FIREWOOD AND TIMBER EXPLOITATION DURING THE THIRD AND SECOND MILLENNIA BC IN NORTHWESTERN IBERIA: WOOD RESOURCES, TERRITORIES AND CHAÎNE OPÉRATOIRE

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Abstract: Human societies established productive strategies in order to obtain the material resources needed for their day-to-day life, including firewood and timber. These strategies were determined by the environmental supply, and also by the cultural characteristics and technical capacities of these communities.

This paper presents charcoal analysis data from four Chalcolithic and Bronze Age open-air settlements located in the northwest of the Iberian Peninsula and occupied during the third and second millennia BC. These results contribute to the knowledge of the exploitation of wooden resources, of the territories where these resources were collected, and of the firewood and timber production process. The identified wood taxa point to a diversified exploitation of the territory, where firewood and timber were collected and/or felled in the deciduous woodland, the river banks and scrubland areas. The characteristics of the wood elements used, the degree of growth ring curvature, the minimum diameter of twigs or logs, etc., as well as other data from archaeological contexts, such as the length of the postholes, were all taken into account to establish hypotheses related to the operative chaine of forest resources. The wooden resources consumed in each site allowed us to hypothesize about the territory of each community.

Key-words: Charcoal Analysis; Dendrology; Northwest of the Iberian Peninsula; Third and second millennia BC; Forest resources; "*Chaîne opératoire*"; Territories.

Resumo: As sociedades humanas estabelecem toda uma série de estratégias produtivas destinadas a obter os meios materiais necessários para a sua existência, entre elas, o aprovisionamento de lenha e de madeira. Estas estratégias, além de estarem condicionadas pela oferta ambiental, são igualmente resultantes das caraterísticas culturais e das capacidades técnicas das comunidades.

Os dados arqueobotânicos que se apresentam procedem de vários lugares de habitação do Calcolítico e da Idade do Bronze da fachada ocidental do Noroeste peninsular com cronologias que abarcam o 3º e parte do 2º milénios AC. Os resultados obtidos permitiram identificar uma exploração diversificada dos recursos lenhosos que combinava a recolha de lenha e de madeira da floresta climácica com a proveniente das áreas de mato. As formações arbóreas situadas nas margens dos cursos de água também constituíram fonte de aprovisionamento de combustíveis e, provavelmente, de madeira. A análise dendrológica das amostras registando o grau de curvatura dos anéis de crescimento

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anual, o diâmetro mínimo dos ramos ou troncos consumidos, entre outras características, em inter-relação com determinados contextos arqueológicos (dimensões dos buracos de poste, por exemplo), proporcionaram hipóteses relacionadas com a cadeia técnica-operativa dos recursos florestais. A caracterização dos recursos usados em cada um dos casos de estudo permitiu, igualmente, colocar hipóteses sobre o território de vivência, de circulação e de exploração de cada comunidade.

Palavras-chave: Antracologia; Dendrologia; Noroeste da Península Ibérica; Terceiro e Segundo milénios AC; Recursos florestais; Cadeia técnico-operatória; Territórios explorados.

1. INTRODUCTION

The exploitation of wood resources in the past was determined by the relationship established between communities and their environment, which is reflected in the archaeobotanical record. 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.) (Piqué 1999).

This article examines evidence related to wood resource (firewood and timber) exploitation and the associated production processes in Northwest Iberia during the third and second millennia BC, drawing on the concept of *chaîne opératoire*. It also aims to estimate the territories in terms of distance covered and time invested. For this purpose four case studies were used: Lamas de Abade; Bitarados; Monte Calvo, and Lavra.

Archaeobotanical and archaeological information from Lamas de Abade (Santiago de Compostela, Galicia), an open-air settlement that was probably occupied repeatedly from the third to second millennia BC, was compared with three other sites (Fig. 1). The significance of the results presented in this article resides in the long occupation of this site during a period of time when archaebotanical samples from Northwest Iberia are quantitatively few (Bettencourt *et al.* 2007b). The third millennium BC data were compared with Bitarados (Esposende, Portugal), a site whose qualitative data has been previously published (Bettencourt *et al.* 2007b: 156-157), with the quantitative results analyzed in this paper. The second millennium data were compared with two recently studied sites: Monte Calvo (Baião, Portugal) and Lavra (Matosinhos, Portugal) (Martín-Seijo 2010, 2011; Martín-Seijo *et al*. 2011).

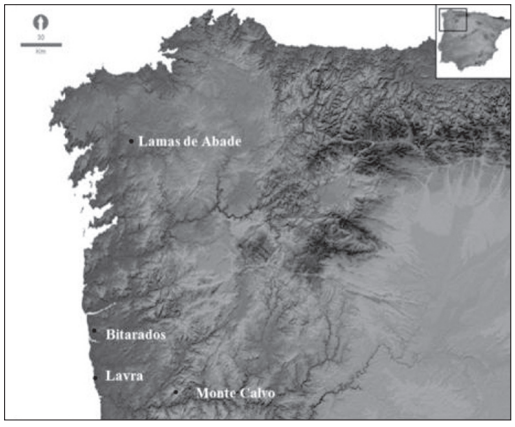

Fig. 1 – Location of the archaeological sites presented in this paper.

