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Abrupt technological change at the 8.2 ky cal BP climatic event in Central Portugal. The Epipalaeolithic of Pena d'Água Rock-shelter

Changement technologique abrupt lors l'événement climatique 8.2 ky cal BP dans le centre du Portugal. L'épipaléolithique de l'abri Pena d'Água

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A B S T R A C T

In central Portugal, the basic structures of the Pleistocene economy, technology and social organization patterns remain fairly similar until the 8.2 ky cal BP climatic event. Their impact has not yet been thoroughly analysed with regard to changes in lithic technology. The Epipaleolithic occupation of Pena d'Água Rock-shelter is dated to ca. 8.19 ky cal BP. In this paper we present a description of its lithic assemblage and put it in context with coeval and later sites of the Middle Tagus, highlighting the observed differences that pre- and post-date this event. Results indicate similarity in raw material acquisition strategies, mainly locally available quartzite cobbles for flake production. After the 8.2 ky event, chert becomes more common, allowing the systematic production of bladelet toolkits with high percentages of geometrics. Reorganized mobility patterns, from forager to logistic, may explain these changes, which remain stable until the Neolithic, ca. 7.4 ky cal BP.

R É S U M É

Dans le centre du Portugal, les structures de base des modèles économiques, technologiques et de l'organisation sociale au Pléistocène sont restées assez semblables jusqu'à l'événement climatique à 8,2 ka cal BP. Cependant, leur impact est rarement analysé en profondeur en ce qui concerne les changements dans la technologie lithique. L'occupation épipaléolithique de l'abri Pena d'Água est datée de ca. 8,19 ka cal BP. Dans cet article, nous présentons une description de son assemblage lithique en le replaçant dans le contexte des sites contemporains et postérieurs du Tage moyen, et en en soulignant les différences visibles avant et après cet événement. Les résultats indiquent une similitude dans les stratégies d'acquisition des matières premières, surtout de galets de quartzite disponibles localement pour la production d'éclats. Après l'événement de 8,2 ka, le chert devient plus commun,

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permettant une production systématique de *toolkits* lamellaires, avec des pourcentages élevés d'outils géométriques. La réorganisation des schémas de mobilité, de l'approvisionnement à la logistique, peut expliquer ces changements, qui resteront stables jusqu'au Néolithique, ca. 7,4 ka cal BP.

1. Introduction

Early Holocene hunter-gatherer societies were first identified in Portugal in 1863 with the discovery of the shell-middens of the Muge Valley (Fig. 1), by the *Commissão Geológica de Portugal* ("Geological Commission of Portugal"). Resembling the Danish *kjøkkenmødings*, these sites immediately captured the researchers' attention for their topographic prominence, complex stratigraphy, faunal composition, material culture and human remains. Their international relevance was acknowledged during the 9th session of the "Congrès international d'anthropologie et d'archéologie préhistoriques", held in Lisbon in 1880, where a major synthesis was published (Ribeiro, 1880).

Two main periods of fieldwork took place at these shell-middens, in the 1930s (A.M. Correia) and the 1950–1960s (J. Roche and O.V. Ferreira), with a focus on the numerous human remains and funerary features along with (during the second research period) the recording of habitation structures (postholes, hearths, pits), the use of radiocarbon dates, and analyses of adornments, bone and lithics. Regarding the latter studies, a global synthesis by Roche (1972) on Moita do Sebastião, Cabeço da Arruda and Cabeço da Amoreira remains today a notable contribution, as it provides a clear picture of a chert bladelet-base industry. For a review of the research history of the Muge shell-middens, see Cardoso and Rolão (1999–2000) and Carvalho (2009: 36–38).

Recent interdisciplinary research projects on the Muge complex have been carried by N.F. Bicho, with special focus on systematic excavations at the Cabeço da Amoreira (e.g., Bicho et al., 2010a, 2013b). Of relevance is a set of around 30 new radiocarbon dates, which point to the 7.9–7.3 ky cal BP time interval (Bicho et al., 2011, 2013a). Together with dates from other sites – see Martins et al. (2008) and references therein, and Jackes et al. (2014) – these indicate an overall period of occupation comprised between ca. 8.1 and 6.9 ky cal BP for the whole Muge complex. This result clearly points to the construction of these monuments soon after the impact of the 8.2 ky cal BP climatic event.

Although well studied in its triggering causes and its effects on climate and oceanic conditions in the Northern Hemisphere (e.g., Alley and Ágústsdóttir, 2005; Barber et al., 1999), the 8.2 ky cold event has been seldom analysed in depth regarding its impact on the palaeoenvironmental conditions of western Iberia and on the way of life of these hunter-gatherers, with only some general overviews (Bicho et al., 2010a, 2010b; Carvalho, 200ç, 2010; Martins et al., 2008; Zilhão, 2003), which suggested an impoverishment of coastal resources due to changes in the upwelling regime. Along with this marine phenomenon, average atmospheric temperatures seemed to have decreased (1.5–3 °C), a trend accompanied by drier conditions (e.g., Abrantes, 2000), whereas both Holocene forest covers (e.g., Van Der Knaap and Van Leeuwen, 1995) and Flandrian transgression (Dias et al., 2000) reached their maximum. Carvalho (2009, 2010) and Bicho et al. (2010b) disagree on the real impact of the decreasing upwelling activity but concur that rising sea levels and forest pressure played a critical role in forcing human groups to reorganize their settlement systems from residential to logistic mobility strategies with centres in the ecologically richer (and protected) estuaries in main river valleys. In such geographical areas – such as the lower section of the Tagus – large shell-middens clustered along river banks may have even supported the emergence of complex hunter-gatherer societies (e.g., Soares, 1996 and Bicho et al., 2013b; but see Carvalho, 2009 for an opposite view).

Much less spectacular but no less interesting is the archaeological evidence from the period between the end of the Last Glacial Maximum and the 8.2 ky event. The Epipaleolithic comprised, according to Araújo (2009, 2011), three distinct archaeological entities: specialized harvesters of marine resources in coastal areas, hunters settled in and around the limestone massifs, and "macrolithic makers" – as the author puts it – exploiting hinterland local lithic raw materials from river terraces (see Section 4). Moreover, environmental changes in this region following the end of the Younger Dryas allowed the shifting of Mesomediterranean forests (Sánchez-Goñi et al., 2008) most probably allowing biotic resources – wild plant foods and small- to medium-sized mammals (lagomorphs, wild boar, red deer) – to support a generalized growth of human population (e.g., Araújo, 2003, 2009; Bicho, 1994).

