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Quartz use in the absence of flint: Middle and Upper Palaeolithic raw material economy in the Côa Valley (North-eastern Portugal)

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A B S T R A C T

Differing from most of European Upper Palaeolithic record, the Côa Valley lithic assemblages reveal an intensive use of a large variety of quartz and quartzite available locally. New surveys of the lower Côa Valley quartz veins were carried out in order to establish potential areas of raw material exploitation by hunter-gatherers through the identification of the raw material sources present in the archaeological record. Upper Palaeolithic lithic assemblages are produced on local quartz varieties, regional fine-grained quartz veins and flint and silcrete from long distance sources. The proportion of raw material and their choice for different tool types reveal some variation through the Upper Palaeolithic sequence, but present the same diversity and large geographical range of supply. Middle Palaeolithic assemblages from the same region are essentially based on local lithic material, showing a more restricted exploitation area and revealing different technology and procurement strategies, possibly evidence of changes in mobility and social networks.

1. Introduction

The discovery of the Côa Valley Upper Palaeolithic open-air prehistoric rock art, located in North-eastern Portugal, along the last 22 km of this left bank tributary of the Douro River (Zilhão, 1997b; Baptista, 1999, 2009) has radically changed our understanding of Late Pleistocene societies and peopling of Iberia. Subsequently, the discovery and study of an archaeological context for the rock art has enabled us to establish a significant occupation in this region of Iberia, during several periods of the Upper Palaeolithic (Zilhão, 1997b; Zilhão et al., 1995; Aubry, 2001, 2002, 2009), partially contradicting the accepted logistic hunting sites model for the Iberian hinterland's scarce occurrences (Davidson, 1986).

The study of lithic raw material used by Upper Palaeolithic foragers of the Côa Valley has revealed an intensive and predominant use of quartz, which is present through its different mineralogical forms in the hydrothermal veins of the site surroundings (Aubry, 2009; Aubry et al., 2012). Such a case is not uncommon in Portugal, where all lithic assemblages series show a systematic use of quartzite and quartz, and rare blade production, even at sites where flint sources exist in the vicinity (Zilhão, 1997a; Almeida, 2000; Bicho, 2000).

The Côa Valley is located in the Hercynian Massif, a long way from the nearest flint sources. In this area, quartz and Ordovician quartzite are available as pebbles and cobbles in secondary position in the Côa, Ribeira de Aguiar and Douro alluvial deposits. These local raw materials are archaeologically associated with small quantities of fine-grained hydrothermal siliceous rocks from regional outcrops and long distance flint and silcrete sources formed in a sedimentary environment, absent from the regional geological context (Mangado Llach, 2005). The interpretation of the discard of flints, coming from Central Portugal and Central Mountain System's northern and southern margins, and silcrete, from the northern and southern Meseta and the Lusitanian basin, has provided an unique opportunity to study the origin and to interpret the displacement of these materials, which show long distance connections with other areas of the Iberian Peninsula, namely Central Spain and Central Portugal, that hint at mobility patterns and long distance social relations (Aubry et al., 2014a).

The aim of this study is to define the origin of quartz materials and their use during the Upper Palaeolithic in comparison with Neanderthal and Holocene foragers of the same geographical area. In order to better understand local resources exploitation and their relation with regional and long distance raw materials, new field

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surveys were carried out to establish more precisely the regional resource availability and variability. To identify patterns in their choice and use through time, Upper Palaeolithic assemblages are compared to the Cardina I Middle Palaeolithic layer, recovered during the 2014 excavation campaign, and the Olga Grande 6 Mesolithic lithic assemblage.

2. Material and methods

The lower Côa River Valley and its confluence with the Douro River, corresponds to the *Alto Douro* region, geologically located in the northern sector of the Central Iberian Geotectonic Zone, part of the Iberian Hercynian Massif, consisting on the most continuous fragment of Variscan basement in Europe (Ribeiro, 1974, 1981; Ribeiro et al., 1979). The regional geology (Ribeiro, 1974; Silva et al., 1989; Ribeiro et al., 1990; Silva and Ribeiro, 1991; Pereira, 2001; Ribeiro, 2001; Pereira, 2006) comprises widespread outcrops of intensely folded and faulted metasedimentary rocks (schist, greywacke and quartzite), intruded by granite, ranging in age from Precambrian to Ordovician (Cabral, 1989; Silva and Ribeiro, 1991; Carvalho, 1992; Ribeiro, 2001). Both granitic and metasedimentary rocks are crossed by quartz, pegmatite, microgabbro/basalte, and rhyolite veins, following the main regional tectonic structures. Cenozoic and Quaternary sedimentary rocks (mainly sandstone and conglomerates) cover the Palaeozoic and Precambrian basement, as well as the Hercynian granitoids.

