Del neolític a l'edat del bronze en el Mediterrani occidental.
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The Pena d'Água rock-shelter (Torres Novas, Portugal): two distinct life ways within a Neolithic sequence

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ABSTRACT
Among testimonies of other occupations, the Pena d'Água Rock-shelter revealed two "stratigraphic blocks" (i.e. sets of layers) reporting, respectively, to the Early and Middle Neolithic, with preservation of organic matter (charcoal and faunal assemblages). The older "stratigraphic block" is characterized by decorated pottery, use of local raw materials, and the balanced exploitation of a large spectrum of animals (both domestic and wild), whereas the younger is characterized by plain pottery, long-distance exchange of raw materials, and specialization in the hunting of cervids and herding of sheep/goat (itinerant pastoralism?). This cultural and subsistence shift coincides with increasing aridity and the emergence of megalithism in Portugal, but sound correlations between these phenomena are still to be made.

KEYWORDS: Portugal, Neolithic, site formation process, economy, palaeo-environment.

RESUMEN
El abrigo de Pena d'Água (Torres Novas, Portugal): dos modos de vida distintos en una secuencia neolítica. Entre los testimonios de otras ocupaciones, el abrigo de Pena d'Água ha revelado dos "bloques estratigráficos" (es decir, conjuntos de capas) referidos, respectivamente, al Neolítico antiguo y al Neolítico medio, con preservación de materia orgánica (restos de carbón y de fauna). El "bloque estratigráfico" más antiguo se caracteriza por la cerámica decorada, el uso de materias primas locales y la explotación equilibrada de un amplio espectro de animales (domésticos y salvajes), mientras que el más reciente viene determinado por la cerámica lisa, el intercambio de materias primas a larga distancia y la especialización en la caza de cérvidos y el pastoreo de ovicápridos (¿pastoreo itinerante?). Este cambio cultural y de subsistencia coincide con el aumento de la aridez y la aparición del megalitismo en Portugal, si bien la correlación entre ambos fenómenos precisaría confirmarse.

PALABRAS CLAVE: Portugal, Neolítico, proceso de formación de yacimientos, economía, paleoambiente.

1. INTRODUCTION

Promoted by the *Servicio de Investigación Prehistórica*, the resumption of the systematic study of the important Cova de l'Or (Alicante, Spain) took place from 1975 onwards under the direction of B. Martí, who studied the remains devoid of a secure context (Martí, 1977) and began excavations with stratigraphic control in the cave's Sector J (Martí et al., 1980). At this very same time, Portuguese Prehistory was experiencing a major methodological turning point regarding cave archaeology. As widely acknowledged, after a promising beginning in the mid-19th century, a decline in the quality of excavation methodologies would characterize most of the following century. It was only in the 1970–80s that a renewed focus on stratigraphy, recording of particular contexts (human-made structures, funerary practices, etc.), the introduction of so-called "ancillary disciplines" (sedimentology, zooarchaeology, radiocarbon dating, etc.), and the thorough sieving of sediments, would become common procedures. Guilaine and Ferreira's (1970) paper on Early Neolithic pottery production in Portugal constitutes an excellent example of the state of the art of cave research before this turning point: pottery chronologies were established through stylistic comparisons with cave sequences from Spain and France rather than by the provenance contexts of the vessels themselves.

An evaluation and discussion of the changing methodologies and techniques put in practice in karst archaeology in Portugal during the 1970–80s is beyond the scope of this text. However, the work by B. Martí on the Iberian Neolithic and cave archaeology impacted Portuguese research perhaps more than usually perceived. Not only a new, sound stratigraphic sequence for the Neolithic in the peninsula was provided by the Cova de l'Or sequence (Martí et al., 1980, 1987)—that would soon become crucial as a comparison framework for the homologous evidence from Portugal—but also a critical perspective on the understanding of cave deposits was introduced in the debate by the often-cited paper in collaboration with J. Fortea on the beginnings of the Neolithic in Mediterranean Spain (Fortea and Martí, 1984/85). These contributions would be developed by J. Zilhão (1992, 1993) in his reinterpretation of several cave sequences in the Iberian Peninsula and the Languedoc, which would revolutionise the whole picture of the transition to farming in the western Mediterranean regions. This methodological turning point inspired my own methodological options in the excavation, among other sites, of the long and rather complex stratigraphic sequence discovered at the Pena d'Água Rock-shelter (Torres Novas, Portugal).

The aim of this text is, thus, to present Pena d'Água by focusing on the current understanding of the processes underlying the formation of its sedimentary deposit and, regarding the Neolithic period as recorded at the site, by noting the main changes observable in both cultural (mainly through pottery production) and economic (raw material and animal exploitation strategies) behaviour. As will be shown, two main moments (corresponding to two "stratigraphic blocks") within the Neolithic sequence were recognized and may bear relevant consequences for the understanding of the Early and Middle Neolithic periods in the southern regions of Portugal. This cultural record is here tentatively framed in the available palaeo-environmental data, either locally obtained or derived from larger-scale proxies.

2. DISCOVERY AND DESCRIPTION

When, in December 1991, a local team of speleologists from the *Sociedade Torrejana de Espeleologia e Arqueologia* (STEA) used a backhoe to open the access to a seasonal spring through the sedimentary deposit that was obstructing it—in a place symptomatically named Pena d'Água (meaning literally "scarp of the water")—numerous fragments of pottery, knapped stone and animal bones emerged from the removed earth. Immediately halted, this operation nonetheless enabled the discovery of a rock-shelter in this sector of the Arrife, a local term derived from the Arabic *ar-rîff* ("coast", "scarp") to name the several kilometre-long fault escarpment that separates the Limestone Massif of Estremadura from the Tagus Basin (Fig. 1).

Indeed, the inspection of the deposit profiles by J. Zilhão and STEA members were able to confirm the presence of strata with human occupation down to a depth of around 5 metres. The scarp wall is very abrupt here—around 30 m in height, culminating at ca. 180 metres a.s.l. in its upper summits—whereas the area in front of the Arrife forms a steep slope due to the accumulation of huge boulders collapsed from the rock-shelter's roof. The deposit reveals itself through a very prominent topography visible at the foot of the limestone scarp (Fig. 1), reaching 125–130 metres a.s.l. It has an estimated length of around 70 metres, with a NE–SW orientation, only affected by the opening of the access at its easternmost end.

At a regional scale, it should be emphasised that there are, along the foot of the Arrife, successive sedimentary deposits whose archaeological interest is evident. These, however, lie under thick vegetation cover (shrubs, olive and oak trees, some of them centennial) and, most probably, collapsed rock-shelters, as in the case of Pena d'Água. Only very intrusive actions may be able to identify similar sites and evaluate their archaeological potential. This was what happened at Pena d'Água, permitting archaeological excavations to be carried out during eight short field seasons between 1992 and 2000.

In a first stage (1992–1995), a 2×3m test pit was excavated in squares L29-30 (Fig. 2). In 1997, this was extended to an adjacent area of 3×7m, corresponding to the I-K/25-30 squares, which allowed the observation that the tip of the deposit was affected by hydrologic processes caused by the local spring, resulting in the thinning of the strata and their truncation by erosive channels in the lower layers. Given these limitations, the excavation had to be focused on the rectangle represented by squares I-K/29-30 in the last, third stage of excavations at the site (1998–2000). Overall, the excavation is very limited in area and only further excavations, in the upper sector of the deposit, would permit the recovery of sounder evidence related to the Neolithic occupation of the site.

