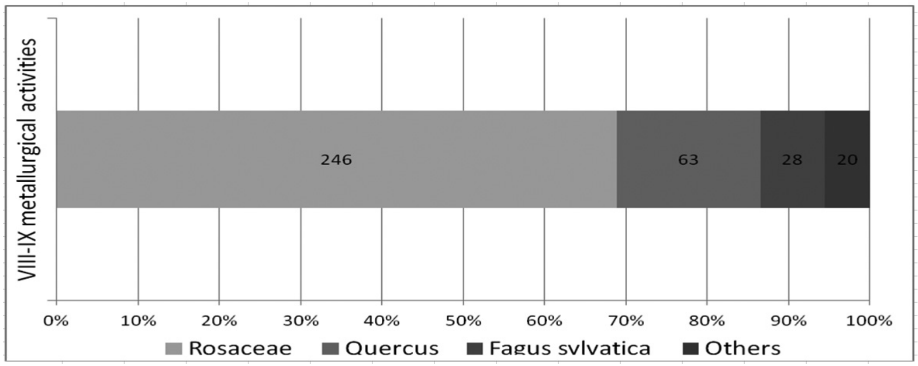

Figure 4. Summary of charcoal results from wood coming from contexts where primary reduction of iron ore has been attested (8th and 9th centuries; n=357).

eventually became the main fuel during the 11th and 12th centuries.

The importance of *Quercus* subg. *Quercus* in our samples can be understood since at present different formations of deciduous oaks are considered the potential vegetation in the vicinity of Gasteiz. The prevalence of deciduous oaks would have been possible due to soil humidity. *Quercus faginea* and *Fagus sylvatica* would not like this condition so much and that is why they would have been located by the slopes of nearby hills and mountains. However, deciduous oak formations disappeared due to human pressure for the production of charcoal and the expansion of crops in the region. The slopes close to the mountains where Gasteiz is located include *Quercus faginea* formations on marlstone and *Quercus pyrenaica* ones when the sediment is siliceous (Aseguinolaza *et al*. 1989, 1992). Besides the proximity of such formations, we should also consider that deciduous oaks offer a very much appreciated material to be used as fuel but also for other purposes such as building timber.

According to our data, the use of beech firewood increased throughout the period studied here. Beech tends to form monospecific woodlands which nowadays cover considerable extensions at medium height altitudes that cross the Basque Country E-W and also on the mountains close to Gasteiz. Beech wood is clear-coloured and hard and it is very much appreciated as raw material for fuel and charcoal making. In Gasteiz it becomes the main taxon identified from the second half of the 11th century (50% of the fragments).

Different explanations may be suggested in order to explain the progressive substitution of *Quercus* by *Fagus* as the main taxon, taking into account that *Quercus* formations would have been the potential ones in the immediate vicinity of the village (Aseginolaza *et al*. 1992): 1) growing impact in *Quercus* woodlands close to the village as a result of overexploitation, 2) extension of *Fagus* in the plateau where the site is located, 3) cultural preferences and changes in fuel and raw material use, and/or 4) changes in wood catchment areas. We think that the importance of *Quercus* wood in the oldest samples suggests the use of woodlands close to the site, whereas the systematic use of *Fagus* from the second half of the 11th century points to the exploitation of further areas on the slopes of the mountains. Beech woodlands on the mountains away from the plateau where the village is located would have been an excellent source for the supply of wood. It is very likely that this exploitation would have been the result of an organized and managed system although we do not have direct anatomical evidence for such practice. Some of these questions will be better assessed when we will be able to contrast our wood charcoal data with the pollen analyses which are in progress. Regarding the written records, the Fuero of Vitoria (1181) suggested a free supply of wood for building purposes and fuel: "*Y donde quiera que halláreis madera para hacer casas, y leña para quemar, tomadlas sin ninguna contradicción, excepto las cosas conocidas y defendidas en las cuales no está permitido su uso*".

THE IMPORTANCE OF ROSACEAE IN METALLURGY

In the samples from the first half of the 11th century and before, the percentages of Rosaceae wood are significant. Rosaceae is a big family that in our region includes at least two groups that can be distinguished by their anatomy: 1) Pomoideae or Maloideae which includes cultivated trees such as the apple tree or the pear tree and wild trees such as hawthorn, and 2) the genus *Prunus* which includes fruit trees such as the cherry tree, plum tree or peach, well documented in the Basque Country since Roman times by their fruits (Peña-Chocarro and Zapata 2005).

In general, in Gasteiz Pomoideae predominates over *Prunus*. In the samples where metallurgical activity is attested the percentages are similar (38% Pomoideae, 31% *Prunus* sp.) and all together Rosaceae sum up 69% of the samples linked with the reduction of iron ore. Therefore, it seems that there was a selection of this type of fuels for this activity. Regarding the causes for this selection, we can point out that Rosaceae are dense woods with high calorific value. It is quite common that small sized wood, like that provided by taxa included in this family, is selected for firing structures such as ovens and furnaces (for baking bread, firing pottery, etc). In Roman and Medieval furnaces, it was common to use fallen branches or pruning material from fruit trees. They were frequent in the Roman furnaces from Aloria (Euba 2005) and in the medieval pottery kiln of Antigua Audiencia (I. Euba com. pers.). In the thermal baths of El Moro olive wood was selected as fuel and the authors suggest that the material burnt there was the sub-product of the pruning of the trees (Euba and Allué 2003: 102). In the Moroccan Rif we also documented the use of pruned fig tree wood for the firing of pottery in open bonfires (Zapata *et al*. 2003). Small branches obtained from pruning and shrubby material would have been used in order to obtain higher temperatures quickly since the size of the material, along with its humidity, is a key factor that conditions the properties of the fuel (Chabal 1997). Unfortunately, because of the poor anatomical definition of these taxa, we cannot shed much light on the origin of these fuels. They could have been the subproduct of the cultivation of fruit trees or they could have resulted from the exploitation of wild/semi-wild communities of thorny species (forest-edge plants of the Prunetalia order) around the village, maybe encouraged by humans by clearing openings in deciduous forests or by the creation of hedges.

In the Basque Country bloomeries, furnaces for smelting iron from its oxides were very abundant in medieval times. They demanded large amounts of fuel, usually wood charcoal. According to estimates suggested by different researchers, 20 tons of wood would have been needed to obtain 1 ton of iron (ratio mineral:wood charcoal, 1:3; ratio wood:charcoal, 5-7:1) (Crew 1990; Mighall and Chambers 1993; López-Quintana 1994). Therefore, the amount of wood needed for this activity is usually very big. We may assume that the impact of such activities on woodlands would have also been important. In fact, local laws from the Basque Provinces included extensive regulations on the exploitation of forests (by pruning, coppicing, establishing tree nurseries for reforestation) at least from the 14th century (Gogeascoechea 1996). These methods were most probably in practice from before and allowed the continuous supply of fuel for the iron industry in a sustainable way (Zapata and Peña-Chocarro 2003; Loidi 2005, 2007).

Wood charcoal found in bloomeries from other European regions shows that various taxa were used for fuel (Mighal and Chambers 1993; Mighal 1997). In the Basque Country, in spite of the importance that iron production has had during history, the studies related to pre-hydraulic methods are very few and the information related to fuels is also scarce. In Biscay we studied two metallurgical sites: Oiola IV (Pereda 1992/93; Zapata 1997) and Ilso Betaio (Zapata 1993) with different results. In Oiola IV during the 10th-13th centuries AD the most common taxa were beech, deciduous oak, alder and hazel. The different contexts analysed (roasting and reduction furnaces, forge structures, wood charcoal deposits) showed high diversity and no specific wood was linked to any activity although deciduous *Quercus* was the only taxon present in all of them. Rosaceae wood was present but only as 3.4% of the total. On the other hand the bloomery of Ilso Betaio dated in the 12th century (Gorrochategui *et al*. 1995) shows the almost exclusive use of *Fagus* wood, with the occasional presence of deciduous *Quercus* and *Ilex aquifolium*. No Rosaceae wood was identified. In this case the use of some fuels was clearly determined by availability since the site was located next to a beech forest which tends to have little arboreal diversity.

In sum, the selection of Rosaceae in the medieval contexts from Vitoria linked to metallurgical activity must be the result of the good properties of these woods (size, burning properties) for furnaces but also of the availability of this type of material from pruning or from the existence of Prunetalia communities in the vicinity.

CONCLUSIONS

Wood charcoal retrieved from early medieval contexts in Gasteiz strongly suggests that the main fuels used in the settlement during the period 700-1200 AD were deciduous oak (*Quercus* subg. *Quercus*), beech (*Fagus sylvatica)* and Rosaceae, a family that, among others, includes important fruit trees. More taxa were identified during the earliest medieval centuries although as cautionary note we stress that the number of fragments and samples analysed was higher for the older periods.

Until the second half of the 11th century a diversified, maybe opportunistic exploitation of woodlands next to the site may be suggested. From that moment, the importance of *Fagus sylvatica* increased significantly. This may reflect a change in the main wood catchment areas of the site, maybe related to an organized and managed exploitation of the beech woodlands located in the mountains away from the plateau where the village is situated. The dynamics of the oak/beech forests and their exploitation by humans will be better assessed in the future through comparison of our results with pollen data.

Prunus and Pomoideae are particularly important in the contexts related to the smelting of iron ore. This might be explained by the properties of these fuels and by their availability from pruning or from the development of shrubby communities around the site.

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CARME CUBERO I CORPAS

SHRUBS AND TREES FROM MEDIEVAL L'ESQUERDA (7TH-13TH CENTURIES AD)

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***Summary**: This paper presents new anthracological results from l'Esquerda (Masies de Roda, Barcelona, Spain). We provide here results of the Early Middle Age and principally the Late Middle Age settlement. In both periods the catchment area of forest resources was reduced to the vicinity of the site, without outside contributions. In domestic contexts the relationship between* Buxus sempervirens *and* Quercus *type deciduous is important. Riparian forest is also represented in the anthracological record. The origin of the deposits discharged into pits, wood selection and the rest of economic activities in relation to forest exploitation are discussed.*

***Key words**: Anthracology, wood selection, vegetal cover, Middle Age, L'Esquerda.*

INTRODUCTION

The medieval village of L'Esquerda is located in the NE of the Iberian Peninsula. The town sits where a wedge of river Ter forms a peninsula facing south. The village is defended by the river, by the surrounding cliffs and on the northern side by the walls (Fig. 1).

The site has provided charcoal samples from the Iberian period (Cubero 1999) to the Middle Age (Bertran, unpublished; Cubero and Ollich 2008; Cubero 2012).

CLIMATE AND VEGETATION

Nowadays, l'Esquerda enjoys a sub-Mediterranean climate with continental trends, without a drought period in the summer and with large amplitude of temperature variation between maximum and minimum throughout the year and day. Low temperatures are due to mountains - Montseny and Guilleries that block the smoothing effect of the sea. In addition, temperature inversion favors the concentration of cold air in lowlands. Dews and mists provide much humidity. All of these factors allow vegetation and crops typical of mountainous areas to grow even at elevations of 400-

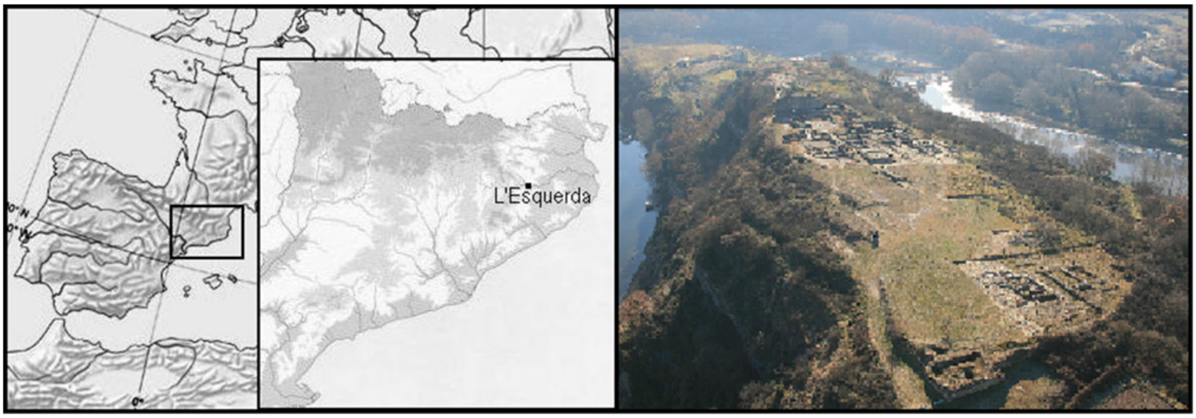

Figure 1. Situation and aerial view of l'Esquerda (Masies de Roda).

500 meters above sea level.

The potential vegetation of l'Esquerda is oak forest and riparian forest. This is the domain of deciduous oak (*Quercus pubescens*) with a poor sub-association of box (*Buxo Quercetum pubescentis*) on marly soils (Folch 1986). On degraded areas oak was replaced by *Plantagini-Aphyllantherum* association. In marly gullies very sparse lavender scrub can be found (*Thymo-Globularietum cordifoliae*). On sunny areas we observe bushes and shrubs of dry environments such as gorse (*Genista scorpius*) and thyme (*Thymus vulgaris*) and *Stipa pennata* as a relic. There are meadows with grass and patches of green oak only on shady areas.

Weed vegetation is common due to large agricultural land use. Side fields and roads are populated by *Hordeions leporini* association, with *Chenopodion muralis*. There are also communities of *Diplotaxietum erucoidis* on dry areas and *Echinochloa* (*Euphorbio-Digitarietum sanguinalis*) on humid ones.

At present, native vegetation has virtually disappeared (Fig. 2). Agricultural, industrial and urban works have deforested much of the territory and there are only a few residual forests, replaced by rainfed crops like cereals, potatoes as well as fodder (Ollich *et al*. 1995).

The riparian forest grows on river banks or near floodplains (Fig. 3). Willows (*Salix aleagnos*, *Salix purpurea)* and ash (*Fraxinus angustifolia*) are common.

Figure 2. View of Salou forest with *Quercus pubescens* to the west of l'Esquerda.

Figure 3. Riparian forest on the Ter bank river. Plantations of poplars (*Populus nigra*).

In Guilleries and Montseny there are few isolated remains of beech forest. Beech forest with box and with almost no species from the Middle European forests may be found in places as Collsacabra. In extreme cases we may speak of oak grove with beech (*Buxus Quercetum pubescentis fagetosum*) (Folch 1986: 328).

DATA AND RESULTS

Charcoal analysis at l'Esquerda is based on the study of material from several samples that were collected during excavation. The collection of samples was grouped and punctual. In the first case, the fragments were collected from the sediment and the material was water sieved or water floated in the laboratory. In the second case, the fragments were picked individually. Punctual collection was related to possible objects or structures clearly visible in the sediment.

We differentiated between samples, a priori, general and monospecific. The first ones were collected from the sediment of rooms or from general habitation levels. In general, these samples come from domestic contexts (fire, rooms, levels of demolition, levels of ash, burning structures, etc.) and the content of pits. The second group of samples were presented as a unit (a beam, wood around the lock of a chest, an item, etc.).

In order to do the wood determination, we selected fragments larger than 3 mm. Each piece of charred wood was broken by hand to observe the three anatomical sections of wood (transverse, tangential and radial). Observation was carried out with the aid of reflected light microscopy with bright field – dark field and x50, x100, x200 and x500 magnification lenses and with the help of atlas of wood anatomy (Schweingruber 1990). The analysis allowed identifying family, type and sometimes species. The degree of precision depended on taxonomic variability, charcoal size and changes affecting the wood.

For the interpretation of the results, we considered the percentage of each taxon in each stratigraphic unit as well as the presence or absence of taxa in one or another unit.

Regarding the Early Middle Age, 9 samples were analysed. In these, 100 fragments belonging to 10 taxa were identified. For the Late Middle Age 22 samples were analyzed, in total 622 fragments corresponding to 15 different taxa.

EARLY MIDDLE AGE

Filling up of the pits was radiocarbon dated to the mid 7th century AD thus documenting medieval occupation at l'Esquerda before the Carolingian fortification. In general, these pits were simple or sometimes double holes where residues were dumped to fill their interior. We present the results of six Early Middle Age samples from pits (Table 1) and the frequency of each taxon (Table 2). The variety of taxa during the Early Medieval period is bigger than in the Iberian period (Cubero 1999). In the Early Middle Age the presence of *Fagus sylvatica*, *Populus* sp., *Alnus* sp., *Prunus avium / cerasus* and *Prunus* cf. *spinosa* is documented for the first time.

In the Early Middle Age *Quercus* type deciduous is the most abundant taxon in number of remains and the most common. Riparian forests are represented by alder, poplar and elm. These taxa together with beech indicate a high degree of humidity. There are a few Rosaceae like Pomoideae (*Sorbus*), *Prunus* sp., *Prunus avium / cerasus*, *Prunus* cf. *spinosa*. As a novelty, box seems to lose some of its prominent role. Box is not quantitatively as numerous as in the Iberian period and its presence is not as widespread as before.

LATE MIDDLE AGE

Most of the samples come from stratigraphic units (hereafter SU) of soils/habitat as room 8, SU 32058, squares MNO/11-12, SU 32459 room 47, SU 32606 room 50 square 0 15, SU 32711, SU 32717 room 52, or SU 31719. However, SU 31061, SU 32020 tile and 32045 originate from monospecific/object samples. We analyzed a total of 22 samples, but to make the

L'Esquerda Early Middle Age (7th century AD)

Sample	SU 05079	SU 05134	SU 05140	SU 09030	SU 09050	SU 09058	SU 09061	SU 09062	SU 09069	
Taxa	pit 23	pit 24	pit 25	pit 11	pit 16	pit 16	pit 11	pit 16	pit 15	Total
Alnus sp.				1		1				2
Buxus sempervirens	1	2	1		2					6
Fagus sylvatica				1				2		3
Pomoideae (Sorbus)		2				1		3		6
Populus sp.						1	1	4		6
Prunus sp.	4			1		1				6
Prunus avium / cerasus								4		4
Prunus cf. *spinosa*	2							1	2	5
Quercus sp.	1	3	1	2		2				9
Quercus type deciduous	1	13	17	4		10	2	3		50
Ulmus sp.			1			2				3
bark						1		3		4
undetermined	1					1			8	10
Total	10	20	20	9	2	20	3	20	10	114

Table 1. Taxa, samples and number of remains from Early Middle Age L'Esquerda (7th century AD).

L'Esquerda Early Middle Age

Taxa	percentage	frequency
Quercus type deciduous	50	7
Quercus sp.	9	5
Buxus sempervirens	6	4
Pomoideae (*Sorbus*)	6	3
Populus sp.	6	3
Prunus sp.	6	3
Prunus cf. *spinosa*	5	3
Prunus avium /cerasus	4	1
Fagus sylvatica	3	2
Ulmus sp.	3	2
Alnus sp.	2	2
Total	100	Samples: 9

Table 2. Taxa, percentage and frequency of remains from Early Middle Age L'Esquerda (7th century AD).

presentation clearer, in Table 3 we have grouped them by stratigraphic units.

In the Late Middle Age at l'Esquerda we note a higher variety of taxa than in previous levels. As in the protohistoric levels, oak, box and elm are still common but fir has disappeared and box seems to lose importance. Walnut, willow, laurustinus, hazel and chestnut tree are the new taxa documented during this period. The most abundant trees are oak, elm, beech, walnut, willow and alder. Others, except box, are not represented by more than five fragments (Table 4).

Walnut, hazelnut and chestnut trees may be exploited for timber but they can also be grown for their nuts. The walnut tree is cultivated and sometimes naturalized in the Mediterranean lands and mountain zone. Hazel grows naturally in deciduous forests of the mountain zone and wet Mediterranean lands (oak and alder forests, alder) and can also be cultivated. Other cultivated species to be considered during this period are the cherry or Pomoideae.