Three of the sites (Lamas de Abade, Bitarados and Lavra) are located in the Atlantic area under an oceanic influence, characterized by a climate with moderate temperatures and abundant winter rain, although Bitarados and Lavra are situated

in coastal areas characterized by short dry summer seasons with rare and irregular rain. Monte Calvo is located near the Douro valley in the Mediterranean climatic area, characterized by very dry summers.

Past environmental conditions in this area were determined around 3000 cal. BC by a cold, relatively dry and windy episode (Martínez Cortizas *et al.* 2009). Geochemical proxies in peat bogs suggest that during this period temperatures decreased, and were up to 2-2.5° C colder than present (Martínez Cortizas *et al.* 2009). Paleotemperature reconstruction indicates a continuous cooling until 2500 cal. BC, at which point temperatures rose by about 1°C, and remained stable until a further cooling trend in the second half of the 2nd millennium (1600-1400 to 1200 cal. BC) (Fábregas *et al.* 2003; Martínez Cortizas *et al.* 2009). Rainfall increased from 2600-2300 to 2200 cal. BC, and then decreased until 1400-1300 cal. BC (Fábregas *et al.* 2003; Martínez Cortizas *et al.* 2009).

2. ARCHAEOLOGICAL CONTEXT

Lamas de Abade is a complex site located at 220 m.a.s.l. in the base of a valley near a river course. The environs of the site are characterized by deep soils suitable for agriculture practices and slopes for grazing and animal husbandry. This site was partially excavated (0.55ha) in 2010, and radiocarbon dates showed that it was occupied repeatedly over a long period of time (Tab. 1). Thirty features were documented, including ten hut structures, six postholes, one hearth, one pit and twelve features of undetermined function. During the third millennium BC the site probably consisted of an open-air settlement comprised of several huts of similar morphology, which suggests that they were built over a short period of time. Pottery which could be predominantly attributable to Penha-type style was recovered from one of the huts which yielded two radiocarbon dates (Beta-289830 and Beta-289831). Later occupations of the site date to the beginning and the end of the second millennium BC.

In contrast, Bitarados is located on the coast and seems to have been a sedentary settlement with a long sequence of episodes of occupation during the first half of the third millennium BC (Tab. 1). It is situated in a granitic alveolus, sheltered from wind and cold, providing excellent conditions for agriculture and grazing. Features found during excavation included several hearths, a pit, and clay floors associated with various postholes, many of which had stone packing and some wooden posts preserved *in situ* by carbonization; cereal and animal bone remains were also recovered (Bettencourt *et al.* 2003, 2007a, 2007b; Cardoso & Bettencourt 2008). Both Monte Calvo and Lavra seem to have been large settlements, the former situated inland in a mountainous area, and the latter located less than 1 km from the current coastline, on a residual hill within the littoral platform. Both settlements contained hearths, pits and structures made of perishable materials, but no carpological remains were recovered from either site (Gonçalves & Bettencourt 2010; Bettencourt & Fonseca 2011).

Tab.1 – Chronology of sites: ^{14}C dates calibrated using OxCal 4.1. (curve IntCal09) (Reimer *et al*. 2009)

Site	Conventinal radiocarbon age (BP)	2 Sigma calibrated result (BC)	Laboratory reference
Bitarados	4125±51	2878-2753	AA63067
	4122±43	2873-2577	AA63066
Lamas de Abade	4090±40	2866-2493	Beta-289830
Bitarados	4046±42	2850-2471	AA63065
Lamas de Abade	3980±40	2580-2450	Beta-289831
	3880±40	2471-2209	Beta-289825
	3530±40	1963-1745	Beta-289832
Monte Calvo	3444±38	1883-1666	AA89562
	3333±74	1870-1444	AA89563
Lavra	3230±40	1609-1428	Beta-258086
	3220±40	1608-1417	Beta-258087
Lamas de Abade	2910±40	1261-996	Beta-289824

During the first half of the third millennium BC communities were probably less mobile than in the Neolithic. This increased lack of mobility was linked to the development of cereal agriculture and animal husbandry, resulting in greater territorialization by these communities (Jorge 1999; Bettencourt 2009). During the second millennium BC (from 3500 BP on) there is evidence of sedentary populations occupying the valley lowlands. These communities probably developed an agricultural subsistence strategy based on the rotation of cereals and legumes, as well as animal husbandry (Jorge 1999; Bettencourt 1999, 2003; Figueiral & Bettencourt 2007). Palynological analysis reveals a consequent impact on forest cover (Ramil 1993).

3. MATERIAL AND METHODS

All the analyzed charcoal samples were preserved by carbonization. In Lamas de Abade the charcoal assemblages were recovered by flotation in the lab using 2mm, 1mm and 0.5 mm meshes, and in Bitarados, Lavra and Monte Calvo by flotation and dry sieving. The fragments (n=1931) were first identified using a compound microscope, and the anatomical features of the wood were observed on the three sections (cross, tangential and radial). The dendrological and taphonomic characteristics were observed and registered on a total of 675 fragments from 3 sites (Lamas de Abade, Monte Calvo and Lavra). The following aspects were considered: part of the plant, presence of tyloses, minimum diameter, season of cutting, and also different types of alterations related to the combustion process (radial cracks, vitrification, cellular collapse, etc.), to growth conditions (scars, compartmentalization, reaction wood etc.) and to taphonomic processes (fragmentation, erosion, biological action, etc.) (Théry-Parisot 2001; Thiébault 2005; Marguerie & Hunot 2007; Macparland *et al.* 2010). Indirect archaeobotanical

evidence, such as clay impressions or postholes, was also analyzed to recover different data on timber or wattle manufacture (Cubero 1997; Nava & Fernández 2001; Gómez 2008; Martín-Seijo & Carballo 2010).