The above work resulted in several publications. After a first modelling of the Neolithic sequence in the regional framework (Zilhão and Carvalho, 1996), a set of studies was published in the 1998 volume of the *Revista Portuguesa de Arqueologia*, where detailed accounts of the 1992–1995 fieldwork, site formation processes and human occupations were made (Carvalho, 1998a) along with studies on anthracology (Figueiral, 1998), insectivores and rodents (Póvoas, 1998), and zooarchaeology of larger mammals (Valente, 1998). More recently, a geo-archaeological analysis of the excavated deposit has also been carried out (Simões, 2012) and further zooarchaeological studies of Early (Carvalho, Valente and Haws, 2004) and Middle Neolithic (Luís, Correia and Fernandes, n.d.) assemblages from the 1998–2000 seasons have been published.

The Early Neolithic has been the occupation phase to which a larger number of studies have been devoted: alongside a more complete approach (Carvalho, 2008a), lithic techno-typological and use-wear analyses (Carvalho, 1998b; Carvalho and Gibaja, 2005; Gibaja and Carvalho, 2005) and ceramic provenance studies (Masucci and Carvalho, 2015) have also been carried out. Other occupations were also published: Medieval and/or Modern potsherds from Layer A (Ferreira, 1998), Iron Age pottery and radiocarbon determinations from Layer B (Carvalho, 2008b), and the Epipalaeolithic occupation from Layer F (Pereira and Carvalho, 2015). A brief synthesis of the site is available in Spanish (Carvalho, 2012: 193–196).

3. STRATIGRAPHY AND SITE FORMATION PROCESSES

Immediately after its discovery, the upper stratigraphic unit, formed by huge limestone boulders, was observed to be the result of the rock-shelter's collapse. All the underlying units with remains of human occupation were sealed under it. At first, this conditioned the excavation methodology (Fig. 3): picks and shovels (and explosives whenever necessary) had to be used to remove this deposit (thereafter, Layer A) and reach archaeologically-rich layers. Sediments were then excavated with trowels and systematically dry-sieved using a 3mm mesh screen. Bulk samples of unsieved sediments (10 litres per artificial level and unit square) were collected for flotation (presently in course) in order to recover very small-sized elements (microfauna, seeds, etc.). Strata were subdivided in 5 or 10cm thick arbitrary levels and materials were given 3D coordinates as exhaustively as possible.

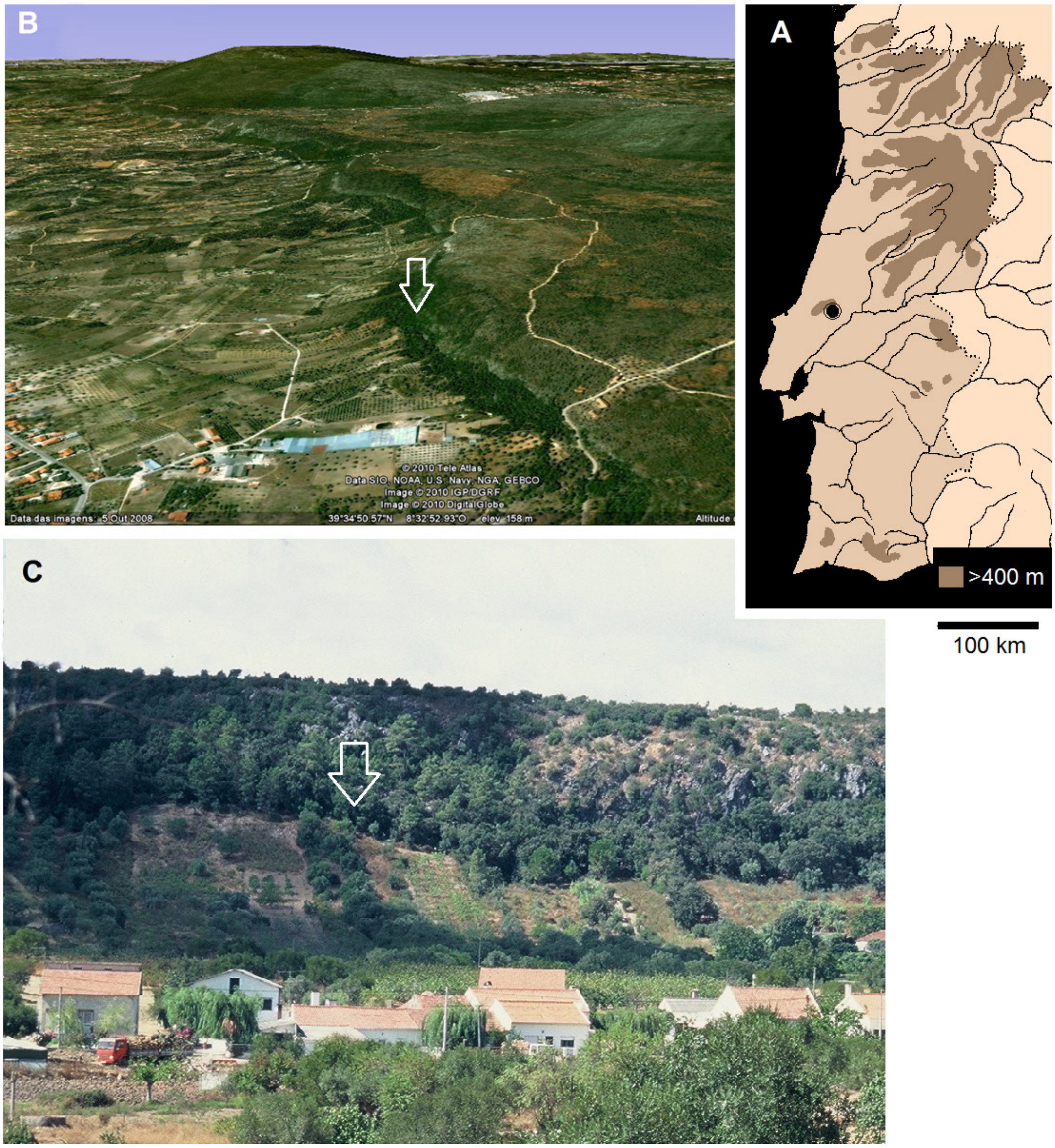

Fig. 1. Location of the Pena d'Água Rock-shelter. A: location in Portuguese Estremadura; B: Google image of the Arrife, with the limestone plateau on the right and the plains of the Tagus Valley on the left; C: photo of the Arrife with indication of the excavated sector (note the rising topography to the left of the arrow due to the rock-shelter deposit beneath the vegetation cover).

This methodology was able to identify nine main stratigraphic units (Fig. 4), designated, from top to bottom, Layers A to F (for a short description of each layer and its respective cultural assignment, see Table 1). Unfortunately, bones preserved insufficient collagen for AMS dating (despite the systematic attempts) and, therefore bulk charcoal samples (mostly of long-lived species) were the only usable type of sample, which implies severe limitations regarding their correlation with human occupational events, the only exceptions being samples of charcoal exhumed from hearths in Layers B and Eb-top (Table 2). However, for the reconstitution of site formation processes the available determinations may be of some help (see below).

Indeed, what seems at first glance to be a simple, straightforward stratigraphic sequence is, however, the result of a rather complex interaction of multiple phenomena. Six main phases in the formation history of the Pena d'Água Rock-shelter deposit can be preliminarily proposed based on stratigraphic observations during excavation, geo-archaeological analyses and various proxies of palaeoenvironmental nature, either local, regional or even global (Table 3).