DISCUSSION

In Figure 4 we present a hypothetical distribution of trees during the Late Middle Age period in the surroundings of the Esquerda peninsula. Oak forest could have been located on the Salou slope, riparian or gallery forest -with ash, willow, alder and poplar-, on the banks of river Ter, elm at some distance from the river and agricultural fields and orchards on the plain per-

L'Esquerda Late Middle Age (12-13th centuries AD)

Sample Taxa	SU 31061	SU 32020	SU 32045 tile	SU 32058 MNO/11 12	SU 32450 H-47	SU 32606 H 50, O 15	SU32711	SU 32717 H 52	SU32719	H-6	Total
Alnus sp.							5	1		1	7
Buxus sempervirens	22				4		5	24	57	44	156
Corylus avellana					2						2
Fagus sylvatica		15							2	1	18
Fagaceae						1					1
Juglans regia	1			13						2	16
Populus sp /*Alnus* sp.				1							1
Populus sp.				5							5
Pomoideae (*Sorbus*)					1						1
Prunus avium / cerasus				1							1
Prunus avium				1							1
Prunus sp.	4									1	5
Quercus cf. evergreen							1				1
Quercus type deciduous	3			8	295		18	5		3	332
Quercus sp.				1							1
Salix sp.			10		3						13
Ulmus sp.					53						53
cf. *Viburnum tinus*										8	8
undetermined					2				1		3
Total	30	15	10	30	360	1	29	30	60	60	625

Table 3. Taxa, samples and number of remains from Late Middle Age L'Esquerda (12th – 13th centuries AD).

L'Esquerda Late Middle Age

Taxa	remains	percentage	frequency
Quercus type deciduous	322	53,3	15
Buxus sempervirens	156	25	9
Ulmus sp.	53	8,5	5
Fagus sylvatica	18	2,9	4
Juglans regia	16	2,6	4
Salix sp.	14	2,2	2
cf. *Viburnum tinus*	8	1,3	2
Alnus sp.	7	1,1	3
Populus sp.	5	0,8	2
Prunus sp.	5	0,8	2
Corylus avellana	2	0,3	1
Prunus avium / cerasus	2	0,3	1
Castanea sativa	1	0,2	1
Populus sp. / *Alnus* sp.	1	0,2	1
Pomoideae (Sorbus)	1	0,2	1
Quercus type evergreen	1	0,2	1
Quercus sp.	1	0,2	1
Total	NR: 623	100	Samples:22

Table 4. Taxa, percentage and frequency of remains from Late Middle Age L'Esquerda (12th-13th centuries AD).

haps with traces of oak.

We did not observe any entire object or signs of craftsmanship or wood processing. This may be the result of the size of the fragments, which measured from 3 mm to 5 cm. The biggest fragments probably were part of medium or large-sized logs.

We have observed irregular fragments and twigs, few of them with traces of bark. The larger fragments had no sign of the bark. In some branches it was possible to observe the entire perimeter edge and retain the evidence of bark.

The proportion of fragments with signs of xylophagous insects' attack was low; indeed, in very few cases, holes, channels or concavities were documented.

We have also observed traces of fungal filaments on some fragments. This effect can be post-depositional or contemporary to the period of wood use. It does not seem that dead wood was systematically used at the site.

The Early Middle Age is represented by only one

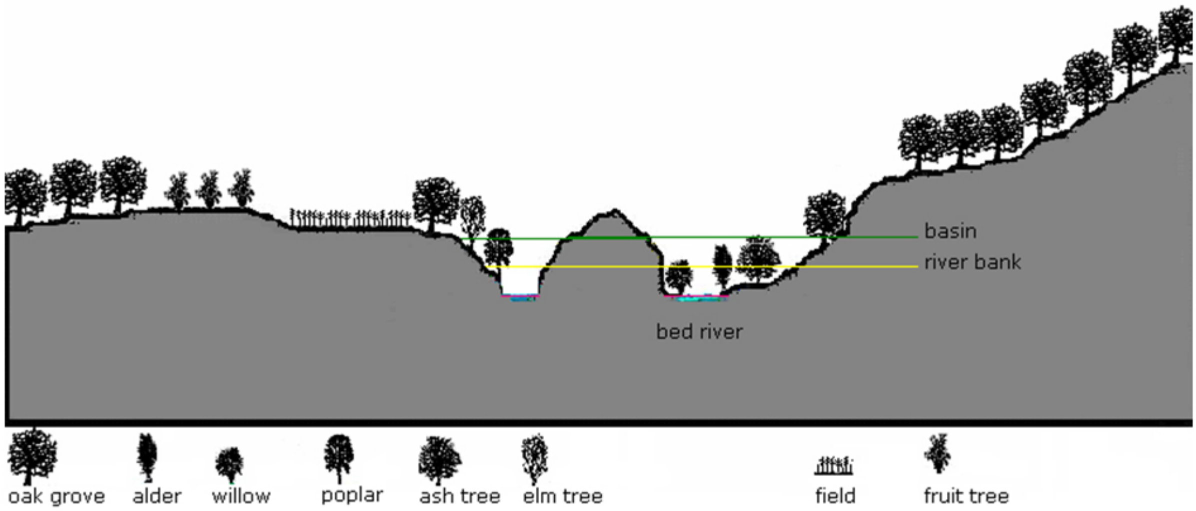

Figure 4. Altitudinal section showing the distribution of the major taxa documented in the Late Middle Age.

type of context: the pits. The wood analyzed may correspond to material from the cleaning of hearths or sediment of the floor to fill up the pits.

In this cultural period oak was the most abundant taxon, box tree was also important while *Populus*, *Ulmu*s, *Alnus*, Pomoideae and *Prunus* were minority. The catchment areas of raw material would have been variable, among oak forest with boxwood, riparian woodland and hedges. Thus, during the Early Middle Age the catchment area was reduced to middle-distances. By contrast, activity in the nearest area intensified and extended according to the evidence provided by the riparian forest trees. Beech continued as minority tree in this period.

During the Late Middle Age, according to the determinations carried out, the situation was very similar to the Early Middle Age. The wood analyzed corresponds to supporting structures or lumber (beams), and possibly furniture (tables, utensils and handles of tools, and household tools such as bowls or spoons) or domestic fires.

Different types of vegetation are represented at the site. The main forest was deciduous oak woodland with box tree, present in all phases of the site. Oak deforestation favoured the expansion of box, which colonized new areas. Nearby formations were riparian woodland, with poplars, willows and alder, and elm. These formations are present in small proportion. This may indicate a limited use of these woods rather than a real lack of riparian woodland. Elm is the most common. Beech is recurrent too. The value of evergreen oak -Mediterranean influence- is imperceptible. Walnut, hazelnut and some *Prunus* were cultivated for their fruit and exploited for timber.

The kinds of wood used by the community of l'Esquerda appear to be enriched over time, but the transfer pattern is not substantial (Fig. 5). It changes the contributions of foreign timber as could be fir and beech. Beech could have come from a place not far away from the site. There would be manufacturing trade in the middle distance or wood would be transported to the village as raw material to be worked there. In recent samples we do not see exploitation of exotic forest resources.

Considering the characteristics and qualities of different woods we suggest that for construction purposes beams of oak and fir could have been used while box tree branches could have covered the structures (Table 5). The flexible twigs of willow and hazel are suitable for baskets. Boxwood, walnut, beech and Pomoideae wood is the adequate raw material for small tools and handles, bowls and spoons For carts and

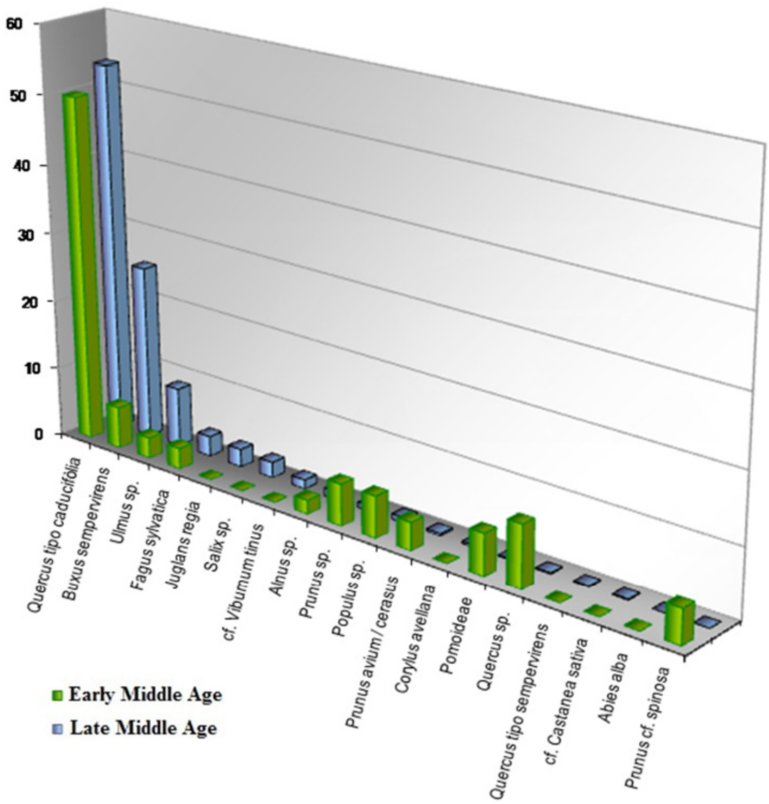

Figure 5. Early Middle Age taxa versus Late Middle Age taxa.

Taxa	Hardness	Density	Quality	Use (Bergos 1951; Sánchez 1984)
Alnus	soft	very low	fuel for bread and glass oven	frames, cabinetmaking, sculpture, craft
Corylus	moderate	moderate	elastic	cooperage, baskets
Buxus	very hard	very dense	heavy	turnery, sculpture, kitchen tools
Prunus	very hard	high	furniture of quality	cabinetmaking, carpentry, shipyards, turnery
Fagus	moderate	moderate	easy to work	carpentry, turnery, charcoal
Juglans	hard	moderate	tolerate immersion water	turnery, craft, furniture
Ulmus	hard	moderate / low	tolerate friction and hits	cart, plough, pillar submergible, shipyard
Populus	very soft	very low	bad quality	toys, clogs
Quercus	very hard	very dense	resist humidity changes	beam, boat, carpentry, cooperage, charcoal
Salix	moderate	very low	elastic	panel, clogs, baskets, ropes

Table 5. Some wood attributes.

furniture walnut, beech and Pomoideae are suitable. Beech and oak charcoal is recognized as good quality fuel. Woods suitable for boats are the walnut and fir for they resist well humidity and immersion (Bergós 1951; Sánchez 1984; Johnston 1991).

CONCLUSION

It is not clear whether each pit from the Early Middle Age was filled with a different type of material. Oak was documented in all the pits; it would have been the dominant tree of the forest formation and also the most used. *Quercus type* deciduous is followed by box tree, Pomoideae, poplar, *Prunus* sp., *Prunus* cf. *spinosa*, *Prunus avium* / *cerasus*, beech, elm and alder. The shrubs could form the underbrush and hedges near the oak grove.

It is difficult to know from the size of the charcoal fragments whether whole wooden objects were thrown in the pits, or rather the remains of the cleaning of hearths or surrounding areas. The distribution of charcoal fragments does not indicate that it is the result of torches used to clean inside the pits, once emptied in order to prepare them for subsequent refill. The charcoal remains could be the result of deliberate and indiscriminate dumping of rubbish and debris from various contexts, but not of a specific material. The variety of species represented supports this suggestion.

Samples of floor sediment should be analyzed in order to compare the results with the materials inside the pits. Unfortunately, there are no houses excavated from that period.

In the Early and Late Middle Age, although oak is still very important in amount and number of samples, there is a higher incidence of riparian forest elements. Elm is attested in medieval levels with higher percentage than in Iberian ones. Walnut and hazelnut trees and some Pomoideae were grown to provide fruit and precious woods.

Worth-mentioning is the coexistence of *Quercus* type deciduous and *Buxus sempervirens*, which was slightly modified during the medieval period. There is not a diverse representation of shrubs and the riparian forest seems little explored.

We considered the qualities (hardness, density, flexibility, etc) of different woods aiming to evaluating possible uses of the resources. In some cases we have assigned a kind of wood to a function, in others only a predisposition.

Few forestry studies based on wood charcoal data from the medieval period exist. There is none in the Osona area. In Catalonia, Olerdola (Buxó *et al*. 2011) and Tarragona (Allué 2003; Allué unpublished; Allué and Euba unpublished) should be mentioned. Although we are still far from providing a synthesis, local or regional studies constitute the first steps towards a better knowledge of the forest and its uses in medieval times.

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THOMAS LUDEMANN

Airborne laser scanning of historical wood charcoal production sites – a new tool of kiln site anthracology at the landscape level

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***Summary**: We have tested if airborne laser scanning data are useful to find historical wood charcoal production sites in the field, especially in forested areas with a dense tree canopy. Therefore we have evaluated digital elevation models (hillshades) based on these data, (1) considering potential kiln site structures at an 1-km^2-testplot and verifying them in the field, (2) testing the visibility of a large number of kiln sites already localized and (3) systematically recording potential kiln site structures at the hillshade images for a large pilot area. Thousands of such sites are recognizable by airborne laser scanning and very high kiln site densities could be established. Exact information could be provided on their geographical positions and distribution patterns. Airborne laser scanning is a valuable tool for kiln site anthracology, facilitating the field work considerably, increasing the efficiency and precision of the site records and highlighting the high historical significance of wood charcoal production. Moreover, it underlines the outstanding scientific potential of anthracological kiln site studies. The large number of analysable sites provides a unique chance to obtain new information on the historical forests and the human impact therein with fine spatial resolution at the landscape level.*

***Key words**: Black Forest, charcoal burning, forest history, kiln site, LiDAR.*

INTRODUCTION

Past fuel supply was heavily dependent on wood charcoal production. Historical sites of charcoal burning (wood charcoal kiln sites) with their distinct anthropogenic ground surface structures and their charcoal layers are widespread in the landscapes, especially in mountainous forest regions. In many areas of western Central Europe they are the most frequent and most important remnants of past wood use and forest exploitation. The wood charcoal macroremains contain comprehensive dendrological and dendroecological information. Therefore anthracological studies of historical charcoal kiln sites are a main key to local forest and land use history, providing results on past fuel wood use and past human impact with fine spatial resolution at the landscape level (Ludemann 2002, 2003, 2011).

However, to establish such studies and results the knowledge of the exact geographical position of a large number of historical wood charcoal production sites is required. Unfortunately these sites generally are not recorded in written sources or in historical maps and they are not visible in the usual aerial photographs and by traditional methods of remote sensing. Up to now time-consuming field surveys had to be undertaken to localize them in the landscape. Indeed, some years ago a new tool has become available for our investigations, airborne laser scanning (ALS, airborne LiDAR), offering completely new and innovative options which we have begun to verify systematically for a large pilot area. We want to know in which cases and to what extent the historical wood charcoal production sites are recognizable by laser scan techniques.

STUDY AREA AND METHOD

Hillshade images with maximum resolution (1 m-grid; vertical resolution < 0.15 m) calculated from the LiDAR data (digital elevation model, DGM1m; FVA/LGL 2011) were evaluated systematically, focusing on the visibility of historical wood charcoal kiln sites. The visual interpretation of the high-resolution digital elevation model from the point of view of kiln site anthracology follows a hierarchical three-step approach:

(1) Verification of a km^2-testplot: A forested landscape section of one km^2 was selected of an area of which a high density of potential kiln site structures was visible. The potential kiln site structures were identified and mapped at the corresponding hillshade image. Then the identified structures were verified by field surveys.

(2) Verification of known kiln sites: A large number of historical wood charcoal kiln sites had already been detected and recorded in the course of many years of previous kiln site anthracological field work. Their

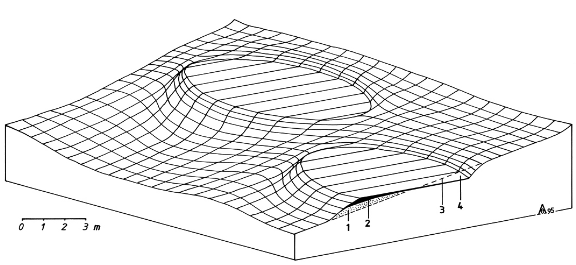

Figure 1. Anthropogenic relief features of two historical wood charcoal kiln sites, schematically. Characteristic field surface structures at a slope. Kiln sites type A: circular terraces with a diameter of 8 to 12 m, soil accumulation downhill (1), charcoal layer (2), original ground level (3) and soil removal uphill (4).

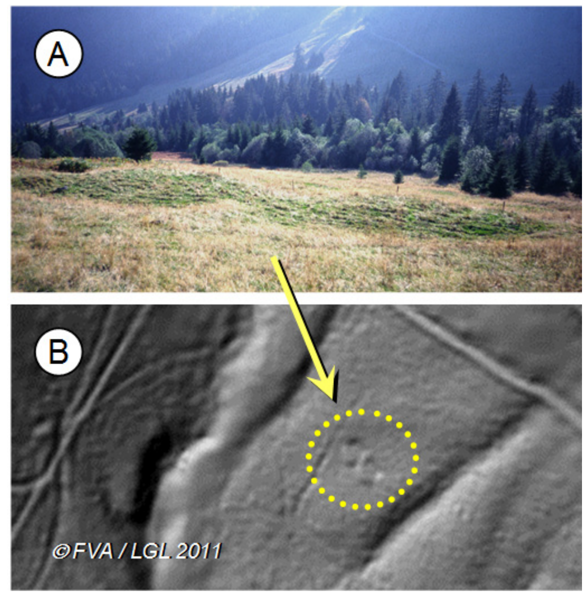

Figure 2. Anthropogenic structure of two historical wood charcoal kiln sites at a slope (Type A, cf. Fig. 1). A: Sites K 590 and K 591 in the field. B: The same kiln sites at the LiDAR-based hillshade image.

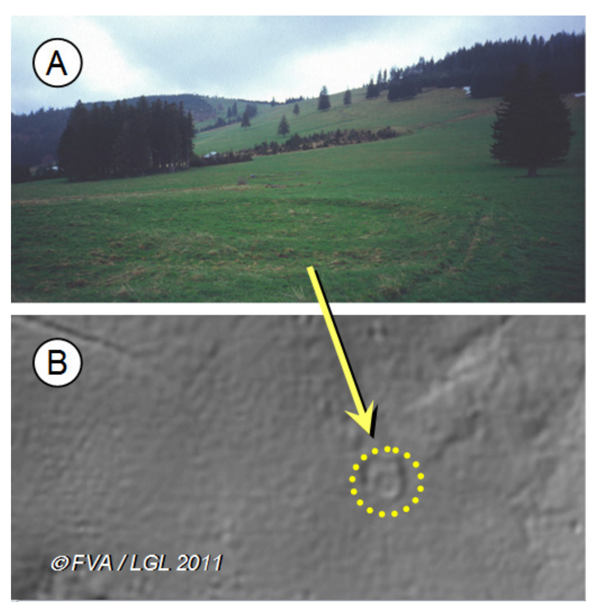

Figure 3. Relief features of historical wood charcoal kiln sites in flat landscapes. Type B with a circular embankment or crater-shaped structure. A: Site K 538 in the field. B: The same kiln site at the hillshade.

visibility at airborne LiDAR-based hillshade images was verified for our main study area (Southern Black Forest) and neighbouring regions in Southwest Germany.

(3) Record of potential kiln site structures: In our main investigation area, we are systematically recording potential kiln site structures at the LiDAR-based hillshade images. In this area a maximum number of historical charcoal kiln sites was already known and an even larger number of still unknown was expected. This successful but also time-consuming work is still in progress.

