

## **A two-stage economic succession at the inception of farming in central Portugal. Preliminary examination of possible causes and consequences**

*A two-stage economic evolution at the inception of farming in Central Portugal. Preliminary examination of possible causes and consequences*

António Faustino Carvalho  
Universidade do Algarve  
Faculdade de Ciências Humanas e Sociais  
afcarva@ualg.pt

Recibido: 09-06-2015; Revisado: 15-09-2015; Aceptado: 13-10-2015

### **Abstract**

Notwithstanding their scarcity and uneven distribution, zooarchaeological and stable isotope data sets on the Early and Middle Neolithic (5500–3200 cal BC) in the region of Estremadura in Central Portugal strongly suggest that two succeeding stages in subsistence strategies took place: sheep and goat itinerant pastoralism (across large areas) and/or renewed focus on wild food sources (cervid hunting, harvesting marine and freshwater food) which replaced livestock farming within smaller areas and less specialised hunting practices. This economic shift seems to have coincided with two other dramatic changes: the 5.9 kyr cal BP climate event and the onset of megalithism. Possible correlations between these past cultural and palaeoenvironmental phenomena are herein preliminarily outlined.

**Keywords:** Neolithic; Portugal; zooarchaeology; stable isotopes; climate change; megalithism.

### **Resumen**

A pesar de su escasez y distribución desigual, el conjunto de datos arqueozoológicos y de isótopos estables para el Neolítico Antiguo y Medio de la región de Estremadura en el centro de Portugal (5500-3200 a. C. cal), sugiere con claridad dos etapas sucesivas en las estrategias de subsistencia: pastoreo itinerante de ovejas y cabras (ocupando grandes territorios) y/o un renovado interés por los recursos alimenticios silvestres (caza de cérvidos, recolección de alimentos marinos y de agua dulce), que reemplazó otras formas de ganadería más confinadas en el espacio acciones con regímenes de mantenimiento reducidos y unas prácticas de caza menos especializadas. Este cambio económico parece haber ocurrido junto con otros dos cambios dramáticos, el evento climático 5.9 k BP (cal.) y el inicio del megalitismo. Aquí se esbozan de forma preliminar las posibles correlaciones entre estos fenómenos culturales y paleoambientales del pasado.

**Palabras clave:** Neolítico; Portugal; zooarqueología; isótopos estables; cambio climático; megalitismo.

## 1. INTRODUCTION

Neolithic research in Portugal has been witnessing major developments in the last four decades. Among other factors, the opening to Anglo-Saxon theoretical perspectives and, more recently, the implementation of large-scale salvage work, forced traditional culture-historical views to be surpassed by processual and post-processual approaches along with a notable accumulation of empirical data derived from excavations carried out with modern methodologies. This allowed the construction of interpretative syntheses aiming at levels of inference higher than those more confined to chrono-typological sequences. Thus, clearer pictures of past economic behaviour, amongst several other research topics, were swiftly acquired. In this context, the perception of asymmetric economic processes occurring at the inception of the earliest farming communities in the country were recognized as soon as the end of the 1980s. For example, according to Jorge (1990: 120; Portuguese original):

«A strong line to note for this period, in South Portugal, is the regional variability observed in terms of settlement and subsistence strategies, rites and sepulchral architectures, and also in the development of asymmetries as verified in many areas of this vast territory.

Thus, in the region of the mouth of the Sado River (Comporta), thanks to a very favourable ecosystem for fishing/gathering, the Neolithic communities “specialized” in a traditional, “broad spectrum” economy that isolated them, at first, from other cultural areas. We believe that further research may find, in other regions of the Alentejo/Algarve (mainly in coastal or estuarine areas), communities with similar “archaic” behaviour».

Indeed, particular sites and settlement systems — like the one evidenced by the Middle and Late Neolithic shell midden sites in the Comporta region (SILVA *et al.*, 1986; SOARES and SILVA, 2013) mentioned above — clearly indicated that hunter-gatherer economies did not completely vanish with the introduction of farming life ways. The open question, however, was to evaluate the economic weight of these more «traditional» practices in overall subsistence strategies and to understand their role as a defining feature of Neolithic societies in Portugal. More or less implicitly following Zvelebil’s (1986) «availability model», some argued that in its earliest phases these were still essentially hunter-gatherer groups that selectively and gradually adopted items of the new economic system (e.g. JORGE, 1990; SILVA and SOARES, 1987) while others considered that a full production economy must have characterized the whole period given the record obtained in Iberian areas where more advanced research was able to assemble larger datasets of botanic and faunal evidence (e.g. ZILHÃO, 1997).

More recent research, namely in the domain of isotope analysis from human bone remains and zooarchaeology of marine and terrestrial animals, along with a progressive refinement of their chronological framework, contributed to increasing awareness of the mentioned asymmetries through time and across space. Yet, the open questions remained the same: To what extent do these results reflect meaningful features and trends, if any, during the Early and Middle Neolithic? What was the real impact of farming economies in the demography and

social organization of these societies? How can the emergence of the megalithic phenomenon be understood in such broader economic and social scenarios? Recent updated, broad-scale syntheses are lacking in spite of the accumulating evidence (see CARDOSO [2007] for an exception), although those would be perhaps the most suitable way to frame and understand particular historical and geographical contingencies observed in smaller territorial units.

The aim of this paper is therefore to present and discuss the available evidence for the Early and Middle Neolithic in the Estremadura region and neighbouring areas of central Portugal and examine its consequences regarding the above issues. Given persisting research limitations in the area under analysis, this approach will be restricted to general aspects of human settlement, zooarchaeological studies and isotopic datasets. It should be stressed that direct evidence for agriculture is completely unknown due to research and/or taphonomic limitations (for a discussion and an account on current evidence, see ZILHÃO [1997] and CARVALHO *et al.* [2013], respectively), radiocarbon determinations may not be sufficient for statistically-based approaches as have been essayed elsewhere in Europe, and population studies still suffer from coarse-grained chronological resolution. Moreover, research has been uneven and disparate, resulting in geographically contrasting amounts of archaeological data.

## 2. CHANGING SUBSISTENCE STRATEGIES IN THE EARLY AND MIDDLE NEOLITHIC

### 2.1. The background

Estremadura is an elongated region sandwiched between the Atlantic and the Tagus River basin, in central-southern Portugal (Fig. 1). The following brief description by RIBEIRO (1945: 153; Portuguese original) is very instructive about its fundamental geographical features:

«[The] main original feature of Estremadura is the limestone massifs where beautiful examples of all karst forms can be found. Into this still impressive relief, generally formed by anticlines crossed by major faults, penetrates a wedge of abundant rainfall; but water flows away through the cracks in the bare rock and a Mediterranean vegetation of kermes oak, mastic, wild olive and fragrant herbs covers the ground with intermittent tufts».

Data is still insufficient for a detailed depiction of the prevailing bioclimatic conditions during the Middle Holocene. However, the geological features mentioned above – namely the sharp contrast between the limestone massifs (that constitute the backbone of the region) and the surrounding coastal or riverine plains – and their implications as a conditioning factor for human settlement can be securely transposed to Neolithic times. Conversely, the geomorphology of the Tagus Valley has been receiving much attention and its evolution since the last glacial maximum is now relatively well-known (Vis *et al.*, 2008; see Fig. 1C). Both aspects either conditioned or stimulated, not only human settlement, but also mobility and subsistence practices.