The earliest, Phase 1, corresponds to the formation of layer F, which took place under a very distinctive condition: according to field observations (Carvalho, 1998a) and sedimentological analysis (Simões, 2012), its accumulation was due to the circulation

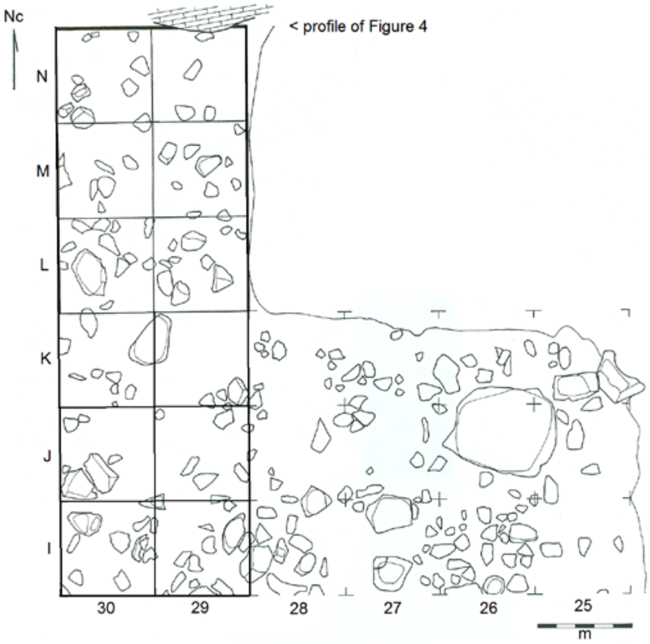

Fig. 2. Excavation plan of the Pena d'Água at top of layer B. Marked squares refer to the excavated area: L-N/29-30 in 1992–1995 and I-K/29-30 in 1998–2000. The blank area on the upper right corresponds to the access opened in 1991.

of water from nearby springs, probably through the remobilizing of the Miocene substratum. Technologically and typologically, its artefacts are of Epipalaeolithic age. This was confirmed by a radiocarbon result, whose calibration makes it broadly coeval with the 8.2 kyr cold event (or Bond 5) which caused major changes in human settlement and mobility in the Estremadura and lower Tagus region (e.g., Pereira and Carvalho, 2015).

After a first episode of roof collapse in an indeterminate moment in time (Phase 2), apparently associated with a sedimentary hiatus, a constant accumulation of sediments with an argillaceous component started to take place (Phase 3). Spring activity resulted in the truncation of layers by channels and in more or less severe—depending to the channels' topography and depth—disturbance of the archaeological horizons. The whole formation of layers Eb to Ea, dated in the Early Neolithic, occurred under such environmental conditions at the local scale. As pointed out above, these limitations constrained the excavation to Squares I-K/29-30 in the last stage of excavations (1998–2000).

Phase 4 is particularly visible in profile due to a major change in stratification (Fig. 4): after a horizontal, slow accumulation of sediments in the previous phase (evidenced by a horizontal level of 30–40 cm large blocks on top of Layer Ea), Layers Db to C, dated to the Middle Neolithic, were accumulated according to a SW–NE inclination (evidenced by a second, sloping level of blocks of the same size). This changing sedimentation angle was due to still unknown reasons. It is also associated with a faster rate of sedimentation, reduction in its argillaceous component and the presence of iron oxides in Layers Db and Da, which may be related to in situ post-depositional alterations associated to soil-forming processes and increasing aridity conditions (Simões, 2012). There is no evidence for spring activity in this phase, which together with the precipitation of iron oxides is therefore congruent with the inferred aridity.

After the formation of Layer B, a long period of time with no significant sedimentation must have taken place at Pena d'Água, thus giving place to Phase 5. This sedimentary hiatus and the continuous human occupation at the site resulted in an archaeological palimpsest (Late Neolithic, Iron Age, Roman), attested by mixed material culture items and disparate radiocarbon determinations (Carvalho, 1998a, 2008b). This means

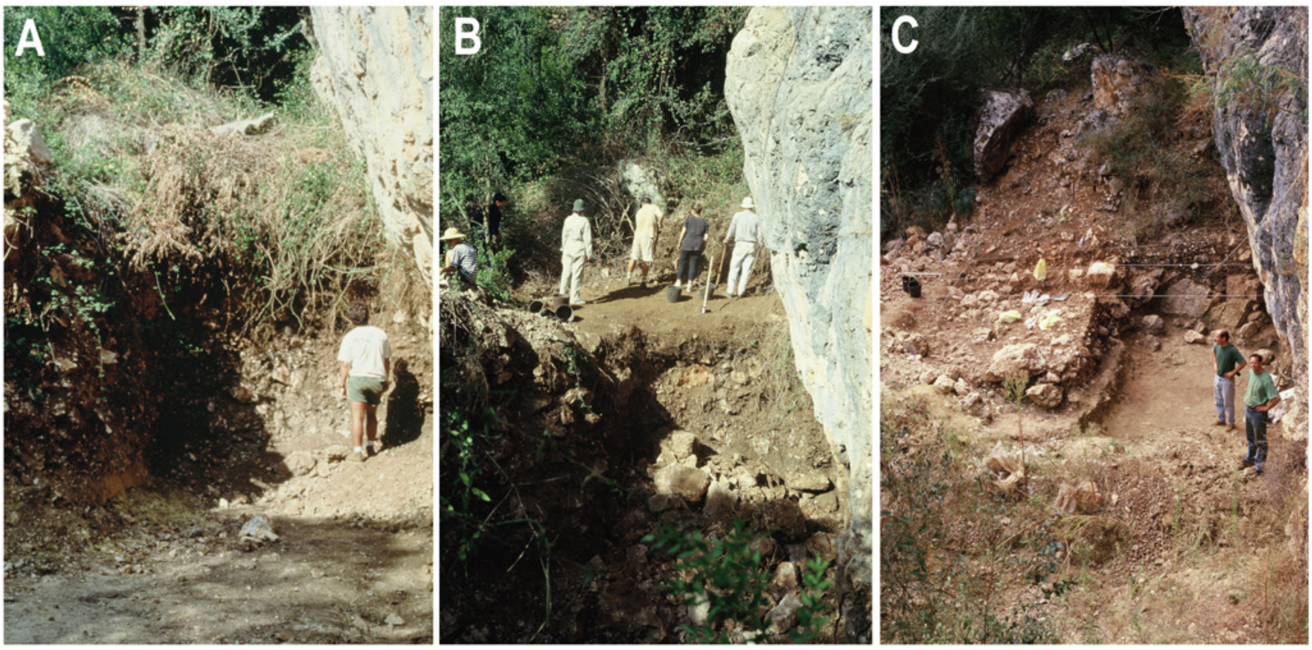

Fig. 3. Evolution of the excavation works at the Pena d'Água Rock-shelter. A: before the beginning of the excavations (1992); B: during the removal of boulders from layer A (1992); C: general overview of the excavated area in 1997 (note the boulders of the collapsed roof).