RESULT AND DISCUSSION

(1) Testplot: Looking for historical wood charcoal kiln sites within the one km^2-test area, we had identified 124 very well visible structures (potential kiln sites) by our first visual interpretation of the corresponding hillshade image. Verified by field surveys, 104 of them are really historical charcoal kiln sites, 20 are other similar anthropogenic or natural relief features, originating from forest management activities, natural erosion processes, windfall, etc. (Fig. 4). Moreover, it has to be highlighted that in the course of the field verification 49 further kiln sites could be detected in this area. Looking at the hillshade image again afterwards, we found out that many of these additional kiln sites are also visible – more or less clearly – at the hillshade. Consequently our first identification of potential kiln site structures at the hillshade was too cautious. Moreover, the visual interpretation needs some experience. On the other hand we found sites in the field, which indeed are not visible at the hillshade

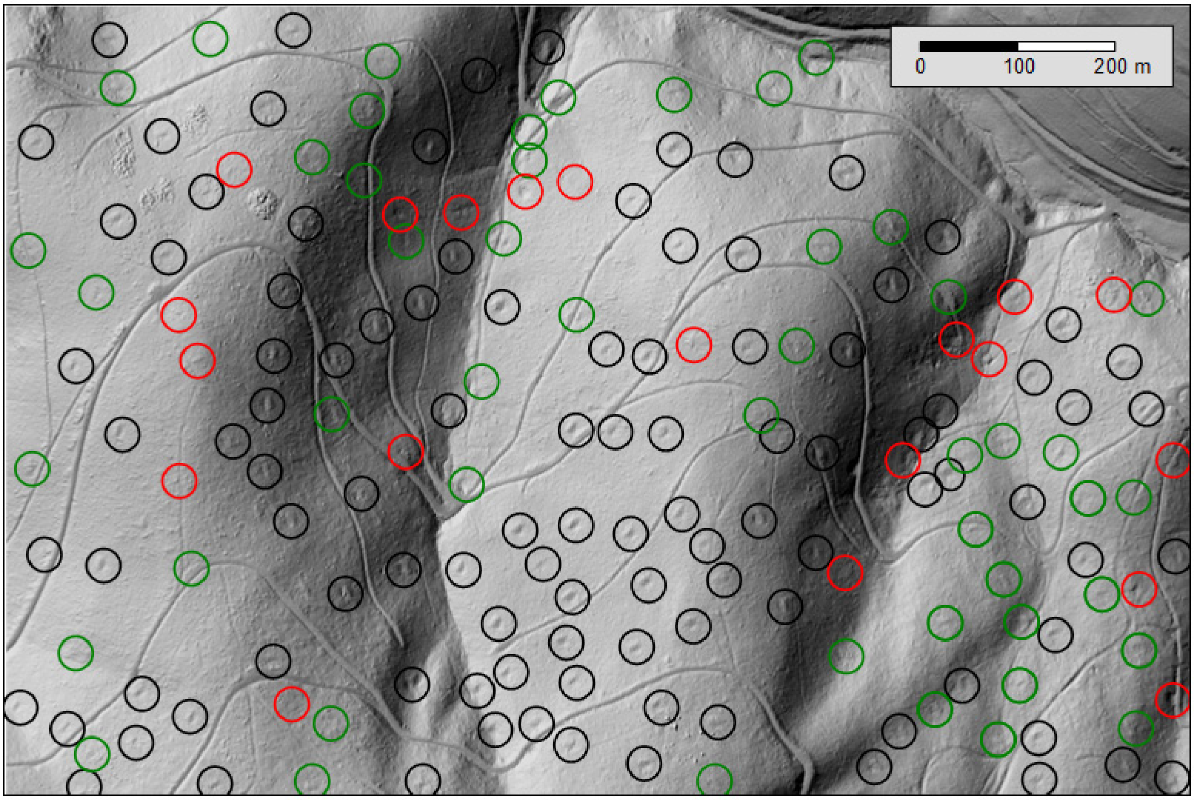

Figure 4. Testplot of a landscape section of one km^2 in the southwestern part of the Black Forest. Total number of kiln sites verified in the field n=153. Black: Potential hillshade structures verified (104). Red: Potential structures not verified = no kiln sites (20). Green: Kiln sites recorded additionally in the field (49); many of them are also visible at the plot and have been overlooked by the first interpretation (hillshade © FVA/LGL).

image and cannot even be visualized by airborn laser scanning. This is particularly the case when the characteristic kiln site structure was heavily modified or even destroyed, e.g. by forest road construction or natural erosion processes by water or rockfall. All in all 153 kiln sites could be verified within the square kilometer of the test area. 146 of them are visible at the hillshade, 125 (82%) very well, 21 (14%) less distinctly, while only 7 kiln sites (5%) are not visible.

(2) Verification of known kiln sites: 2448 historical wood charcoal kiln sites had already been detected and recorded in the course of previous field work in Southwest Germany. Testing their visibility at hillshade images, we found that the large majority of them, nearly 2000 sites (81%), indeed is visible, even in forested areas. 1326 (54%) are visible very well, 668 (27%) less easily. 19% (454 sites) are not visible. However, using a LiDAR-based site prospection, only very well visible sites are useful to find unknown sites, for those kiln sites, which have been visible less distinctly, could only be identified unequivocally at the hillshades after their detection in the field. It should be verified if even better results could be provided by using more specialized methods of data processing (e.g. Hesse 2010).

Two characteristic types of kiln site structures could be distinguished (Kiln site type A and B, cf. Figs. 1–3). Type A is the most common one, predominant in the western parts of the Black Forest where steep slopes dominate the landscape. Kiln site type B as well as sites with intermediate structures can be found especially in the eastern parts of the Black Forest and in other areas with smooth relief features and plain ground surface.

Despite the large number of already known sites, we were sure that they are only the smaller part of the historical charcoal kiln sites really preserved within the study area. This expectation is highlighted and even exceeded by step 3 of our LiDAR verification.

(3) Record of additional kiln sites: The systematic evaluation of the LiDAR data provides a very large number of (potential) kiln site structures additionally. Considering the exemplary field verifications (cf., steps 1+2, testplot and known sites), we are sure that most of them really are historical wood charcoal kiln sites. Exact information on the geographical position could be provided for all of them. Maximum kiln site densities of more than 150 sites per km^2 could be established, so that the average distance from site to site in such areas comes to less than 100 m (cf. Figs. 5 and 6).

Figures 5 and 6 give the preliminary result of the ongoing evaluation of the LiDAR data set. In the area considered, large parts of the Southern Black Forest, 2024 kiln sites at a total number of 360 km^2 had been detected without using LiDAR and recorded within about 20 years of kiln site anthracological studies. By using airborne LiDAR this even large number could be quadrupled within a short time (9115 sites at 679 km^2) and we are far from finishing the LiDAR-based kiln site prospection and verification in this area. Cautiously estimated and taking into account the results of the field studies, we are sure, that at least 10,000 historical kiln sites are well preserved within the Southern Black Forest.

Moreover, considering the exemplary field surveys and previous field work, we expect that there is a remarkable number of kiln sites which could not be detected at the hillshades. This could be due to (1) bad

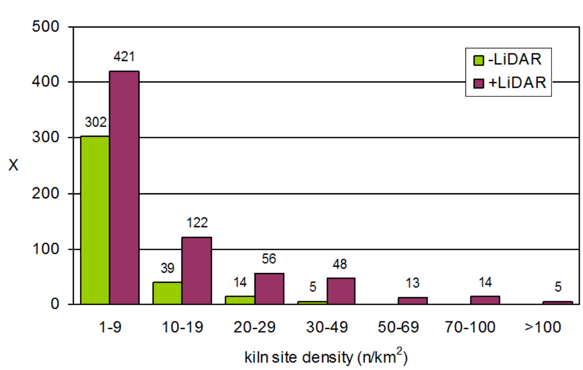

Figure 5. Number (X) of km^2 with a distinct kiln site density (kiln sites n/km^2) in the Southern Black Forest recorded by previous field studies (green) and including potential LiDAR structures (red) (preliminary result, record in progress). Total km^2 with kiln sites: 360 (green), 679 (red).

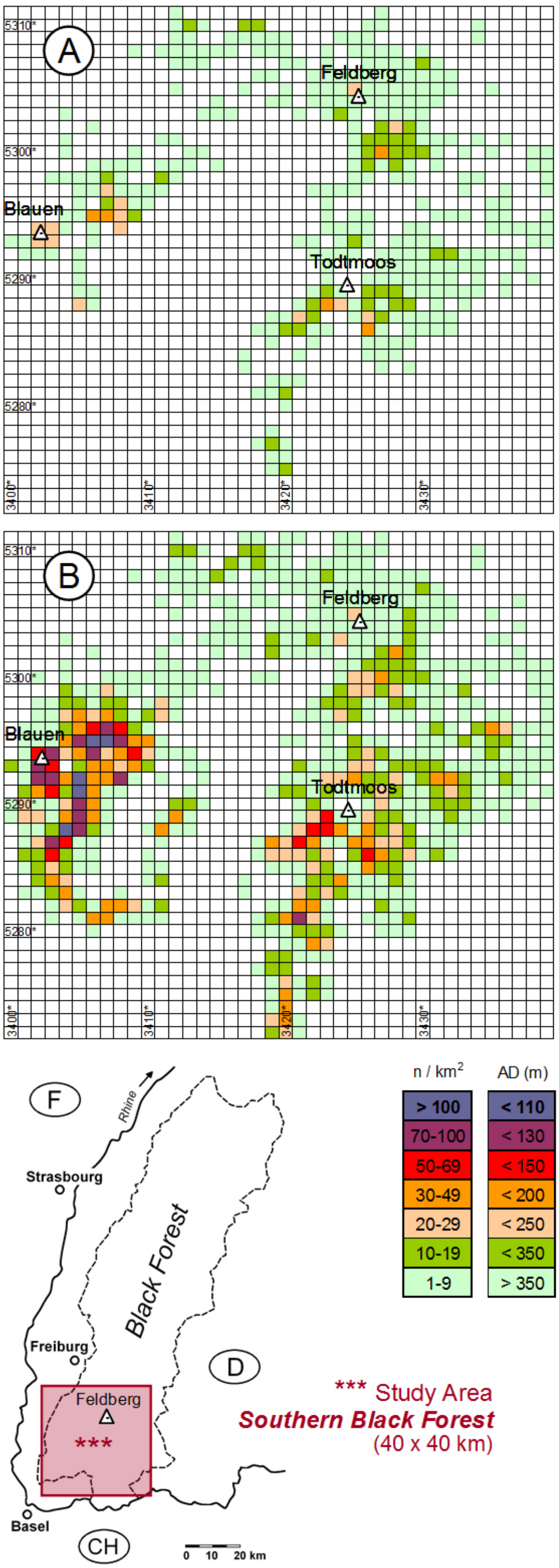

Figure 6. Kiln site density (kiln sites n/km²) in the Southern Black Forest. A: Verified by field record without LiDAR survey (total n=2024 kiln sites). B: Including LiDAR survey, verified and potential kiln site structures (total n=9115 sites; preliminary result, record in progress). AD Average distance of sites. *Gaus-Krüger-km²-grid, 40x40 km, 1600 km²).

conservation, e.g. by erosion, forest road construction, wood transport etc., (2) heterogeneities of the ground surface or vegetation, e.g. dense herb or shrub layer, (3) problems with the laser scan data, e.g. flight too late in the spring, when deciduous trees already had developed their leaves, or (4) less distinct anthropogenic structure and weak anomalies of the ground surface.

Consequently, field work could not be substituted completely by airborne laser scanning. Field work is still necessary for the verification of LiDAR-visible structures and for finding not visible sites.

CONCLUSION

Airborne laser scanning is a valuable tool for kiln site anthracology, providing exact information on the geographical position of the historical sites, facilitating the field work considerably and increasing the efficiency and precision of the site records. Kiln site distribution and density indicate the high significance of wood charcoal burning in the past. Moreover, it underlines the outstanding scientific potential of kiln site anthracological studies for forest history and vegetation science. The large number, wide distribution and high densities of historical kiln sites provide a unique chance to obtain new exact information on the ancient forests and the changes therein with fine spatial resolution at the landscape level. Impressive examples of local and regional scale results and of the high spatial resolution of kiln site anthracology have already been given (e.g. Ludemann 2002, 2003, 2010, 2011; Ludemann *et al*. 2004).

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GINA FARACO BIANCHINI, RITA SCHEEL-YBERT

Plants in a funerary context at the Jabuticabeira-II shellmound (Santa Catarina, Brazil) – feasting or ritual offerings?

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***Summary**: Anthracological and archaeobotanical analysis from the Jabuticabeira-II shellmound site presents evidence of plant selection related to mortuary practices. Sediments from excavated areas were sampled and charcoal remains obtained by flotation. Among the 2193 charcoal fragments analyzed in funerary features, 264 correspond to seeds and palm fruits. The presence of these edible plants, strictly associated to funerary features, corroborates the hypotheses of feasting practice and/or mortuary offerings.*

***Key words**: Shellmound, archaeobotany, feasting, charcoal.*

INTRODUCTION

Shellmound builders occupied the Brazilian coast during the Holocene. They are considered efficient and well succeeded fisher-gatherers, highly adapted to the coastal environment. These archaeological mounds, locally named *sambaqui*, usually have a complex stratigraphy, including alternating sequences of shell deposits and thin dark layers composed by burials, hearths and frequently postholes (Gaspar 2000).

Issues related to diet and subsistence have always been amongst the main interests of Brazilian shellmound research. The importance of plant resources in the diet of these populations begins to be widely accepted (Scheel-Ybert *et al*. 2009b), however, the participation of plants in ritual activities had never been suggested.

Sambaqui Jabuticabeira-II (southern Brazil) is formed by numerous alternate layers of funerary and “constructive” deposits. The latter are characterized by small mounds of shells and sandy sediments virtually devoid of cultural archaeological remains, disposed above the funerary structures. Funerary layers are extremely rich in hearth features, charcoal, artifacts and faunal remains (Fish *et al*. 2000).

The presence of nuts and seeds in the site sediments had already been perceived (DeBlasis *et al*. 1998; Fish *et al*. 2000; Gaspar *et al*. 2002); however, the possibility that these food remains were associated with the funerary rites was never hypothesized. Nor did previous anthracological analysis at the site raise this issue, as analysis of the material of constructive layers did not reveal any trace of food, not even palm nut fragments, which tend to be particularly frequent in *sambaqui* sediments (Scheel-Ybert 2001b).

Gaspar (2004) considers that funerary ceremonies were central in the lives of *sambaqui* people, something particularly evident in the case of the Jabuticabeira-II site. At this site, funerary features (pits and burials) were found either in the excavation areas or along several profiles. Abundant fish remains in these features point to the practice of ritual food offerings to the dead and/or funerary feastings (Klökler 2001, 2008). However, these ceremonies have always been associated with consumption of seafood only.

MATERIAL AND METHODS

The site Jabuticabeira-II, which measures 400 m x 150 m and up to 8 m in height, is situated in the Jaguaruna region, on the southern coast of Santa Catarina State, Brazil, *c*. 1 km from the southwestern margins of Garopaba do Sul Lagoon and *c*. 6 km from the sea (22J 699489/6835694 UTM) (Fig. 1).

The climate is temperate sub-hot, with winter mean temperatures over 15ºC and no dry season. Mean annual temperature is 20ºC and mean precipitation is 1400 mm/yr. The natural vegetation is almost absent from this region nowadays, but the site is situated in the phytosociological domain of the *restinga* ecosystem, typical of the Brazilian coast while the Atlantic Forest is situated inland, in more elevated topographical areas.

Anthracological sampling was carried out in a profile of Trench 18 (T18), in Locus I (Fig. 2). The samples analyzed and presented in this paper were collected from a funerary area located between 3.30 and 4.00 m deep. The excavation followed the natural stratification, separating the sediment samples of each identified feature. All the sediment taken from this excavation unit was floated for charcoal recovery.

Charcoal samples obtained through this procedure were grouped according to archaeological features, resulting in 15 samples named according to an alphanumeric code (A1 to A15).

The charcoal pieces were manually broken along the fundamental wood anatomical sections and examined under a reflected light microscope for systematic determination. Fruit and seed identification was based on external morphology and morphometric data, compared to the relevant literature and to a reference collection. The frequency of carpological remains in each sample was calculated from the ratio *number of*

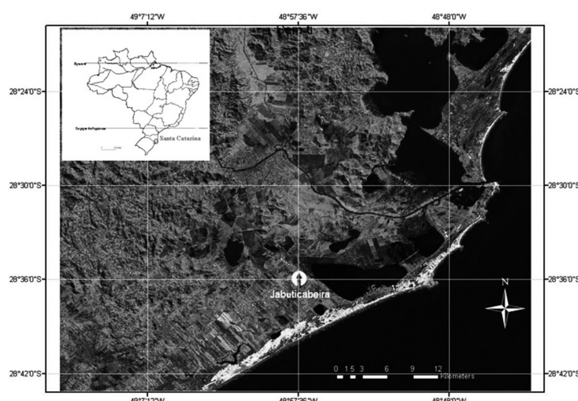

Figure 1. Jabuticabeira-II site location. Cartographic base Landsat 5 (1984).

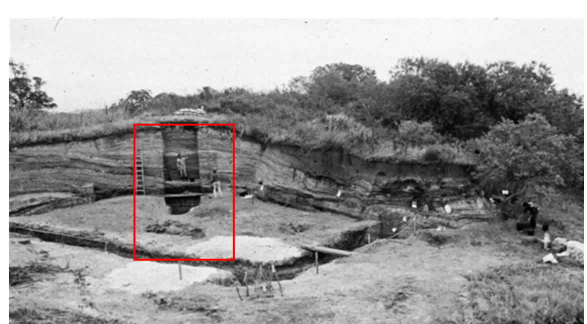

Figure 2. Jabuticabeira-II site, Trench 18-Locus 1, anthracological sampling.

seeds and palm nuts / number of charcoal fragments. The aim of using the number of charcoal fragments in the denominator, rather than simple percentages, is to control for differential preservation of the remains (Miller 1988).

Due to the particularities of the different classes of plant remains, charcoal fragments, root pickings, tubers, fruits and seeds are generally differentially preserved in the sediment. Charcoal remains, resulting from the fuel that feeds the fires, are easily preserved, especially because they constitute one of the most resistant to degradation biological elements that exist. In the case of food remains, however, their potential for preservation depends, among other things, on the characteristics of the plant tissues involved – hard parts, in principle, preserve more easily than fleshy parts.

In addition, one must consider that the conservation of plant residues under humid tropical climates occurs almost exclusively by carbonization, and depends on the material being exposed to fire or not, intentionally or accidentally, seeking its preparation or consumption (Scheel-Ybert 2001a).

In a ritual context, the preservation of these elements will depend both on the characteristics of plant tissues as on the way they are offered or used in the ceremony. Therefore, using the number of charcoal fragments in the denominator allows comparing data from different samples.

RESULTS AND DISCUSSION

All charcoal fragments over 4mm were analyzed, attaining almost 4000 analyzed pieces. The 1788 charcoal fragments analyzed from "constructive" layers allowed the identification of 40 taxa in 28 botanical families (Scheel-Ybert 2001b). In the funerary layer, the analysis of 2193 charcoal fragments provided 116 taxa from 40 families (Bianchini 2008). The number of taxa varies between 30 and 50 per sample, which represents a high floristic diversity.

Most of the identified specimens correspond to taxa found in the open *restinga* and *restinga* forest formations (the *restinga* being a mosaic of different xerophyte vegetation types typical to the coastal beach ridges), demonstrating that Jabuticabeira-II was situated in a similar environment to that related to other *sambaquis* (Scheel-Ybert 2000, 2001b; Scheel-Ybert and Dias 2007; Scheel-Ybert *et al*. 2009a). Myrtaceae and Lauraceae were the most representative plant families. A large proportion of Atlantic Forest (an ombrophilous tropical forest) species suggest that this plant formation occurred not very far from the site, probably in the more elevated slopes inland. Araucaria forest elements, especially in the constructive layer, attest to the exploitation of farther subtropical forests (Scheel-Ybert 2001b).

Charred remains of fruits and seeds were abundant in virtually all samples of the funerary features, conversely to the constructive package, where strictly no trace of carpological elements was found (Scheel-Ybert 2001b) (Fig. 3). This is particularly significant considering that the samples from the burial layers correspond to 70 cm of the profile, while the constructive package totals 3 meters.

Among the charcoal fragments analyzed in funerary features, 264 correspond to food remains, with 149 seeds and 115 palm nuts present in most features.

A high proportion of fruits and seeds remain as yet unidentified, due to difficulties in determining the charred material, particularly because of the strong fragmentation and lack of supporting material. The intense fragmentation of charred fruits and seeds greatly complicates the determination based on morphometric characters. Although their internal anatomy, as a rule, is quite characteristic, descriptions in the relevant literature are rare. Besides, fruits and seeds are generally fragile structures and studies on the processes of change, both by the action of fire as by the action of post-depositional processes, are practically nonexistent.