The *chaîne-opératoire* alludes to the sequence of actions involved in the production processes of firewood and timber, and emphasizes every stage of wood resource production, particularly supply and the properties of raw materials (Martinón-Torres 2002). The present research focuses not only on the archaeobotancial remains, but also on the sequence of actions, techniques and gestures that they represent. To reconstruct the main stages of the *chaîne-opératoire* direct evidence (archaeological and archaeobotanical data) was used, along with indirect evidence derived from the compilation of the historical and ethnographic data of this geographical area (Piqué 1999; Dufraisse 2011).

Territorial spatial distribution of resources was estimated by the presence of riverine forest species, which would have been associated with water courses due to their ecological requirements. To calculate the models of distance costs from the settlement to the resources (in this case to the nearest water course), surfaces of anisotropic costs were used. The digital terrain model ASTER [1] was the base mapping used to calculate the speed of movement, using Tobler's [2] procedures. The GIS used in the calculations was the ArcInfo version of ArcGIS 9.2 and the commands applied were slope, aspect, and path distance. The isochrones for 15, 30, 60 and 120 minutes and for distances of 1 and 2 km from the settlement were calculated.

4. WOOD RESOURCES AND PRODUCTION PROCESS (*CHAÎNE OPÉRATOIRE*)

Lemonier (1986:149) used Creswell's (1976: 6) definition of *chaîne opératoire* or operational sequence "as a series of operations which brings primary material from its natural state to a fabricated state". The technical choices involved in the wood resource production and use processes were woven into a social, economic and ideological tapestry that is, in many ways, unique to a particular place and time (Skibo & Schiffer 2008: 1-2). In order to study the firewood and timber production process in these contexts, the concept of *chaîne opératoire* was used to organize the archaeological and archaeobotanical record (Gosselain 2010-2011). Four main stages in this process were distinguished: i) raw material procurement (supply); ii) preparation (transport, support configuration: to cut off branches or bark, to rough-hew and split the trunk, etc.); iii) product preparation (storage, drying and shaping); iv) final product (energy or structures/objects). This concept also allows the integration of interrelated elements which underlie the manufacturing process, such as the individual, environment, raw material, tools, skills, knowledge, social and economic relations, etc.

4.1. Raw material procurement

The main data relating to the raw material supply consisted firstly of the identification of the species and plant part collected, and secondly, the plant communities exploited (Tables 2 to 6). The wood resources were obtained primarily from trees and bushes, such as *Quercus* sp. deciduous, Rosaceae/Maloideae, *Salix* sp./*Populus* sp. and *Alnus* sp. Scrubs, such as Fabaceae, *Erica* sp., *Erica arborea* or Cistaceae were identified in the samples dating to the third millennium BC from Bitarados, and in all of the sites occupied during the second millennium. Wasteland vegetation such as Fabaceae was predominant since the Chalcolithic, as has been previously shown by I. Figueiral and A.M.S. Bettencourt (2004, 2007). Although in two structures (a hut and hearth) related to the earliest occupations of Lamas de Abade no scrub species were documented, with only woodland taxa identified.

Tab. 2 – Absolute and relative frequencies of the samples analyzed (concentrated charcoal) from Lamas de Abade.

Site	**LAMAS DE ABADE**					
Chronology	**3rd Millennium**				**2nd Millennium**	
	29th-23th cal. BC		20-18th cal. BC		13th-11th cal. BC	
Archaeological contexts	**Hut**		**Fireplace**		**Hut**	
Communities/Taxa	**Nb.**	**%**	**Nb.**	**%**	**Nb.**	**%**
Temperate mixed woodland						
Quercus sp. deciduous	85	81,73	96	96	38	38
Rosaceae/Maloideae	3	2,88			8	8
Corylus avellana					29	29
Quercus sp.	1	0,96			1	1
Prunus sp.			3	3		
Quercus/Castanea	1	0,96				
Riverine woodland						
Salix sp./*Populus* sp.	2	1,92			6	6
Alnus sp.	12	11,54				
Betula sp.					1	1
Scrubland						
Fabaceae					14	14
Others						
Pteridium aquilinum					1	1
Non-identified					1	1
Non-identifiable			1	1		
Number of taxa	6	–	2	–	8	–
Number of fragments	104	100	100	100	100	100

The *Quercus/Castanea* fragment of Lamas de Abade was too small to determine which of these species it belongs to. *Castanea sativa* is difficult to differentiate from *Quercus* sp. deciduous as both species have similar anatomical features, the absence of multiseriate rays is the most significant in identifying *Castanea*. Chestnut dating to the Middle Bronze Age was identified in the charcoal samples (Figueiral 2000a) and the pollen assemblages (Aira Rodríguez & Ramil Rego 1995; Bettencourt 2000) from the settlement site of Sola, and also from the Late Bronze Age at the sites of S. Julião (Figueiral & Bettencourt 2004) and Carballeira do Espíritu Santo (Blanco & Prieto 2009).