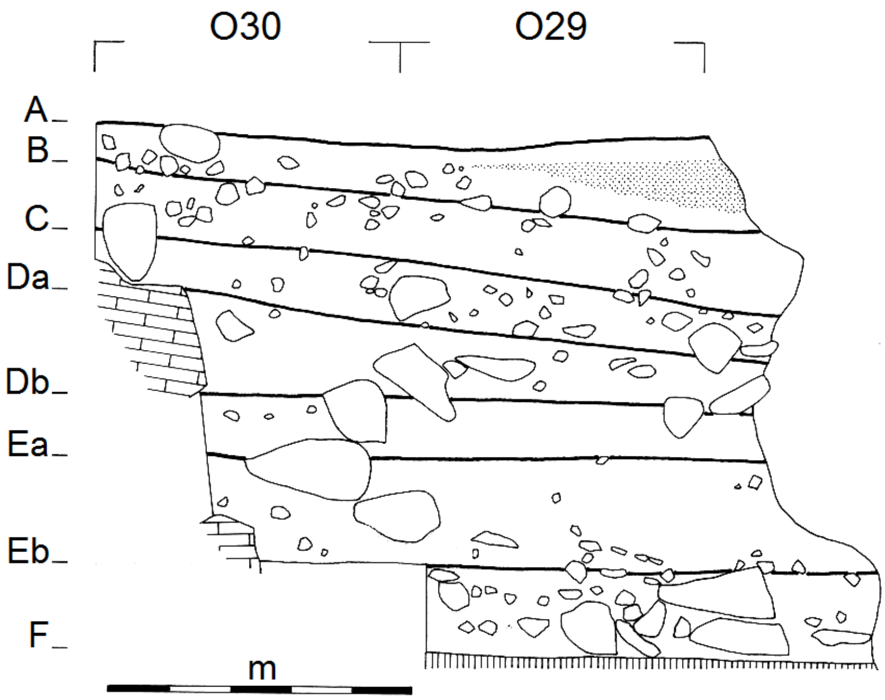

Fig. 4. Stratigraphic profile of the Pena d’Água (layer A removed). Note the inclination of the upper layers (C and Da) while the lower ones (Ea to F) show a horizontal stratification.

Table 1. Summary of the stratigraphy and archaeology of the Pena d’Água Rock-shelter.

Layer	Stratigraphy	Archaeology
A	Big boulders (>2 tons) from collapsed roof and loose sediments of miscellaneous colours with penetrating tree and shrub roots.	Scattered Medieval and Modern potsherds.
B	Medium-sized clasts (10-15 cm) in a sandy-argillaceous matrix of greyish to brownish / reddish sediments away or closer to the shelter’s wall, respectively. In outer squares (rows I–J) part of the matrix was slope-washed.	Palimpsest of Late Neolithic, Iron Age and Roman occupations.
C	Small-sized clasts (<10 cm) in a sandy-argillaceous matrix of greyish to brownish/ reddish sediments away or closer to the shelter’s wall, respectively. In outer squares (rows I–J) part of the matrix was slope-washed.	Middle-to-Late Neolithic transition with Iron Age intrusions.
Da	Scattered small-sized clasts (<10 cm), mostly in it top level, in abundant, more compacted sedimentary matrix of a sandy-argilleous sediments, of homogeneously greenish-to-brownish colours. Slope-wash phenomena not recorded. An alignment of large blocks (30-40 cm) indicates an south–north inclination of the layer,	Middle Neolithic with Iron Age intrusions.
Db	Scattered small-sized clasts (<10 cm), mostly in it top level, in abundant, more compacted sedimentary matrix of a sandy-argillaceous sediments, of homogeneously greenish-to-brownish colours. An alignment of large blocks (30-40 cm) in the lower level indicates a horizontal stratification.	Initial Middle Neolithic.
Ea	Loose sandy-argillaceous sediments with small-sized clasts (<10 cm), some weathered, with brownish colours.	Evolved Early Neolithic
Eb-top	Loose sandy-argillaceous sediments with small-sized clasts (<10 cm). Numerous micro-fragments of charcoal induce a more greyish tonality in otherwise brownish sediments.	Evolved Early Neolithic
Eb-bottom	Loose sandy-argillaceous sediments of brownish colours with small-sized clasts (<10 cm).	Cardial Neolithic
F	Yellowish (light-greenish when wet) coarse sands with small-sized clasts (<10 cm), very dense and compacted. There are also larger blocks (40–60 cm) and fragments of limestone tuff. It lies on top of a local Miocene substratum of very coarse sands with pebbles.	Epipaleolithic

Table 2. Radiocarbon determinations for Pena d'Água Rock-shelter.

Sample provenance (1)	Lab code (2)	Sample type / species	^{14}C result (BP)	Calibration BC (3)	Calibration BP (3)
Roman					
N29.B.2 [hearth]	ICEN-965 (St.)	bulk charcoal (*Olea*?)	2000±50	161–132 BC (3.5%) 118 BC–87 AD (90.3%) 105–121 AD (1.6%)	2110–2081 (3.5%) 2067–1863 (90.3%) 1845–1830 (1.6%)
Iron Age					
K29.Da.1 + K30.Da.1	Wk-9742 (AMS)	bulk charcoal (*Olea*?)	2428±56	757–679 (21.0%) 672–402 (74.4%)	2706–2628 (21.0%) 2621–2351 (74.4%)
I30.Da.5	Wk-9215 (AMS)	bulk charcoal (4)	2410±59	756–679 (19.0%) 671–396 (76.4%)	2705–2628 (19.0%) 2620–2345 (76.4%)
Initial Middle Neolithic					
N30.Db.4 + N29.Db.4	Beta-137945 (AMS)	bulk charcoal (5)	4250±50 (6)	—	—
N29.Db.4	Sac-1822 (St.)	bulk charcoal (*Olea*?)	3430±60 (6)	—	—
L29.Db4	ICEN-1147 (St.)	bulk charcoal (*Olea*?)	5180±240	4522–3515 (95.0%) 3412–3405 (0.1%) 3399–3384 (0.3%)	6471–5464 (95.0%) 5361–5354 (0.1%) 5348–5333 (0.3%)
Evolved Early Neolithic					
M29.Ea.2	ICEN-1148 (St.)	bulk charcoal (*Olea*?)	5170±200	4448–4416 (0.8%) 4404–3631 (93.9%) 3562–3536 (0.7%)	6397–6365 (0.8%) 6353–5580 (93.9%) 5511–5485 (0.7%)
K29.Ea.3.48 + K29.Ea.3.50	Wk-9743 (St.)	bulk charcoal (*Olea europaea*)	5856±114	4998–4459 (95.4%)	6947–6408 (95.4%)
Evolved Early Neolithic					
K29.Eb-t.1 [hearth]	Wk-16418 (AMS)	single charcoal (*Olea europaea*)	5831±40	4791–4580 (94.4%) 4567–4559 (1.0%)	6740–6529 (94.4%) 6516–6508 (1.0%)
K29.Eb-t.1.65 + K30.Eb.1.43	Wk-9744 (AMS)	bulk charcoal (*Olea europaea*)	5753±62	4763–4759 (0.3%) 4728–4457 (95.1%)	6712–6708 (0.3%) 6677–6406 (95.1%)
L29.Eb-t.4.116	OxA (AMS)	single bone (*Ovis aries*)	(7)	—	—
Cardial Neolithic					
N29.Eb-b.10	ICEN-1146 (St.)	bulk charcoal (*Olea*?)	6390±150	5623–5011 (95.4%)	7572–6960 (95.4%)
K29.Eb-b.3	Wk-9214 (AMS)	bulk charcoal (*Olea europaea*)	6775±60	5777–5610 (91.8%) 5592–5563 (3.6%)	7726–7559 (91.8%) 7541–7512 (3.6%)
M29.Eb-b.11.154	OxA (AMS)	single bone (*Sus scrofa*)	(7)	—	—
N29.Eb-b.11.177	Wk (AMS)	single bone (*Ovis aries*)	(7)	—	—
Epipalaeolithic					
K29.F.1	Wk-9213 (St.)	bulk charcoal (*Quercus suber*)	7370±110	6436–6034 (95.4%)	8385–7983 (95.4%)

(1) Respectively: square, layer (t = top; b = bottom), artificial level, 3D coordination number.
(2) St.: standard determinations; AMS: accelerator determinations.
(3) Calibration with IntCal13 (Reimer et al., 2013) using version 4.2 of the OxCal program (Bronk-Ramsey, 2009).
(4) Bulk sample of short-lived plant species (Leguminosae, Arbutus unedo and Rosaceae or Ericaceae).
(5) Bulk sample of short-lived plant species (Leguminosae).
(6) Aberrant result (due to the mixture of charcoal of different ages).
(7) Abandoned due to lack of collagen.