From the 55 specimens already determined, there are individuals belonging to the families Cucurbitaceae (1), Myrtaceae (17), Annonaceae (19) and Are-

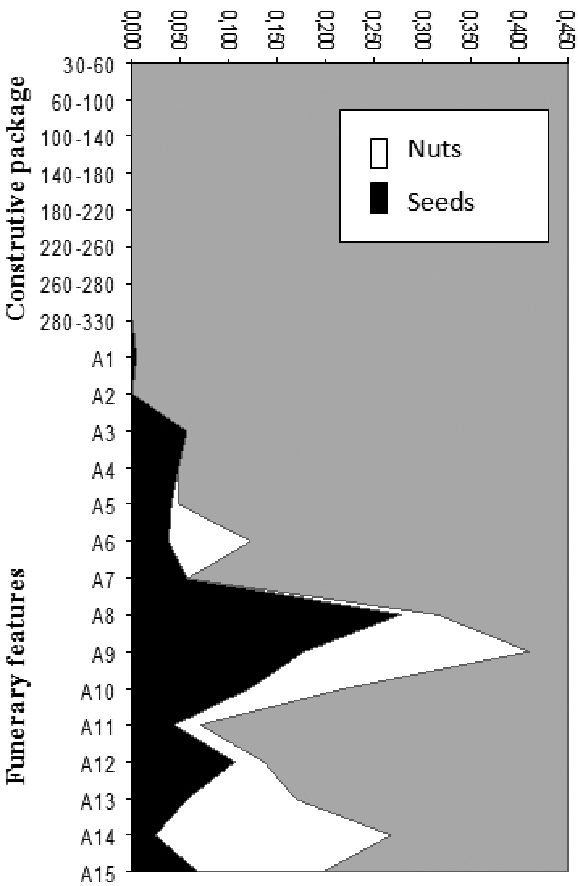

Figure 3. Jabuticabeira-II site, Locus 1, Trench T18. Seeds and palm nuts ratios.

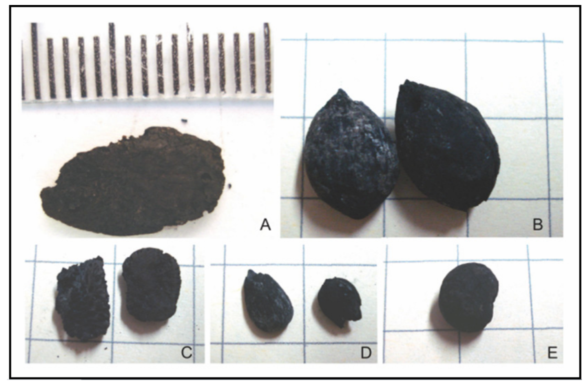

Figure 4. Seeds from the funerary area in Trench T18 anthracological sample of sambaqui Jabuticabeira-II. A – Cucurbitaceae; B - *Syagrus* sp (Palmae); C – Annonaceae; D – *Rollinia* sp (Annonaceae); E – Myrtaceae.

caceae (18) (Fig. 4), all of which produce edible fruits.

The significant frequency of seeds and fruits in certain features clearly demonstrates they were food remains. The archaeological context indicates that they are certainly related to the practice of funerary feastings or offerings. All the samples of the funeral package included fragments of seeds and/or palm nuts.

The abundance of carpological vestiges related to the total number of charcoal fragments was 12%, which is quite significant, given all the factors that lead to differential preservation of these elements compared to wood. Contrary to expectations, most of these (149) are seed fragments, suggesting a major contribution of fleshy fruits in detriment of palms in the funerary ritual.

The highest proportions of these elements were verified in samples A8, A9, A10 and A12. Samples A8 and A9 correspond to sediments with heavy concentrations of fire traces, fish bones, shell, oysters and thermal flakes. The evidence suggests that they represent the “apex of the ritual”, the product of an ordered series of collection activities and disposal of different types and materials. Sample A10, in turn, is a fireplace next to the burial with many charcoals, while A12 has been described as a layer of ash with postholes. Both samples are clearly related to important parts of the funerary ritual.

Several recent studies have associated the presence of plant foods in funerary contexts with the practice of feasting (Pauketat *et al*. 2002; Rosenswig 2007). Along the same lines, the data presented here might support the hypothesis of feasting or funerary offerings suggested by zooarchaeological analyses (Klökler 2001, 2008).

Feastings, in general, require considerable investments of time, effort, and resources. In traditional societies, this is one of the main occasions of mobilization work, where power is highlighted and sociopolitical relations of values established and solidified. As a result, a great feast involves a major investment in the production of surplus (Adams 2004).

The data obtained from the anthracological and archaeobotanical analysis of funerary layers of Trench 18, either regarding charcoal or carpological remains, are suggestive of a series of ordered activities and intense mobilization, not only for the construction of the burial mounds themselves, but also with regard to aspects such as collecting firewood, collecting and placing stakes and mobilization regarding the collection of fruits and other foods and/or offerings.

How long and how often would the fires be lit to produce such a rich anthracological record? How many fruits would be needed? Would there be major investment in the collection of specially selected fruits for the feast?

Feasts do not justify the use of "luxury foods", but are an ideal reason for their existence. It is also suggested that the first domestication may have occurred from the intensification of the processes of collection and management, especially of foods which consumption context was ritual (Hayden 2003).

On the other hand, the funerary rituals are part of the routine of a group. They are strategies of operation in which people reproduce the conditions of their own lives (Barrett 1990). Thus, ritual practices and domestic activities may be closely related in many ways (Hodder 2005). Therefore, it is very likely that these foods were also consumed daily.

At this stage of knowledge, we cannot say if these seeds are the product of gathering, management or cultivation. Whatever the case, their presence at the site and intentionality may be taken to mean a large investment of labor. On the other hand, draws our attention the fact that all the identified seeds (Cucurbitaceae, Myrtaceae, Annonaceae and Palmae) have a long history of relationship with human populations, all of them belonging to families in which several species have been domesticated.

It cannot in any way be said that these mound-builders were farmers or that they were performing the domestication of plants, as there is, so far, no clear indication of this. However, the hypothesis that these people managed horticultural plants has already been presented and has been corroborated by several evidences (Scheel-Ybert *et al*. 2009b).

CONCLUSIONS

All the samples related to the funerary layer analyzed here showed the presence of seeds and/or palm nuts, contrary to the samples of the constructive package, where no evidence of these elements was found. The highest proportions of carpological elements were obtained in samples with higher concentration of vestiges associated to the funerary ritual. The significant frequency of food remains in certain features of the burial structure is certainly related to the practice of funerary offerings or feasts, corroborating the hypothesis proposed by zooarchaeological research.

New studies are still needed aiming to a better comprehension of the use of plants in domestic and ritual contexts of Brazilian shellmounds. Still, the results here presented are quite revealing, not only for their unprecedented nature, but mainly because of the context to which they are related.

The data presented, as well as all the issues raised, point to the urgent need for strengthening archaeobotanical research in Brazilian sites, hoping they can bring, as soon as possible, some answers to these questions.

ACKNOWLEDGEMENTS

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WERNER H. SCHOCH

Information content of anthracology

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Summary: *Anthracology is a part of woodanatomy. The contribution presents possibilities, problems and their solutions for the analysis of charcoal. Careful sampling and the assessment of the overall findings are essential for the interpretation of the results.*

Key words: *Wood anatomy, anthracology, archaeobotany, mining.*

INTRODUCTION

Wood has been used by animals since very early in evolution. For example, birds and other animals have long used wood to build nests and the apes are known to dig and poke at things with branches. We can get some idea about how the first humans used wood from several spectacular archaeological finds. The spears from Schöningen near Helmstedt in Lower Saxony are the oldest completely preserved hunting weapons of *Homo erectus* ever found, and could be as much as 320,000 years old (Schoch 2007). The outlines of some wood constructions from simple dwellings found in Bilzingsleben were dated to the same period.

At some point fire began to play a role (Badal *et al*. 2002). When wood burned, some of it became charcoal. That changed the world: not only had animals and hominids settled the earth, but a new species developed as well: anthracologists appeared, and for them very specific problems started (Fig. 1). Take, for instance, the case of an anthracologist having a great holiday on a wonderful beach far away from everyday work, – enjoying the waves coming and going, rippling in and out (Fig. 2). All is peaceful until he or she suddenly spots something black that one of the waves brings in. It's just something black for most

Figure 1. Cova de les Cendres, a famous place for vegetation history.

people, and rather inconspicuous, but it is still in a sizeable quantity, it is charcoal! Peace belongs to the past – now the anthracologist cannot wait to find out more. The bits of charcoal are clearly rounded. That means they had been moving around for quite some time. Could they possibly have been transported over a considerable distance? What types of wood do they come from? What is the best way to take a sample to get a representative selection? Various attempts have been made to standardize the methodology in archaeobotany. One example is that of Jacomet and Kreuz, who published a book called "Archaeobotany" (Jacomet and Kreuz 1999). They recommend dividing an excavation site into squares, and taking the samples according to a particular pattern and then evaluating them.

ANALYSING THE CHARCOAL

According to the University of Applied Sciences or "Hochschule für nachhaltige Entwicklung" in Eberswalde, 25,000 to 30,000 wood species exist worldwide. About 5000 of these species would be suitable for commercial use, but only about 1000 are actually traded. Of these, 200 to 300 wood species are commercially important and therefore also have identification keys. It is obvious that there is often a need to identify pieces of wood and wood remains. This may seem simple and straightforward at first sight, but in tackling this task, we are often faced with almost insoluble problems. Both wood and charcoal have structures that are species-specific. It is possible to make these structures visible by examining the surfaces along a split, break or thin section. The techniques for

Figure 2. At the beach, waves rippling in and out – and bringing charcoals.

determining wood and wood charcoal have improved enormously since 1864, when the Italian G. Passerini, first had the idea of analysing prehistoric wood charcoal macro-remains, and since Oswald Heer and later Jakob Messikommer, determined the charcoal found in Neolithic and Bronze Age lake-dwellings, e.g. at Robenhausen, in Switzerland. In 1970, Marcel Couvert described in "Etude des charbons préhistoriques" how to produce thin sections. From these, he was able, with great effort, to obtain good microphotos of the processed charcoal. But these cannot compare with the detailed, high-quality pictures of charcoal pro-

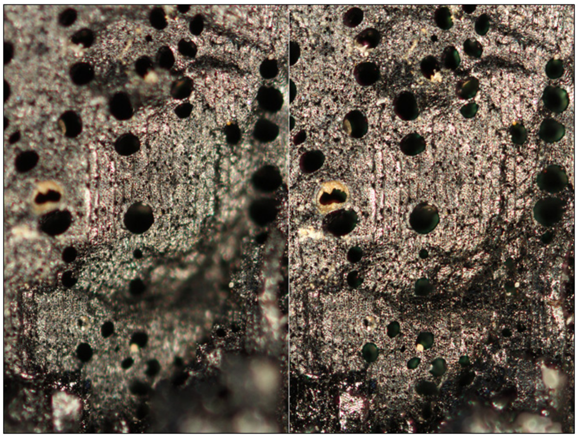

Figure 3. The best possible picture, taken by optic microscope, left. The same charcoal picture composed with special software (Helicon focus) from 110 photos, right.

duced today with all the technical possibilities now available. It is just amazing what can be done. Take a look, for example, at REM images that today appear in publications.

To determine large quantities of charcoal pieces, it is usually sufficient to have clean surfaces along the split or break that can be analysed under a reflecting microscope. With a bit of experience and the help of some software, it is possible to produce pictures that are good enough for documenting the material (Fig. 3), even though their quality is nothing like as good as that of the REM images.

IDENTIFYING CHARCOAL FINDS FROM PREQUARTERNARY-PERIODS

The study of fossil wood is sometimes called palaeoxylology and somebody who studies fossil charcoal is called a “palaeoanthracologist”. Sometimes the only preserved part of a plant may be in the form of fossil charcoal and the rest of the plant may be completely unknown. Such charcoal is then often given a special kind of botanical name, which usually includes the suffix “xylon” and a prefix indicating its presumed affinity. Examples are *Araucarioxylon* (for wood from *Araucaria* or some related genus), *Palmoxylon* (wood from an indeterminate palm) or *Quercoxylon* (wood from an indeterminate *Quercus*).

One incredibly fascinating area of our work is to try to reconstruct what the earth’s atmosphere could have been like on the basis of the presence or absence of traces of forest fires (Scott 2010). Similarly, we can use wood charcoal to try to work out what the vegetation could have consisted of during the Jurassic and Cretaceous periods (Marynowski 2011).

CHARCOAL FROM THE QUARTERNARY

To determine the charcoal pieces we need sample collections or at least good pictures of the wood specimens. But unfortunately these are often not available, many taxa are not described anywhere or those that are described are not evaluated concerning diagnostic characters and similarities to other taxa. This means

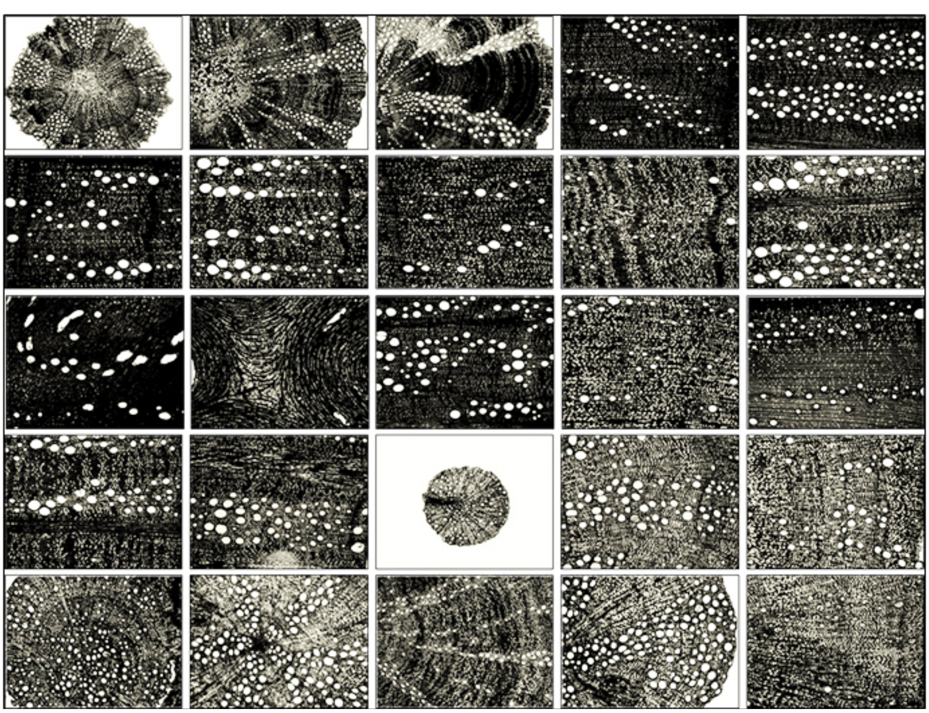

Figure 4. Variability of wood structure in *Quercus* ilex, twig, branches, stem, root, all transversal sections from the same tree, in the same magnification.

that sometimes we have to put together a collection of wood pieces before they can be potentially determined in order to produce preparations. This only makes sense, of course, if the plants can be identified to the species level, which usually requires involving local specialists (Neumann *et al*. 2001).

In many identification keys images of just one example are given. This is not at all satisfactory because the structural variability inside one single tree can be great. Differences in the structure of different parts of one individual can be greater than between two species belonging to the same family (Fig. 4). Whenever possible, samples from the stems, branches and twigs of as many individuals as possible should be collected. All too often only a few fragments of charcoal are available, which means no statistical assignment of their microfeatures is possible, unlike with the present-day material used for comparison (Schoch *et al*. 2004). Unfortunately, it is usually impossible to identify charcoal down to the species level solely on the basis of the anatomy of wood.

SAMPLING

Archaeologists must know what questions they want to answer. It makes little sense to analyse and date the charcoal found in a dig just because "nothing else was found" (comment made by someone on a dig). The other findings from the excavation can help to analyse the charcoal and ensure that the efforts needed to extract them are in a reasonable relationship with the anticipated results. If it is possible to clearly identify carbonised beams as such during a dig, then taking a adequately labelled sample from each beam is normally sufficient. If charcoal from a fireplace can be identified in assembly, then all that is needed is one sample from each piece of wood documented accordingly. It makes no sense in such cases to simply collect a bag of charcoal – sometimes people determine as many as 100 fragments from what was originally a single piece of wood, and thus overestimate their significance. This raises the question once again about how to take samples and how many fragments/samples should be determined. The answer depends very much on the archaeological finds and the research questions as numerous papers that deal with this problem have shown. Even when samples are taken very carefully, there are still enough unknown factors to make the interpretation of the results of the analysis difficult. For instance, how did the charcoal originally formed, where does it come from, and what sedimentation, distribution and deterioration processes have been involved?

CHARCOAL AND QUALITY OF USED WOOD

Insects and fungi attack the wood in many different cases. Traces can be found in charcoals usually from burned deadwood (Fig. 5). We are not able to distinguish between deadwood which was still on the tree or already lying on the forest soil.

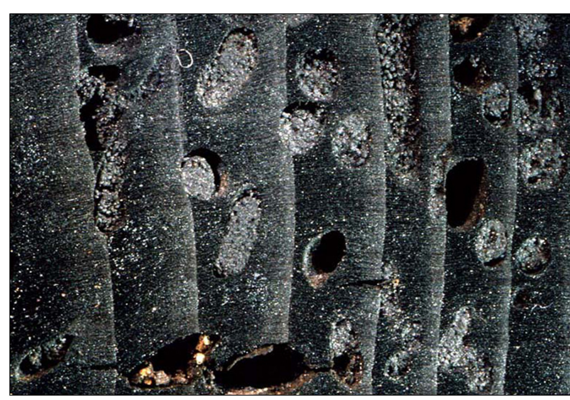

Figure 5. Insect galleries, partially with faecal pellets from larvae.

RECONSTRUCTING THE STEM DIAMETER

Stem diameters can be estimated on the basis of tree-ring curvature, particularly when using pieces of charcoal from charcoal kilns to reconstruct the forest management system (Ludemann, 2008). If large enough pieces of charcoal are available, then this is a very suitable method (Paradis 2007). If, however, the pieces are small, then estimates must be treated carefully as not all stems are round and their growth may have not been concentric.

CHARCOAL AND DENDROCHRONOLOGY

In the alpine region, often charcoal pieces in connection with old mining are found. Due to the growing conditions these trees formed very narrow rings; on charcoal fragments often we can observe much more than 100 rings! This material is very suitable to be dated by dendrochronology. With a good cutting technique also these very narrow rings can be precisely measured (Fig. 6).

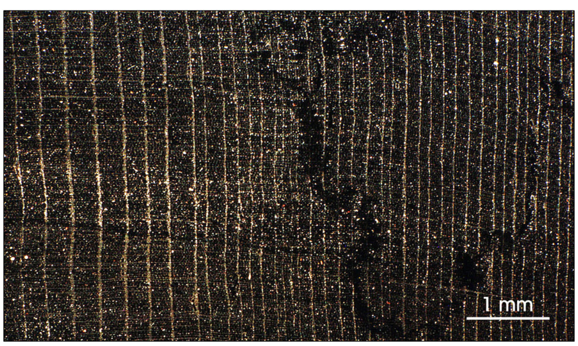

Figure 6. Charcoal from an alpine mining place, cut with diamond-wire saw.

CHOOSING SAMPLES FOR 14C-DATING

Archaeologists will normally select the most suitable sample for ^{14}C-dating. The charcoal pieces should not, of course, be contaminated or become contaminated during the dating process. Pieces of charcoal with roots in them, for example, should be carefully cleaned, or preferably not even used if other material is available. When dating charcoal, the hope is, as with all ^{14}C-dating, that the age obtained will correspond to that of the archaeological find. In the early days, a large quantity of charcoal was needed for dating. Today, a typical sample for Accelerator Mass Spectrometry weighs about 5 mg. This makes it much easier to prepare a suitable sample and just a few tree rings can be chipped off. It is best to take the last tree ring that grew on a branch or stem, where possible, in order to determine the year when the tree was felled? Some methodological problems of ^{14}C-dating need to be discussed, e.g. in connection with sunspot-cycles. In any case the bark must be removed because it stores the material of the full age of the tree. Alternatively, one-year-old twigs (Fig. 7) or certain fruit can be used. Pine-cones of *Pinus sp*. are, however, less suitable, as these may remain on the tree for years, although exactly how long will depend on the species.

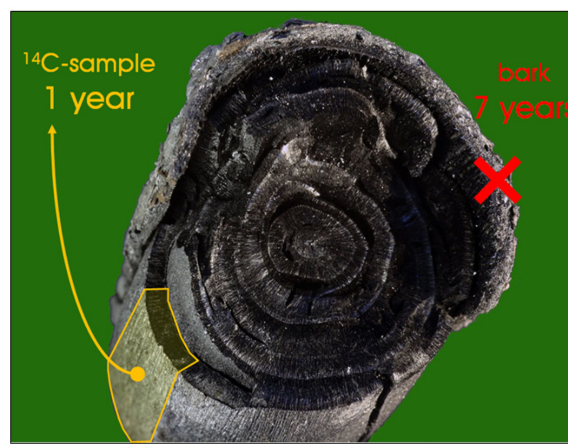

Figure 7. A sample preview for AMS-dating consists of only one tree-ring.