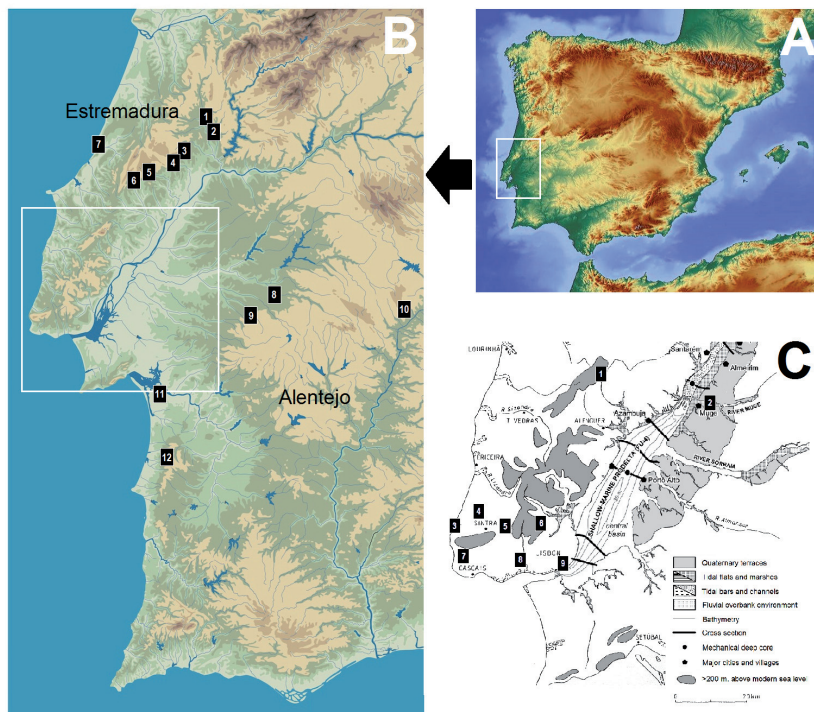


Figure 1: A) Location of the study area in the Iberian Peninsula. B) Estremadura and neighbouring areas. 1 - Cadaval Cave; 2 - Caldeirão Cave; 3 - Pena d' Água Rock-shelter and Costa do Pereiro (open-air site); 4 - Picoto Cave, Cerradinho do Ginete (open-air site) and Galeria da Cisterna (Almonda karstic system); 5 - Barrão Cave; 6 - Lugar do Canto Cave; 7 - Meu Jardim (shell-midden); 8 - Cabeceira 4 (megalithic tomb); 9 - Cabeço da Areia (megalithic tomb); 10 - Sobreira 1 (megalithic tomb); 11 - Comporta shell-middens; 12 - Pedra Branca (megalithic tomb). C) The «Lisbon Peninsula» (after Daveau [1980: 25] and Vis et al. [2008: fig. 12], adapted). 1 - Bom Santo Cave; 2 - Muge shell-middens; 3 - Magoito (shell-midden); 4 - Lapiás das Lameiras (open-air site); 5 - Carrascal de Agualva (megalithic tomb); 6 - Pedras Grandes (megalithic tomb); 7 - Porto Covo Cave; 8 - Carrascal de Leceia (open-air site); 9 - Encosta de Sant' Ana (open-air site).

Indeed, before the Neolithic, the last Mesolithic foragers were established in the mid/lower-section of the Tagus as the outcome of major changes in human geography, from scattered settlement during the Preboreal and Boreal to settlement concentration during the Atlantic. This transition is being understood as the result of new environmental conditions derived from the 8.2 kyr cal BP climatic event that forced clear cut transitions at various levels, from settlement and subsistence strategies to lithic technology (ZILHÃO, 2003; CARVALHO, 2010; BICHO *et al.*, 2010; PEREIRA and CARVALHO, 2015). One of its most notable archaeological manifestations is the large shell-midden sites in the Muge complex (Fig. 1C), where a broad spectrum of food sources, ranging from birds and mammals to sea/estuarine molluscs and fish, is evident in the zooarchaeological record (for

a synthesis, see CARVALHO [2009] and references therein). One of the discussions about Mesolithic adaptations has thus focused on evaluating the relative weight of terrestrial and marine/estuarine resources in overall human subsistence. A first contribution to solve this issue quantitatively – indeed one of the earliest of the kind on the Atlantic façade of Europe – was provided by stable isotope analyses of human remains by LUBELL *et al.* (1994), whose work clearly indicated that subsistence was equally dependent on marine and terrestrial foods throughout the ca. 1,300 years of Mesolithic occupation of these sites. More recent results pointed to the same conclusions (UMBELINO *et al.*, 2007; BICHO *et al.*, 2013).

Dated to 5500/5400–5200 cal BC, the oldest archaeological sites in Estremadura with pottery vessels and polished stone tools associated with a production economy are located in the limestone massifs, not in the Tagus Valley. This is not the place to discuss the causes underlying the appearance of the earliest Neolithic communities in Portugal, but the joint observation of several aspects – geographically unconnected site clusters, their coastal location, presence of domesticated plants and animals whenever organic preservation exists, etc. – indicates a maritime colonisation model by seafaring groups as the one best capable of explaining these traits at the very beginning of neolithisation (ZILHÃO, 1993; CARVALHO, 2010). Moreover, despite variable percentages of cardial vessels, their mere presence integrates these groups in the same historical processes and cultural traditions as documented elsewhere in the Western Mediterranean.

Soon after its arrival, the Neolithic spread to inland sectors of the country, namely to the regions north of the Mondego River (5200 cal BC onwards). Regarding Estremadura, however, the major trend is the notable increase in the number of sites and the concomitant occupation of all existing ecosystems, from hilly limestone massifs to the lower coastal or riverine areas (see below). When the earliest dolmens started to be built – ca. 3600 cal BC, if the older TL dates obtained by WHITTLE and ARNAUD (1975) to the dolmens of Poço da Gateira 1 and Georginos 2 are excluded (see discussion in BOAVENTURA [2011] and references therein) – the whole territory had already been occupied.

These processes have experienced important research developments in two particular areas of Estremadura: the Limestone Massif of Estremadura (hereafter, LME) and the «Lisbon Peninsula» (Fig. 1), thus deserving more detailed characterisation:

- Studied by MARTINS (1949), who provided its most comprehensive description, the former area is a roughly triangular massif that stands out within the region as an impressive uplifted block, well delimited by the 200 metres a.s.l. contour line. Extensive fault escarpments that border its limits, particularly along the Tagus basin, emphasise its orographic individualization that culminates at 677 metres a.s.l. in the Aire Mountain summit. It induces sharp climatic variation between the Atlantic coastal plains, with more abundant rainfall, and the Tagus river basin. Surficial water bodies on the massif only form in the rainy season, thus permitting the development of a sclerophyllous vegetal cover formed by scrubs and maquis. A number of springs rise around its periphery, at the foot of the escarpments, draining to the coast and to the Tagus across plains of sandy or sandstone substrata.

- Strictly speaking, the so-called «Lisbon Peninsula» is not a geographic region *per se* but instead a convenient designation to refer to the territory south of the LME. Its «peninsular» character would be more notable during the Neolithic due to the large Tagus palaeoestuary at the time. In general traits, this sector of Estremadura is formed by limestone plateaux – of which the Montejunto Mountain is the highest, reaching 666 metres a.s.l. – and dense drainage systems flowing to the Tagus right bank or directly to the Atlantic through narrow valleys. Discordant in this landscape is the eruptive massif of the Sintra Mountain, with an East–West orientation, which contributes significantly to the environmental diversity that characterizes the region. However, its most remarkable palaeogeographic feature was undoubtedly the Tagus transgressive palaeoestuary – ca. 15 km wide at the Montejunto latitude – that penetrated deep inland through its main tributaries. This ecologically rich environment surely played a significant role in human subsistence strategies and mobility during the Mesolithic and Neolithic.

## 2.2. Zooarchaeological evidence and herding practices

A synthesis of the available zooarchaeological data for medium and large sized mammals from Early and Middle Neolithic contexts is presented in Table 1 (for site locations, see Fig. 1). As can be seen, faunal remains are very scant in open-air sites (Cerradinho do Ginete, Encosta de Sant’Ana), larger quantities occurring only in deeply stratified sedimentary deposits (Caldeirão Cave, Pena d’Água Rock-shelter). This taphonomic limitation results from thin, superficial archaeological layers in the open-air. It biases not only original faunal representativeness according to types of contexts, but also their systematic taxonomic classification due to higher bone fragmentation patterns. The limitation further pushes researchers to arrive at disparate conclusions – as in the case of wild versus domestic statuses – that prevent firm characterisations of stock-keeping and hunting strategies (see discussion in VALENTE and CARVALHO [2014] and references therein). This is particularly the case of swine – perhaps more than of bovines – since frequent interbreeding between pigs and wild boars and overlapping biometric parameters further hamper their specific differentiation. For this reason, swine remains have been counted as undifferentiated species in Table 1.

If swine are removed from the equation, Early Neolithic faunal assemblages are clearly dominated by domestic cattle and caprines (sheep and goat) with averages of around a quarter of the total number of identified specimens (Fig. 2). This pattern would reverse in favour of wild species if all – or at least most – swine remains are re-classed as wild boar, as initially proposed by ROWLEY-CONWY (1992) for the Caldeirão assemblage (for an opposite view, see DAVIS, 2002). Hunting is represented by a variety of species, mostly red and roe deer, to which variable quantities of lagomorphs not shown in Table 1 should be added.