One of the open questions is to evaluate what changes occurred across the 8.2 ky cal BP event boundary and their impact over the hunter-gatherer-fishing communities living in Estremadura. The aim of this paper is thus to present the lithic assemblage of the Epipaleolithic layer at Pena d'Água Rock-shelter and its regional integration – the Tagus Valley (Fig. 1) – as a proxy to approach this climatic event impact over strategies of acquisition and use of lithic implements and, consequently, human mobility.

2. The Pena d'Água Rock-shelter

Pena d'Água is located in central Estremadura, at 125 m a.s.l., ca. 100 km northeast of Lisbon and 47 km from the present Atlantic coastline. It is ca. 70 m wide, with a >10 m sedimentary deposit formed along an escarpment resulting from a tectonic fault, commonly known as the Arrife (from the Arabic "*ariff*", scarp, coast) of the Aire Mountain. This tectonic fault separates the densely drained plains of the Tagus basin (to the east) from the dry, hilly limestone massifs (to the west), thus marking the boundary between two quite contrasting ecosystems. The site faces the former

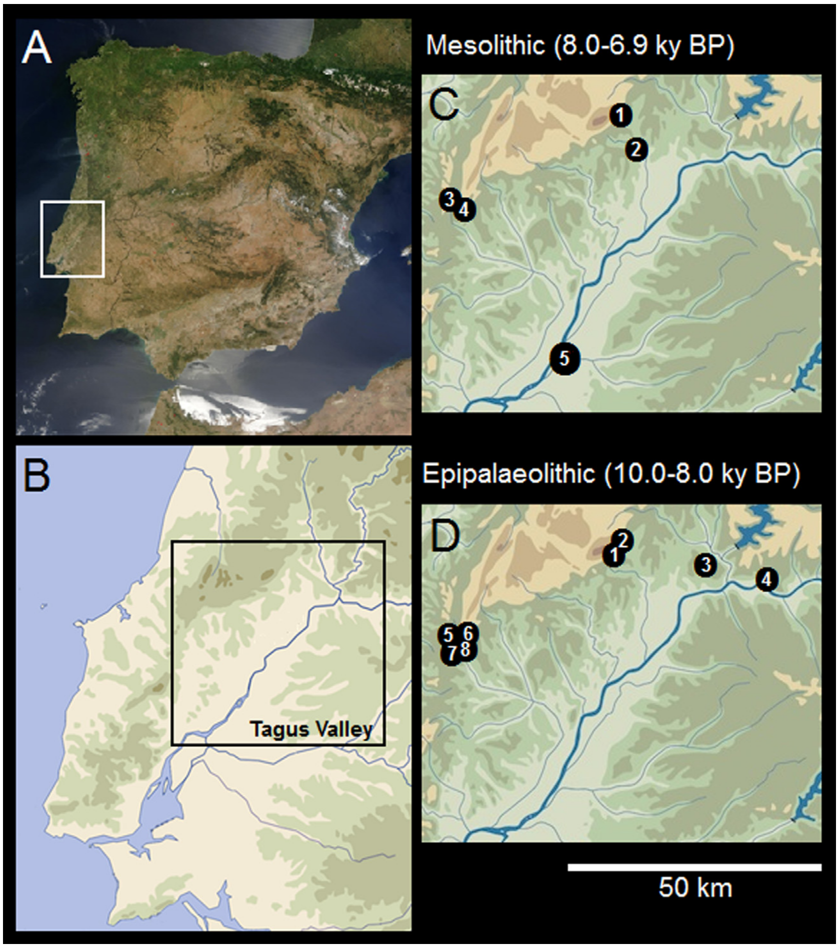

Fig. 1. (Color online.) A. Location of Estremadura. B. Location of the study area. D. Epipaleolithic sites (ca. 10.0–8.0 ky cal BP): 1. Amoreira; 2. Costa do Pereiro; 3. Pena d'Água; 4. Cabeço de Porto Marinho V; 5. Areeiro III; 6. Fonte Pinheiro; 7. Bocas Rock-shelter. C. Mesolithic sites (ca. 8.0–6.9 ky cal BP): 1. Costa do Pereiro; 2. Pessegueiros; 3. Forno da Telha; 4. Bocas Rock-shelter; 5. Muge shell-middens.

Fig. 1. (Couleur en ligne.) A. Localisation de l'Estrémadure. B. Localisation de la zone d'étude. D. Sites épipaléolithiques (ca. 10.0–8.0 ky cal BP) : 1. Amoreira ; 2. Costa do Pereiro ; 3. Pena d'Água ; 4. Cabeço de Porto Marinho V ; 5. Areeiro III ; 6. Fonte Pinheiro ; 7. Abrí Bocas. C. Sites mésolithiques (ca. 8.0–6.9 ky cal BP) : 1. Costa do Pereiro ; 2. Pessegueiros ; 3. Forno da Telha ; 4. Abrí Bocas ; 5. Coquilliers de Muge.

landscape with thick, extensive fluvial terraces; on its back, stands out the Aire Mountain (679 m a.s.l.) dominating the entire region (Fig. 2).

In the vicinity are several chert outcrops and the adjacent Cenozoic deposits are rich in chert nodules in secondary position along with good quality quartzite and quartz. The Arrife also has abundant permanent and seasonal freshwater springs, one of them just to the side of the archaeological site ("Pena d'Água" means "scarp" and "spring", respectively), which may have made the site attractive for settlement. In sum, Pena d'Água is in a privileged location, with natural shelter, in an ecotone strip connecting a limestone mountain and wide river basin landscapes, with short-range access to high-quality lithic raw materials.

Eight field seasons between 1992 and 2000 in a 4 × 2 m test pit in the northeastern limit of the deposit revealed a ca. 5 m thick stratigraphic sequence encompassing eight main layers preserving six periods of almost uninterrupted human presence: Roman and Iron Age (layer B), Early to Late Neolithic (layers Eb-bottom to B) and Epipaleolithic (layer F). The primary observations regarding the site's stratigraphy, formation processes, cultural periods and their broader integration were published by Carvalho (1998a). In addition, special focus has already been given to Iron Age (Carvalho, 2008b) and Early Neolithic (Carvalho, 2008a: 58–62) occupations.