THE CONDITION OF CHARCOAL

In principle, it is easier to determine a wood species if the size of the charcoal pieces available is at least a few centimeters. Then it is very easy to find places on them where diagnostically important features can be identified. Charcoal from wood that had biologically decomposed or become deformed already before carbonization presents problems. The structures in such material may be so compressed and deformed that it is almost impossible to determine them (Kaiser *et al.* 2009). Only if some practically intact parts in the charcoal can be found where some identification features have been at least in part preserved, will it be possible to determine the material (Fig. 8). With charcoal remains that have been so severely burnt that the wood has mostly turned to ash and only a few bundles of fibres in the charcoal are still present, the chances of identifying the wood species are slim. The wood structure may still be macroscopically visible, but the wood fibres will be isolated and lying mixed up in different directions. In a few cases, it may be possible to identify a few isolated wood fibres or vascular elements and thus determine the wood species. The more fragmented the pieces are, the more difficult it becomes to identify or even find all such features. If many charcoal fragments from a find deposit have been identified, the spectrum of species that occur can be used as the basis for determining the wood species of very small fragments with certainty, so long as some typical features of the species can be clearly determined. Sometimes, it is also possible to determine very small fragments, as e.g. remains included in pollen analysis samples (Drescher-Schneider *et al*. 2007).

Embedded minerals often cover the microstructure. Their composition varies, but calcium deposits are widespread, and traces of metals in the form of iron and manganese oxides, copper compounds and iron sulphides (pyrites) may occur. Carbonates in particular can be dissolved with strongly diluted formic, hydrochloric or acetic acid. Great care, however, should be taken not to destroy the structure of the charcoal as it may break open if too much CO_2 is formed too quickly.

Often the soft early-wood becomes completely decayed or mechanically destroyed in the sediment and disappears. Nevertheless, the structure of the latewood allows in many cases the determination of the species. Opposite to the bad preservation from heavily burned wood we find the glass-like charcoals, partially without any structure from wood (Fig. 9). The example shows some parts only in such glass-like condition, the structure is in all visible and can be attributed to a monocotyledonous, may be Liliaceae.

CHARCOAL AND METALLURGY

Wood was normally used in the form of charcoal for ore-smelting and processing metals. In experimental archaeology, however, it has been shown that it is possible to extract copper from ore using wood. This area of anthracology seems to offer a promising starting point for determining the firing temperature through reflection measurements of charcoal.

We know two cases for converting wood in connection with metal and metal salts. On an axe handle with

Figure 8. Isolated fibres and vessels in a charcoal infiltrated by minerals.

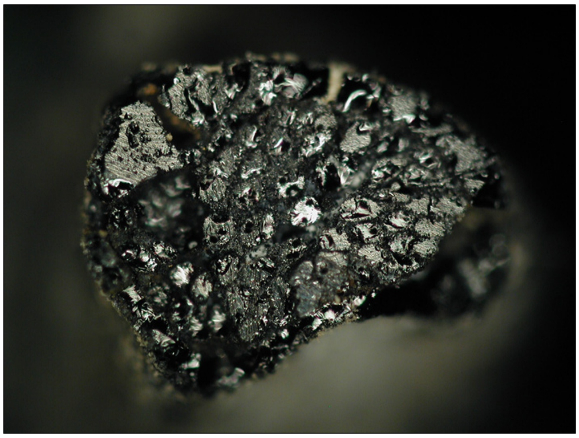

Figure 9. Glass-like structure in charcoal from a Liliaceae.

a bronze blade, dissolved copper salts saturate the wood and replace the organic material, preserving perfectly the cell structures. In the other case, a fragment from an axe handle is charred and the charcoal gets penetrated from the dissolved copper-minerals, which are later deposited on the charcoal.

In material from a dig that consists predominantly of slag, charcoal fragments are often embedded and well-preserved. Sometimes they may even become partially or completely mineralized by infiltrating metal salts (Fig. 10). An analysis of charcoal from Sagalassos / TR (Schoch 1995) showed that many of the wood remains had become mineralized. The metal salts had preserved the cell structure, but even the cell walls were mineralized. Thus, it seems likely that wood and not charcoal was used to heat the ovens, especially as mostly coniferous wood was used, possibly in order to obtain higher temperatures. Small parts of not completely charred wood could be preserved in this way. If it had been charcoal that was mineralized, the cell walls of the charcoal would have most likely remained.

At Elba, slag from Roman iron processing was found which contained clear negative imprints of charcoal (Fig. 11) and sometimes even traces of partially preserved charcoal. The angular shapes of the negatives are clear indications that they originate from charcoal and not wood. The partially mineralized pieces of charcoal are especially brittle and may disintegrate with even very slight mechanical loads. This means that studying them under a microscope is a delicate procedure requiring great care. The charcoal bits should be stored on a glass bead or quartz sand bed and not on putty or plasticine.

In the case of charcoal from the gold mines in Sakdrisi in Georgia, the species composition of the wood used to make fires in the mines differs clearly from that of the wood used in the corresponding settlement.

MINING AND FOREST MANAGMENT

On the island of Cyprus deposits of an estimated amount of 4 million tons of slag exist. In this material we find a lot of charcoal that can be well analysed. These slags are the remains from copper production since the Bronze Age and allowed calculating the amount of copper to 0.2 million tons. For this production, an estimated charcoal amount of 60 million tons was necessary, which in turn means, that about 160 tons of wood was needed! If we calculate with the possible density of forest and assuming that the forest would cover the whole island, Cyprus must have been deforested 16 times during the last 3000 years! This amount of wood only represents the need for copper production, without including the wood used for the mining gallery support system, for the famous

Figure 10. Completely mineralized wood (*Populus* sp.) from mining process.

Figure 11. Negatives from charcoal pieces in Roman slag, species microscopically determined (*Quercus* sp.).

Cyprus shipbuilding industry, for fuel for ceramic production and for all other applications (Schoch 2000). At Tamassos, the Kings' town, all charcoals from all periods were collected and analysed too. In the plan of the town the building phases are in clearly visible accordance with the conspicuous decrease of the richness of species. Forest management is directly visible in different woods from this time: slow growth reduction and sometimes abrupt increase of tree-ring width shows the lapse of the concurrence by cutting the close-by standing trees (Fig. 12).

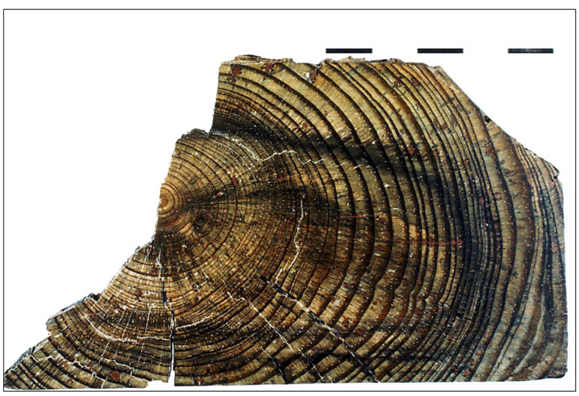

Figure 12. Phases of slow growth reduction and abrupt increase of tree-ring width in a *Pinus brutia* specimen.

TWO SPECIAL EXAMPLES

In charcoal material from Mochlos, Crete, thorny burnet (*Sarcopoterium spinosa*) was identified and appears to have been "used as fuel for outdoor bread ovens and lime kilns' (Soles *et al*. 2004). It was found only in Kiln B on the Mochlos coast, where it was used with olives in the fuel mix. This result corresponds with a passed down technique in pottery.

During the excavations of the prehistoric lake biotope at Neumark-Nord in Germany by Dietrich Mania, bones of straight-tusked elephants (*Elephas antiquus*), were discovered by him (Schoch 2010). The museum for prehistory in Halle (Saale) showed the reconstructed elephant in his impressive bigness and the environment in which he lived. With an abundance of abiotic and biotic evidence, the environment of the elephants could be reconstructed; in charcoal from *Acer sp*. density fluctuations were regularly found (Fig. 13), which indicate strong summer droughts 150,000 year ago!

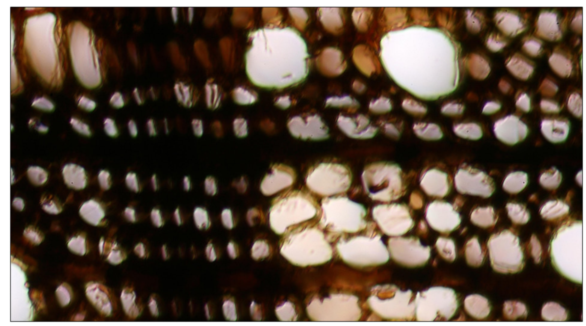

Figure 13. Density-fluctuation in *Acer campestre* indicates heavy summer-drought in Neumark-Nord.

CONCLUSIONS

The analysis of charcoals produces data for the history of the climate, the vegetation and the fire events and it can also provide information about the uses of wood. With careful sampling it can provide evidence for selective use of wood species for building and tool making. The remains also allow us to identify different crafts and techniques according to the selection of wood species and different burning temperatures.

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ARNE PAYSEN

Charcoal research before modern anthracology

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Summary: *Long before charcoal analysis was used for reconstructing climate, vegetation history and human environment-impact, philosophers, metal-workers, engineers and foresters collected a broad knowledge about different kinds of charcoal and its properties. Beginning with Theophrastus and Plini in ancient Greece and Rome to the fire-workers of the Renaissance and the engineers of the industrial revolution the history of charcoal-analysis leads to the first modern anthracologists. Efficient and economic use of wood and charcoal for technical purposes can be named as a main reason for the ancient charcoal research. Nevertheless, quite modern observations concerning archaeology and forest-management are mentioned already in the 16th century. On the whole, many questions concerning the use of charcoal in the past are answered from a contemporary view. The knowledge about this could be helpful for interpreting anthracological samples from pre-industrial working places where modern anthracology is used to write part of the technical history.*

Key words: *Renaissance and Baroque literature, technical charcoal use, history of charcoal analysis.*

INTRODUCTION

The production and use of charcoal have been described since ancient Greek and Roman times. Similar and forth going descriptions can also be found in Renaissance and Baroque literature until the industrial revolution. Beside the description of different ways of charcoal burning, the properties of charcoals from different woods are often mentioned. It seems that not every kind of charcoal fits for every technical process. The reason for these efforts was the permanent lack of wood and charcoal for the upcoming industry and the need to avoid an unnecessary waste of wood caused by the use of wrong types of charcoal. With these detailed descriptions of different charcoal qualities, fireworkers should be able to differentiate the quality of the bought fuel. During the 19^{th} century knowledge about the technical use of charcoal was used for the first time in archaeobotanical and modern anthracological research. The history of charcoal analyses and modern anthracology developed over centuries and combine botanical, physical, chemical and economical research since the Renaissance.

ANTIQUE DISCRIPTIONS OF CARBONISATION

The oldest mention of the properties of different charcoals comes from the Greek philosopher Theophrastus (371-287 BC). He explained the production of charcoal in kilns and described the charcoal of young trees and coppices as longer-lasting in fire than other coal. According to Theophrastus, iron-smelters prefer charcoal from *Picea* and silversmiths from *Pinus* in order to run their workshops (Theophrastus, History of plants, Book 5, chapter 9).

In Roman times the philosopher Plinius Secundus (ca. 23-79 AD) mainly quoted the observations of Theophrastus but he distinguished between charcoals from soft and hardwood. Additionally he gives the information that iron-smelters prefer charcoal from *Quercus*, *Fagus* and *Carpinus* (Plinius, Nat. hist. lib. 16, 27-29). Both philosophers did not make any experiments or observations themselves; they only described the state of common knowledge in their time.

FIRST CHARCOAL RESEARCH DURING THE RENAISSANCE PERIOD

During the Renaissance the antique descriptions of nature, mathematics and medicine led to a modern way of scientific thinking. In the attempt to continue the great times of the Roman Empire the foundations of modern science were laid.

One of the most famous researchers about the so called "fireworks" was Vanoccio Biringuccio. In his Venetian book "de la pyrotechnia" (about fire techniques) from 1540, he describes casting of metals, glass production and also different techniques of charcoal making. Additionally he gives practical advice for quality-tests and points out several new observations about charcoal. Biringuccio writes:

"*Often you find Charcoal from the same wood species, which is charred more or less or was charred with different techniques. It is even a big difference by which soil the Charcoals where covered during the Carbonisation. It is also a difference, if the wood was from a young or old tree, if it had branches or not and if the tree was healthy and strong. Sometimes it makes a difference, when the charcoal was made from dead and dry branches. In general there is a difference between the carbonisation of dried and fresh wood..."* (Biringuccio 1540, 61 v).

In his opinion it is important for every metal worker to be able to distinguish between these different kinds of charcoal to ensure a good production process. For iron smelters Biringuccio insists on the use of hardwoods. By this he means *Quercus*, *Fagus* and *Carpinus*. The use of charcoal from *Populus*, *Salix*, *Abies* and *Acer* is considered waste because of the much higher consumption for the same result. Charcoal from softwoods on the other hand can be used for work needing less intensive heat; only the charcoal of *Betula* was unusable for gold and silversmiths (Biringuccio 1540, 61 v).

Special mention deserves one paragraph in which Biringuccio describes some kind of archaeological-anthracological research. He writes:

"It is also well known, that charcoal is made from burned wood. About its other properties can be said, that it lasts for years and centuries. I remember an excavation in old ruins, where I have seen charcoals, which were lying in the soil at this very place more than 400 years" (Biringuccio 1540, 62 r).

The knowledge of Biringuccio was quoted and translated several times. The German Engineer Georg Agricola (1557) based his *Zwölf Bücher vom Berg- und Hüttenwesen* (Twelve books of mining and smelting) widely on the works of Bringuccio. Agricola himself has been quoted by the Italian Antonio Neri (1612), the Englishman Christopher Merret (1662) and the German Johannes Kunckel (1679). The observations of Biringuccio seem to have been common knowledge for fire workers for more than 100 years. All quoted works name the importance of fuel quality for good results and are afraid of needless waste.

EXPERIMENTAL RESEARCH DURING THE BAROQUE PERIOD

During the 17th and 18th centuries the lack of fuel for supplying upcoming manufactures and industry led to the first experimental research in order to save fuel. The main interest was a combination of sustainable forest-management, efficient carbonisation and fuel-saving ovens and furnaces. Out of a wide number of publications two works deserve a special mention.

The first is "*Silvicultura oeconomica*" (economic forest culture) from the German forester Hanß Karl von Carlowitz (1713). His mission was fuel support for the early iron industry in Saxony. He described the efficiency of several carbonisation techniques and made experiments on the best kind of wood for charcoal-production. According to his observations the charcoal from kilns gives the best results; stumps and twigs charred in a pit (the usual practice until the 19th century) only produce small charcoal-pieces which are useless for industrial usage. Only big charcoal pieces give the necessary draught inside the furnaces. Hardwood must be preferred to softwood for nearly every metal-work (Carlowitz 1713: 391). His most relevant points for an efficient charcoal-production are:

§42 The more compact the wood, the better the charcoal.

§43 Fast carbonisation process makes the charcoal less valuable and more wood is burned to ashes.

§45 Wet weather during carbonisation makes the charcoal better.

§46 Dry soil in the cover makes the charcoal light and valueless.

§47 Too dry, foul or too wet wood gives sparking charcoal without any heat.

§ 48 Dry wood can be charred better after rafting.

§49 The best wood for charcoal production is fresh wood.

Besides his observations concerning charcoal, his main accomplishment consists in the invention of the basic rules for sustainable forest management which are still relevant today.

Another publication which has to be mentioned is *L'art du charbonnier* (The art of charcoal burning) by Henry Louis Duhamel du Monceau (1761). It is the first scientific work especially about charcoal. In the beginning of his work Monceau distinguishes the appearance of charcoal from kilns with low impact of air from the more porous and lighter charcoal from extinguished fires with high impact of air. He also describes carbon as one of the main elements (not in the modern meaning) of wood, the others he identified as a small amount of sulphur, tar or wood-oil, a kind of alcohol (methylene), burning gases (acetylene) and a kind of acid (acetic acid) (Duhamel du Monceau 1761: 6-8). He describes the process of carbonisation as a kind of drying or distillation process, where the fibres of the wood stay in shape, but lose their stability (Monceau 1761: 9-11).

Another of Monceau's experiments shows reduction of size of about 25% as well as loss of weight to 1/4 or 1/5 of the weight of the wood used in the carbonisation process (Duhamel du Monceau 1761: 32-33). By comparing burning charcoal with burning wood he observes completely different properties of the produced gases and describes the reducing effect on metal-salts and the deadly effect of carbonmonoxide on animals (Duhamel du Monceau 1761: 5). He also points out the better forging and smelting results on iron ore in comparison to fossil coal. As Biringuccio before him, Monceau confirms the enduring character of charcoal which is not affected by soil, worms or insects (Duhamel du Monceau 1761: 10).

In comparison to the earlier literature about charcoal he concretizes the practical hints for analysing the charcoal quality. He states that the highest quality charcoal consists of big pieces and is made from round sticks or coppices instead of logs; furthermore it is very light and gives a high sound (Duhamel du Monceau 1761: 33). In general charcoal from hardwood burns hotter, but especially oak sometimes gives heavy sparks, which is not very pleasant for the workers. Charcoal from softwood burns not as hot and does not spark. In context with the waste of wood by ineffective charcoal burning Duhamel du Monceau describes the problem of too fast and ineffective burning kilns due to the use of dried wood. He also points out the worse production output of charcoal by the use of big logs or wet wood respectively due to the risk of incomplete carbonisation (Duhamel du Monceau 1762: 13).

The investigation of Duhamel du Monceau shows a wide and scientifically proved knowledge of the physical and chemical properties of different kinds of charcoal. His work was, similar to Biringuccio, the basis for charcoal research until the late 19th century.

The development of artillery also had some influence on charcoal research, because grinded charcoal is one of the indigents of gunpowder. The charcoal quality is very important for the power of the powder, so artillerist experimented with different kinds of charcoal. The artillery lieutenant J. C. Plümicke (1821: 146-147) investigated old orders, quoting several experiments about the quality of gunpowder made by different kinds of charcoal. In France all woods of *Frangula* were signed over to the powder mills by law as early as 1669. Later experiments had also good results by using *Populus* and *Tilia* charcoal.

CHARCOAL RESEARCH DURING THE INDUSTRIAL REVOLUTION

The development of steam engines during the last decades of the 18th century offered the opportunity for rapid increase of coal- and ore-mining. Even with fossil coal being very common in use, charcoal still was indispensable especially far away from rivers and railways where fossil coal could be transported. All over Europe engineers and foresters made extensive research about carbonisation techniques, wood management and physical and chemical properties of charcoal, mostly based on the works of Duhamel du Monceau. Important work was conducted by Zanger (1773), who described a new carbonisation technique for coniferous wood in lying kilns and F. Klein (1836) who made a similar research on the traditional standing kiln. Most impressive seem the works of the Swedish Director Carl-David Af Uhr (1820) and the German landlord Carl Heinrich Edmund von Berg (1830). Af Uhr made several experiments concerning the carbonisation of wood under different conditions. Besides the discussion about the efficiency of lying and standing kilns, he gives calculation rules for kiln sizes compared to the quantity of wood used and the produced amount of charcoal. He also investigated the properties of the charcoal of different wood species and key data like energy-load, heat, density, shrinking and duration of burning. The special value of the works of Af Uhr consists in the detailed description and discussion of his experiments and his clearly structured tables and plates which finally catch up with nowadays standards. Af Uhr's works were translated in different languages in whole Europe.

The work of von Berg is as extensive as the work of Af Uhr, but less precise in explaining the charcoal experiments. Indeed he focuses more on social and economic facts e.g. payment and health standards of charcoal burners.

The technical knowledge about charcoal increased amazingly at least during the late 18th and 19th century, but at the same time charcoal became more and more replaced by fossil coal. D. F. Unger (1846) first used the technical knowledge for the determination of wood species from archaeological contexts by using a microscope. He compared his samples with technical samples from J. D. Büsching and E. v. Berg (1830). Unger started to reconstruct the forest history by analysing the combination of species in different samples from different ages and he assumed a spreading of coniferous wood in northern Germany during the last centuries. His article can be considered the first modern anthracological research.