Tab.3 – Absolute and relative frequencies of the samples analyzed at Monte Calvo and Lavra (concentrated and dispersed charcoal) (Martín-Seijo 2010, 2011; Martín-Seijo *et al*. 2011)

Site	**MONTE CALVO**		**LAVRA**	
Chronology	**2nd Millennium**			
	19th-17th cal. BC		17th-15th cal. BC	
Communities/Taxa	**Nb.**	**%**	**Nb.**	**%**
Temperate mixed woodland				
Quercus sp. deciduous	212	70,67	15	21,13
Rosaceae/Maloideae	10	3,34	4	5,63
Corylus avellana	3	1	1	1,41
Ilex aquifolium	1	0,34	1	1,41
Riverine woodland				
Salix sp./*Populus* sp.	1	0,34	6	8,45
Alnus sp.	4	1,34		
Betula sp.			2	2,82
Frangula alnus			1	1,41
Fraxinus sp.			6	8,45
Scrubland				
Fabaceae	65	21,67	30	42,25
Cistus sp.			1	1,41
Others				
Pinus tp. *pinea/pinaster*			4	5,63
Non-identifiable	3	1		
Number of taxa	7	–	11	–
Number of fragments	300	100	71	100

The presence of *Ilex aquifolium* in charcoal samples from Northwest Iberia is very infrequent, although this evergreen tree grows in association with temperate

Tab. 4 – Absolute and relative frequencies of the concentrated charcoal of Bitarados 1 and 2 (level 3), this analysis was done by Isabel Figueiral and was partially published in Bettencourt *et al.* (2007)

Site	BITARADOS													
Chronology	3rd Millennium 29th-28th cal. BC													
Communities/Taxa	Persihable construction--Burning event		Huts-Abandon-ment levels		Pavement		Pavement		Pit		Post hole		Fireplace	
	Nb.	%	Nb.	%	Nb.	%	Nb.	%	Nb.	%	Nb.	%	Nb.	%
Mixed deciduous forest														
Quercus sp. deciduous	59	45,4	328	58,9	133	66,8	52	49,5	78	57,8	63	–	44	–
Corylus avellana	31	23,8	24	4,3	13	6,5	3	2,9	8	5,9	1	–		
Rosaceae/Maloideae	7	5,4	19	3,4	1	0,5	3	2,9	1	0,7				
Quercus sp.	3	2,3	10	1,8	8	4,02	2	1,9	3	2,2	3	–	6	–
Quercus sp. evergreen	2	1,5	3	0,5	13	6,5	1	0,9	1	0,7	2	–		
Quercus suber			8	1,4							2	–		
Riverine woodland														
Fraxinus sp.			45	8,1			18	17,1						
Salix sp./Populus sp.	1	0,8	9	1,6	1	0,5	1	0,9	5	3,7				
Sambucus cf. *nigra*	1	0,8	5	0,9	2	0,01			2	1,5				
Alnus sp.					4	2,01	2	1,9	1	0,7				
Frangula alnus			1	0,2										
Scrubland														
Fabaceae	20	15,4	87	15,6	21	10,6	17	16,2	31	23,0	5	–		
Erica sp.	2	1,5	1	0,2					2	1,5				
Compositae			2	0,4										
Cistaceae	1	0,8												
Erica arborea			1	0,2										
Others														
Pinus tp. *pinea/pinaster*											1	–		
Clematis vitalba			1	0,2										
Quercus/Clematis (root)			1	0,2										
Cork							1	0,9						
Non-identifiable	3	2,3	12	2,2	3	1,5	5	4,8	3	2,2	3	–		
Number of taxa	10	–	15	–	9	–	9	–	10	–	7	–	2	–
Number of fragments	130	100	557	100	199	100	105	100	135	100	80	–	50	–

mixed woodlands. The presence of holly was identified in anthracological samples from several Bronze Age sites: Monte Calvo (Baião, Portugal) (Martín-Seijo 2010); Lavra (Matosinhos, Portugal) (Martín-Seijo 2011); Lavra (Baião, Portugal) (Figueiral 1995) and São Julião (Vilaverde, Portugal) (Figueiral 2000b). *Prunus* sp. another rare genera in this area during the Chalcolithic, and Early and Middle Bronze Age, was documented at Lamas de Abade in the 3rd to the 2nd millennium BC transition (Early Bronze Age), at Castelo Velho (Freixo de Numão, Portugal) from the 20th to 14th centuries BC (Figueiral 1999), and from the 19th to 13th centuries BC at Pala da Vella (Biobra, Ourense) (Carrión 2005). While the presence of *Pteridium aquilinum* in the charcoal assemblages of this area is infrequent, this taxa was documented at Lamas de Abade during the 13th to 11th centuries BC and could be related to forest clearance. These ferns could be used as raw material for roofing or even as firewood when dry.