Layer F is the bottom unit of the stratigraphic sequence, lying on the local Miocene bedrock, and separated from the upper Eb-bottom layer by large boulders collapsed from the roof. Sediments are significantly different from those above. The matrix has very dense and compact coarse sand in a clayish matrix, and lacks the pottery, charcoal and bone that characterize all of the upper layers. It presents evidence for low-energy hydric action: calcium carbonate tuffs, rolled artefacts (sometimes accumulated in shallow pockets), faunal remains with taphonomic alterations (Valente, 1998) and conditions allowing the poor preservation of micromammal teeth (Póvoas, 1998). This hydric action might be related to a partially blocked spring located

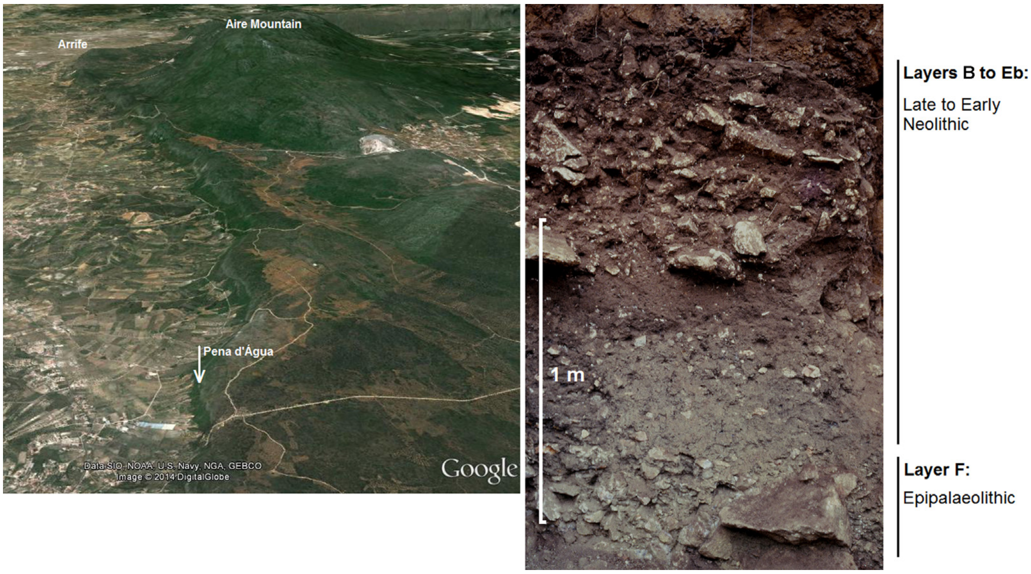

Fig. 2. (Color online.) Location of the Pena d'Água Rock-shelter (left) and stratigraphic profile (right).

Fig. 2. (Couleur en ligne.) Localisation de l'abri Pena d'Água (à gauche) et profil stratigraphique (à droite).

slightly above the excavation area, which may have been particularly active when layer F was formed (Simões, 2012).

Charcoal of wild olive tree predominates throughout the sequence, ranging from 74.4% in layer F to 92.7% in layer Eb, testifying to the Middle Holocene expansion of sclerophyllous vegetation and the decline of pine (Fiueiral, 1998). Layer F, however, shows the highest percentage of oak tree varieties (12.5%); cork oak (*Quercus suber*), in particular, reaches 7.5%. This is a slight, but relevant difference between layer F and the overlying layers at the botanic level. Faunal remains, on the other hand, are composed of a small number of rabbit ($n = 1$) and cervids ($n = 2$). In addition, some sheep/goat ($n = 3$) were interpreted as due to "[...] infiltrations from Layer Eb-bottom or to deficient dating of the Eb-base/F layers interface [...]" during excavation (Valente, 1998: 93; Portuguese original).

The absence of hearths providing charcoal of unquestionably anthropic origin as well as deficient preservation of bones meant having to get a radiocarbon date from a bulk sample of cork oak charcoal. The result (Carvalho, 2008b: Table 18), was 7370 ± 110 BP (Wk-9213), corresponding to 8385–7983 cal BP (95.4% prob.), with a median value of 8.19 ky cal BP, after calibration with the INTCAL13 curve (OxCal program, version 4.2) (Fig. 3). Although caution is advisable due to the fact that it is a long-lived species, it is nonetheless a useful broad chronological estimate of when layer F was formed.

3. Lithic assemblage from Layer F

3.1. General overview

An assemblage of 746 artefacts (Tables 1–3) was recovered from layer F, comprised of quartzite, chert and quartz, with rare occurrences of schist and granite, divided into manuports, cores, flakes, blades, bladelets, retouched tools, crests, cornices, blanks, fronts, tablets, unclassifiable fragments, fire-cracks and chips (see methodology in Pereira, 2010).

Quartzite dominates (64.7%), followed by chert (24.7%) and quartz (9.8%). Schist and granite are rare (0.7% and 0.1%, respectively). Flakes are the most abundant products (58.4%), followed by indeterminate fragments (13.4%), chips (9%), cores (7.1%), elongated blanks (4.7%) and maintenance/preparation products (3.7%). Fragments, chips and fire-cracks represent 47.4%. The combination of complete blanks, proximal ends and side fragments gives a minimal number of 398 blanks: 299 in quartzite, 73 in chert, 25 in quartz and 1 in schist.

The presence of fire-cracks or burned artefacts and of refitted artefacts, debris and chips, attest to the use of fire and knapping procedures at the site. The low number of chips is congruent with low energy passage of water – as was observed during excavation (Carvalho, 1998a) and confirmed by geoarchaeological analyses (Simões, 2012) – this could be responsible for removing the smallest implements during the formation process of layer F.