Table 3. Preliminary phasing and associated events related to the formation of the deposit at the Pena d’Água Rock-shelter (1).

Phase	Description	Local palaeoenvironment	Events (local, regional or global)
1	Deposition of layer F (by redeposition of the Miocene substratum?).	Spring activity. Weathering of the limestone wall. Oleo-Lentiscetum association.	8.2 kyr event (~ 6.2 cal BC).
2	Limestone boulders collapsed, marking the layer F–E interface (with sedimentary hiatus?).	Spring activity truncating top of layer F.	1st stratigraphic discontinuity (partial roof collapse).
3	Deposition of layers Eb and Ea by horizontal accumulation (ratio: 1 cm / 32 yrs) of small-sized sediments with argillaceous component.	Spring activity with formation of erosional channels. Oleo-Lentiscetum association.	Hearth dated to 4791–4580 cal BC.
4	Deposition of layers Db, Da and C with increasing accumulation pace (ratio: 1 cm / 2.5 yrs) of small-sized sediments with minor argillaceous component (due to deforestation and/or increasing aridity).	Spring shutdown. Sedimentation change indicating absence of water. Oleo-Lentiscetum association and degraded maquis.	2nd stratigraphic discontinuity (strata inclination). 5.9 kyr event (~ 3.9 cal BC).
5	Deposition of layer B followed by sedimentary hiatus (archaeological palimpsest) with formation of limestone tufa along the wall.	Forest growth?Presence of vine and possible domesticated olive tree.	3rd stratigraphic discontinuity (sedimentary hiatus). Hearth dated to 118 cal BC–87 cal AD.
6	Deposition of layer A, sealing the underlying deposit.	Definitive roof collapse.	60 cal BC earthquake.

(1) After stratigraphic, botanical and geo-archaeological studies by Carvalho (1998a, p. 52, updated), Figueiral (1998) and Simões (2012), respectively.

that the top of Layer B was the deposit surface for around three millennia, from the end of the Neolithic to Roman times. Limestone tufa deposits formed at the contact between Layer B and the rock-shelter wall reinforce this conclusion. This sedimentary hiatus remains to be adequately explained; because of reforestation due to human abandonment of the region in the 4th–3rd millennia BC transition, as initially put forward (Carvalho, 1998a).

Phase 6 corresponds to the final collapse of the rock-shelter roof. Given the impressive size and number of the collapsed boulders, only a major event could be responsible for such a dramatic and sudden change in local topography. If one considers the radiocarbon result obtained from the Roman hearth in Layer B: 118 cal BC–87 cal AD, at 90.3% probability (Table 2), the event may have been the catastrophic earthquake (M=8.5) and tsunami that occurred around 60 cal BC in coastal Portugal and Galicia (Baptista and Miranda, 2009), with an estimated impact similar to the Lisbon event of AD 1755 (M=8.5 ± 0.3).

4. THE EARLY AND MIDDLE NEOLITHIC: MAJOR TRENDS IN MATERIAL CULTURE, LITHIC ACQUISITION AND ANIMAL EXPLOITATION STRATEGIES

Phases 3 and 4 in the site formation process (Table 3) cover, respectively, the Early and Middle Neolithic occupations recorded at the Pena d’Água. Each period is represented by a “block” of three stratigraphically and/or culturally independent, successive layers (Table 1): Eb-bottom, Eb-top and Ea in the former period, and Db, Da and C in the latter (Figs. 4 and 5).

In the following sections the most relevant aspects of their material culture, lithic raw material acquisition and strategies of animal exploitation will be described. It should be noted that the two “stratigraphic blocks” are still unequally studied: whereas a full inventory and analysis has been made of all the Early Neolithic contents, the Middle Neolithic material culture items are still under study. However, a quantitative approach to pottery and lithics in presented below for the first time.

4.1. Early Neolithic

A full study of the Early Neolithic “stratigraphic block” is provided by Carvalho (2008a: 56–62). Regarding material culture, the most relevant aspect is the presence of decorated pots. If the Minimum Number of Vessels (hereafter MNV) is taken into consideration, decorated specimens show decreasing percentages over time: 59% (7 out of 12 vessels), 41% (6 out of 19) and 32% (9 out of 22), from Layer Eb-bottom to Ea, which is a well-marked pattern (Fig. 5). Some other trends at this level are observable. Cardial sherds were found in all Early Neolithic layers but only form a coherent, systematic assemblage in Layer Eb-bottom (Fig. 6), where, despite the low absolute numbers involved (MNV=2 plus one loose sherd), they represent a qualitatively distinct production within a very homogenous assemblage—channelled and corded pots represent the remaining decorated types—that match the stylistic variability of the earliest pottery productions in Portugal (Carvalho, 2011). This was one of the findings that led to the conclusion we were indeed facing a different archaeological horizon at Pena d’Água. A higher stylistic diversity occurs in Layers Eb-top and Ea, with varying percentages of impressions, incisions, “*boquique*”, “false acacia leaf” impressions, and bowls with a incised line below the rim—or “*sulco sob o bordo*”, the Portuguese term for this type-fossil that marks the Early-to-Middle Neolithic transition in Southern Portugal (e.g., Silva, 1987)—in Layer Ea. Recipient sizes are usually medium or small, and of simple shapes (hemispherical, spherical) together with some short necked pots.

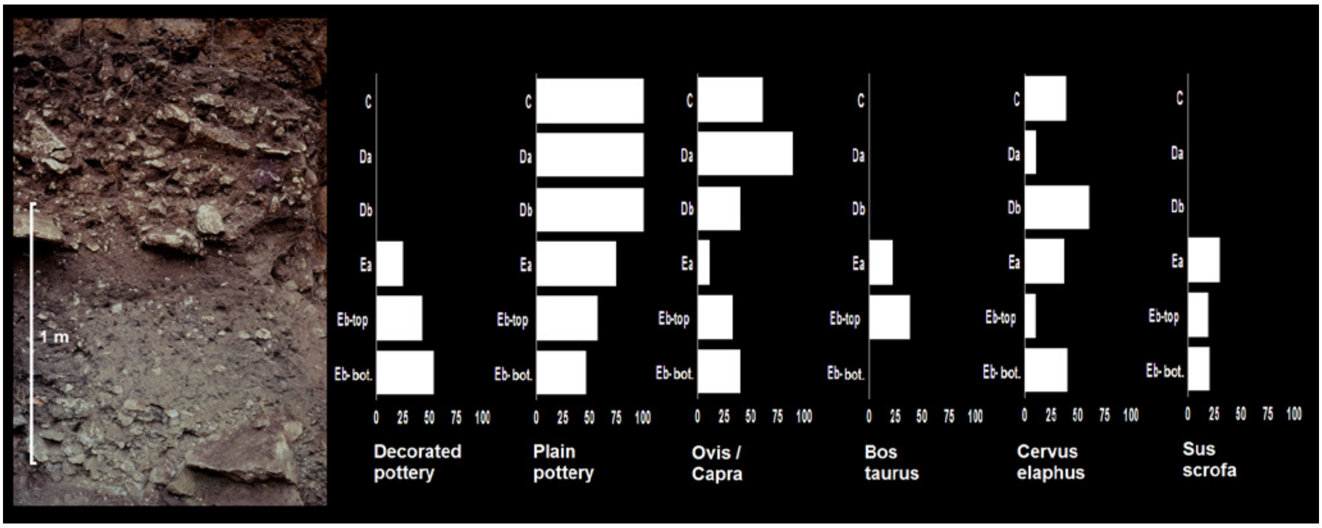

Fig. 5. Stratigraphic variation of decorated versus plain pottery and of main mammal species (from left to right, sheep/goat, cattle, red deer and wild boar) and photo of profile.