Charcoal fragments of *Pinus* tp. *pinea/pinaster* were identified sporadically in Bitarados and Lavra. The presence of this pine during Late Prehistory in Northwest Iberia was sporadic and limited to coastal areas, while it had a significant presence in northeast and central-east Portugal (Figueiral 1995; Figueiral & Bettencourt 2004). Data from these two sites indicate its presence in coastal areas since the Chalcolithic (first half of the third millennium BC) in Bitarados, and continuing into the Middle Bronze Age (first half of the second millennium BC); until now, sites where this taxon was identified include Sola (Braga, Portugal) during the Middle Bronze Age (Figueiral 2000a) and in several sites dated in the Late Bronze Age (Figueiral & Bettencourt 2004). These pine communities in coastal areas could be associated with another undergrowth species as *Erica* sp., *Cistus* sp. and Cistaceae.

The identified taxa formed part of different plant communities, coming predominantly from mixed deciduous forest (*Quercus* sp. deciduous, Rosaceae/Maloideae and *Corylus avellana*) and riverine woodland (*Salix* sp./*Populus* sp. and *Alnus* sp.). The exploitation of scrubland formations was identified in a representative percentage from Bitarados during the third millennium, and during the second millennium at Monte Calvo and Lavra. Forest clearance by human populations may have favored the establishment of early colonizing species such as legumes followed by heathers (Figueiral 1995).

Identification of the plant part and the growth ring curvatures (Fig. 2) indicate that twigs and branches were the preferred firewood, probably the result of coppicing or pruning of lower and small branches of some trees and shrubs or the harvesting of dead wood (Tab. 7). Cross-sections of several fragments of deciduous oak showed an area of narrow tree rings comparable to those found today on pollarded trees (Schweingruber 1996; Thiébault 2006). Scars were also identified on *Quercus* sp. deciduous and *Salix* sp./*Populus* sp. The evidences of biological action (xylophagus or hyphae) in several samples could be related to the harvesting of dead wood, to the storage of firewood or to taphonomic processes (Théry-Parisot 2001; Moskal del Hoyo *et al.* 2010). The presence of alterations such as cellular collapse could be related to the burning of high humidity or green firewood (Théry-Parisot 2001).

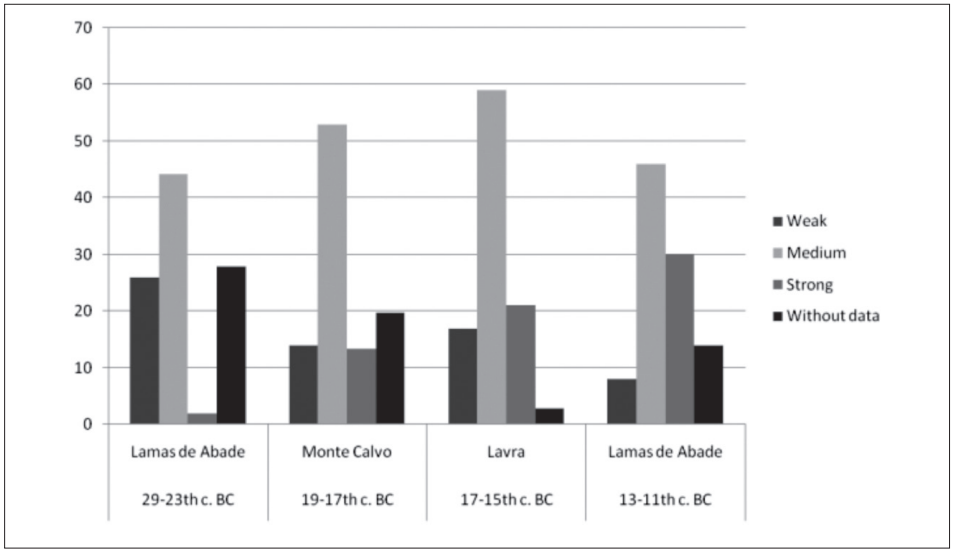

Fig. 2 – Growth rings curvature observed in the fragments of charcoal.

Tab. 5 – Absolute and relative frequencies of the dispersed charcoal from Bitarados 1 and 2 (level 3b), this analysis was done by Isabel Figueiral and was partially published in Bettencourt *et al.* (2007)

Site	**BITARADOS**	
Chronology	**3rd Millennium** 29th-28th cal. BC	
Communities/Taxa	**Nb.**	**%**
Mixed deciduous forest		
Quercus sp. deciduous	64	56,1
Corylus avellana	7	6,1
Quercus suber	4	3,5
Quercus sp.	4	3,5
Riverine woodland		
Fraxinus sp.	13	11,4
Alnus sp.	1	0,9
Frangula alnus	1	0,9
Sambucus cf. *nigra*	3	2,6
Salix sp./*Populus* sp.	1	0,9
Scrubland		
Fabaceae	14	12,3
Non-identifiable	2	1,8
Number of taxa	10	–
Number of fragments	114	100

Tab. 6 – Absolute and relative frequencies of the dispersed and concentrated charcoal of Bitarados 3 (level 2), this analysis was done by Isabel Figueiral and was partially published in Bettencourt et al. (2007)