3.1.1. Quartzite

The quartzite assemblage is dominated by flakes whether complete or fragmented (69.3%). This is the only raw material with fire-cracks, which is congruent with the pattern of its use in structured hearts (e.g. Pereira, 2010). Cobbles were reduced to produce flakes through a unipolar, unidirectional and unifacial strategy based on parallel detachments following the thickness of the volume, according to a right angle, without preparation. This resulted in a chopper-like assemblage – perhaps the most notable trait of the lithic assemblage (Fig. 4) – though sometimes other core types occur. This resulted in flakes with cortical butts and diffuse bulbs (Fig. 5). Flakes have diverse edge contours, flat profiles and trapezoidal or

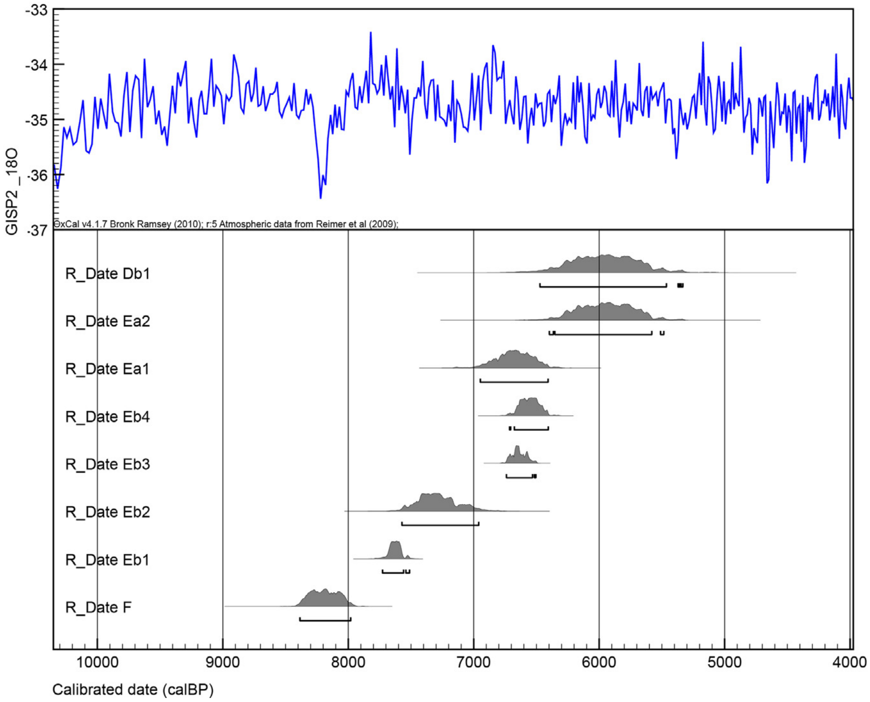

Fig. 3. (Color online.) Pena d'Água Rock-shelter: radiocarbon dates and GISP2 curve for Holocene climate (after Simões, 2012: fig. 9).
Fig. 3. (Couleur en ligne.) Abri Pena d'Água : datation radiocarbone et courbe GISP2 pour le climat de l'Holocène (d'après Simões, 2012 : fig. 9).

triangular cross-sections, and feathered, stepped or fractured ends. Dorsal patterns are unidirectional and parallel, without or with less than 50% cortex. The mean dimensions of the flakes are 34.72 × 29.69 × 12.24 mm. The core/blank ratio is of 1:10.

Flakes are primarily complete (70.7%). Core maintenance was restricted to the removal of cornices and of core flanks and fronts during debitage. Retouched tools represent 9.6% of theis assemblage and are mostly sidescrapers (n = 16), notches (n = 11) and denticulates (n = 10). The core and blank assemblages are congruent between them and the few elongate blanks probably reflect occasional detachments, not any existing knapping strategy.

3.1.2. *Chert*

Chert is dominated by flakes (36.1%) and debris (25.7%). A variety of chert was used, some available in a daily forager radius from the site (Fig. 6). Nodules were usually

Table 1
Techno-typological inventory of Layer F from Pena d'Água.
Tableau 1
Inventaire techno-typologique de la couche F de Pena d'Água.

	Quartzite		Chert		Quartz		Schist		Granite		Total	
	#	%	#	%	#	%	#	%	#	%	#	%
Manuport	1	0.1							1	0.1	2	0.3
Core	35	4.7	7	0.9	10	1.3	1	0.1			53	7.1
Flake complete	235	31.5	40	5.4	19	2.5	1	0.1			295	39.5
Flake fragment	99	13.3	27	3.6	13	1.7	2	0.3			141	18.9
Blade complete	5	0.7	1	0.1	1	0.1					7	0.9
Blade fragment	1	0.1	3	0.4	2	0.3					6	0.8
Bladelet complete	1	0.1	7	0.9							8	1.1
Bladelet fragment	3	0.4	9	1.2	1	0.1	1	0.1			14	1.9
Crested flake			1	0.1							1	0.1
Crested blade			1	0.1							1	0.1
Crested bladelet			1	0.1							1	0.1
Tablet			2	0.3	1	0.1					3	0.4
Cornice	6	0.8	5	0.7	1	0.1					12	1.6
Flank	1	0.1	2	0.3							3	0.4
Front	3	0.4	4	0.5							7	0.9
Fragment	37	5.0	47	6.3	16	2.1					100	13.4
Chip	31	4.2	27	3.6	9	1.2					67	9.0
Fire-crack	25	3.4									25	3.4
Total	483	64.7	184	24.7	73	9.8	5	0.7	1	0.1	746	100

Table 2
Inventory of the cores of Layer F from Pena d'Água.
Tableau 2
Inventaire des nucléus de couche F de Pena d'Água.

	Quartzite		Chert		Quartz		Schist		Total	
	#	%	#	%	#	%	#	%	#	%
Chopper 1 platform	10	18.9					1	1.9	11	20.8
Chopper 2 unifacial platforms	1	1.9			1	1.9			2	3.8
Chopper unipolar unifacial	7	13.2							7	13.2
Chopper unipolar bifacial	2	3.8							2	3.8
Centripetal unifacial	1	1.9			1	1.9			2	3.8
Centripetal bifacial					1	1.9			1	1.9
Discoidal	2	3.8							2	3.8
Prismatic 1 platform	2	3.8			1	1.9			3	5.7
Prismatic 2 opposed platforms					1	1.9			1	1.9
Prismatic 2 separate platforms	3	5.7	2	3.8	1	1.9			6	11.3
Prismatic multiple platforms					1	1.9			1	1.9
Poliedric	4	7.5	2	3.8	1	1.9			7	13.2
Kombewa	1	1.9	1	1.9		0.0			2	3.8
Bipolar			1	1.9	3	5.7			4	7.5
Core fragment	1	1.9	1	1.9					2	3.8
Total	34	64.2	7	13.2	11	20.8	1	1.9	53	100

Table 3
Typological Inventory of the Layer F from Pena d'Água.
Tableau 3
Inventaire typologique de la couche F de Pena d'Água.