DISCUSSION

At first sight the expressions of many old scientific texts look strange to us today. However, with a second view we can see that they did what we do: observe, describe and explain. Even if the interpretations differ significantly from ours today, most observations are still correct. We have to accept that as the older interpretations are different from ours at present, ours will differ from future ones. As we have seen, charcoal and its properties was the subject of scientists' interest for a very long time. In difference to current research, efficient production, technical use and the quality of products build by the power of charcoal were mainly discussed. In this respect, the early charcoal research is more part of the technical history than anthracology. However, beside their technical use the comments of Biringuccio and Duhamel du Monceau for example, are an expression of general interest in the subject of charcoal. Observations like the durability of charcoal in the ground and the abiding shape of fibres during carbonisation were the base for the first modern anthracological studies. A differentiation of wood-diameters seems to be common knowledge of fireworkers since the time of Biringuccio. He too, like all scientists who worked on charcoal, explained the importance of distinguishing charcoal from different woods because of their different burning properties. Unfortunately the method for this distinction is not known. At least since the time of Monceau, the differentiation of several species by looking on the macroscopic pattern of charcoal like a carpenter on wood can be assumed.

Even if the motivation of the early charcoal researchers was different from ours today, many aspects of their work are still relevant for modern anthracological research. Any anthracological and archaeological research on kiln-sites, furnaces or brickworks is also part of the history of industry and technology, as the written sources are. Modern and ancient anthracologists are working on the same subject, just from different sides. If modern anthracology is able to distinguish the diameters and species of the used wood by analysing charcoal from a kiln site, the historical sources are able to give a hint if this kiln was meant to be for high quality charcoal or not for example. The written sources give us an idea about the technical knowledge, the theory of charcoal burning and the ancient quality standards and they enable us today to rate the work of ancient charcoal-burners.

CONCLUSION

With the exception of ancient descriptions of charcoal in antiquity, charcoal and its properties are a subject of interest for scientists throughout the last 500 years. While during the Renaissance mainly metalworkers and miners were interested in charcoal properties, the importance of this knowledge increased during the Baroque period. The permanent lack of fuel all over Europe and the increasing demand for resources forced miners, metal-workers, foresters, engineers, scientists and even the military officers to carry out research on charcoal and its economic and technical use. During the industrial revolution charcoal was more and more replaced as fuel by fossil coal, but the collected knowledge about charcoal now started to be used for palaeobotanical research. Paleoclimatic and ecologic research using information from charcoal samples is the most modern form of anthracology. Old intentions and interpretations of charcoal samples differ from ours today but many of the current questions have been discussed for centuries.

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Charcoal sample guidelines: new methodological approaches towards the quantification and identification of charcoal samples retrieved from archaeological sites

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***Summary**: A data set of over 17,000 charcoal fragments from 56 archaeological excavations located in the Irish midlands is used to develop recommended sampling protocols for archaeological charcoal analysis. The charcoal data were derived from three distinctive site types:* Fulachta fiadh *(burnt mounds), industrial and occupation sites. These sites range in age from the Neolithic to the Post Medieval Period. The analysis focused on saturation curves used to ascertain the minimum number of samples that should be collected from each site type to obtain consistent sampling. The same technique is also used to derive the optimal number of fragments that should be identified from each sample to obtain estimates of taxon identification and abundance. The precision of taxon proportion estimates from samples is also addressed. The* Fulachta fiadh *and industrial sites produced similar results which suggest that a minimum of 25 charcoal fragments from at least six samples per site should be analysed. For occupation sites a minimum of 17 charcoal fragments should be analysed from at least 24 samples. Higher fragment counts are required to achieve taxon proportion estimates with margins of error below 2.5%.*

***Key words**: Charcoal sampling methods, saturation curves, woodland resource usage, guidelines and recommendations, Ireland.*

INTRODUCTION

The reconstruction of past landscapes and landscape dynamics using archaeological wood and charcoal has been demonstrated through a variety of studies (Smart and Hoffman 1988; Heinz and Barbaza 1998; Asouti 2001; Dufraisse 2002; Asouti 2003; Nelle 2003; Marguerie and Hunot 2007; O'Donnell 2007; Veal 2009; O'Donnell 2011). Charcoal is the most frequent of the plant remains recovered during archaeological excavations and it is present in almost every archaeological feature and site type excavated. It is thus important to analyse and quantify the data produced from charcoal identifications using consistent and reliable methods especially when site types and dates vary (Asouti and Austin 2005).

Determining environmental change as well as arboreal vegetation reconstructions from charcoal samples relies on the systematic quantification of macro charcoal remains to ensure sufficient sample numbers and fragment counts are analysed for a complete and full understanding of the immediate environment. A key consideration for anthracologists involved in the analysis of charcoal samples is whether a representative sample set is being identified from archaeological sites to determine wood function, wood use and reconstruction of local woodlands. Previous recommendations for both optimal charcoal sample numbers to analyse and quantities of charcoal fragments to identify per sample vary hugely and are constantly debated (Miller 1985; Johannessen and Hastorf 1990; Thompson 1994, 1999; Asouti 2003; Veal 2009; O'Donnell 2011).

This paper aims to address two fundamental sampling issues facing anthracologists. The first is the optimal number of samples that should be analysed from a site and the second is the optimal number of charcoal fragments that should be analysed from each sample. These two aims will be addressed by analysing numerous samples from a range of site types covering several archaeological time periods. Meeting these aims will provide guidance for optimal sampling and analysis of charcoal from archaeological settings.

DATA AND RESULTS

Archaeological excavations associated with the construction of a major road across the midlands of Ireland provided a range of archaeological sites of varying ages. The study area is defined by a 61 km stretch of the N6 roadway between the towns of Kinnegad and Athlone (Egan 2007).

During excavation soil samples for flotation were systematically collected from each excavated context. The soil samples ranged in size from 0.1 litres to 40 litres but were on average 5 litres in volume. A mechanical flotation tank using a pump and water recycling system was used for soil flotation. The soil was washed using a 1mm mesh in the flotation tank and a 300 micron and 1mm sieve was used to catch floated material. Systematic 'grab sampling' of charcoal fragments was adopted because this method closely mirrors the day to day analysis of the anthracologist. Therefore a variety of different fragment sizes and shapes from 1mm upwards were used in the identifications (Smart and Hoffman 1988). Charcoal was identified by comparing the anatomical structure of fragments with known comparative material or keys (Schweingruber 1990).

Overall charcoal identification results from the whole data set show that *Quercus*, *Corylus avellana*, *Fraxinus excelsior* and *Alnus* are represented most frequently at all sites investigated although variation in dominant types can be ascertained between site types. The overall results from the data set are divided into five site types and graphed below (Fig. 1). These include *Fulachta fiadh,* industrial sites, isolated pit sites, occupation sites and burial sites. *Fulachta fiadh* are the most frequent archaeological prehistoric site found in Ireland; they are thought to have functioned as cooking troughs, sweat houses or bathing areas (Buckley 1990). Industrial sites include cereal kilns, charcoal production pits and metalworking activity while occupation sites include both Bronze Age habi-

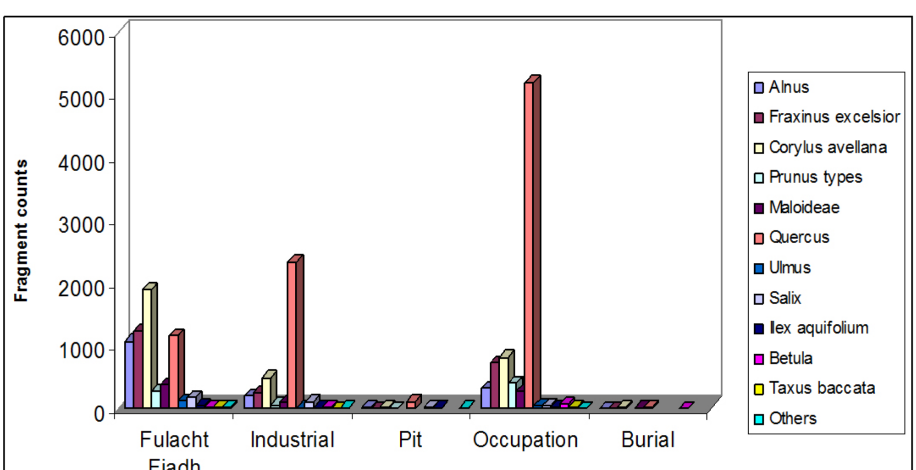

Figure 1. Total charcoal identifications per site type N= 17,997 fragments. Others = *Sambucus, Ulex, Euonymus, Viburnum, Cornus, Hedera*.

tation sites and Medieval dated ringforts.

Corylus avellana, *Fraxinus excelsior*, *Quercus* and *Alnus* are the major wood types identified from the *fulachta fiadh* sites followed by pomaceous fruitwood (Maloideae), *Prunus* types, *Salix,* and *Ulmus* also found in relatively frequent amounts. Small fragment counts of *Taxus baccata*, *Betula*, *Ulex europaeus*, *Cornus sanguinea, Euonymus europaeus* and *Viburnum opulus* were also identified.

Quercus dominated the industrial assemblage. The next most commonly identified taxon from the industrial features is *Corylus avellana* followed by *Fraxinus excelsior*, *Alnus*, *Salix* and Maloideae. Minor wood taxa represented included *Prunus* types, *Ulmus*, *Ilex aquifolium*, *Taxus baccata, Betula* and *Viburnum opulus*. *Quercus* again dominates the isolated pit category with *Corylus avellana*, *Salix*, *Alnus*, *Ilex acquifolium*, *Ulex*, *Prunus* types, and *Fraxinus excelsior* also present in smaller amounts. *Quercus* also dominated the pit features analysed while a smaller fragment count with a variety of taxa types were present in the burial data set (Fig. 1).

Occupation sites from all periods have higher quantities of *Quercus* wood accounting for 66% of the total occupation assemblage (Fig. 1). *Corylus avellana* represented 10% of the total charcoal count and *Fraxinus excelsior* 9%. Minor taxa (under 5% respectively) identified from the occupation sites included *Alnus*, *Prunus* types, Maloideae, *Ulmus*, *Salix*, *Betula* and *Taxus baccata*.

Cumulative saturation curves were constructed by adding successive samples or charcoal fragments cumulatively to determine whether the information provided by new samples or fragments is unique or redundant compared to information provided by earlier samples (Lymana and Amesb 2007). When no new information is obtained by the addition of more samples or fragments (i.e. taxon) the curve levels off and is said to be saturated.

The cumulative saturation curves for the optimal number of samples record the relationship between the number of samples identified per site and taxa diversity/recovery. The shape of the saturation curve can vary depending on the order of identification of samples and the number of fragments per sample so the data were displayed along three different curves. The samples were ordered either by: 1) ascending order of the number of fragments in each sample, 2) descending order of the number of fragments in each sample, or 3) the order in which they were identified (Fig. 2).

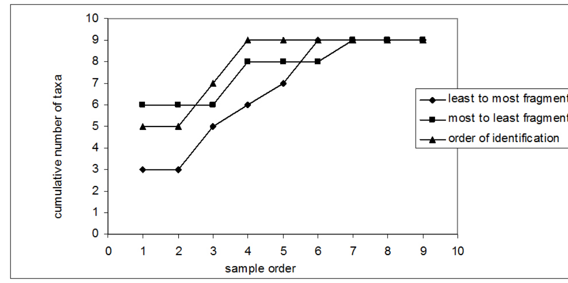

Figure 2. Example of a number of samples saturation curve, data from a Bronze Age *Fulachta fiadh* site.

Three hundred and six charcoal samples from 20 sites covering an age range from the Early Bronze Age to the Medieval were analysed to address the first aim of the number of samples to analyse per site (Table 1). In this paper we focus on the three most common site types excavated: *Fulachta fiadh,* industrial and occupation sites.

Site type	No. Sites	Mean no. samples (range)	Mean fragment count (range)	Mean Saturation point (±SE)
Fulachta fiadh	8	9 (4-16)	367 (141-645)	5.4 ±0.9
Industrial	6	8 (5-12)	507 (221-959)	5.7±1.2
Occupation	6	29 (4-72)	1317 (126-3463)	23.4±6.1

Table 1. Summary of site types, sample numbers and fragment numbers used to complete the cumulative saturation curves used to quantify optimal number of samples per site type.

The saturation curves illustrate that for both *Fulachta fiadh* and industrial sites at least six samples should be analysed but for occupation sites at least 24

Site type	No. Sites	Mean no. Samples (range)	Mean fragment count (range)	Mean Saturation point (±SE)
Fulachta fiadh	10	3 (1-6)	311 (102-467)	24.2 ±4.78
Industrial	3	4 (4-4)	740 (600-945)	23.9±5.7
Occupation	3	5 (1-8)	215 (100-329)	16.6±5.8

Table 2. Summary of site types, sample numbers and fragment numbers used to complete the cumulative saturation curves used to quantify optimal number of fragments to identify per sample.

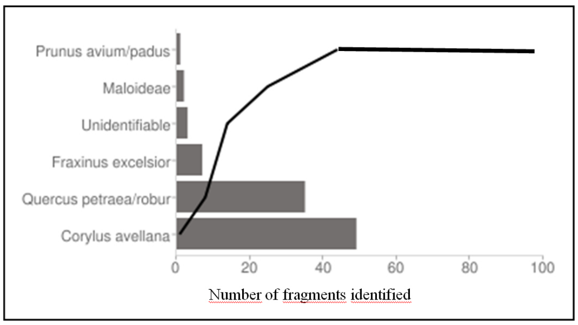

Figure 3. Example of a saturation curve for taxa occurrence within one sample (Early Bronze Age *Fulachta fiadh*). The line registers the fragment number from which a taxon was first recorded.

Fragment counts required to achieve 95% confidence in taxon proportions for a range of margins of error					
Margin of Error (%)	1	2	3	4	5
Fragment count	2401	600	267	150	96
Precision of determining taxon proportions at 95% confidence for a range of fragment counts					
Fragment count	30	50	100	200	500
Margin of Error (%)	8.9	6.9	4.9	3.5	2.2

Table 3. Precision of taxon proportions derived from subsets of charcoal fragments.

samples should be analysed (Table 1).

A total of 5,138 identified charcoal fragments from 61 samples were analysed to address the second aim of how many fragments should be analysed per sample (Table 2). One hundred fragments of charcoal were identified from samples used to create the saturation curve profiles. Saturation curves were drawn in the archaeological wood and charcoal database –WODAN (see Stuijts and O'Donnell this volume). The saturation point illustrates the point at which all new taxa have been identified from a sample so the levelling off of the curves can be used to determine the minimum number of fragments to identify to ascertain the taxa present in the sample (Fig. 3).

Saturation points tended to increase with the number of taxa identified but overall, fragment counts from *Fulachta fiadh* and industrial sites reached similar saturation points at around 25 fragments with occupation sites reaching saturation point by 17 fragments (Table 2).

The precision of estimates of the proportions of taxa from the subset of fragments identified was determined using standard equations (Moore and McCabe 2006). This reveals fragment counts in excess of 500 are required to achieve a 95% confidence of deriving taxon proportion estimates with a margin of error below 2.5% (Table 3).

DISCUSSION

By identifying the saturation points of taxa diversity from different site types through cumulative saturation curves we demonstrate important differences between site types. For both *Fulachta fiadh* and industrial sites the results are similar and suggest that optimal sampling should aim at the analysis of at least 25 charcoal fragments from at least six samples per site. For occupation sites at least 17 fragments should be analysed from at least 24 samples. The essential difference here is that greater effort should be put into a smaller number of samples for the first two site types while for occupation sites it is advisable to excavate a greater number of samples where less fragments need to be analysed. This variance in the data set is related to some selection of wood at occupation sites for structural features and therefore the more samples analysed the greater variety of taxa identified. Larger sample amounts are also expected from occupation sites and were also used in the cumulative saturation curve profiles.

Fulachta fiadh, a common Irish type site, required substantial quantities of fuel wood for heating processes and this wood would have been collected from whatever was closest to hand and was unlikely to have been deliberately selected. In the case of industrial sites it is expected that more wood selection was employed. It is thus surprising that both site types return such similar saturation points for both the number of samples and the number of fragments. However the results reflect the variety of the industrial sites which consisted of cereal kilns as well as metalworking and charcoal production pits. The recommendations therefore cover a broad spectrum of site types under the umbrella of 'industrial sites'.

It is important to note that the order in which samples are added to a saturation curve influences the sample size at which the saturation curve levels off (Lymana and Amesb 2007). In this investigation some variation in the saturation point was observed when data were collated in three different orders: 1) ascending order of the number of fragments in each sample, 2) descending order of the number of fragments in each sample, or 3) the order in which the author identified them. For this reason it is important to note that the saturation points are absolute minima and that sampling should include more samples to reduce the impact of ordering. These recommendations are intended to provide minimum sampling and analysis requirements to ensure reliable capture of the taxa that are represented within the charcoal excavated from archaeological sites but the precision of proportion estimates of these taxa is also dependent on fragment counts which will need to be much higher if margins of error below 2.5% are desired.

The results are in line with previous recommendations, albeit at the lower end of the spectrum, by Keepax (1988) and Asouti (2001) of between 25 and 100 samples and fit with current practice in Ireland which is to identify between 30 and 50 fragments per sample where possible (Stuijts 2007; OCarroll *et al*. forthcoming). The low saturation points when compared with studies by Chabal *et al* in France (1999) and Veal (2009) in Pompeii may be accounted for due to lower taxa diversity both within the samples and in Irish woodlands. It is however important to note that the levelling off of saturation curves is not wholly a function of the number of examined fragments but also depends on the spatial extent of the sample population across the excavated level (Badal-Garcia 1992). It was possible to clearly define and constrain the site types within our investigation and so has probably also contributed to lower saturation points. Needless to say, where this level of constraint is not possible, then it would be advisable to increase the sample and fragment numbers.

CONCLUSIONS

The saturation curves illustrate important differences between site types. For both *Fulachta fiadh* and industrial sites the results are similar and suggest that minimum sampling should aim at the analysis of at least 25 charcoal fragments from at least six samples per site. For occupation sites a minimum of 17 fragments should be analysed from at least 24 samples. These recommendations are intended to provide **minimum** sampling and analysis requirements to capture the range of taxa that are represented within the charcoal excavated from archaeological sites but the precision of proportion estimates of these taxa is also dependent to fragment counts which will need to be much higher if margins of error below 2.5% are desired. These analyses were confined to three site types that were commonly found in the study area. Due to their rarity other distinctive site types, for example, cremation/burial sites, were not included and thus do not fall within these recommendations.

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Correction factors on archaeological wood diameter estimation

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***Summary**: This paper proposes two correction factors designed to improve the accuracy of dendrometric tools. The development of a referential framework on* Pinus halepensis *suggests that the "trigonometric tool" is the most appropriate technique for this estimation. The error rates associated with this tool are proposed as a first correction factor on archaeological measurements. The second correction factor is related to wood shrinkage. The percentage of radial and tangential shrinkage on* P. halepensis *sections is calculated. A test that applies this corrective factor on trigonometric measurements shows that tangential correction is more accurate than radial for treating archaeological data. Finally, an example of the application of both correction factors in the prehistoric site of Barranco de la Viuda is presented.*

***Key words**: Dendrometry, firewood,* Pinus halepensis*, Bronze Age, Iberian Peninsula.*

INTRODUCTION

Archaeological charcoals reflect management patterns of forest areas in the past. In addition to the species, an important criterion of wood selection could be the diameter, which influences aspects such as the intensity and duration of fire. Therefore, the development of dendrometric tools designed to estimate the calibre of prehistoric exploited firewood is an important line of research in anthracology.

The measurement of the radius of the curvature of growth rings involves calculating the distance between the pith (absent) and the charcoal fragment under study. Following early studies based on the degree of ring curvature (Lundström-Baudais 1986; Marguerie 1992; Ludemann and Nelle 2002; Dufraisse 2002, 2006; Marguerie and Hunot 2007), image analysis software has enabled the implementation of more accurate qualitative techniques such as the "circle tool" (Chrzazvez 2006) or others based on trigonometric principles (for a state of the art, see Dufraisse and García Martínez 2011).

The application of these tools involves a margin of error on the result. Its accuracy depends on the technique used, the distance from the pith, the wood anatomy and the intraspecific variability. This problem must be addressed through the development of referential frameworks that assess the reliability of these techniques for different species. In this research, a referential framework that evaluates the "circle tool" and the "trigonometric tool" on *Pinus halepensis* sections is presented. The percentages of error obtained serve as the first corrective factor on measurements made on archaeological charcoals (García Martínez and Dufraisse 2011).