Table 1. Faunal abundance (total number of identified specimens) by periods and contexts.

Site	wild	domestic	unknown	CE	CC	S	B	BT	BP	C	OA	CH	total	ref.
Caldeirão Cave	EN 112 (11%)	40 (26%)	96 (63%)	13	3	96		20	-	14	6	-	152	[1]
Pena d'Água	EN 22 (33%)	16 (25%)	28 (42%)	21	-	13	14	-	1	17	-	-	66	[2]
Cerradinho do Ginete	EN 1 (14%)	6 (86%)	0 (0%)	1	-	-	6	-	-	-	-	-	7	[2]
Encosta de Sant'Ana	EN 4 (12.5%)	8 (25%)	20 (62.5%)	4	-	14	-	6	-	8	-	-	32	[3]
Carrascal	EN ?	?	?	-	-	+	-	+	+	+	-	-	?	[4]
Cadaval Cave	MN 6 (7%)	73 (81%)	11 (12%)	3	11	+	+	5	-	8	8	10	90	[5]
Pena d'Água	MN 22 (27%)	61 (73%)	0 (0%)	22	-	-	-	-	-	61	-	-	83	[2]
Costa do Pereiro	MN 47 (65%)	9 (13%)	16 (22%)	47	-	13	3	-	-	7	-	2	72	[2]

Period = EN: Early Neolithic; MN: Middle Neolithic. Taxa (Leporidae and carnivores not included) = CE: *Cervus elaphus* (red deer); CC: *Capreolus capreolus* (roe deer); S: Swine (no species classification); SS: *Sus scrofa* (wild boar); SD: *Sus domesticus* (pig); B: Bovines (no species classification); BP: *Bos primigenius* (aurochs); BT: *Bos taurus* (cattle); C: Caprines (no species classification); OA: *Ovis aries* (sheep); CH: *Capra hircus* (domestic goat) +: unquantified presence.

References: [1] Rowley-Conwy (1992); [2] Valente and Carvalho (2014); [3] Muralha and Costa (2006); [4] Cardoso (2010, preliminary results); [5] Almeida et al. (TOMÉ et al. (2013)).

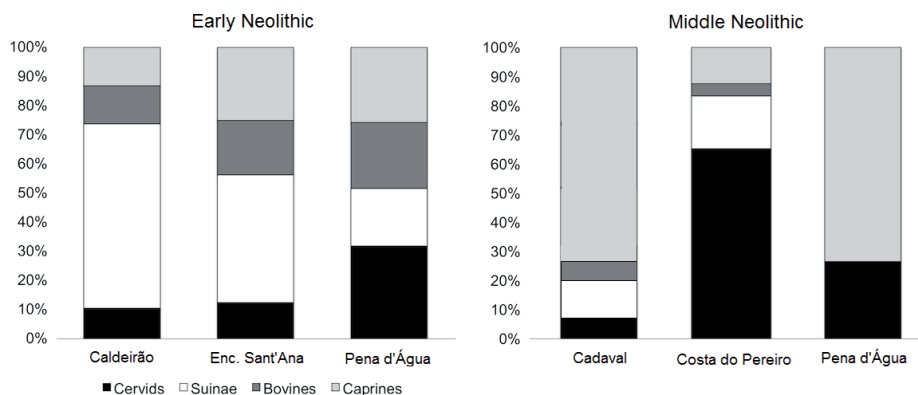


Figure 2. Early and Middle Neolithic main taxa and respective abundance.

Faunal data for the Middle Neolithic are much scarcer (Fig. 2). Only three contexts with fully published faunal assemblages are known in terms of NISP (Table 1): the Pena d'Água Rock-shelter, its neighbouring open-air site of Costa do Pereiro (VALENTE and CARVALHO, 2014; the latter currently in revision; TOMÉ et al. 2013) and Cadaval Cave (ALMEIDA *et al.*, 2015). These sites, however, show contrasting patterns in which herding of sheep/goat and hunting of red deer take turns in abundance, with caprines reaching 73% at Pena d'Água and 75% at Cadaval, and red deer 47% at Costa do Pereiro. These changes seem to point to a dual, more specialized but complementary strategy during this period. It is true that the available evidence is scarce, geographically confined to the LME and further datasets are needed, but the abruptly decreasing percentages of bovines and swine must be symptomatic of some important shift in animal exploitation during the Early to Middle Neolithic transition

In the LME, faunal assemblages come from sites located along the contact rim between the massif and the Tagus basin (Fig. 1B). If the geo-ecological conditions provided by both the massif and the Tagus basin are taken in consideration, the herding of caprines must have been favoured in the limestone plateaux and mountains. During the Early Neolithic this was coupled with the more or less permanent agricultural occupation of the lower plains. Here, other domesticates (pigs?, cattle) were kept until replaced in the following period by the above-mentioned specialization in the herding of caprines and hunting of red deer.

Furthermore, the combined geologic and orographic features of the LME provide interesting research avenues to be explored when more zooarchaeological data become available. In fact, according to MARTINS (1949: 54; Portuguese original), we may be dealing here with quite original herding practices:

«The singularity of the Massif reveals itself in the fact that, unlike other mountains, this is a centre of rejection of animals in the summer; flocks come down to the confines of the lower lands in this season, searching for water and grass. It must be said that, at present, this short-course transhumance – they sometimes reach Nazaré – is tending to end».



Reaching Nazaré, on the Atlantic coast, this recent traditional «short-course transhumance» – as the author puts it – nonetheless had a range of 30–40 km in a straight line from the core areas of the LME and suggests, not only a (minimum?) radius for Neolithic itinerant pastoralism in Estremadura, but also contrasting behaviour if compared with the pastoral occupation of other mountain areas in Portugal (Ribeiro, 1941, 1948): its seasonal abandonment during the summer. Ethno-historical research on the subject may provide a useful framework for prehistoric practices.

Regarding the «Lisbon Peninsula», CARVALHO (2005) and CARDOSO (2010) have stressed the environmentally-diversified character of the region as a key-feature allowing the acquisition of a large spectrum of food-sources. Indeed, several sites show evidence for the consumption of estuarine/marine molluscs while the same domestic mammal species as recognized in the LME are also recorded (Table 1). However, these zooarchaeological assemblages are scant – or almost totally absent, in the case of the Middle Neolithic – and prevent further considerations on animal exploitation strategies, a limitation that may be surpassed only when the assemblages from Lapiás das Lameiras (DAVIS and SIMÕES, 2015) and Carrascal (CARDOSO, 2010) are published in detail. It should be noted in this regard that strontium analyses of sheep/goat remains from Bom Santo Cave showed the frequentation of geologically older regions (PRICE, 2014), a fact interpreted as testimony of itinerant pastoralism between lower Estremadura and neighbouring areas of the Alentejo during the Middle Neolithic (CARVALHO, 2014). Thus, the same practice as suggested by zooarchaeological data from the LME seems to have taken place also in this region.

### 2.3. Stable isotope datasets and quantitative approaches to subsistence

The scatterplot in Figure 3 presents all stable isotopic determinations available for Mesolithic, Early and Middle Neolithic sites in Portuguese Estremadura (for site locations, see Fig. 1B–C). It compiles previously published data (see CARVALHO and PETCHEY [2013] and references therein) and recently-obtained results from the Cardial sites of Caldeirão (ZILHÃO, 1993) and Galeria da Cisterna in the Almonda karst system (ZILHÃO, 2009), and from Cabeceira 4, one of the earliest megalithic tombs in the Alentejo region (ROCHA and DUARTE, 2009; CARVALHO and ROCHA, n.d.). In face of the above-acknowledged scarcity of palaeobotanic and zooarchaeological datasets, this research topic has been seen as a viable avenue to overcome such limitations by providing quantitative insights on palaeodiets for the geographical areas and time periods here in question (LUBELL *et al.*, 1994; CARVALHO and PETCHEY, 2013).

The methodological principles underlying stable isotopic analyses are well-established but the increasing number of results for Neolithic Portugal required the development of specific protocols to cope with latitude variations and the lack of a local faunal and plant database. These protocols were proposed and discussed by CARVALHO and PETCHEY (2013; see in particular pp. 371–372), which included a calculation of the likely percentage of marine or freshwater values for each sample. Thus, the values cited below can be found in Tables 1 and 2 in the mentioned paper, with the associated chronologies being the median of their radiocarbon date calibrated at 2 sigma.