	Quartzite		Chert		Quartz		Schist		Granite		Total	
	#	%	#	%	#	%	#	%	#	%	#	%
Atypical carenated endscraper			1	0.8							1	1.2
Thick nosed endscraper	1	0.8									1	1.2
Nucleiform endscraper			1	0.8							1	1.2
Rabot	4	3.4									4	4.7
Perforator-endscraper			1	0.8							1	1.2
Perforator	1	0.8	1	0.8							2	2.4
Atypical perforator			1	0.8							1	1.2
Dihedral burin					1	0.8					1	1.2
Dihedral burin (on angle)	1	0.8			1	0.8					2	2.4
Angle burin			1	0.8							1	1.2
Burin in concave truncation			1	0.8							1	1.2
Transversal burin on lateral truncation			1	0.8							1	1.2
Notch	11	9.3	5	4.2	3	2.5					19	22.4
Denticulate	10	8.5					1	0.8			11	13
Splintered piece			8	6.8	3	2.5					11	13
Wedge			9	7.6	5	4.2	1	0.8			15	17.7
Sidescraper	16	13.6	2	1.7							18	21.2
Hammerstone	4	3.4									4	4.7
Anvil	2	1.7							1	0.8	3	3.5
Retouched flake	1	0.8									1	1.2
Backed bladelet			1	0.8							1	1.2
Flake with atypical retouch	3	2.5	3	2.5	1	0.8					7	8.3
Retouched tool fragment	2	1.7	2	1.7	1	0.8					5	5.9
Chopper	5	4.2									5	5.9
Microburin					1	0.8					1	1.2
Total	61	51.7	38	32.2	16	13.6	2	1.7	1	0.8	118	100

reduced to produce flakes (77%) and elongate blanks (23%). Cores are few, small and usually exhausted. Flakes were produced according to unidirectional parallel or convergent detachments; bladelets according to unidirectional parallel detachments while blades through bidirectional detachments. Cores were knapped using multiple plain or faceted platforms, with right angles, following the volume's thickness.

The mentioned strategies resulted in flakes with cortical or plain butts, while blades and bladelets show faceted and plain butts, respectively. Pronounced bulbs are more common in larger flakes and blades, while diffuse bulbs are restricted to smaller flakes and bladelets. Flakes have irregular, divergent and convergent edges, while bladelets are convergent or parallel and blades are convergent or irregular. All blank types have plain profiles but blades are

Fig. 4. (Color online.) Pena d'Água Rock-shelter: quartzite cores in river pebbles, with single cortical platforms and right angle with the surface of debitage. Some with pitting due to their use as hammerstones.

Fig. 4. (Couleur en ligne.) Abri Pena d'Água : nucléus de quartzite en galets de fleuve, avec plates-formes corticales simples et à angle droit avec la surface de débitage ; certains avec corrosion due à leur utilisation comme percuteurs.

Fig. 5. (Color online.) Pena d'Água Rock-shelter: quartzite flakes with cortex in the platform and dorsal faces.

Fig. 5. (Couleur en ligne.) Abri Pena d'Água : éclats de quartzite, avec cortex dans les plates-formes et les faces dorsales.

slightly more concave. Flakes' cross-sections are diverse but bladelets and blades are respectively triangular and trapezoidal or triangular. Flakes and blades have feathered distal ends while bladelets have fractured, feathered or pointed. Flakes show unidirectional parallel, crossed and convergent negatives, while bladelets and blades evince unidirectional and bidirectional scars, respectively. Cortex is absent or covers less than 25% of the dorsal

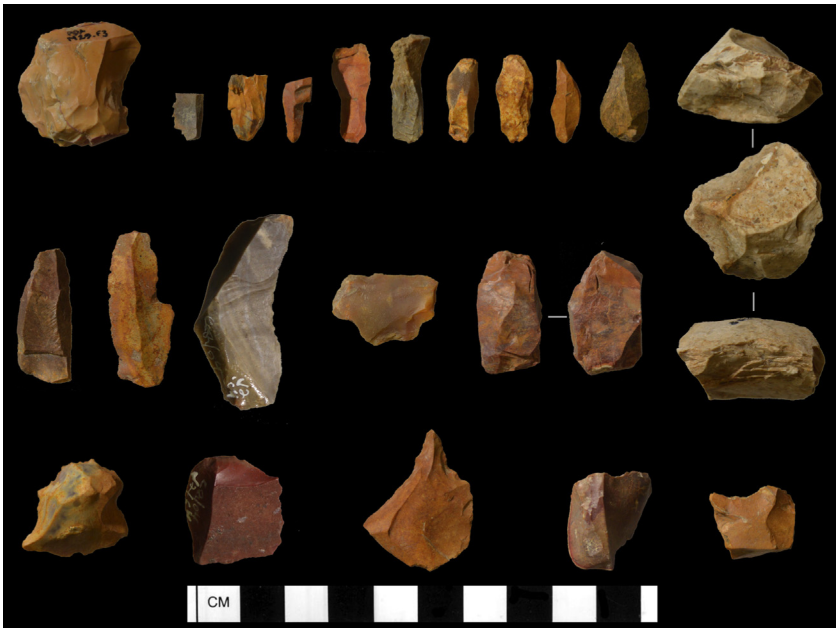

Fig. 6. (Color online.) Pena d'Água Rock-shelter: chert flakes, bladelets, blades, a core with two opposed platforms, sidescrappers, endscrappers, burins and perforators.

Fig. 6. (Couleur en ligne.) Abri Pena d'Água : éclats, lamelles, lames, un nucléus avec deux plates-formes opposées, grattoirs, racloirs, burins et perçoirs en chert.

surface, usually in the lateral or distal areas. The mean dimensions of the chert flakes are 21.98 × 16.76 × 7.01 mm. The core/blank ratio is of 1:12.

Flakes are mostly complete (58.2%) whereas blades are represented mostly by distal ends and bladelets are complete or proximal. Crests, sometimes semi-cortical, were used to prepare elongated blank cores. Core maintenance consisted on the removal of cornices, flanks and fronts during debitage.

Retouched tools represent 21.3% of the assemblage and are mostly comprised of wedges ($n = 9$), splintered pieces ($n = 8$) and notches ($n = 5$). There is only one armature: a dorsal bladelet.