Another factor that influences the calculation of the archaeological wood calibre is the shrinkage caused by carbonization. This shrinkage occurs in all directions (radial, tangential and longitudinal) and is influenced by physical variables such as length, thickness or density (Perstorper *et al.* 2001; Washusen and Ilic 2001; Clair *et al.* 2003) and chemical variables, such as the composition of the woody cells (Leonardon *et al.* 2010).

It has been noted that generally this shrinkage would be around 25% (Schweingruber 1978). Some experiments at 900°C observed a radial reduction close to 30% and tangential up to 40% (Byrne & Nagle 1997). The shrinkage of the vessel diameters of early *Quercus robur* wood was between 20-25% at 400°C and 40% at 1000°C (Braadbaart and Poole 2008). Davidsson and Pettersson (2002) observed tangential shrinkage between 25-40% and radial of 15-40%, with maximum tangential shrinkage at 400ºC and radial between 500-700 °C.

The application of this second correction factor on archaeological wood calibre estimation implies addressing new questions such as (1) if the shrinkage is homogeneous in the different parts of the wood (centre / periphery, compression / opposite wood) or (2) under what criteria it is possible to integrate this correction value with the use of dendrometric tools. To demonstrate this, an exploratory approach on the shrinkage experienced by two *Pinus halepensis* sections is proposed. Subsequently, an experimental test makes it possible to evaluate the most appropriate way to combine these two correction factors on charcoals found in an archaeological context.

Finally an example of the application of these correction factors on firewood from the prehistoric site of Barranco de la Viuda (SE Spain) is presented.

METHODS

REFERENTIAL FRAMEWORK

The referential framework has been developed using two fresh and charred *Pinus halepensis* sections sampled from the Region of Murcia (SE Iberia). The section 1 (R1) belongs to a 55-year-old tree which was 19.5 x 19.5 cm in diameter (without bark). The section 2 (R2) comes from a 30 year-old pine tree and was 17 x 15.5 cm in diameter. The carbonisation was conducted in a muffle furnace at 300 °C, without oxygen supply, for 2'45'' (R1) and 2'30'' (R2).

Measurements were made with binocular (x10) and NIS Elements D 3.1 image analysis software, on a surface of 0.84 x 0.63 cm. The "circle tool" generates a perfect circle from several reference points positioned on the edge of the growth ring. Between 15 and 20 reference points for each ring under study were marked. The "trigonometric tool" was applied by tracing the angle formed by two wood rays and the perpendicular distance between them. The radius of growth ring curvature was calculated by using the right triangle trigonometric formula (hypotenuse = opposite side / sine α). For this tool, a preliminary series of measurements made it possible to determine the minimum angle and distance values required to avoid systematic occurrence of marginal results, 3 degrees and 3 mm. This first stage also enabled the most appropriate diameter classes for this species: [0-2] cm, [2-5] cm, [5-10] cm, [10-14] cm, > 14 cm to be established. The dataset consists of 1882 measurements (Dufraisse and García Martínez 2011).

TEST ON WOOD SHRINKAGE

The experimental test on wood shrinkage has been conducted using two *Pinus halepensis* sections. The first one (R3) was 19.6 x 19.5 cm in diameter and the second one (R4) was 6.8 x 6.1 cm. Both of them were scanned to create a cross-shaped planimetry (Fig. 1) on the surface to obtain data concerning compression, opposite and normal wood. References indicating diameter classes, preset distances (1 cm for R4 and 2 cm for R3) and reference growth rings were marked.

The carbonization was conducted in a muffle furnace at 400 °C under reduction conditions, for 2’30’’. Charred sections were scanned and the planimetry was adjusted to the shrinkage incurred. Then, comparative measurements of benchmarks to calculate percentages of radial and tangential shrinkage (opposite distance and angle) were made.

Finally, a test developed to correct the trigonometric measurements with these shrinking percentages was conducted. The radial correction was calculated by adding the average shrinkage percentage to the raw result. For the application of tangential correction, we firstly corrected the raw angle and opposite distance measurements, and then the radius was calculated.

RESULTS

REFERENTIAL FRAMEWORK

The referential framework compares the actual radius of the studied growth ring with the result obtained using dendrometric tools. The difference between them has been expressed as a percentage of error.

The average percentage error of the trigonometric tool is around 25%, while the circle tool error reaches 50%. The median is also lower with the trigonometric tool (between 19-22%), whilst it exceeds 25% for the circle tool. Therefore, the trigonometric tool proves to be the most appropriate technique to calculate *Pinus halepensis* calibres.

Results of reliability graphs by diameter classes have already been described in a previous publication (Dufraisse and García Martínez, 2011). These showed that the circle tool is accurate only for diameters less than 2 cm, acceptable up to 5 cm and demonstrates predominantly marginal results for calibres exceeding 10 cm. The trigonometric tool provides very reliable measurements (above 50%) up to 10 cm in diameter. The margin of error increases for larger diameters, however unreliable measurements are a minority. In both cases, the results are reproducible across all fresh and charred sections. Consequently, trigonometry would also be better suited to estimating *Pinus halepensis* calibres considering diameter classes.

TRIGONOMETRIC TOOL CORRECTION

The validity of the circle tool to estimate *Pinus halepensis* calibres being dismissed, the correction applied on archaeological charcoals will take into consideration only the trigonometric results.

We notice that the trigonometric tool involves an overestimation of small diameters (less than 10 cm) while an underestimation of the larger ones. The correction values have been established by calculating the average percentage error (including positive and negative percentages) for each diameter class studied. It is necessary to apply a different correction value on each diameter class (García Martínez and Dufraisse 2011) and the correction curve provides increased accuracy for diameters between 5 and 10 cm (Fig. 2).

WOOD SHRINKAGE

The shrinkage experienced by the wood sections following carbonization demonstrates no significant differences between compression, opposite and normal wood. R3 and R4 radial shrinkage is about 20% and similar values are given in the tangential direction. The percentage reduction of angles formed by several reference points is around 3% (Table 1).

SHRINKING CORRECTION

The criteria for applying this correction factor on trigonometric measurements were evaluated by means of an experimental test. We seek to determine which

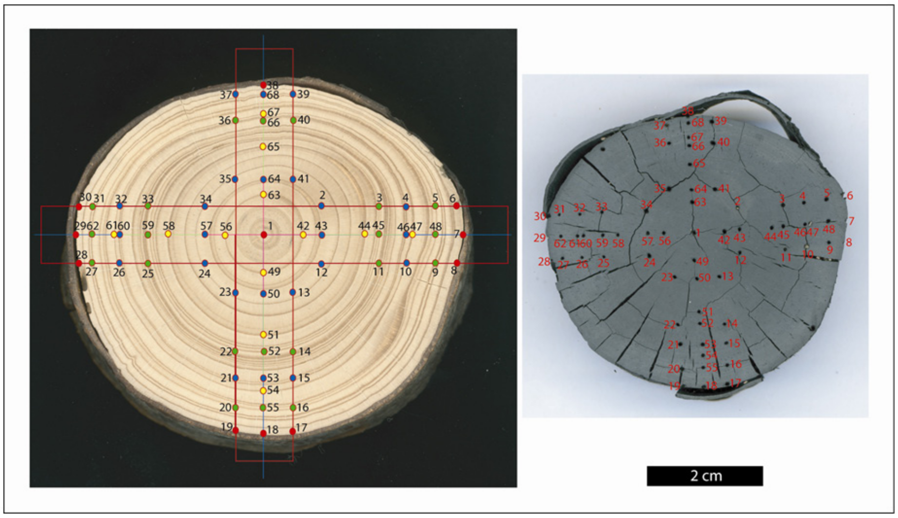

Figure 1. Cross-shaped planimetry designed on the section R4. Shrinkage is clearly noticeable in carbonised section.

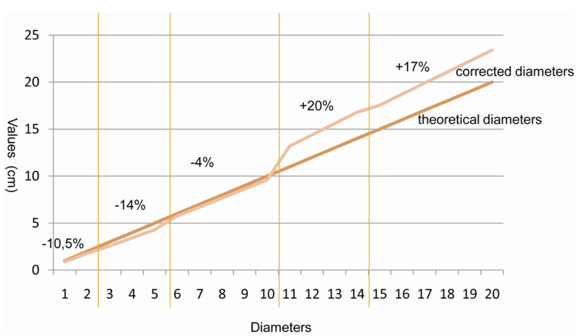

Figure 2. Correction values to be applied on the archaeological trigonometric measurements.

shrinking correction (radial or tangential) provides a more reliable approach to the initial diameter of exploited firewood.

The average percentage error of raw trigonometric measurements is around 7%, but shows very high standard deviation (Table 2). The shrinking correction applied to raw data provides the best results. The radial correction provides very accurate corrected measurements, with the average margin of error decreasing to 1.8%. The average percentage error is almost zero when applying tangential correction (0.004%). The standard deviation is similar in both cases, being slightly lower for tangential correction. Even though differences are not notable, tangential correction can be considered as the most appropriate corrective factor for measurements on archaeological charcoals, due to the slightly lower error rates (Table 2).

AN ARCHAEOLOGICAL EXAMPLE: BARRANCO DE LA VIUDA (SE SPAIN)

The dendrometric measurements and correction factors proposed have been tested on the Bronze Age site of Barranco de la Viuda (*c.* 3400 BP). Here, the anthracological spectrum is dominated by *Pinus halepensis* (García Martínez *et al.* 2010, 2011). 384 charcoal fragments from two archaeological levels (I and II) and two structures associated with level II (a vessel-ashtray and a fireplace) were measured (Fig. 3).

Level I, Level II and the vessel-ashtray provide similar raw measurements. Small calibres are dominant; especially between 2 and 5 cm. Diameters between 5 and 10 cm have acceptable percentages while large diameters are a minority. None of these contexts show charcoals larger than 14 cm in diameter. The fireplace shows some differences compared with the other contexts. Firewood between 2 and 5 cm was also mainly used, but diameters between 0-2 cm are not well represented. For this structure, medium and large calibres have notable percentages and raw data show the presence of wood over 14 cm in diameter.

Diameter classes (cm)	R3 Radial Shrinkage (%)	R4 Radial Shrinkage (%)	R3 Tangential Shrinkage (Distance) (%)	R4 Tangential Shrinkage (Distance) (%)	R3 Tangential Shrinkage (Angle) (%)	R4 Tangential Shrinkage (Angle) (%)
[0-2]	22.9	21.25	18.9	20.25	0.76	3.36
[2-5]	17.63	23.32	19.58	22	6.97	2.34
[5-10]	17.79		22.41		3.17	
[10-14]	20.94		19.67		1.71	
[>14]	22.38		20.97		4.25	
Average Shrinkage	20.328	22.285	20.306	21.125	3.372	2.85

Table 1. Percentages of radial and tangential shrinkage experienced by *Pinus halepensis* sections.

Diameter classes (cm)	Raw data - Percent error	Corrected data - Percent error	
		Radial correction	Tangential correction (distance + angle)
[0-2]	163.9161961	8.564297085	2.629656031
	-8.560718894	1.07594019	6.409961156
	-18.8	-10.19073721	-6.215135623
	1.290130885	13.05725543	17.37234018
	-4.427394294	5.78044635	13.49521115
[2-5]	17.45732643	16.63399444	0.379964597
	6.721853593	5.631636891	0.250854678
	11.5339181		1.319274422
	-15.35870986	-0.90689968	-2.006457473
	-11.44144771	3.581313065	7.628330829
	-14.4558236	3.242803003	2.330492623
	-19.07458572	-7.943372759	-2.665990228
[5-10]	5.272752085	-2.203774391	-7.427471243
	15.31667139	-10.87972745	-5.433260499
	10.56905128	-1.261300024	-3.663267027
[10-14]	-6.75568934	1.686532077	-2.070385846
	-4.063044736	-5.120717076	-5.515868927
	22.95336833	5.869721595	-4.609488265
	9.682938091	-2.487278811	-2.395795689
[>14]	-7.175084958	2.768009026	
	17.31929505	5.472365732	0.959572517
	3.522599781	5.629975431	-9.432214487
	-1.453592416	2.341492748	-1.246553608
Mean	7.56478	1.83373	0.00426224
Median	1.29013	2.55475	-1.62651
Standard Deviation	36.2101	6.80777	6.54108

Table 2. Results of the test designed to combine shrinking correction with trigonometric measurements.

Corrected data show some changes with respect to the raw measurements. In general, the distribution of the different diameter classes is similar, with a dominance of small calibres. 5-10 cm diameter class is also well represented. The correction of the results has highlighted the emergence of firewood larger than 14 cm in diameter in all studied contexts. This correction could also increase the percentage of diameters between 10 and 14 cm where they were weak.

Therefore, firewood exploitation in Barranco de la Viuda was primarily directed towards small-calibre branches, and especially up to 5 cm in diameter. These

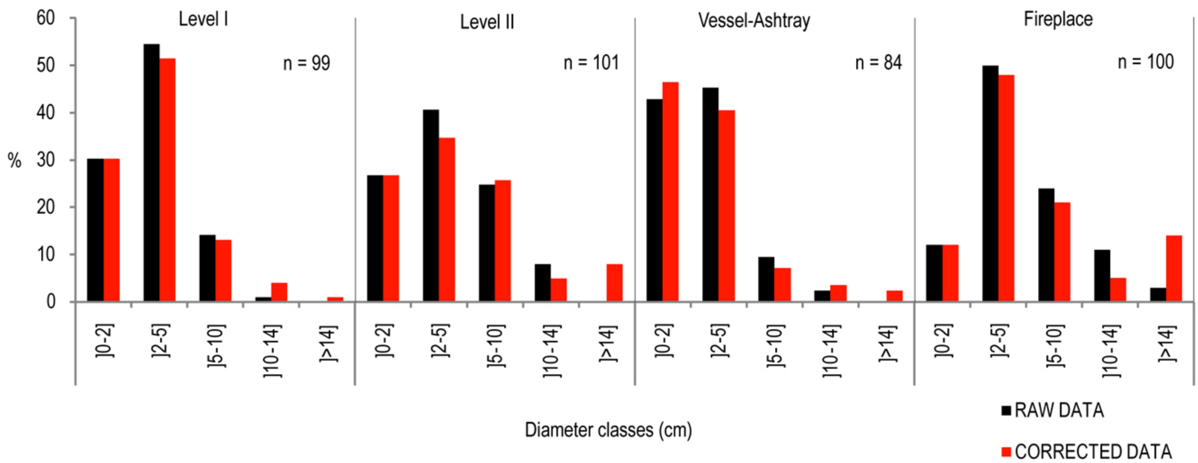

Figure 3. Raw and corrected measurements made on Barranco de la Viuda charcoal fragments.

branches were possibly dead branches recovered from the ground or damaged branches ripped straight from the trees. The presence of saproxylophagous species of Buprestidae, Cerambycidae and Siricidae families in some of these branches would confirm this hypothesis. Conversely, in the studied contexts there is a less significant presence of high calibre wood, while data correction reveals some trunk fragments larger than 14 cm in diameter, but less than 20 cm. This can suggest occasional but not systematic felling of whole trees. This activity could be linked to the periodic supply of firewood to the combustion structures associated with roasting and processing of cereal activities documented in the site. The presence of trunks of this size is also a possible indicator of the opening stage of the surrounding vegetation, which could have reduced the range of exploitable resources.

CONCLUSIONS

In this paper, we have proposed two correction factors that expand the accuracy limits of methods for estimating the radius of growth ring curvature on archaeological charcoals.

The development of a referential framework on *Pinus halepensis* sections has confirmed that the circle tool is inappropriate for this estimation. In contrast, the trigonometric tool provides reliable results. The error rates associated with the application of this tool for each diameter class studied have been proposed as a first correction factor on raw archaeological measurements.

The second correction factor is related to wood shrinkage. The experimental carbonisation of pine sections made it possible to calculate the percentage of radial and tangential shrinkage. A test designed to apply this corrective factor on trigonometric measurements shows that tangential correction is more accurate than radial for treating archaeological data.

Finally, an example of the archaeological application of both correction factors has been presented. In the prehistoric site of Barranco de la Viuda the patterns of firewood exploitation were focused on collection of thin branches. Correction of the raw data has highlighted the minority use of firewood larger than 14 cm in diameter.

This paper opens up new research perspectives. A more complete understanding of prehistoric patterns of wood calibre exploitation requires the development of referential frameworks for other tree species. The test of wood shrinkage presented here is exploratory. In the future, it will be necessary to increase and diversify experimental criteria, such as temperature, species and wood properties.

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Cloud-computing in Anthracology – Experiences with the WODAN online database in Ireland

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***Summary**: The WODAN charcoal and wood database was launched in 2011, from INSTAR funding received through the Heritage Council in Ireland (Ref grants 16679, 16705 and AR01042, 2008-2010). The WODAN project established an online database for wood and charcoal from archaeological sites which can also be used to store literature. The database itself may serve a multitude of purposes but first and foremost it is a digital archive using cloud-computing. The datasets can facilitate scientific research as well as optimise future sampling strategies. WODAN helps to identify key research agendas for environmental archaeology. This will feed back to other aspects of archaeology, thus facilitating more fully integrated archaeological reports and unlocking data for interdisciplinary research. Another key aim currently being achieved is the standardization of charcoal and wood analysis methods in Ireland.*

***Key words**: WODAN, cloud-computing, database, charcoal, standardization.*

INTRODUCTION

In 2007, specialists working on wood and charcoal analysis from Irish archaeological sites came together to form the Irish Wood Anatomists Association (IWAA). Discussions within this group flagged the issue that specialists were using different methodologies for charcoal quantification. Archives of wood and charcoal identifications were stored in various ways. Some were on paper as part of site archives, some as excel sheets and others within project based databases. During these meetings, the idea of a centralized database for wood and charcoal results, available to everybody, was born. It was clear also that the recording methods used by the specialists also needed to be standardized. INSTAR offered us the opportunity to materialize the wishes and create a database. Here, the WODAN database and its initial results are presented. One case study using WODAN (Tulsk, County Roscommon) is shown, as well as future prospects for using the database.

APPROACH

The WODAN database holds wood and charcoal data in the form of identifications, wood technology and usage, dating and general site information. These data are especially useful for reconstructing past vegetation histories and for studying human factors in woodland development. The records suggest future research areas and demonstrate optimal sampling strategies. The database will form a sustainable and integrated repository of Irish data, supported by all wood specialists working in Ireland, with a potential to host international data (Stuijts 2008).

An international dimension was established by collaboration with several partners, including Dr Otto Brinkkemper (Cultural Heritage Agency, Amersfoort, Netherlands), Prof Dr Mitchell Power (Geography Faculty, Utah, USA), Prof Dr Oliver Nelle (Ecology Center CAU, Kiel, Germany), and BIAX *Consult* (Zaandam, Netherlands). These contacts have been instrumental in highlighting the differences between methodologies employed on the continent and in Ireland.

Initially, interest for a database was evaluated through a survey. Ideas were also compared and discussed with designers of existing databases. European methodologies were reviewed to reach a consensus for Ireland. After consultation with our partners, the database was designed to allow both European methods (recording information per single fragment) and Irish/British methods (recording information per taxon) (Stuijts *et al*. 2008/2009).

A hierarchical system of recording was developed (Figs. 1 and 2). The data model employed within WODAN allows users to record information at many levels, from the archaeological site down to individual fragments of charcoal and wood. Where possible the WODAN application also utilizes consistent and standardized terminology for specialists to describe their samples, enabling greater success in comparative analysis.

The construction of the WODAN web application has employed as much open source software as possible, thus enabling a more sustainable data resource for future researchers to utilize. Help functions which demonstrate how to use the site are online. Templates have been designed assisting in recording of site, sample and charcoal fragment information.

Figure 1. Introduction page to WODAN.

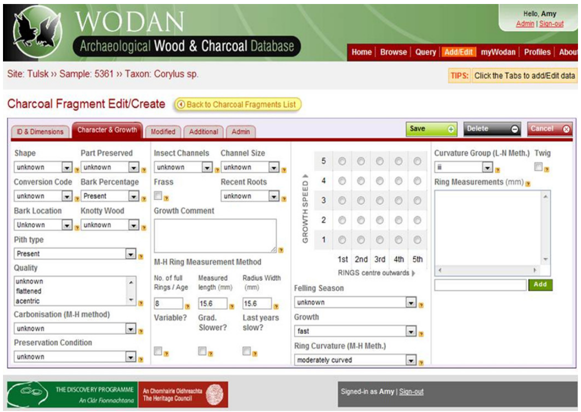


Figure 2. Detailed recording of charcoal at Fragment level.