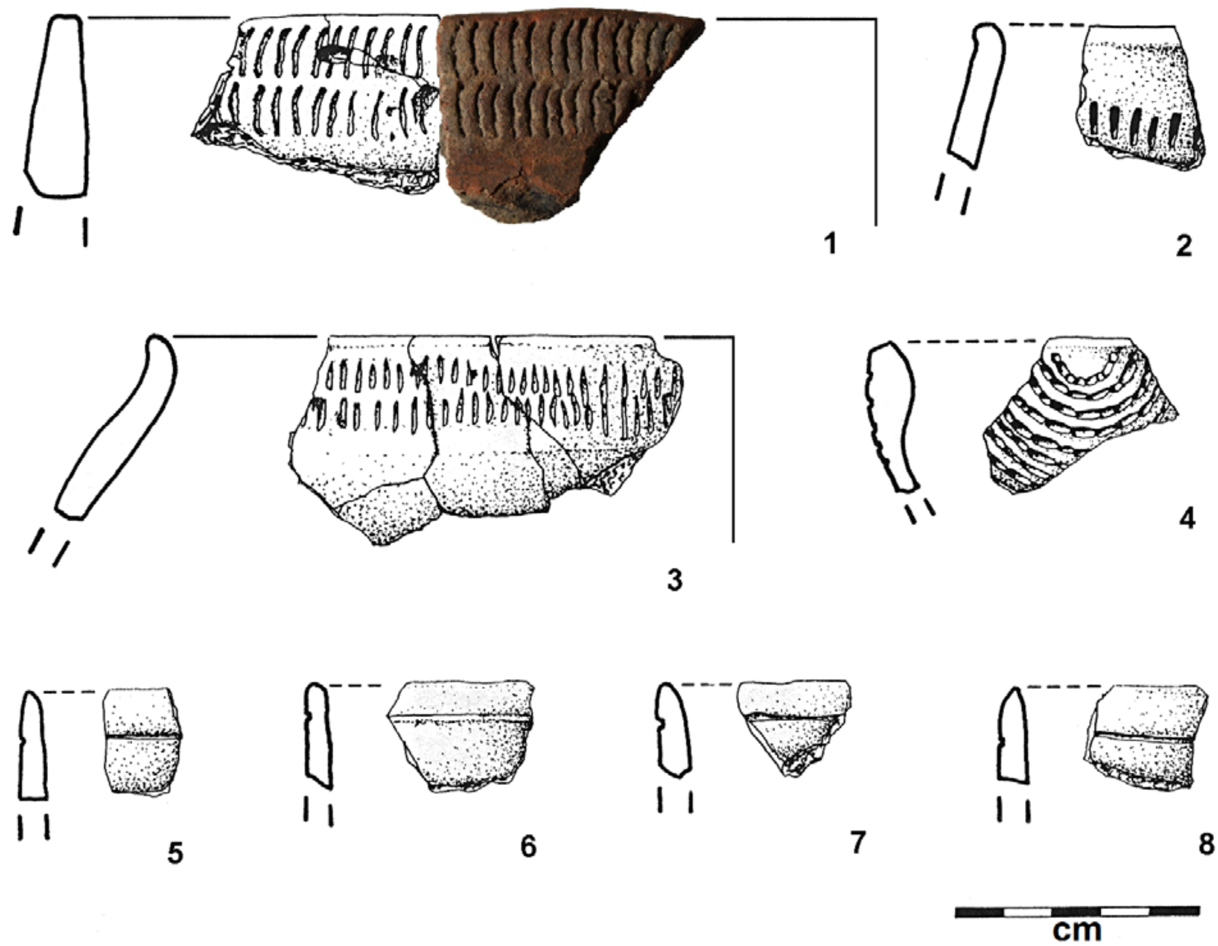

Fig. 6. Examples of Early and Middle Neolithic pottery types from Pena d'Água. 1–2: cardial and impressed rimsherds from layer Eb-bottom (Cardial Neolithic); 3–4: impressed and "boquique" sherds from layer Ea (Evolved Early Neolithic); 5–8: rimsherds decorated with an incised line below the rim from layer Db (Initial Middle Neolithic).

Until recently, it was commonly accepted that chert sources in the Arrife would be restricted to its NE (near Ourém) and SW (Rio Maior) ends (e.g., Zilhão, 1997), with the exception of some minor sources of poor quality recorded elsewhere in the area, "[...] at Paredinhas and at the Arrife summit between the source of the Almonda River and Moitas Vendas" (Carvalho, 2003: 144; Portuguese original). Systematic geological surveys, however, confirmed that chert sources do exist in the massif (Aubry et al., 2014) and, in particular, in the area around Pena d'Água (T. Pereira, pers. inf.). For this reason chert has commonly been considered a non-local, regional resource, whereas quartzite and quartz are locally-available raw materials obtainable in the surrounding Quaternary terraces of the Tagus Valley (Carvalho, 1998b, 2008a). However, whatever its specific geographical provenance, an internal trend can be observed in the use of chert within the Early Neolithic (Table 4): from 51% in Layer Eb-bottom, it decreases to 21% and 14% throughout the succeeding, upper levels in favour of quartz and, especially, quartzite. As put forward elsewhere, "[...] the most parsimonious interpretation of this shift seems to be the existence of changes in lithic resource procurement strategies in the passage from the 6th to the 5th millennia BC" (Carvalho, 2008a: 59; Portuguese original), probably related with changes in human mobility. The relative abundance of chert in the bottom of Layer Eb, associated with the cardial pottery, was also considered to be testimony of a distinct archaeological occupation. The prevailing trend during the period will be the preponderance of quartzite (Table 4), a fact also observable in most post-Cardial sites in the Arrife region (Carvalho, 2008a). Lithic tools, in all raw materials, consist mostly of side-retouched or notched blanks—flakes in particular—while truncations, perforators or composite tools are less common. Geometric microliths are dominated by segments, from the Cardial onwards, and these represent around 10% of the total chert tools.

Regarding animal exploitation strategies, there is no clear diachronic trend within the Early Neolithic "stratigraphic block" (Fig. 5). The only possible exception may be the absence of cattle (*Bos taurus*) and/or aurochs (*Bos primigenius*) in the Cardial occupation, but this is likely an artefact of the available sample and the taphonomic conditions of Layer Eb-bottom. Indeed, the high total number of remains from the Cardial occupation sharply contrasts with the Number of Identified Specimens

Table 4. Lithic inventory of knapped stone raw materials in Pena d'Água Rock-shelter (1).

	Layers	Chert	%	Quartzite	%	Quartz	%	Total	%
Early Neolithic	Eb-bottom	0.455	51	0.320	36	0.122	13	0.897	100
	Eb-top	0.658	21	1.875	51	0.620	20	3.153	100
	Ea	0.493	14	1.925	57	0.983	29	3.401	100
Middle Neolithic	Db	0.396	3	9.271	73	2.962	24	12.629	100
	Da	0.205	4	3.355	71	1.155	25	4.715	100
	C	0.050	<0	2.530	66	1.240	33	3.820	100

(1) Weight (in kg) and relative percentage of each raw material.