3.1.3. Quartz

The quartz assemblage is dominated by flakes (43.8%) and fragments (20.5%); there is only one bladelet and three blades. Quartz pebbles were obtained locally, and reduced to produce flakes according to different methods, including prismatic, centripetal and bipolar, often in splintered pebbles (Fig. 7). In most cases blanks were detached using a parallel unidirectional reduction, following both the length and the thickness of the volumes, with a right angle, always without preparation. This strategy resulted in blanks with cortical or plain butts, diffuse and pronounced bulbs, variable edge contours, flat profiles, trapezoidal or triangular cross-sections, feathered distal ends, and unidirectional parallel dorsal scars, usually without cortex, or with less than 50% of the lateral area. The mean dimensions of the quartz flakes are 31.45 × 24.07 × 15.50 mm. The core/blank ratio is of 1:3.

Flakes are mostly complete or, less frequently, represented by their distal ends. Core maintenance consisted solely of the removal of cornices. Retouched tools represent 21.9% and are mostly wedges ($n = 5$), splintered pieces ($n = 3$) and notches ($n = 3$).

3.1.4. Schist and granite

Schist is represented by one bladelet, three flakes and a large core for the production of flakes with a single platform, reduced following the thickness of the volume, with a right angle and a plain platform. This core is in between what would be considered a prismatic core for flakes and a chopper. Granite is represented by one fractured manuport that might have been used as a groundstone tool, e.g. abrader, pestle or grinding tool (Fig. 8).

4. Discussion

The plethora of data available from across Europe and Northern Africa seem to concur with an increase of demographic density in the end of the Pleistocene, probably as a result of adaptive strategies to survive through climatic crises such as the LGM or the Younger Dryas. Because the transition from the Pleistocene to the Holocene was one of melioration in climatic and environmental conditions, it might not demand an abrupt technological shift to overpass major difficulties. This may be the reason why we do not see an abrupt change in lithic technological traditions, at least in the western coast of Eurasia and probably the adjacent northern coast of Africa. However, by opposition, the 8.2 cal BP event was, in fact, an abrupt climatic crisis that affected all the Northern Hemisphere (Alley and Ágústsdóttir, 2005; Kleiven et al., 2008; Klitgaard-Kristensen et al., 1998; Rasmussen et al., 2007; Renssen et al., 2007) and happened when demographic density

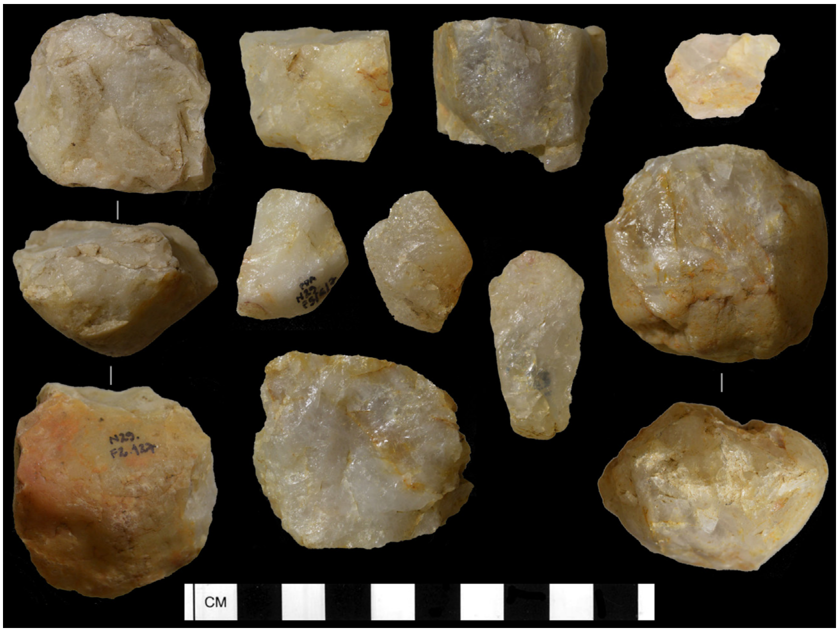

Fig. 7. (Color online.) Pena d'Água Rock-shelter: quartz assemblage showing cores, some with pitting related with their probable use as hammerstones, retouched flakes and blades, splintered pieces and wedges.
Fig. 7. (Couleur en ligne.) Abri Pena d'Água : assemblage de quartz avec nucléus, certains avec corrosion liée à leur utilisation probable comme percuteurs, éclats et lames retouchés, pièces esquillées et coins.

was very likely higher than before. Such phenomenon demanded a rapid adaptation in the behavioural patterns of the hunter-gatherers populations, seen in regions such as the westernmost coast of Eurasia in multiple traits, such as settlement patterns, the appearance of shell-middens, more or less large burial grounds, and indirect data suggesting social inequality. All these aspects had consequences in the corresponding lithic assemblages.

Thus, the post-Younger Dryas amelioration does not seem to have had major impact in the settlement, technological and economic strategies of the hunter-gatherers of Estremadura (for a different view, see Araújo, 2009). Indeed, in this region (at least where research has been intensive), the archaeological record seems to be consistent in showing only very discrete changes on those cultural traits; as mentioned above, several authors even recognize strong similarities between the Late Magdalenian (Bicho, 2000; Gameiro, 2012; Zilhão, 1997) and the Epipaleolithic (e.g., Araújo, 2003, 2009, 2011; Bicho, 1994) with respect to lithic production. The question that is still to be answered is how fast the shift to the typically Mesolithic "blade and trapeze techno-complex" was, which can only be possible using assemblages dated to around the 8.2 ka cal BP event – as is the case of the Pena d'Água layer F – which seems to mark the transition to the Mesolithic.

The Pena d'Água assemblage shows that the techno-typological features prevailing *at the time* of the 8.2 ky event have much more resemblance to the Magdalenian industries (Araújo, 2003, 2009; Bicho, 1994; Zilhão, 1997) rather than with the subsequent Mesolithic ones (Carvalho, 2009; Marchand, 2001; Roche, 1972). Those features are a close range acquisition of raw materials, even when these are not the best available within a wider region, a balance between

Fig. 8. (Color online.) Pena d'Água Rock-shelter: the only fragment of groundstone tool, in granite.
Fig. 8. (Couleur en ligne.) Abri Pena d'Água : seul fragment d'outil de *groundstone*, en granite.

chert, quartz and quartzite that typically depends on locally available sources, a strong coarse raw material component (e.g. quartzite and/or greywacke), and small and irregular bladelets knapped through Upper Palaeolithic-like technology (Araújo, 2012,Bicho, 1998, 2002; Marchand, 2005). According to the Pena d'Água evidence and the references cited above, technological features predating the 8.2 ky event show the predominance of flakes produced from cores with right angle (80°–90°), platforms with unidirectional parallel detachments, flat profiles, diverse cross-sections, irregular or parallel edges, and cortical or flat butts. With the exception of some backed and/or truncated points (such as Microgravette, Istres, Sauveterre, or La Malaurie points) and a smaller number of geometrics (usually trapeziums and rarely crescents or triangles), the large majority of the assemblages are comprised of marginally retouched flakes (notches, denticulates) or bladelets (such as Dufour bladelets), awls and splintered pieces. This is more obvious along the eastern borders of the limestone massifs (Santa Cita, Costa do Pereiro) and particularly in its southernmost tip (the Rio Maior area: Areeiro III and CPM V), where good quality chert occurs abundantly (Araújo, 2003, 2009, 2011; Bicho, 1994), in contrast to the Tagus terraces (Araújo, 2012; Bicho, 1998; Marchand, 2005).