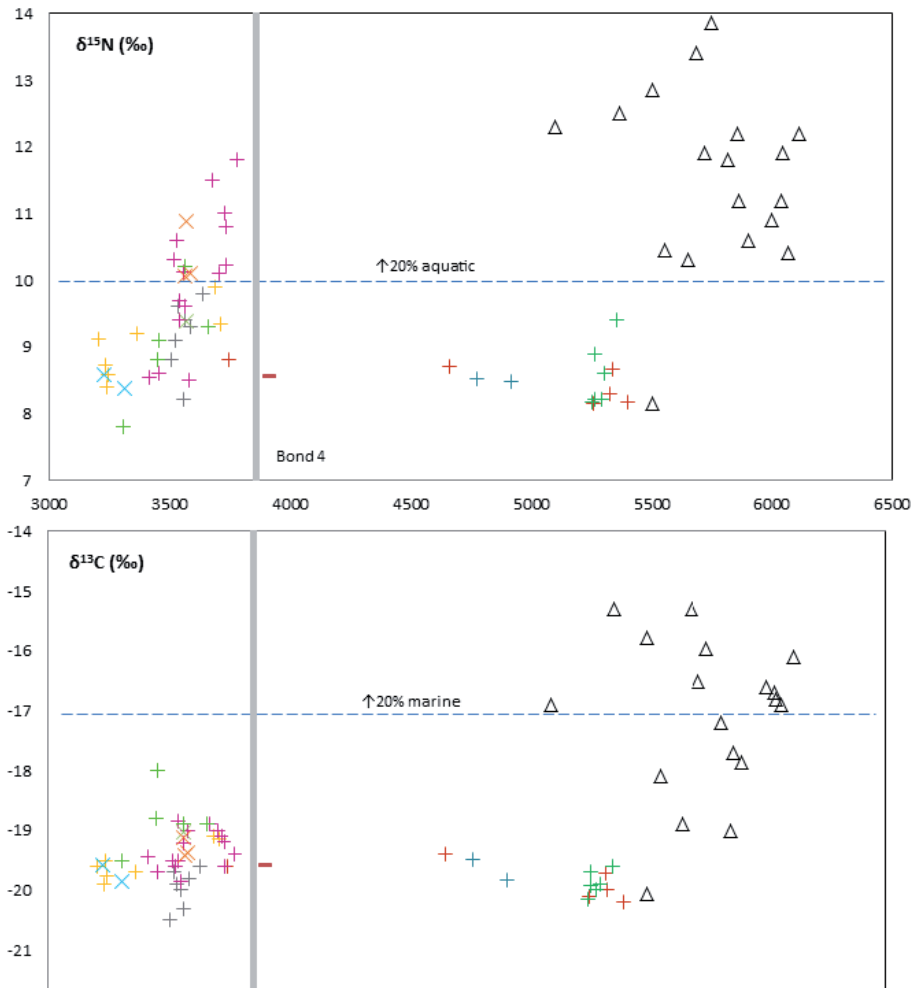


Figure 3. Plotting of isotope results ( $\delta^{15}\text{N}$  and  $\delta^{13}\text{C}$ ) from human bone remains according to absolute chronologies (data from Carvalho and Petchey [2013] and unpublished results). +: cave cemeteries; -: habitation site; x: megalithic monuments;  $\Delta$ : shell-midden sites from the Mesolithic Muge complex

Overall, these isotope results indicate a clear picture of predominantly terrestrial-based subsistence strategies throughout the Neolithic, in keeping with the first results obtained by LUBELL *et al.* (1994). This constitutes the most remarkable quantitative feature characterising these communities' palaeodiets. As exceptions to the rule, some individuals also show variable degrees of consumption of marine or freshwater – i.e., wild – foods and therefore deserve a closer examination.

It should be noted that these exceptions are not found in the Early Neolithic. Indeed, at Caldeirão, Almonda and Picoto marine food intakes are almost

inexistent (average of 2.5%) and freshwater remain below 10% (average of 5.5%). If the former tendency is not surprising given the ca. 50 km that separates these cave cemeteries from the nearest coast, the lower percentages of freshwater foods points definitively to a full terrestrial-oriented subsistence system with riverine ecosystems playing a negligible role. Comparable data from the «Lisbon Peninsula» is, however, necessary to verify in absolute terms the dietary role represented by the occasional finding of sea and/or estuarine molluscs in Early Neolithic sites, such as at Encosta de Sant'Ana (MURALHA and COSTA, 2006) and Carrascal (CARDOSO, 2010).

In the Middle Neolithic, a contrasting behaviour seems to oppose the LME to the «Lisbon Peninsula». Whereas a very clear trend in the consumption of terrestrial foods is still evident in the former – only individuals #01 from Barrão and #36 from Lugar do Canto show percentages of aquatic food sources around 20% (CARVALHO and PETCHEY, 2013) –, the latter area seems to witness a trend through time. Indeed, at Porto Covo, older samples (3600 cal BC *versus* 3400 cal BC) seem to exhibit >20% of marine and freshwater foods. This also seems to be the case if the two dolmens are compared: while the older (3600 cal BC) Carrascal de Aqualva has yielded 12% and 15% marine and aquatic diets, the later (3300 cal BC) Pedras Grandes has, respectively, an average of 3.5% and 5%. This trend seems to correlate well with the fact that only in the middle phase of the Neolithic there are some shell middens known along the Atlantic coast (Fig. 1B–C), at Magoito (SOARES, 2003) and Meu Jardim (VALERA and SANTOS, 2010).

It can be reasonably argued that the above isotopic results are skewed by the greatly reduced sample size. However, at Bom Santo, where a larger number of 15 individuals were analysed, it was possible to verify, not only that nine (60%) had isotope values indicative of a diet composed of  $\geq 20\%$  of freshwater foods, but that a diachronic trend was also observable: during the 3800–3600 cal BC time span there is an average consumption of aquatic foods of 32% (six individuals), which decreases to 18% (nine individuals) in the following 3600–3400 cal BC period. This assessment of high freshwater input in the diet has been interpreted as in keeping with the landscape of the «Lisbon Peninsula» during the mid-Holocene, a time when the northern limit of the Tagus's brackish waters was to the north of Bom Santo and resulted in the formation of peat deposits in the main tributaries and on a very large estuary, permitting therefore the economic exploitation of its presumably abundant wild resources (CARVALHO, 2014).

Moreover, strontium and oxygen isotope analyses of the same population (PRICE, 2014) indicated very high levels of mobility, suggestive of regular occupation of the adjacent Alentejo sector, across the Sorraia Valley, where megalithic tombs have been radiocarbon dated to the same time period (Fig. 1B). This was the case of the Cabeceira 4 dolmen (ROCHA AND DUARTE, 2009), whose human remains, dated to 3600 cal BC, were thought to belong to the same population as Bom Santo's (CARVALHO, 2014) and thus expectably with similar palaeodietary signals. Recently obtained carbon and nitrogen isotope data from the three buried individuals coherently indicated  $\geq 20\%$  of freshwater foods and allowed this hypothesis to be fully confirmed (CARVALHO and ROCHA, n. d.).

In conclusion, a significant trend of decreasing consumption of marine and aquatic foods in the southern part of Estremadura and neighbouring areas of Alentejo through the 3800–3400 cal BC time period is now evident. The open question is to determine why it began.

### 3. DISCUSSION

From the above it seems clear that the available zooarchaeological and stable isotopic evidence for Estremadura show signs of an important economic shift at the Early-to-Middle Neolithic transition or, more precisely, at the passage from the 5th to the 4th millennia BC. In summary:

- in the LME, a specialization in (seasonal?) itinerant pastoralism combined with the hunting of cervids replaces more settled and diversified stock-keeping and hunting practices;
- in the «Lisbon Peninsula», the same Early Neolithic patterns as in the LME seem to be present but the difference is their replacement by itinerant pastoralism (as isotopically detected in Bom Santo sheep/goat specimens) alongside increasing exploitation of estuarine and marine foods, as observed isotopically and in the presence of mollusc debris in contemporary middens.