Site	BITARADOS			
Chronology	3rd Millennium			
	29th-25th cal. BC			
Communities/Taxa	Dispersed		Fireplace	
	Nb.	%	Nb.	%
Mixed deciduous forest				
Quercus sp. deciduous	236	58,7	84	67,2
Corylus avellana	28	7,0	5	4
Rosaceae/Maloideae	17	4,2	4	3,2
Quercus sp.	13	3,2	3	2,4
Quercus sp. *evergreen*	4	1,1	3	2,4
Quercus suber	3	0,7	1	0,8
Rubus sp.	2	0,5		
cf. *Castanea* sp.	1	0,2		
Castanea/Quercus	1	0,2		
Arbutus unedo	1	0,2		
Riverine woodland				
Fraxinus sp.	5	1,2		
Salix sp./*Populus* sp.	2	0,5		
Sambucus cf. *nigra*	1	0,2	1	0,8
Alnus sp.	1	0,2		
Scrubland				
Fabaceae	77	19,2	23	18,4
Others				
Monocotiledonea	1	0,2		
Root	1	0,2		
Non-identifiable	8	2,1	1	0,8
Number of taxa	15	–	8	–
Number of fragments	402	100	125	100

This kind of gathering required a simple technology: firewood could be collected by hand, using a rope or simple cutting tools. The trees and the forest varied with a seasonal rhythm, as did the energy demands of cooking and heating; consequently, the work invested in gathering firewood probably varied throughout the year and was higher during autumn and winter. These seasons also correspond to a time of year when communities engaging in cereal agriculture had less work to do, in comparison to the labor intensive spring and summer periods, as is indicated by ethnographical data from northwest Portugal and Galicia (Lorenzo 1982; Blanco

Tab. 7 – Presence of alterations on the analyzed charcoal fragments.

Site	LAMAS DE ABADE		MONTE CALVO	LAVRA	LAMAS DE ABADE
Chronology	3rd Millennium		2nd Millennium		
	29th-23th cal. BC	20-18th cal. BC	19th-17th cal. BC	17th-15th cal. BC	13th-11th cal. BC
Plant conditions of growth					
Growth changes	•		•	•	•
Scars			•	•	•
Reaction wood				•	
Combustion process					
Radial cracks	•	•	•	•	•
Vitrification	•	•	•	•	•
Tangential cracks	•	•	•		
Cellular collapse	•	•			•
Biological action					
Xylophagus	•	•	•		•
Hyphae		•	•	•	•

1996). The season of plant death was registered in a few cases: in Monte Calvo (19th-17th centuries cal. BC) one fragment of Rosaceae/Maloideae branch was cut during spring or summer, and one fragment of *Quercus* sp. deciduous branch was cut during autumn or winter; and in Lamas de Abade (13th-11th centuries cal. BC) five fragments of a Rosaceae/Maloideae branch were cut during autumn or winter.

Firewood gathering was probably a daily activity, which contrasts with the sporadic demand for timber and other wood resources for construction. For construction purposes, the distance and time invested in the supply of raw material was probably greater due to the selection of these resources on the basis of physical and mechanical properties and morphological characteristics e.g. high quality trunks (long-lasting wood, straight logs, etc.) for structural elements, flexible branches for frameworks, etc. The trees were felled using axes or sometimes by pulling them down with ropes (Abella 2003).

4.2. Preparation

Preparation of the raw material consisted primarily of transportation (using human or animal effort) and support configuration. The images compiled by Ruth Matilda Anderson in Northwest Iberia (Lenaghan & Seixas 2011), and those from the Spanish Forest Photographic Library DGN-INIA (Montero *et al.* 2007), showed that the

Fig. 3 – Ethnographic examples of firewood (3.1 and 3.2) and timber transport (3.3 and 3.4) using human effort and using animal effort (3.5 and 3.6) [3.1 and 3.3 from Lenaghan & Seixas 2011; 3.2 and 3.4 from Montero *et al.* 2007].

transportation of firewood and timber was achieved essentially using human or animal effort (Fig. 3.1 to 3.4), and even floating, as was done in the Lima river (unpublished data compiled by AMSB in the Celebração da Cultura Costeira – CCC project). Ethnographical evidence can be used to inform a greater understanding of the gestures involved in the transport of wood resources. Firewood and timber transport using human effort could cause postural lesions similar to those degenerative lesions described by Balaguer *et al.* 2002 or Barroso *et al.* 2007, as this work involves long walks carrying heavy weights, and repetitive strain.

During this period the transportation of large logs or big firewood bundles could have been accomplished using animal traction. Ethnographic data shows that traditionally mules and oxen were the preferred draught animal in the Iberian Peninsula (Fig. 3.5 and 3.6). The most common types of timber or firewood transportation in the recent past consisted of dragging the material or the use of a cart to carry it. The configuration of the supports was probably essential before large trunks or branches, suitable for hut construction in the open-air settlements, were transported. Although archaeological evidence of these practices have not yet been identified, ethnographic data shows that branches and bark were usually removed from the trunk, or even the support could be rough-hewn and split.

4.3. Product preparation

Product preparation in relation to both firewood and timber could include storage, drying and shaping. However, preservation by carbonization and other taphonomical processes made it difficult to identify these activities. While there is no identifiable evidence which indicates the preparation of firewood, there is indirect evidence of product preparation of structural timbers. It seems that the trunks used as posts were probably used whole and without splitting, with minimal shaping limited to the end which would be set into the ground. The fragmentation of the charcoal analyzed prevented the registering of this feature.