This scenario strongly contrasts with that seen after the beginning of the Atlantic phase, the Mesolithic, where good quality raw material, especially chert, is acquired at longer distances in the areas where it has better quality, such as the Rio Maior valley (Pereira et al., 2015), and was used to produce longer, regular and standardized bladelets and blades probably through the soft hammer and/or indirect percussion techniques (Marchand, 2005). The retouched tools became dominated by regular geometrics while backed and marginal retouched tools almost disappear (Marchand, 2005; Paixão, 2014).

Despite this is beyond the scope of this paper, it should be mentioned that considerable information already exists on local raw material sources (e.g., Aubry et al., 2014; Matias, 2012), which will be crucial for far-reaching conclusions in the very near future. Indeed, ongoing surveys for chert sources in the Arrife area revealed new ones, still unpublished, some of which congruent with the assemblage in cause. These results will be published soon elsewhere.

A rather different pattern of raw material use emerges in areas where chert is rare. The nature and chronology of numerous macrolithic quartzite assemblages from the Tagus River have been long debated. The abundance of high-quality quartzite pebbles and cobbles made the production of chopper-like cores and semi-cortical flakes (with recurrent edge modification by retouch or use) easy. From the 19th century until the 1980s, research was based on surface collections, with sites being dated according to the terraces' altimetry and the patina on the artefacts. This approach led to the proposal of a myriad of entities where Acheulean, Mousterian, Mirian, Languedocean and Clactonian were recurrently found associated within each surface collection (e.g., Breuil and Zbyszewski, 1942, 1945; Raposo, 1986; Zbyszewski, 1943, 1958).

Since the 1990s, long-term projects (e.g., Oosterbeek et al., 2002, 2010), including geomorphological approaches (Corral, 1998; Grimaldi et al., 1998; Mozzi, 1998), absolute dating (Burbidge et al., 2014; Cunha et al., 2008; Martins et al., 2010) and the study of quartzite assemblages dated from the Acheulean to the Neolithic (e.g., Carvalho, 1998b, 2008b; Cura, 2002; Cura et al., 2004; Pereira, 2010; Pereira et al., 2012; Rosina et al., 2004), permitted the confirmation of chronological markers, such as handaxes in the Lower Palaeolithic, or the Levallois in the Middle Palaeolithic. During the Upper Palaeolithic, the chronological differences in quartzite are more discreet, such as rarity of elongated blanks in the Gravettian, the dominance of prismatic and stepped reduction in the Solutrean and Magdalenian, and, in this case, the frequency of massive tools with edge damage. Consequently, the most used and – at present – reliable criterion to classify any post-Palaeolithic assemblage is the presence of diagnostic artefacts (pottery, leptolithic reduction sequences, retouched tools mostly in chert, or polished stone tools), even when the sites count with absolute dates. Such is the case of Amoreira (Fig. 1).

The interpretation by the same team on Amoreira resulted in two opposing views (for general overviews, see Cruz et al., 2000 and Rosina et al., 2010). Salvage works during 1992–1994 and 2005 recorded a stratigraphic sequence where layer C stands out for its quartzite macrolithic industry (with some leptolithic cherts), apparently associated to postholes, polished stone tools and potsherds. A radiocarbon date on a bulk sample of unidentified charcoal (I-17332: 7460 ± 120 BP) indicated a 8459–8014 ky cal BP (at 94.5% prob.) time interval, with the median at 8.27 ky cal BP, an Epipaleolithic result slightly older than Pena d'Água's. However, while the excavators consider the site "*en place*" (Cruz, 1997: 301), where "[. . .] pottery and polished stone axes first occur" (Oosterbeek, 2004: 85), the geoarchaeologists argued that layer C was formed over Pleistocene terraces where macrolithic industries were already present, thus presenting a more complex scenario based on the site's formation process (e.g., Grimaldi et al., 1998).

The detailed lithic analysis of Amoreira's layer C (Cura, 2002; Cura et al., 2004, 2005) shows that quartzite dominates (55.8%) followed by quartz (22.7%) and chert (17.7%). These proportions are argued as most likely related to the high abundance of the first two raw materials and the low frequency of the third in the Tagus deposits. Chert was exploited via prismatic reduction to produce bladelets. Whereas core preparation elements are absent in the assemblage, core maintenance is observed, suggesting its long-distance acquisition with on-site knapping. Quartz reduction was in part similar to that of chert but this raw material was also used to produce a high frequency of flakes. The absence of refitting does not allow one to know if these flakes are related to an independent production or the configuration of prismatic cores. As in the case of Pena d'Água, quartzite is the most abundant raw material. It was exploited by knapping pebbles directly in the cortical platform, without preparation or configuration to produce flakes. The reduction sequence gave preference to detachments that kept some lateral cortex. Some cores seem to have been used also as choppers. Finally, there are some amphibolite fragments associated with polished stone axes and net weights.

When comparing Pena d'Água with Amoreira it seems that the chert assemblages are considerably different: the former has more retouched tools, while the latter shows a prismatic, more regular reduction strategy (closer to Mesolithic and Neolithic patterns). Relevant differences also exist with the quartzite assemblage. Although overall dominant in both cases, at Pena d'Água we do not have any net weight, but only a small granite groundstone that might have been used as anvil or pestle. Comparisons between the quartzite reductions in both sites show differences despite the use of the same river gravels: Pena d'Água has a wider variety of cores while Amoreira only has choppers; Amoreira flakes have almost only cortical platforms while in Pena d'Água the frequency is of 58%; and retouched tools are more diversified at Pena d'Água. However, some similarities also occur, such as cores reuse as choppers and predominance of notches and marginally retouched flakes.