As mentioned in the introduction, a similar phenomenon can be observed, not only in the Sorraia Valley (CARVALHO, 2014; CARVALHO and ROCHA, n. d.), but also in the case of the seven shell-middens in the Comporta area of the Sado river mouth (SILVA *et al.*, 1986; SOARES and SILVA, 2013), immediately south of Estremadura (Fig. 1B). Here, intensive exploitation of estuarine and marine resources (fish, molluscs, seabirds and salt) occurred between 3700 and 2900 cal BC (Middle Neolithic to Initial Chalcolithic) with very little participation of terrestrial foods. According to SOARES and SILVA (2013), mammal remains are only represented at the Barrosinha midden (96 identified specimens): mostly rabbit (73% of total mammals) and, to a much lesser extent, pig and sheep/goat (16%), and carnivores (11%). The community settled at Comporta is understood by the same authors as descendant of the last Mesolithic hunter-gatherers of the Sado – given similar subsistence strategies and burial practices – who incorporated domestic animals and new material culture items (mainly pottery) through exchange. The reason for their displacement downriver is hypothesised as due to river infill processes and consequent estuary retreat (SOARES, 2013).

Despite the small number of radiocarbon determinations available for the period in question and the inherent difficulty in matching historical and past environmental processes, the transitions in subsistence strategies examined in this paper started at ca. 3800 cal BC and seem to be in-between two major climate and cultural phenomena: deteriorating environmental conditions post-dating the 5.9 kyr cal BP (3900 cal BC) climatic event (BOND *et al.*, 1997), and the building of the earliest megalithic architectures for collective burials in the southern regions of Portugal at around 3600 cal BC (Fig. 4; Table 2).

The impact of the 5.9 kyr cal BP event – also referred to as Bond 4 –, defined by increasing aridity and cooler temperatures, must be scrutinised and evaluated in its implications over these cultural systems.

An analysis of climatic variability in the Holocene by MAYEWSKI *et al.* (2004) allowed the identification of several «rapid climatic changes» (RCC) characterised by the co-occurrence of high-latitude cooling and low-latitude aridity: in particular, «[...] the RCC interval from 6000 to 5000 cal yr B.P. [ca. 4000–3000 cal BC] marks

the end of the early to mid Holocene humid period in tropical Africa, beginning a long-term trend of increasing rainfall variability and aridification [...]» (p. 250), due to solar oscillation, not to ice-rafting as initially thought by BOND *et al.* (1997). But, more importantly, «[...] during the 8.1 kyr event [BOND 5], the climate turned colder and drier, becoming warm and humid afterwards. In contrast, during the 5.9 kyr [BOND 4] and the 4.2 kyr [Bond 3] events, the climate turned very dry, but it did not return to its previous warm and humid state afterwards» (WANG *et al.*, 2013: 4). Although it is necessary to reappraise the available palaeoenvironmental proxies from small-scale geographical units within Estremadura – which is not within the scope of this paper – non-return bioclimatic changes seem indeed to have affected the region. Data retrieved from marine core MD95-2042, off southwest Iberia, indicates eight successive events of forest setbacks (CHAUBAUD *et al.*, 2014). One of them, dated to 3.4 kyr cal BC, consists of a reduction of 17% in the deciduous and evergreen *Quercus* forests, resulting in semi-desert expansions and heathland contractions. This is clearly a further episode in the continuous increasing in dryness and cooling following the Bond 5 event; the striking point, however, is that the pollen percentages of Mediterranean forest species now reaches their minimum values in the whole Middle Holocene. This means that

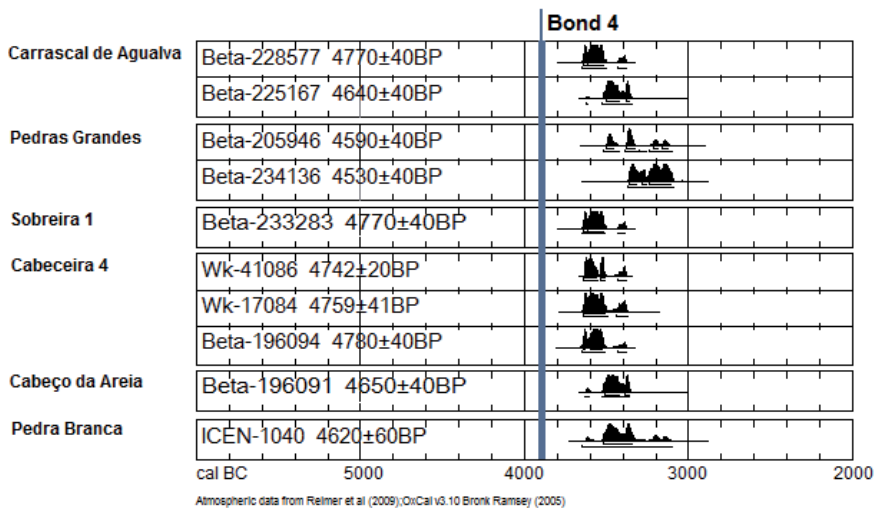


Figure 4. Radiocarbon dates on human bone remains from the oldest megalithic monuments of Estremadura and neighbouring areas of central-southern Portugal (see Fig. 1 for site locations) with indication of the 5.9 kyr cal BP climatic event (Bond 4). Dates plotted with version 3.10 of the Oxcal program (Bronk-Ramsey, 2009).

human responses had to be based on long-term cultural changes. In central Portugal, these responses may have been a stronger emphasis on pastoralism and a renewed focus on available wild foods (terrestrial or aquatic), which acted as a twofold solution to solve this «pre-crisis» scenario within subsistence strategies.

Within this broad context, how can the onset of megalithism be understood? This is a particular acute question given the subsistence scenario described above

Table 2. Radiocarbon dates on human bone remains from the oldest megalithic monuments of Estremadura and neighbouring areas from central-southern Portugal.

Site	<sup>14</sup> C Lab number	Years BP	Calibration range (% prob. BC) (¹)	Ref.
Carrascal de Aqualva	Beta-228577	4770 ± 40	3644–3507 (85.5%), 3427–3381 (9.9%).	[1]
	Beta-225167	4640 ± 40	3620–3612 (0.9%), 3521–3350 (94.5%).	
Pedras Grandes	Beta-205946	4590 ± 40	3511–3425 (30.7%), 3383–3316 (37.8%), 3293–3289 (0.3%), 3274–3266 (0.6%), 3238–3108 (26.1%).	[1]
	Beta-234136	4530 ± 40	3365–3097 (95.4%)	
Sobreira 1	Beta-233283	4770 ± 40	3644–3507 (85.5%), 3427–3381 (9.9%).	[2]
Cabeceira 4	Wk-41086	4742 ± 20	3635–3553 (64.0%), 3541–3512 (19.2%), 3424–3382 (12.2%).	[3], [4]
	Wk-17084	4759 ± 41	3641–3500 (80.6%), 3431–3379 (14.8%).	
	Beta-196094	4780 ± 40	3648–3513 (88.8%), 3424–3383 (6.6%).	
Cabeço da Areia	Beta-196091	4650 ± 40	3621–3608 (2.0%), 3522–3356 (93.4%).	[3]
Pedra Branca (chamber)	ICEN-1040	4620 ± 60	3629–3585 (4.3%), 3531–3312 (75.2%), 3295–3287 (0.4%), 3275–3265 (0.6%), 3239–3106 (14.9%).	[5]

(¹) Calibration of radiocarbon dates at the 2 sigma interval with the IntCal13 curve (Reimer *et al.*, 2013) using calibration program OxCal 4.2.

References: [1] Boaventura (2009); [2] Boaventura *et al.* (2013); [3] Rocha and Duarte (2009); [4] Carvalho and Rocha (n.d.); [5] Soares (2010).

and the processual *versus* post-processual debate on the economic background necessary for societies to build megalithic monuments; i.e., to determine whether or not a fully-established farming economy is a pre-requisite. With very few exceptions (JORGE, 2000: 64–67), this issue received little attention in Portuguese archaeology. A look at what was happening at the same time in the Sahara, which constitutes a roughly parallel process in chronological, palaeoecological and cultural terms, may shed light on this question (for syntheses, see BARICH, 2002; CREMASCHI and ZERBONI, 2006; DI LERNIA, 2006; GIFFORD-GONZÁLEZ, 2005; LE QUELLEC, 2006; VERNET, 2002).