WODAN includes the possibility to create an individual research (MyWODAN). Each specialist can thus add their own identifications and essentially create their own, personal archive. Specialists can choose to make results available on a site by site basis. The results are accessible to be browsed and queried by everybody, except in cases that specialists choose to keep their results from view for their own use (Stuijts *et al*. 2010; Stuijts and O'Donnell 2011).

The development of an online database is a fundamental departure from other environmental databases. By using cloud-computing, the catchment area of the database may be greater than previously designed environmental databases. Internet hosting allows the data to be searchable, uploadable and always relevant and up-to-date, independent of locality.

Queries were designed allowing research of particular fields in the database. These produce pro-formatted tables for incorporation into reports. This latter possibility has already been used in a number of reports and doctoral research (O'Donnell 2011).

The database is implemented with Ruby on Rails 2.0. MySQL, Apache and Passenger Phusion are used to manage the persistence and serve the content. The Project is using cloud computing, the database is hosted from the agency Blacknight.

CASE STUDY 1: TULSK, CO. ROSCOMMON

The site of Tulsk in County Roscommon was excavated by the Discovery Programme between 2004 and 2009. The licensed director was Dr Niall Brady and the excavation team largely comprised students during 12 weeks each summer. The WODAN database has been instrumental in charcoal and wood analysis from the site.

Tulsk is a multi-period site within the O'Connor Roe gaelic lordship. Tulsk is located on a natural mound overlooking significant lowlands at the crossroads of two ancient routeways (Fig. 3). Iron Age occupation was revealed during excavation, before the construction of an early medieval ringfort. This rath was later raised and subsequently divided when a tower house was constructed to the north-western side. Ditch fortifications were re-dug but were later built over following the final collapse of the tower. Later medieval occupational evidence is located just off the mound while the top of the mound is truncated during Elizabethan military garrisoning.

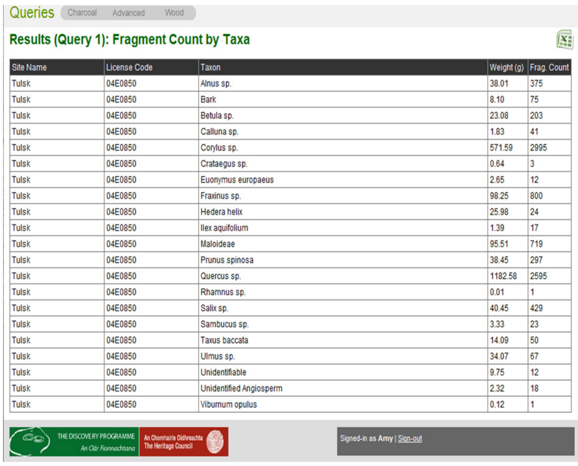
Figure 3. The archaeological site at Tulsk.

The site was systematically sampled with at least one sample from each context. Some significant contexts, such as the main fills of the external ditch and the base of the garderobe chute, were 100% sampled. Sample sizes range from handpicked individual lumps to small bags with 0.5ℓ soil samples, to large buckets with 10ℓ of soil. Almost all samples were floated in the field resulting in charcoal fragments in both the residue (retent) and as part of the floated material (flot).

A significant number of samples consists of hand-picked charcoal fragments. These charcoal samples can be compared to the identified charcoal from retent and flot remains. To date all analyzed samples (N=410) have been entered into the WODAN database and manipulation of the data is now possible.

The sampling technique of the Tulsk samples makes it particularly relevant because it includes all contexts and not just the 'interesting' data. Although this has led to many samples being comprised of just a few fragments, in many samples a broader picture of species selection can be seen. Whether the larger samples have also managed to produce saturated results (see Fig. 9), whereby the limit of species present is deemed to have been reached after a certain amount of counting with no new species identified, remains to be seen. However the discipline during analysis necessary for a saturation curve to be produced, that of not visually selecting in which order to analyse fragments, was closely followed therefore any bias within the material will be that of on site selection rather than bias introduced during post-excavation.

The vast majority of samples taken were from the medieval layers (early to late medieval) as these were the ones encountered most frequently on site. Using the pre-built query 1 within the database produces a


Queries Charcoal Advanced Wood

Results (Query 1): Fragment Count by Taxa

Site Name	License Code	Taxon	Weight (g)	Frag. Count
Tulsk	04E0850	Alnus sp.	38.01	375
Tulsk	04E0850	Bark	8.10	75
Tulsk	04E0850	Betula sp.	23.08	203
Tulsk	04E0850	Calluna sp.	1.83	41
Tulsk	04E0850	Corylus sp.	571.59	2995
Tulsk	04E0850	Crataegus sp.	0.64	3
Tulsk	04E0850	Euonymus europaeus	2.65	12
Tulsk	04E0850	Fraxinus sp.	98.25	800
Tulsk	04E0850	Hedera helix	25.98	24
Tulsk	04E0850	Ilex aquifolium	1.39	17
Tulsk	04E0850	Maloideae	95.51	719
Tulsk	04E0850	Prunus spinosa	38.45	297
Tulsk	04E0850	Quercus sp.	1182.58	2595
Tulsk	04E0850	Rhamnus sp.	0.01	1
Tulsk	04E0850	Salix sp.	40.45	429
Tulsk	04E0850	Sambucus sp.	3.33	23
Tulsk	04E0850	Taxus baccata	14.09	50
Tulsk	04E0850	Ulmus sp.	34.07	67
Tulsk	04E0850	Unidentifiable	9.75	12
Tulsk	04E0850	Unidentified Angiosperm	2.32	18
Tulsk	04E0850	Viburnum opulus	0.12	1

THE DISCOVERY PROGRAMME An Clár Fionnachtana
An Chomhairle Oidhreachta The Heritage Council
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Figure 4. Tulsk charcoal results: frequencies and weight per taxon using query 1.

pre-formatted table with the results for Tulsk (Fig. 4). The fragments counts and weights can easy be exported and graphically represented.

An interesting facet of the Tulsk data is comparing the charcoal from the processing retent and that from the floated material, who were analysed separately. An example within the database can be found with sample 3590. This was sampled from context 3152, a later medieval ditch fill from the internal ditch 4317 in area 3C. The flot was relatively small while the retent was 1.5ℓ in volume from a 10ℓ soil sample.

There are only a limited number of species within the flot (Figs. 5 and 6) when comparing to the retent. *Quercus* (oak) dominates the retent (Figs. 7 and 8, five

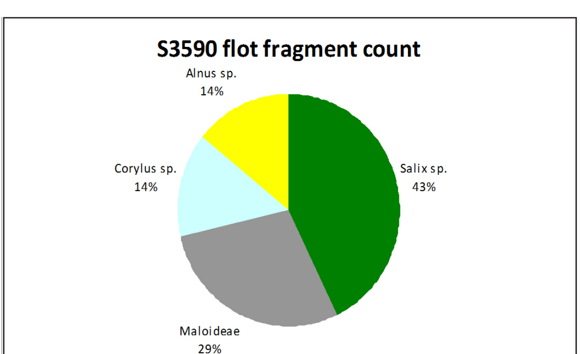

Figure 5. S3590, Flot fragment count.

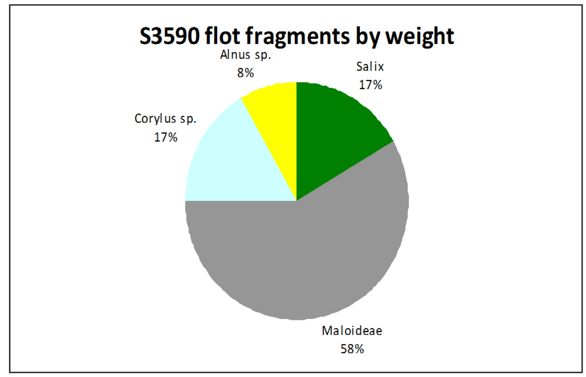

Figure 6. S3590, Weight of flot fragments.

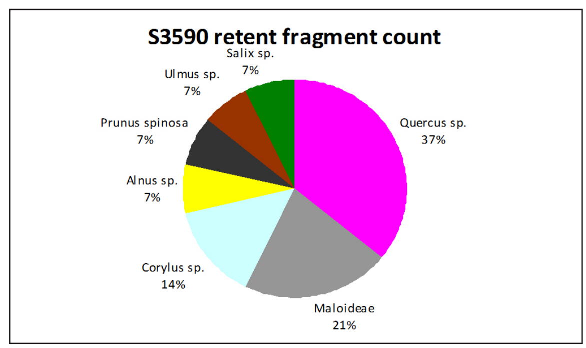

Figure 7. S3590 Retent fragment count.

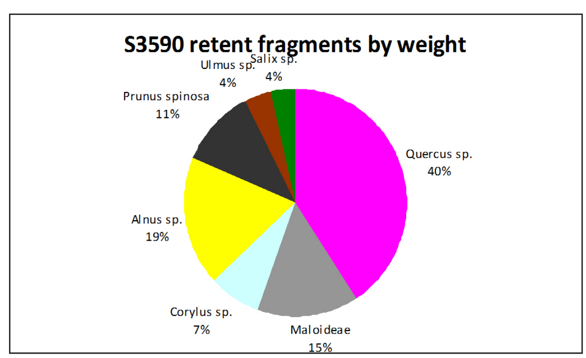

Figure 8. S3590 Weight of fragments in retent.

fragments), but is absent from the flot. *Salix* (willow) is perhaps the species most affected by the difference between flot and retent results, but a larger sample size would be preferable to really draw conclusions since this is based on seven flot fragments and 14 retent fragments. Still, this provides a substantially more valid picture of the species represented within this context than that produced by hand-picked samples from the site.

Most significantly the results from sample 3590 reasonably closely match that of the dominant species from the site as a whole (Fig. 4). Those outliers from the whole site results are context specific with *Calluna* sp. (heather/ling), *Ilex aquifolium* (holly) and *Sambucus* sp. (elder) being largely from individual contexts while *Taxus baccata* (yew) represents a possibly worked piece that has later been disposed of in fire.

In general the WODAN database enables results to be quickly pulled up and whole site trends observed. Advanced queries can isolate stratigraphic variations and saturation curves can confirm that a sample is statistically valid. It is a valuable tool even before post-excavation work has been completed and, perhaps most importantly, enables anyone to use the same data to produce results tailored to their specific queries.

CASE STUDY 2: SATURATION CURVES

One key aim of the WODAN database is to produce simple and effective saturation curves. When analysing a sample, the specialist notes at which fragment number each new taxon occurs. Saturation curves then plot this data graphically (Fig. 9). When curve line levels off, the sample is considered to be 'saturated'. This is a new area of research for charcoal

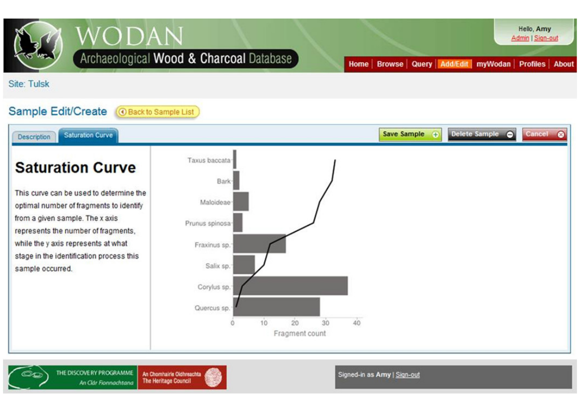

Figure 9. Saturation curve example.

data from both Irish and British sites, though this has already been good practice in France and Netherlands for some time.

The method using saturation curves has recently been used in the course of doctoral research to produce guidelines on the number of fragments to identify from prehistoric sites in Ireland (O'Donnell 2011). By examining cumulative saturation curves, it is thus advised to identify at least eighty fragments per sample.

CASE STUDY 3: STANDARDIZATION

In order to design a database with relevant information it was important to ensure wood specialists are recording similar information from their samples. Thus standardization of methods formed an integral part of the database design. Analysis of archaeological wood and charcoal is a relatively new discipline, and Ireland is a small country. It became integral to research the standards and recording methods in other countries in order to come to the consensus on the methods the IWAA would use. It was also vital to be able to incorporate as many methodologies as possible as this would greatly add to the internationality of the database. For these reasons, the methods used particularly by European specialists were researched. Specific thought was given to the French methodologies used, as the Montpellier and Valbonne schools in France (Vernet 1968; Chabal 1992). This research resulted in the WODAN database design incorporating identifications at the Taxon level (grouped recordings by species identification) and at the Fragment level (single recordings per each fragment of charcoal) (Fig. 10).

Other methodologies of recording were also incorporated in the WODAN database, including a template recording sheet from Ludemann and Nelle (2002) and a recording method used by Marguerie and Hunot (2007). Furthermore, it was vital that the database could be linked in with as many other existing databases as possible. For these reasons

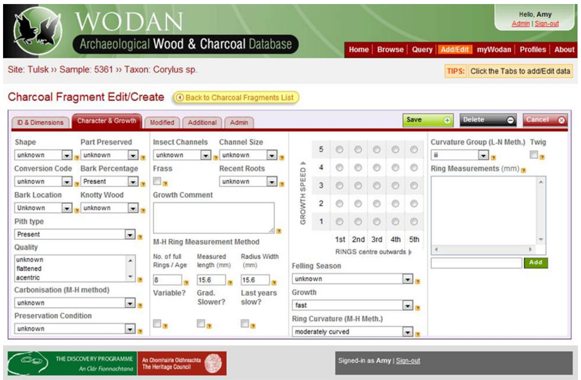

Figure 10. Character and growth, fragment level.

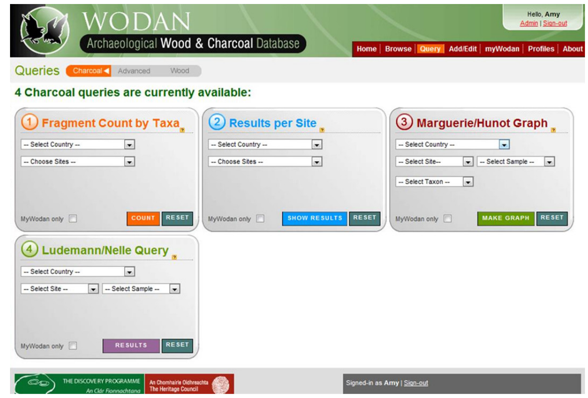

Figure 11. Query interface of the database.

linking fields were used for WODAN which in the future will allow collaboration between the DCCD and TriDAS database.

Wood specialists in Ireland have now agreed to use standard methods of recording charcoal observations. Further standardization is achieved by queries incorporated in WODAN (Fig. 11). These produce several pre-formatted tables which results in all the specialists using the same tables and graphs within their reports. The standard tables were used to present charcoal from O'Donnell's doctoral research (2011).

FUTURE AIMS AND RESEARCH EXAMPLE

Due to the time constraints imposed, it was not possible to achieve everything in the original aims of the WODAN project. Further development would include a rapid data entry tool; a computer programme tailored to a particular specialist or project. The programme would automatically incorporate data from excel sheets currently in use. Feedback from the user community also flagged the need for further development of the worked wood forms, for example to incorporate components of domestic wooden artifacts.

We would like to apply for future funding to enter existing charcoal and wood information into WODAN.

WODAN has already been used to store and standardize charcoal data from two doctoral research projects (O'Donnell 2011; O'Carroll and Mitchell 2011; O'Carroll 2012). In the future it will be used for other research in Ireland, such as a PhD project entitled '*Wood management and resource use in Medieval Ireland: An environmental and landscape study'*. This will be undertaken by Susan Lyons commencing October 2012 through the Department of Archaeology at University College Cork.

The project will use a multi-disciplinary approach to provide a better understanding of wood use and woodland dynamics in Ireland during the medieval period (500-1550AD). Charcoal identification analysis will form the primary basis for this research, which will be supplemented by archaeological evidence, historical sources and other palaeo-ecological disciplines, such as pollen records and plant macrofossils.

The study area for this research will be a section of the M8 (N8) road corridor running northeast to southwest through County Tipperary in the south of Ireland and includes the medieval town of Cashel and medieval monastic site at Toureen, Peckaun. A total of 6432 charcoal fragments from 318 features associated with 14 medieval sites have been identified to date from this area (Lyons in progress). At Toureen, Peckaun, located c. 15 km south of Cashel, a total of 2527 charcoal fragments from 59 features associated with occupational and industrial activity have also been identified and analysed (Lyons 2010). Charcoal samples for this research are selected based on a broad range of parameters which will include date of site, type of site, relationship of sites to each other, context of specific samples and their relationship to a feature or group of features.

The WODAN Wood and Charcoal Database will play a significant part in this research. Primarily, the database will serve as a central storage facility where all metadata recorded will be entered into a personal archive (MyWODAN) which will allow query building and comparative analysis with similar datasets.

One aspect of the PhD research will be to discuss the wood-pasture tradition in medieval Ireland and the effects of clearance for settlement and agriculture on local woodland. The detailed list of site and context classifications within WODAN will assist to filter out the relevant sources required to record large areas of occupation and settlement. In most cases, samples selected for charcoal identification have also been selected for archaeobotanical (plant macrofossil) analysis. Recording the presence of other plant remains, such as cereal grain, wild taxa, tubers, fruitstones and nutshell, within a charcoal assemblage will assist the search for specific sites/features within the database and in turn will help to identify other key research agendas.

The identification of plant macrofossil remains associated with wood species especially (buds, leaves, seeds, fruitstones and nutshell) could highlight species that may not be represented in the wood/charcoal record and can therefore be a very valuable addition to reconstruction studies. Such information, when available, would also be very useful in aiding the identification of specific wood species, such as the woods within the Maloideae and *Prunus* genera, which can be difficult to identify anatomically. WODAN has provided a 'Notes' box within the 'Environmental & Notes' section, which will be used to highlight the presence of such plant macrofossil remains and their relevance to the site, where applicable.

WODAN will also be used to create saturation curves. This method will build on current and previous studies undertaken in Ireland (O'Carroll and Mitchell 2011; O'Donnell 2011) and elsewhere (Keepax 1988; Chabal *et al*. 1999; Asouti 2001; Veal 2009) and will further strengthen methodological results to date. The use of a saturation curve for the medieval period in Ireland will be an interesting exploration. Ireland's limited woodland diversity became more varied during the later medieval period with the increase in foreign settlement and trade. Implementing such statistical applications will therefore help to highlight any changes to Ireland's medieval woodland, which will add a further dimension of woodland diversity to Ireland's medieval landscape. Another aspect to consider when creating saturation curves for the medieval period is the complexity of settlement size and variation for both rural and urban contexts.

The success of standardizing and improving Irish methodologies in conjunction with British and European standards provides a recognised framework which will help to achieve workable outputs and give credence to the results of this research. This will not only advance Irish wood studies, but will inevitably increase and develop international collaboration and integration of anthracological and archaeological results.

DISCUSSION

The WODAN database project has resulted in an environmental database that is housed online. It is accessible anywhere through cloud-computing.

Standardization of methods is a key result of the the WODAN project. This has been achieved through the development of database fields after various discussions and workshops. As a result, all specialists working in Ireland currently use the same recording sheets and methods. An international element has been added with wood and charcoal specialists from England, Belgium, Netherlands, France, Germany, Australia and America, all of whom have played an active role in the creation of the database.

The large-scale investment in Ireland's

infrastructure under the National Development Plans (2000-2006/2007-2013) has led to significant transects of the Irish countryside being archaeologically monitored and excavated over the last 12 years. This work has produced large volumes of charcoal, which are largely identified and discussed on a site by site basis. Thus there exist many opportunities for the data to be rigorously analysed, evaluated and synthesized.

Many wood/charcoal identifications are currently housed on the database, with more being added daily. The scope for synthesis of woodland data is immense. Development of queries have allowed all data to be queried across the database, thus allowing specialists to compare their data with other specialists work in a comprehensive manner.

CONCLUSIONS

The WODAN database is online and fully functional at www.wodancharcoal.ie. At the time of writing information from 500 sites has been added. The aim for the database is to be a sustainable repository. The next stage is output of results, to interpret data from Ireland and beyond. We would be delighted to collaborate with people who are interested in adding to, or using the database in the future. Interested specialists can ask for an entry code to enter their own data.

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