Table 5. Zooarchaeology of the Pena d'Água Rock-shelter (1).

Species	Early Neolithic (2)			Middle Neolithic (3)		
	Layer Eb-bottom	Layer Eb-top	Layer Ea	Layer Db	Layer Da	Layer C
Sheep (*Ovis aries*)		1				
Goat (*Capra hircus*)						1
Sheep / goat (*Ovis aries* / *Capra hircus*)	2	11	3	24	9	27
Red deer (*Cervus elaphus*)	1	1	8			18
Undetermined cervids	1	5	5	3	1	
Cattle / aurochs (*Bos* sp.)		7	5			
Aurochs (*Bos primigenius*)		1				
Cattle (*Bos taurus*)		1	1			
Wild boar (*Sus* cf. *scrofa*)	1	4	8			
Rabbit (*Oryctolagus cuniculus*)	1	3	3	133	73	4
Total NISP	6	34	33	160	83	50
Total Number of Remains (TNR)	155	118	118	260	108	145

(1) Birds and carnivores not included.
(2) Values based on the analyses by Valente (1998) and Carvalho, Valente and Haws (2004).
(3) Layer Db analysed by Valente (1998) and Luís, Correia and Fernandes (n.d.); layers Da and C analysed by Valente (1998).

(hereafter, NISP): 6 out of 155! This is further indirect evidence for the destructive impact of the nearby springs during the formation of Layers Ea and Eb.

From a general viewpoint, the most striking aspect is the very broad spectrum of species represented in the Early Neolithic at Pena d'Água, as evidenced in Table 5 (sheep, goat, red deer, cattle, aurochs, swine and rabbit), which gains further relevance in view of the relatively small NISP exhumed from Layers Eb-bottom to Ea (NISP=73). Taken all three layers together, the domestic specimens are clearly outnumbered by wild species (n=19 vs. n=35, rabbits excluded), but in this count swine have all been classed as wild boar (*Sus scrofa*), not domestic pig (*Sus domesticus*), which is an assumption far from consensual in Portuguese Neolithic zooarchaeology (Valente and Carvalho, 2014). For example, at the Caldeirão Cave, in the near Nabão Valley, Davis (2002) has reconsidered Rowley-Conwy's (1992) observations and concluded that most—if not all—swine remains in this cave would belong the domestic species instead.

4.2. Middle Neolithic

Despite the relatively well preserved record observed in the 1992–1995 seasons in Layers C to Da in Squares L-N/29-30, the 1998–2000 seasons exposed severe post-depositional disturbances affecting the same layers in Squares I-K/29-30 (Fig. 2). Intrusive Iron Age remains constituted here the majority of both ecofacts (charcoal and fauna) and material culture items, limiting the study of the Middle Neolithic to Layer Db only.

Plain vessels overwhelmingly dominate the pottery assemblage (Fig. 5). According to the MNV, they represent 100% in Layers C and Da, with 29 and 56 individualized vessels, respectively. In Layer Db decorated vessels reach 9% (6 out of 71 vessels) and, among these, four correspond to the transitional Early-to-Middle Neolithic type of bowls with an incised line below the rim (Fig. 6). If loose decorated sherds (those that could not be securely associated with any individualized vessel) are counted, the above scenario remains unchanged: 0.09% in Layer C (1 out of 1020 sherds); 0.4% in Layer Da (4 out of 911); and 2.9% (17 out of 581). This is a very typical trait of so-called "dolmenic potteries" in the southern regions of Portugal, where decoration is rare during the Middle and Late Neolithic. With the exception of a couple of carinated fragments from Layer C, pots are of simple shapes (hemispheric and spherical) and small sizes.

As evident in Table 5, quartzite abundantly dominates the lithic assemblages. It already represented 50–60% of all exploited raw materials in the Early Neolithic but now reaches about 70%, while chert decreases dramatically to 3%, 4% and less than 0% in Layers Db, Da and C, respectively, testifying a major change in the acquisition of this raw material. The type of relation this trend has with the recently-acquired notion that chert sources exist in the area (see above) is still to be clarified (exploitation shutdown due to small nodule size? Oblivious of its existence?). However, the fact that blades/bladelets represent 50% and 44% of the chert debitage in Layers C (3 out of 6 blanks) and Da (11 out of 25), respectively, indicates a rather important technological change in the later stages of the Middle Neolithic, now focused on the circulation of elongated blanks rather than of cores and/or nodules. Indeed, both in Layer Db and in the Early Neolithic the obtained ratios are quite distinct: 22% (33 blades/bladelets out of 148 blanks) in Layer Db, 31% (29 out of 93) in Layer Ea, 23% (39 out of 169) in Layer Eb-top and 22% (15 out of 67) in Layer Eb-bottom. Tool types remain similar to those that characterize the Early Neolithic, with the predominance of side-retouched or notched flakes. Only the microlithic assemblage suffers some changes: its total percentage decreases and a balanced segment/trapezium composition of the toolkits emerges.

As in pottery decoration, the zooarchaeological contrast between the two Neolithic "stratigraphic blocks" could not be sharper (Valente, 1998; Luís, Correia and Fernandes, n.d.). If rabbits, birds and carnivores are excluded, in Layers Db to C there are only cervids—exclusively red deer (*Cervus elaphus*) whenever species is defined—alongside domestic sheep and/or goat (Table 5; Fig. 5). Species that were exploited in the previous Early Neolithic occupations—such as swine and bovids, either domestic or wild—seemed to have been excluded from the regular animal exploitation strategies during the Middle Neolithic. Given the species in question, these new strategies of animal exploitation correspond to a rather more specialized and mobile pastoralism in the framework of which hunting practices—focusing on red deer only—also took place. Different NISP values between the Early and Middle Neolithic "stratigraphic blocks", favouring the latter (NISP=83 vs. NISP=66, rabbits excluded), is the best testimony that this reduction in the species spectrum is not biased by sampling and must reflect instead the past reality.

5. DISCUSSION AND CONCLUSIONS

A chronological framework based on a solid batch of radiocarbon determinations is surely the major limitation to the study of the Neolithic at Pena d'Água. As shown in Table 2, only determination Wk-16418 obtained from charcoal collected from a hearth in Layer Eb-top is relatively reliable for cultural inferences. The Early-to-Middle Neolithic boundary at the site is rather blurred due to the similar results obtained by determinations ICEN-1148 from Layer Ea and ICEN-1147 from Layer Db (Table 2), as evident from their plotting in Fig. 7. It can only be concluded that the boundary may be situated some time around the passage from the 5th to 4th millennium cal BC.