It is now well-known that the end of the African Humid Period (AHP) follows the Bond 5 event (DEMENOCA *et al.*, 2000). While in the eastern Sahara people tended to migrate and settle along the riverine environments of the Nile – where water was available year-round – giving rise later to the Egyptian dynastic civilisation, in the western and central regions archaeological evidence provides a rather distinct cultural process. Increased human mobility and itinerant pastoralism in arid areas alongside sedentism in relict oases were the responses to aridity (for local/regional case-studies, see BROOKS *et al.*, 2009; DI LERNIA, 2006; DI LERNIA and TAFURI, 2013; DI LERNIA *et al.*, 2014; DUNNE *et al.*, 2012; JOUSSE, 2006; KUPER, 2006; SERENO *et al.*, 2008; SMITH, 2006). Stone funerary architectures also started to be built, first for the inhumation of cattle according to elaborate rituals (4400 cal BC) and later to receive human burials (3000 cal BC). Itinerant pastoralism and stone monuments seemed to have been, respectively, the socioeconomic and ideological responses in the face of the Sahara's desiccation. If the former acted as buffer against more arid conditions, the latter has to be related to pastoralist groups that used these stone structures as aggregation sites to mark their territories and travelling routes, an interpretation explicitly evoking similar scenarios frequently put forward to explain megalithism in Western Europe. Recently, MANNING and TIMPSON (2014) also stated that broad-scale population dynamics in the Sahara went through a «major and irreversible population collapse» at around 4000 cal BC, closely coinciding with the end of the AHP.

In spite of the obvious differences in aridity magnitude, geographical settings and particular historic-cultural backgrounds, the above evidence supports the notion that Saharan hunter-gatherer-shepherd groups provides an analogue to frame their broadly coeval Portuguese counterparts. If this analogy is confirmed in the future to be workable, it strongly suggests that social imperatives, more than a simple farming *versus* non-farming equation, were the determining causes that pushed human groups to build durable monuments in stone. Moreover, in both regions megalithism triggered more profound changes towards higher levels of inequality and social complexity.

#### 4. CONCLUSIONS

To our knowledge, the emergence of megalithism in Portugal has seldom, if ever, been explained as a response to climate fluctuations in the Holocene. Research history shows nuanced but cyclic perspectives balanced between exogenous/migration or local/evolutionary-based explanations. Even under the most marked processual perspectives of the 1980/90s such views were excluded from interpretations (e.g. JORGE, 1990; SILVA, 1997). However, accumulating

palaeoclimate evidence from several proxies—and also acquired awareness of present-day global climate change—suggested that the collapse of the earliest urban civilisations and empires could be reanalysed from this perspective. This took place at the turn of the century and was carried out in some cases by researchers directly involved in palaeoenvironmental studies (e.g. DEMENOCAL, 2001). Approaches like this have since then been reintroduced in the archaeological agenda and will expectably receive renewed attention in the 21st century as one of its «grand challenges» (KINTIGH *et al.*, 2014).

The proposals presented in this paper are only preliminary, tentative and obviously require further investigation in a number of research fields, not to mention that sound correlations between climate and culture are often complex and rather imprecise, especially when evaluating possible delayed effects of the former over the latter. Moreover, comparative approaches to cultural processes—as attempted above—must always be mediated by the pre-existing socioeconomic structures and ideology of the human societies under study; indeed, strict deterministic views tended to underestimate cultural resilience as a crucial factor in human responses, and this has been neglected in the past.

With these reservations in mind, some aspects derived from the Saharan evidence in the 4th millennium BC, however, can be retained at this point of the research as analogue to the regions of central-southern Portugal—or even the whole southern regions of Iberia, where palaeoenvironmental explanations of culture change were proposed in the past (e.g. GILMAN and THORNES, 1985)—and should receive further attention in the future as research topics: (1) that aridification, resulting in decreasing carrying capacity of ecosystems to support farming or forager economies, led human groups to rely more effectively on pastoralism (and wild resources, whenever available); (2) that the most adequate type of pastoralism to cope with aridity is itinerancy (especially of sheep/goat, rather than cattle), to exploit sparse availability of water and pastures more efficiently; (3) that these processes of extending economic territories carries a social/ideological «side effect»: the building of ritual and funerary stone architectures to mark the landscape and to establish new strategies of social interaction between groups; (4) that such processes may have resulted, in due time, in the emergence of more permanent forms of inequality within and between communities (through competition?); and (5) that a «boom-bust» process in population sizes may have occurred during these stages of the Neolithic in both regions.

## 5. ACKNOWLEDGMENTS

I would like to thank the two anonymous reviewers, respectively, for their encouraging comments and criticisms.

## 6. REFERENCES

ALMEIDA, N.J.O., CERRILLO, E., OOSTERBEEK, L. and SALADIÉ, P. (2015): «Algumas considerações em torno das dinâmicas paleoeconómicas durante o Neolítico médio na bacia do baixo e médio Vale do Tejo: o contributo da Gruta do



- Cadaval, Alto Ribatejo», in: A.R. Cruz and E. Cerrillo (eds.), *Tráfego de objetos, tráfego tecnológico. Sintomas das ideologias dominantes na Ibéria*. Instituto Politécnico de Tomar, Tomar: 38–42.
- BARICH, B.E. (2002): «Cultural responses to climatic changes in North Africa: beginning and spread of pastoralism in the Sahara», in F.A. HASSAN (ed.), *Droughts, food and culture. Ecological change and food security in Africa's later Prehistory*, Kluwer Academic / Plenum Publishers: New York: 209–224
- BICHO, N.F., PEREIRA, T., GONÇALVES, C., CASCALHEIRA, J., MARREIROS, J. and DIAS, R. (2013): «Os últimos caçadores-recolectores do Vale do Tejo: novas perspectivas sobre os concheiros de Muge», in J. SOARES (ed.), *Pré-História das zonas húmidas. Paisagens de sal*, Museu de Arqueologia e Etnologia do Distrito de Setúbal, Setúbal: 57–68.
- BICHO, N.F., UMBELINO, C., DETRY, C. and PEREIRA, T. (2010): «The emergence of Muge Mesolithic shell middens in central Portugal and the 8200 cal yr BP cold event», *Journal of Island & Coastal Archaeology* 5(86): 86–104.
- BOAVENTURA, R. (2009): *As antas e o Megalitismo da região de Lisboa*, Universidade de Lisboa: Lisbon (unpublished Ph.D. dissertation).
- BOAVENTURA, R. (2011): «Chronology of megalithism in South-Central Portugal», *Menga*, 1: 159–190.
- BOAVENTURA, R., FERREIRA, M.T. and SILVA, A.M. (2013): «Perscrutando espólios antigos: a anta de Sobreira 1 (Elvas)», *Revista Portuguesa de Arqueologia*, 16: 63–79.
- BRONK-RAMSEY, C.B. (2009): *OxCal program v.4.2*. University of Oxford, Radiocarbon Accelerator Unit: Oxford <<https://c14.arch.ox.ac.uk/oxcal/OxCal.html>>.
- BROOKS, N., CLARKE, J., GARFI, S. and PIRIE, A. (2009): «The archaeology of Western Sahara: results of environmental and archaeological reconnaissance», *Antiquity*, 83: 918–934.
- CARDOSO, J.L. (2007): *Pré-História de Portugal*, Universidade Aberta, Lisbon.
- CARDOSO, J.L. (2010): «O Neolítico antigo da Baixa Estremadura: as investigações dos últimos cinco anos», in J.F. GIBAJA and A.F. CARVALHO (eds.), *Os últimos caçadores-recolectores e as primeiras comunidades produtoras do sul da Península Ibérica e do norte de Marrocos*, Universidade do Algarve, Faro: 23–48.
- CARVALHO, A.F. (2005): «As mais antigas sociedades camponesas da Península de Lisboa (c. 5.200-4.500 cal BC)», in: V.S. Gonçalves (ed.), *Cascais há 5000 anos*. Câmara Municipal de Cascais, Cascais: 33–43.
- CARVALHO, A.F. (2008): *A neolitização do Portugal meridional. Os exemplos do Maciço Calcário Estremenho e do Algarve ocidental*, Universidade do Algarve, Faro.
- CARVALHO, A.F. (2009): «O Mesolítico final em Portugal», in: P. Utrilla and L. Montes (eds.), *El Mesolítico geométrico en la Península Ibérica*, Universidad de Zaragoza, Zaragoza: p. 33–68.
- CARVALHO, A.F. (2010): «Le passage vers l'Atlantique. Le processus de néolithisation en Algarve (Sud du Portugal)», *L'Anthropologie*, 114(2): 141–178.
- CARVALHO, A.F. (2014): «Bom Santo Cave in context. A preliminary contribution to the study of the first megalith builders of Southern Portugal», in: A.F. Carvalho (ed.), *Bom Santo Cave (Lisbon) and the Middle Neolithic Societies of Southern Portugal*, Universidade do Algarve, Faro: 209–230.
- CARVALHO, A.F., ALVES-CARDOSO, F., GONÇALVES, D., GRANJA, R., CARDOSO, J.L., DEAN,