In sum, the acknowledged differences between the two sites may be explained by an admixture of Epipaleolithic and Neolithic components at Amoreira, the first represented by the radiocarbon result, the second by the chert artefacts, potsherds, and polished stone tools. Similar traits in the quartzite technology and typology of both periods may have prevented a clear distinction between the two. This is the case of the Neolithic massive tools/cores component – which were made on large, relatively thin, elongated pebbles with unifacial detachments on one end (or "parallelepiped cores", as Carvalho, 1998b named them), often showing macroscopic edge damage related with heavy duties – and the high percentages of retouched or notched flakes among the tools. This precise pattern of quartzite exploitation was observed in the Early Neolithic assemblages from the overlying layers at the Pena d'Água itself (Carvalho, 1998b). Thus, in addition to the site initial formation processes identified by Grimaldi et al. (1998), this admixture may be the result of two events: one during the Neolithic occupation, another during heavy disturbance due to modern construction.

Despite recent major developments on the Muge shell-middens, little is still known regarding the lithic management, thus making of Roche's work (1972; see also Marchand, 2001) the main frame of comparison. According to this author, quartzite in the form of cobbles and other non-chert rocks were randomly used throughout the midden sequences, while chert was used extensively in the production of small blades/bladelets that were systematically retouched into multifunctional tools (side-retouched, notched, truncated) or especially transformed into geometric microliths through the use of the microburin technique. Indeed, unpublished results (Paixão, 2014) from the upper levels of Cabeço da Amoreira (7685–7600 cal BP) show that the knapped assemblage is overwhelmingly dominated by chert (98.7%). Similar trends in other Mesolithic assemblages have also been recorded closer to the regional limestone massifs (Fig. 1 top), such as Forno da Telha (Araújo, 1993) and Pessegueiros (Carvalho, 2008b).

However, the striking difference between these and the production methods pre-dating the 8.2 ky event, including that from Layer F of Pena d'Água, is the much higher regularity of blank production (small blades and bladelets), probably due to the introduction of indirect percussion techniques (Marchand, 2001; see also Carvalho, 1998b, 2008b, 2009), and the much higher blank/core ratio. Geometric triangles in particular, a category completely absent in all Epipaleolithic sites from the region, become very abundant in Mesolithic shell-middens such as Cabeço da Amoreira (Paixão, 2014; Roche, 1972) or Forno da Telha (Araújo, 1993), clearly reinforcing the idea of a consistent and abrupt shift in the technological patterns after the 8.2 ky climatic event.

In sum, the interpretation for the layer F of Pena d'Água here presented result from the congruency between the triangulation of data acquired by different and independent methods which are:

- a detailed and systematic geo-archaeological study that included micromorphology;
- a radiocarbon determination on a charcoal specimen;
- a technological analysis of the whole lithic assemblage.

Each of these methods has roots in different fields of science, has its own consolidated strategies, is consistently accepted in archaeology and often stand-alone as diagnostic. Therefore, it is free of circular reasoning.

5. Conclusions

According to our current state of knowledge, the environmental transition from the Pleistocene to the Holocene did not include any abrupt impact on the social, economic, settlement and technological patterns of the hunter-gatherer-fisher communities in Portugal, who retained similar ways of life for millennia. Rather, these patterns changed abruptly – not progressively – at the 8.2 ky cal BP climatic event.

Layer F of Pena d'Água Rock-shelter, dated to ca. 8.1 ky cal BP, thus provides an excellent context for the analysis of the lithic industries predating the mentioned climatic event. In this paper we presented a detailed description of this assemblage and put it in context with evidence from both sides of this boundary event. Our results show that in layer F of Pena d'Água each raw material was reduced according to very distinct strategies, especially regarding the chert and quartz vs. quartzite, and that each raw material was reduced congruently within the available data published from contexts with accepted absolute dates that fit the Epipaleolithic from central Portugal. Moreover, our results show that at this time and place the assemblage is balanced between chert and quartz with a strong coarse raw material component (quartzite), small and irregular bladelets knapped through Upper Paleolithic-like technology, one of them transformed through back retouch and is absent of geometrics. Together, these features make it clearly closer to the Epipaleolithic rather than to the Mesolithic, reinforcing our argument of the abrupt technological change in the transition from the Borial to the Atlantic and not a progressive shift through the Epipaleolithic.

Comparisons highlighted important shifts in raw material acquisition (from opportunistic to strategically obtained) and main technological features (from expedient to standardized). Both aspects can be best explained by a generalized change in human mobility patterns (from residential to logistic) as an adaptive response to changing environments. The identified technological shifts show correlation with other cultural realms of these communities – such as funerary practices, palaeodiets, social organization, etc. – all of which deserve future inquiry.

Because of its coastal position, the western coast of Eurasia is one of the best regions to study such transition. In this context, the layer F of Pena d'Água is an exceptional study case because its chronology falls immediately before the 8,2 cal BP event. Our study clearly shows that its lithic assemblage has technological and typological characteristics that fits it within those known from the Pre-Borial and Borial climatic periods instead of those of the Atlantic, dated from immediately after.

The combination of the available record complemented by the present study shows that the major dramatic shift in the lithic assemblages occurred, not with the passage from the Pleistocene to the Holocene, but during the Holocene, from the Borial to the Atlantic. This dramatic shift was, thus, directly associated with the impact of the 8.2 cal BP event. Presently, the most probable explanation for such fact is that the Pleistocene–Holocene transition was of amelioration in environmental conditions, thus not demanding major changes in the tool-kits. By opposition, the 8.2 cal BP event was an abrupt climatic degradation with strong impact at the environmental and resource availability throughout the Northern Hemisphere, in an epoch when demographic density was high. Such crisis demanded a rapid adaptation of the dispersed hunter-gatherers populations, precipitating their confluence into the areas where resources were more available and stable, forcing an aquatic adaptation, sedentism and social complexity. At this level, the striking changes in the lithic assemblages seen with the 8.2 cal BP event and in the ways to produce them become the formula to build better tools that would suit them to face both the complex environmental and social setting in hand.

More detailed analysis and comparison between contexts dating immediately before and after this climatic event are needed across Eurasia, eastern coast of North America and the northern coast of Africa in order to understand the impact of the phenomenon in the daily live, social and economical patterns of the Early Holocene societies in the Northern Hemisphere.

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