Palaeobotanic data from the Pena d'Água sequence seems to denote variations in vegetation cover over time, subtle but likely reflecting changing palaeoenvironmental conditions at broader scales. In fact, the Neolithic vegetation is overall dominated by wild olive tree (*Olea europaea*) in all layers, with ca. 93% and 81% of total taxa in layers Ea+Eb and Da+Db, respectively. However, while in the Early Neolithic "[...] the presence of *Olea* and *Pistacia lentiscus* suggests the Oleo-Lentiscutum association, with olive tree and mastic forming the arboreal and the shrubby strata, respectively", during the following period "[t]he presence of arbutus, heather, rockrose and leguminosae seem to be testimony of areas characterized by a degraded *maquis* (brushwood)" (Figueiral, 1998: 75; Portuguese original). Likewise, a preliminary analysis of the microfauna (Póvoas, 1998), although devoid of quantitative data, showed that house mouse (*Mus musculus*) and Algerian mouse (*Mus spretus*)—which are indicative of farming activities—along with wood mouse (*Apodemus* sp.) were the dominant genera in all Neolithic layers but

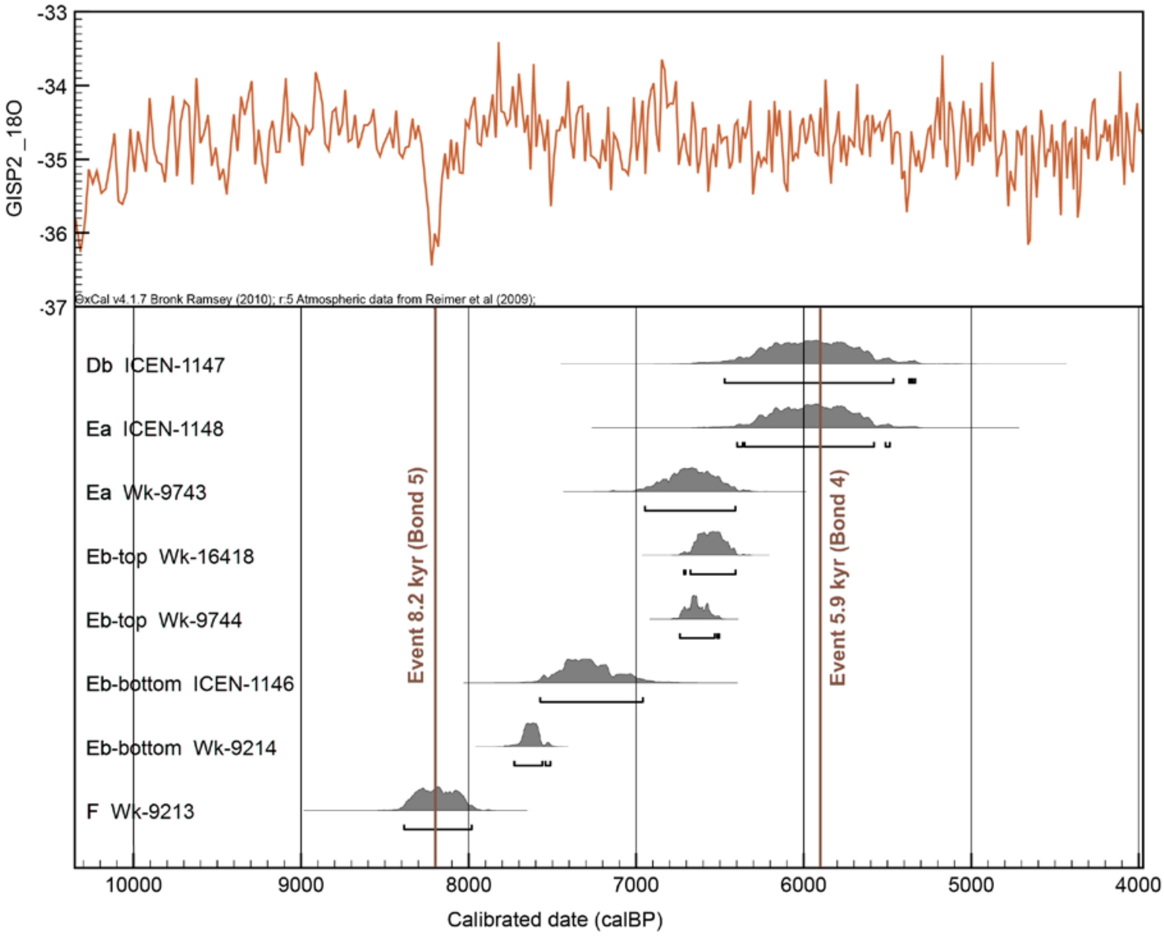

Fig. 7. Plotting of radiocarbon dates from Pena d'Água (Epipalaeolithic and Neolithic only) with GISP2 curve and correlation with climatic events 8.2 and 5.9 (after Simões, 2012: fig. 9, adapted).

pine vole (*Microtus (Terricola)* sp.), a species usually inhabiting moist habitats with thick vegetation cover, decreases in representativeness from the bottom to the top of the sequence.

Both types of biological evidence, coupled with results from geo-archaeological analyses (Simões, 2012), converge on the conclusion that changing bioclimatic conditions towards deforestation and aridity coincided with cultural changes. Put in other words, the Early and the Middle Neolithic people settled at Pena d'Água witnessed different environmental conditions and seem to have experienced distinct life ways.

Indeed, in the former period, included in the Phase 3 of the site formation history (Table 3), locally obtained resources clearly predominate. Even in the case of chert, which was thought to have been brought to the site from sources located in the northern or southern ends of the limestone massif (ca. 25 km and 80 km, respectively), it is possible today to hypothesize its local acquisition. Recent petrographic and geochemical analyses of sherd samples showed that Early Neolithic pottery was also made with local clays and tempers (Masucci and Carvalho, n.d.). Non-local raw materials are restricted to two schist flakes from Layers Ea and Eb-top, suggesting episodic exchange or travels to geological formations located 30–40 km to the northeast. Finally, the presence of cattle—and of pig, if the swine remains are classed as domestic in the future (Valente and Carvalho, 2014)—indicates a more geographically restricted scale of herding practices in the Early Neolithic.

The above data does not necessarily mean we are dealing with fully sedentary human groups at Pena d'Água during this time period; indeed some degree of mobility can be inferred from small pottery sizes, expedient knapped stone exploitation patterns, ephemeral site structures, etc., as observed not only at this rock-shelter but also at other sites in the Arrife region (Carvalho, 2003, 2008a). The open question is whether this is a complete depiction of the whole settlement system or if there are permanent settlements still to be found, for example in riverine locations near the Tagus or its tributaries where more fertile soils exist and a fully developed farming economy would have occurred, as documented elsewhere in Iberia.

In the Middle Neolithic, corresponding to the deposit's formation Phase 4 (Table 3), although characterized by the use of local knapped raw materials (quartzite and quartz), the chert assemblage reveals a new type of debitage economy: the circulation of elongated blanks (blades and bladelets) tends to replace the local knapping of chert cores and/or nodules. This new trend in chert exploitation and use is likely associated with the acquisition of non-local raw materials, such as schist (which is found in the form of knapped flakes), granite (a grindingstone from Layer C) and amphibolite (one fragmented polished axe from Layer C and flakes from recycling polished stone tools in Layers Db to C). The latter rock type implies long-distance movements or exchange networks, since the nearest sources are located in the Hesperian Massif, some 100km to the east. Zooarchaeological data indicate what seems to be "economic specialization" in the herding of sheep/goat—therefore suggesting itinerant pastoralism practices—associated with red deer hunting.

In sum, there is a major change towards greater human mobility during the Middle Neolithic, a hypothesis perhaps more probable than an increasing flow of goods in existing exchange networks. If this is confirmed by future research to be a regional phenomenon—and not the biased effect of site function—it bears far-reaching consequences in two aspects. First, it apparently parallels the model obtained from the study of the coeval Bom Santo Cave necropolis where a Neolithic community exploited a ca. 100km-long territory and practised itinerant sheep/goat pastoralism as detected at Pena d'Água (Carvalho, 2014). This may mean that Middle Neolithic societies in Estremadura and neighbouring sectors of the Alentejo province were organized as evidenced by both sites. Second, this moment in time—the 5th-to-4th millennium transition onwards—corresponds to the onset and development of megalithism in central and southern Portugal, which raises a series of questions regarding socioeconomic features of the human communities and the palaeoenvironmental conditions (Fig. 7)—namely the role played in this scenario by the 5.9 kyr climate event (Bond et al., 1997)—underlying the advent of the above cultural phenomenon.

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