- R.M., GIBAJA, J.F., MASUCCI, M.A., ARROYO-PARDO, E., FERNÁNDEZ, E., PETCHEY, F.; PRICE, T.D., MATEUS, J.E., QUEIROZ, P.F., CALLAPEZ, P.M., PIMENTA, C. and REGALA, F.T. (2015): «The Bom Santo Cave (Lisbon, Portugal): catchment, diet and patterns of mobility of a Middle Neolithic population», *European Journal of Archaeology* (available on-line).
- CARVALHO, A.F. and CARDOSO, J.L. (2015): «Insights on the changing dynamics of cemetery use in the Neolithic and Chalcolithic of Southern Portugal. Radiocarbon dating of Lugar do Canto Cave (Santarém)», *Spal*, 24: 35-53.
- CARVALHO, A.F., GIBAJA, J.F. and CARDOSO, J.L. (2013): «Insights into the earliest agriculture of Central Portugal: sickle implements from the Early Neolithic site of Cortiçóis (Santarém)», *Comptes Rendus Palevol*, 12: 31-43.
- CARVALHO, A.F. and PETCHEY, F. (2013): «Stable isotope evidence of Neolithic palaeodiets in the coastal regions of Southern Portugal», *Journal of Island & Coastal Archaeology*, 8(3): 361-383.
- CARVALHO, A. F. and ROCHA, L. (n. d.): «Datação direta e análise de paleodietas dos indivíduos da anta de Cabeceira 4.<sup>a</sup>: contribuição para o estudo das origens do megalitismo do centro-sul de Portugal», *XI Congresso Ibérico de Arqueometria*. Universidade de Évora, Évora (accepted for publication).
- CHABAUD, L., SÁNCHEZ-GOÑI, M.F., DESPRAT, S. and ROSSIGNOL, L. (2014): «Land-sea climatic variability in the eastern North Atlantic subtropical regions over the last 14,200 years: atmospheric and oceanic processes at different timescales», *The Holocene*, 24(7): 787-797.
- CREMASCHI, M. and ZERBONI, A. (2006): «Early to Middle Holocene landscape exploitation in a drying environment: two case studies compared from the central Sahara (SW Fezzan, Libya)», *Comptes Rendus Geoscience*, 341: 689-702.
- DAVEAU, S. (1980): «Espaço e tempo. Evolução do ambiente geográfico de Portugal ao longo dos tempos pré-históricos», *Clio*, 2: 13-37.
- DAVIS, S.J.M. (2002): «The mammals and birds from the Gruta do Caldeirão, Portugal», *Revista Portuguesa de Arqueologia*, 5(2): 29-98.
- DAVIS, S.J.M. and SIMÕES, T. (2015): «O Lapiás das Lameiras (Sintra): um sítio paradigmático para o conhecimento da neolitização da fachada atlântica da Península Ibérica», communication presented at the meeting: *O Neolítico em Portugal antes do Horizonte 2020: perspectivas em debate*, Associação dos Arqueólogos Portugueses, Lisbon.
- DEMENOCAL, P.B. (2001): «Cultural responses to climate change during the Late Holocene», *Science*, 292: 667-673.
- DEMENOCAL, P.B., ORTIZ, J., GUILDERSON, T., ADKINS, J., SARNTHEIN, M., BAKER, L. and YARUSINSKY, M. (2000): «Abrupt onset and termination of the African Humid Period: rapid climate responses to gradual insolation forcing», *Quaternary Science Reviews*, 19: 347-361.
- DI LERNIA, S. (2006): «Building monuments, creating identity: cattle cult as a social response to rapid environmental changes in the Holocene Sahara», *Quaternary International*, 151: 50-62.
- DI LERNIA, S. and TAFURI, M.A. (2013): «Persistent deathplaces and mobile landmarks: the Holocene mortuary and isotopic record from Wadi Takarkoru (SW Lybia)», *Journal of Anthropological Archaeology*, 32: 1-15.
- DI LERNIA, S., TAFURU, M.A., GALLINARO, M., ALHAIQUE, F., BALASSE, M., CAVORSI, L., FULLAGAR, P.D., MERCURI, M.A., MONACO, A., PEREGO, A. and ZERBONI, A. (2014):

- «Inside the “African Cattle Complex”: animal burials in the Holocene central Sahara», *PLoS ONE*, 8(2) <<http://doi.org/10.1371/journal.pone.0056879>>
- DUNNE, J., EVERSLED, R.P., SALQUE, M., CRAMP, L., BRUNI, S., RYAN, K., BIAGETTI, S. and DI LERNIA, S. (2012): «First dairying in green Saharan Africa in the fifth millennium BC», *Nature*, 486: 390–394.
- GILMAN, A. and THORNES, J.B. (1985): *Land-use and Prehistory in south-east Spain*. George Allen & Unwin, London.
- GIFFORD-GONZÁLEZ, D. (2005): «Pastoralism and its consequences», in A.B. STAHL (ed.), *African archaeology. A critical introduction*. Blackwell, London: 187–224.
- GONÇALVES, V.S. (2008): *A utilização pré-histórica da gruta de Porto Covo (Cascais)*, Câmara Municipal de Cascais, Cascais.
- JORGE, S.O. (1990): «A consolidação do sistema agro-pastoril», in J. ALARCÃO (ed.), *Nova História de Portugal. Portugal: das origens à romanização*, vol. 1, Presença, Lisbon: 102–162.
- JORGE, S.O. (2000): «Domesticating the land: the first agricultural communities in Portugal», *Journal of Iberian Archaeology*, 2: 43–98.
- JOUSSE, H. (2006): «What is the impact of Holocene climatic changes on human societies? Analysis of West African Neolithic populations dietary customs», *Quaternary International*, 151: 63–73.
- KINTIGH, K.W., ALTSCHUL, J.H., BEAUDRY, M.C., DRENNAN, R.D., KINZIG, A.P., KOHLER, T.A., LIMP, W.F., MASCHNER, H.D.G., MICHENER, W.K., PAUKETAT, T.R., PEREGRINE, P.; SABLOFF, J.A., WILKINSON, T.J., WRIGHT, H.T. and ZEDER, M.A. (2014): «Grand challenges for Archaeology», *American Antiquity*, 79(1): 5–24.
- KUPER, R. (2006): «After 5000 BC: the Libyan desert in transition», *Comptes Rendus Palevol*, 5: 409–419.
- LE QUELLEC, J.-L. (2006): «L’adaptation aux variations climatiques survenues au Sahara central durant l’Holocène», *Le Sahara et l’Homme, un savoir pour un savoir faire*, Douz: 109–129.
- LUBELL, D., JACKES, M., SCHWARCZ, H., KNYF, M. and MEIKLEJOHN, C. (1994): «The Mesolithic-Neolithic transition in Portugal: isotopic and dental evidence of diet», *Journal of Archaeological Science*, 21: 201–216.
- MARTINS, A.F. (1949): *Maciço Calcário Estremenho. Contribuição para um estudo de Geografia Física*. Universidade de Coimbra, Coimbra.
- MAYEWSKI, P.A., ROHLING, E.E., STAGER, J.C., KARLÉN, W., MAASCH, K.A., MEEKER, L.D., MEYERSON, E.A., GASSE, F., VAN KREVELD, S., HOLMGREN, K., LEE-THORP, J., ROSQVIST, G., RACK, F., STAUBWASSER, M., SCHNEIDER, R.R. and STEIG, E.J. (2004): «Holocene climate variability», *Quaternary Research*, 62: 243–255.
- MURALHA, J. and COSTA, C. (2006): «A ocupação neolítica da Encosta de Sant’Ana (Martim Moniz, Lisboa)», *IV Congresso de Arqueologia Peninsular. Do Epipaleolítico ao Calcolítico na Península Ibérica*, Universidade do Algarve, Faro: 157–169.
- PEREIRA, T. and CARVALHO, A.F. (2015): «Abrupt technological change at the 8.2 ky cal BP climatic event in Central Portugal. The Epipaleolithic occupation of the Pena d’Água Rock-shelter», *Comptes Rendus Palevol*, 14: 423–435.
- REIMER, P.J., BARD, E., BAYLISS, A., BECK, J.W., BLACKWELL, P.G., BRONK-RAMSEY, C., BUCK, C.E., CHENG, H., EDWARDS, R.L., FRIEDRICH, M., GROOTES, P.M., GUILDERSON, T.P., HAFLLIDASON, H., HAJDAS, I., HATTÉ, C., HEATON, T.J., HOFFMAN, D.L., HOGG, A.G., HUGHEN, K.A., KAISER, K.F., KROMER, B., MANNING, S.W., NIU, M., REIMER,