4.4. Final product

In relation to the wood manufacture processes, the episodes of burning noted in several occupation levels at Bitarados facilitated the preservation of wooden structural elements. Several wooden posts, preserved by carbonization, were associated with postholes and clay floors in layer 3 (Bettencourt *et al.* 2003: fig. 9 and unpublished data). On this site, the posts were predominantly of oak (*Quercus* sp. Deciduous), and the roof covering of *Fabaceae* branches and twigs. The presence of branch impressions in clay at Bitarados (Bettencourt *et al.* 2003) and Lavra (Bettencourt & Fonseca 2011) suggest that wattle and daub walls were used to enclose the structures, probably using long and straight branches of different species.

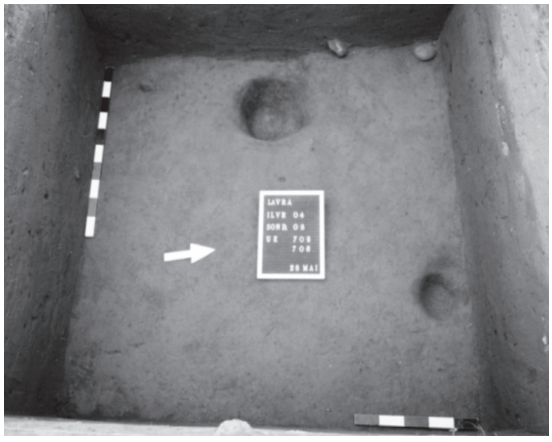

Fig. 4 – Post holes documented during the excavation at Lavra (Bettencourt & Fonseca 2011).

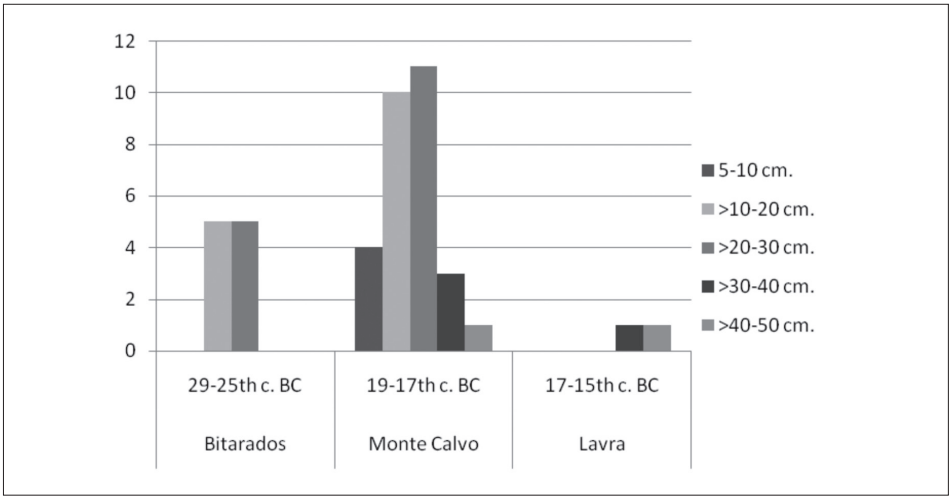

Fig. 5 – Postholes maximum diameter.

Posthole measurements from Bitarados (Bettencourt unpublished data), Monte Calvo (Gonçalves & Bettencourt 2010) and Lavra (Bettencourt & Fonseca 2011) (Fig. 4), show that the posts ranged in diameter from 6 – 50 cm, with the most common size measuring between 10 – 30 cm in diameter (Fig. 5). Several postholes with a diameter greater than 30 cm could have contained a post and a smaller supporting timber. Other postholes of oval shape could have contained a post and stone packing.

5. WOOD RESOURCES EXPLOITATION TERRITORIES

The pattern of wood fuel collection and use is related to the nature of the supply sources (availability), their location (accessibility and proximity), and social and economic factors (settlement type, duration of occupation, group size, technological development, etc.). These factors conditioned the distance covered and time invested by these communities in firewood gathering. By estimating path distance the hypothetical exploitation territories of these communities can be approximated. It is difficult to delimitate the wood resources exploitation territories of past communities on the basis of the archaeobotanical record. Plant distribution is determined by abiotic (substrate type and climate) and biotic (derived of the plant species themselves) factors (Spikins 2000) that change through time. In this case, the spatial distribution of resources within the territory was estimated by the presence of different riverine species associated with water courses, which because of their hydric requirements probably did not experience great variations in their past distribution. Only the main water courses were considered in calculations of distance and time, as smaller courses could have suffered alterations in relation to climatic conditions of the 3rd and 2nd millennia BC, which were drier and colder compared to the present (Martínez Cortizas *et al.* 2009); in reality in certain cases the distances to riverine species could have been even less.