- R.W., RICHARDS, D.A., SCOTT, E.M., SOUTHON, J.R., STAFF, R.A., TURNEY, C.S.M. and VAN DER PLICHT, J. (2013): «IntCal13 and Marine13 Radiocarbon Age Calibration Curves, 0–50,000 years cal BP», *Radiocarbon*, 55(4): 1869–1887.
- ROCHA, L. and DUARTE, C. (2009): «Megalitismo funerário no Alentejo central: os dados antropológicos das escavações de Manuel Heleno», in M. POLO and E. GARCÍA-PRÓSPER (eds.), *Investigaciones histórico-médicas sobre salud y enfermedad en el Pasado. Actas del IX Congreso Nacional de Paleopatología*. Grupo Paleolab, Valencia: 763–781.
- RIBEIRO, O. (1941): «Contribuição para o estudo do pastoreio na Serra da Estrêla», *Revista da Faculdade de Letras de Lisboa*, IV(1-2): 213–303.
- RIBEIRO, O. (1945): *Portugal, o Mediterrâneo e o Atlântico*, Sá da Costa, Lisbon.
- RIBEIRO, O. (1948): «Notícia do pastoreio na Serra do Montemuro», *Miscelânea de Estudos à Memória de Cláudio Basto*, Porto: 333–339.
- ROWLEY-CONWY, P. (1992): «The Early Neolithic bones from Gruta do Caldeirão», in: J. Zilhão, *Gruta do Caldeirão. O Neolítico antigo*, Instituto Português do Património Arquitectónico e Arqueológico, Lisbon: 231–257.
- SERENO, P.C., GARCEA, E.A.A., JOUSSE, H., STOJANOWSKI, C.M., SALIÈGE, J.-F., MAGA, A., IDE, O.A., KNUDSON, K.J., MERCURI, A.M., STAFFORD JR., T.W., KAYE, T.G., GIRAUDI, C., N'SIALA, I.M., COCCA, E., MOOTS, H.M., DUTHEIL, D.B. and STIVERS, J.P. (2008): «Lakeside cemeteries in the Sahara: 5000 years of Holocene population and environmental change», *PLoS ONE*, 3(8), <<http://doi.org/10.1371/journal.pone.0002995>>.
- SILVA, C.T. (1997): «O Neolítico antigo e a origem do Megalitismo no Sul de Portugal», in: A. Rodríguez (ed.), *O Neolítico atlântico e as orixes do Megalitismo*, Universidade de Santiago de Compostela, Santiago de Compostela: 575–585.
- SILVA, C.T. and SOARES, J. (1987): «Les communautés du Néolithique ancien dans le Sud du Portugal», in: J. Guilaine, J.-L. Roudil and J.-L. Vernet (eds.), *Premières communautés paysannes en Méditerranée Occidentale*, Centre National de la Recherche Scientifique, Paris: 663–671.
- SILVA, C.T., SOARES, J., CARDOSO, J.L., CRUZ, C.S. and REIS, C.S. (1986): «Neolítico da Comporta: aspectos cronológicos (datas <sup>14</sup>C) e paleoambientais», *Arqueologia*, 14: 59–82.
- SMITH, A.B. (2005): «Creating a landscape for Saharan pastoral archaeology», in B.E. BARICH, T. TILLET and K.H. STRIEDTER (eds.), *Hunters vs. pastoralists in the Sahara: material culture and symbolic aspects*, Archaeopress: Oxford (British Archaeological Reports, International Series; 1338): 47–50.
- SOARES, A.M. (2003): «A duna de Magoito revisitada», *Revista Portuguesa de Arqueologia*, 6(1): 83–100.
- SOARES, J. (2010): «Dólmen da Pedra Branca. Datas radiométricas», *Musa*, 3: 70–82.
- SOARES, J. (2013): «Caçadores-recolectores semi-sedentários do Mesolítico do paleoestuário do Sado (Portugal)», in: J. Soares (ed.), *Pré-História das zonas húmidas. Paisagens de sal*, Museu de Arqueologia e Etnologia do Distrito de Setúbal, Setúbal: 13–56.
- SOARES, J. and SILVA, C.T. (2013): «Economia agro-marítima na Pré-História do Estuário do Sado. Novos dados sobre o Neolítico da Comporta», in J. SOARES (ed.), *Pré-História das zonas húmidas. Paisagens de sal*, Museu de Arqueologia e Etnologia do Distrito de Setúbal, Setúbal: 145–170.
- TOMÉ, T., ALMEIDA, N.J.O., SILVA, A.M., SALADIÉ, P. AND OOSTERBEEK, L. (2013): «UMA PERSPECTIVA OSTEOARQUEOLÓGICA SOBRE DUAS GRUTAS NEOLÍTICAS DO VALE DO NABÃO

- (ALTO RIBATEJO, PORTUGAL CENTRAL)», in: A.R. CRUZ, A. GRAÇA, L. OOSTERBEEK AND P.L. ROSINA (EDS.), 1.º CONGRESSO DE ARQUEOLOGIA DO ALTO RIBATEJO. CEIPHAR: TOMAR: 131-142.
- UMBELINO, C., PÉREZ-PÉREZ, A., CUNHA, E., HIPÓLITO, C., FREITAS, M.C. and CABRAL, J.P. (2007): «Outros sabores do Passado: um novo olhar sobre as comunidades humanas mesolíticas de Muge e do Sado através de análises químicas dos ossos», *Promontoria*, 5: 45-90.
- VALENTE, M.J. and CARVALHO, A.F. (2014): «Zooarchaeology in the Neolithic and Chalcolithic of Southern Portugal», *Environmental Archaeology*, 19(3): 226-240.
- VALERA, A.C. and SANTOS, H. (2010): «O concheiro do Neolítico antigo do “Meu Jardim” (Nazaré): informação preliminar», *Apontamentos de Arqueologia e Património*, 6: 21-27.
- VERNET, R. (2002): «Climate during the Late Holocene in the Sahara and the Sahel : evolution and consequences on human settlement», in: F.A. Hassan (ed.), *Droughts, food and culture. Ecological change and food security in Africa's later Prehistory*, Kluwer Academic / Plenum Publishers: New York: 47-64.
- VIS, G.-J., KASSE, C. and VANDENBERGHE, J. (2008): «Late Pleistocene and Holocene palaeogeography of the Lower Tagus Valley (Portugal): effects of relative sea level, valley morphology and sediment supply», *Quaternary Science Reviews*, 27, 1682-1709.
- WANG, S., GE, Q., WANG, F., WEN, X. and HUANG, J. (2013): «Abrupt climate changes of Holocene», *Chinese Geographical Science*, 23(1): 1-12.
- WHITTLE, E.H. and ARNAUD, J.M. (1975): «Thermoluminescent dating of Neolithic and Chalcolithic pottery from sites in central Portugal», *Archaeometry*, 17(1): 5-24.
- ZILHÃO, J. (1997): «Maritime pioneer colonisation in the Early Neolithic of the West Mediterranean. Testing the model against the evidence», *Documenta Praehistorica*, XXIV: 19-42.
- ZILHÃO, J. (2003): «Algumas observações acerca do Mesolítico do interior peninsular e do modelo de passagem ao Neolítico através de colonização pioneira por via marítima», review of: A.F. CARVALHO, «A emergência do Neolítico no actual território português: pressupostos teóricos, modelos interpretativos e a evidência empírica», *O Arqueólogo Português*, IV, 21: 108-118.
- ZILHÃO, J. (2009): «The Early Neolithic artifact assemblage from the Galeria da Cisterna (Almonda karstic system, Torres Novas, Portugal)», *De Méditerranée et d'ailleurs... Hommages à Jean Guilaine*, Archives d'Écologie Préhistorique, Toulouse: 821-835.
- ZVELEBIL, M. (1986): «Mesolithic societies and the transition to farming: problems of time, scale and organisation», in M. ZVELEBIL (ed.), *Hunters in transition. Mesolithic societies of temperate Europe and their transition to farming*, Cambridge University Press, Cambridge: 167-188.