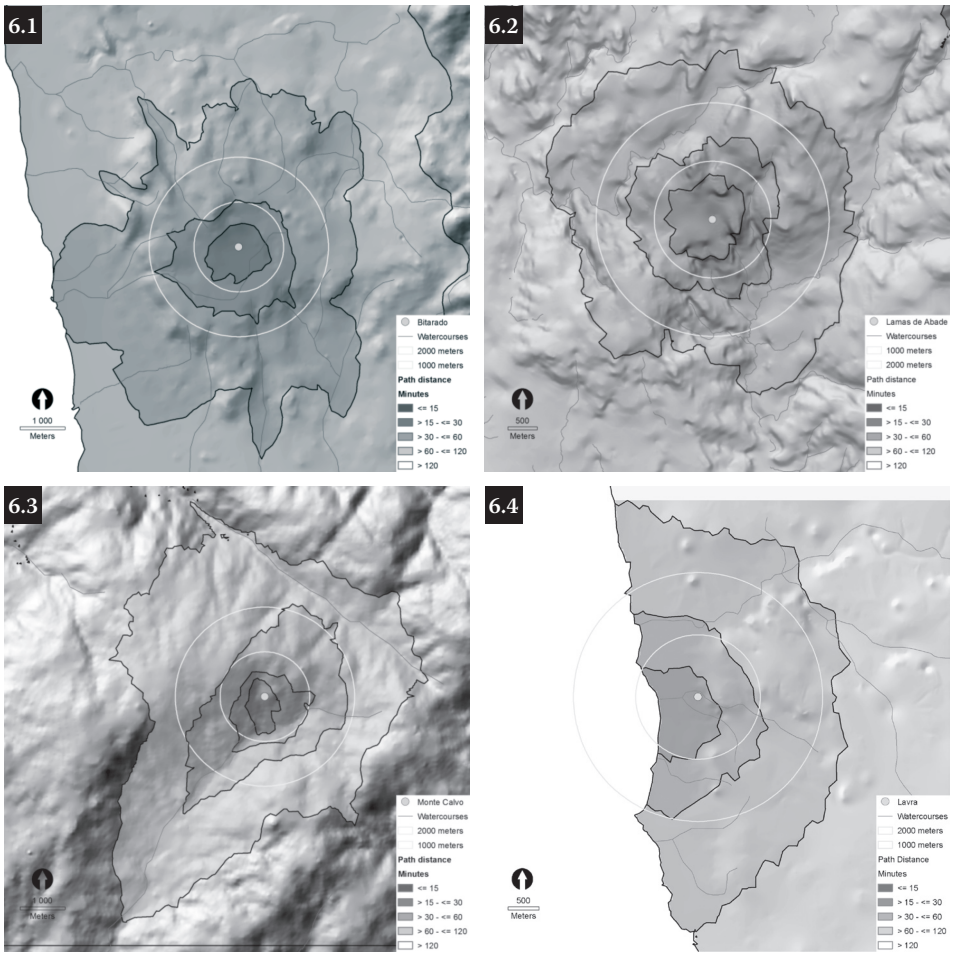

Fig. 6 – Path distances from the sites: minutes and meters. 6.1 – Bitarados; 6.2 – Lamas de Abade; 6.3 – Monte Calvo; 6.4 – Lavra.

Mindful of these constraints, it appears that the Chalcolithic, Early and Middle Bronze Age communities of the northwest of Iberian Peninsula probably collected and transported riverine species within a distance of 1 km (less than 15 minutes). For the sites of Bitarados, Monte Calvo and Lavra these resources were within 15 minutes walking distance (less than 1 km), and for Lamas de Abade the distance was between 1 km to 2 km (between 15 and 30 minutes) (Fig. 6.1, 6.2, 6.3 and 6.4). However, we have to take into account that the main wood resources were deciduous oak or Fabaceae, which in some cases could be harvested in the surroundings of the settlements, within the theoretical territory of 15, 30 and 60 minutes (Fig. 6.1 to 6.4).

6. CONCLUSIONS

The variety of taxa identified at the four archaeological sites reflects the exploitation of the following type of plant communities during the third and second millennia BC:

– Temperate mixed woodland characterized by the presence of *Quercus* sp. deciduous, Rosaceae/Maloideae and *Corylus avellana;*
– River banks with *Salix* sp./*Populus* sp., Alnus sp., *Betula* sp., *Frangula alnus, Fraxinus* sp. and *Sambucus* sp.;
– Scrubland formations including Fabaceae, Cistaceae, *Cistus* sp. and Ericaceae. Although the preliminary anthracological data of Lamas de Abade did not confirm the binomial *Quercus* sp. deciduous and Fabaceae from the Chalcolithic and Early Bronze Age, at Bitarados (Figueiral & Bettencourt 2007), Monte Calvo (Martin-Seijo 2010; Martin Seijo *et al.* 2011) and Lavra (Martín-Seijo 2011) both taxa were identified;
– Plant communities with *Pinus* tp. *pinea/pinaster*. Their presence in Bitarados and Lavra established the distribution of these species along the Iberian coastline during the Chalcolithic and Middle Bronze Age in the Northwest.

The identification of the plant part and growth rings curvature showed a preferential use of twigs and branches as firewood. There was some direct evidence for the use of large logs in the construction of huts (structural timbers preserved by carbonization within postholes), primarily oak (*Quercus* sp. deciduous), as well as indirect evidence (morphology and dimensions of the postholes). As the path distances to the river courses were short, it is probable that firewood was carried using human effort, and timber using human or animal effort.

The construction of the huts required a high investment of time and labor over a number of stages: selection of the plant (species, diameter) and the plant part (trunk, branches), felling the tree or pruning the branches, transport to the settlement, shaping, and erection into place. It is probable that there was also a seasonal organization of work, with trees felled during the autumn or winter, branches cut during the spring to favor the formation of scar tissue.

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