Since 1995, more than 15 Upper Palaeolithic archaeological sites have been identified in the Côa Valley (10 of which were tested or excavated) in an area of less than 400 km^2, along the river's lower 9 km, both on the valley bottom and on the granitic bedrock of the surrounding plateau (Zilhão et al., 1995; Aubry et al., 2002; Aubry and Sampaio, 2008; Aubry, 2009). A relative chronology of the different phases of the Côa Valley Upper Palaeolithic settlement was established from stratigraphic sequences identified at the sites where a geoarchaeolological approach was applied (Aubry et al., 2010). The knowledge of Middle Palaeolithic settlement in the area was initially based on surface survey findings, revealing Levallois technology, and the stratigraphical position of few lithic remains recovered in layer 4, at the bottom of the Olga Grande 4 sequence. This settlement is now attested under Cardina's Middle Gravettian occupation level 4b and Early Upper Palaeolithic remains recovered at the top of layer 5 (5.1 to 5.12) (Fig. 1).

Radiometric dates were obtained at four Côa Valley sites, by luminescence applied on burnt quartz and quartzite pebbles and by Optically Stimulated Luminescence on sediments at Cardina 1, Olga Grande 4, Quinta da Barca Sul and Fariseu (Valladas et al., 2001; Mercier et al., 2001, 2006, Fig. 1). The acid soils developed on schist and granite bedrock of the region do not favour the preservation of macro organic remains. However, bones and teeth were recovered in the stratigraphic level 4 of Fariseu (Aubry et al., 2007; Aubry and Sampaio, 2008; Aubry, 2009), where faunal remains are unusually preserved (Gabriel and Béarez, 2009), and in the Magdalenian and Gravettian occupation levels of Cardina I site. Upper Palaeolithic radiocarbon ages were obtained on bones from the layer 4 at Fariseu. The N content tested on Cardina I faunal remains has revealed that collagen is not sufficiently preserved in the remains analysed in order to obtain radiocarbon ages (Monge Soares, ITN, pers. comm.). Nevertheless, a charcoal fragment from Fariseu's layer 9 was dated by AMS to 19,020 ± 80 ^{14}C BP (GrA-40167; 22,878 ± 296 calBP, using CalPal_2007_HULU [www.calpal-online.de]), which demonstrates the potential conservation of Last Glacial Maximum macro organic materials in alluvial deposits. The ages obtained at the four sites have confirmed the typological attribution of the stone tool assemblages found therein and attest human presence during several phases in the 31,000–12,000 interval (Aubry, 2009; Aubry et al., 2014b).

The method used to detect, characterize and study extra regional flint and silcrete, relying on field work and microscopic analysis on thin section of selected samples, in order to identify the sources of the lithic raw material found at Côa Valley Upper Palaeolithic sites, is discussed elsewhere (Aubry et al., 2012, 2014a). For the regional and local hydrothermal vein quartz varieties, the approach is based on systematic descriptions and comparisons of archaeological and geological samples following the genetic and gytological classification, which considers *in situ* outcrops (0), subprimary outcrops (1), colluvial gathering (2), recent river deposits (3) and old alluvial deposits (4), as proposed by Fernandes et al. (2008). We have included recent data resulting from new surveys of hydrothermal quartz vein from the Côa Valley, Massueime and Douro tributaries, which were carried out from December 2014 to March 2015. The field work was based on geological data provided by the Instituto Geológico e Mineiro de Portugal (Carta Geológica de Portugal, Scale 1:50,000) and the inventory of Portuguese mineral occurrences and resources (SIORMINP, <http://geoportal.lneg.pt/geoportal/egeo/bdssiorminp>). In this study, the definition of the quartz varieties and sources is based on a macroscopic approach, with no further data. Petrological and geochemical analyses of quartz materials are under development. In order to analyse the relation between typology, chronology and the raw material we have considered the retouched flakes, blades and bladelet types from the two excavation campaigns led in 2014 on the northern area of the Cardina site. For the same reason we have done a principal component analysis for the Côa Valley sites' blades and bladelets (typology from Zilhão, 1997a), using R Language (R Core Team, 2013) and its package FactoMineR (Husson et al., 2013). The respective factor maps were then reworked in Illustrator CS3 to enhance their legibility.

3. Results

3.1. Quartz resources

The lithic resource survey in the context of the PaleoCoa project has confirmed the existence of a large variety of quartz forms that composed the epithermal veins filling the Hercynian fracture network and has located the sources of most of the regional fine-grained epithermal quartz vein sources that were systematically used during the Upper Palaeolithic in the region (Table 1, Figs. 2 and 3).

The most frequent form is milky quartz (J9), followed by grey (J12) and translucent anhedral quartz (J10) (Fig. 4). These are widely available as vein outcrops, highly fragmented by tectonics, or as fragments removed in slope or alluvial deposits, around all the archaeological sites studied (Figs. 2 and 3). Other quartz forms which have been observed are geographically more restricted. These very specific forms are closely related with successive deformation and filling phases (zoned translucent quartz - J11) or are found in direct association with uranium or gold mineralization (J1, J2, J5 and J8), confirmed by their mining exploitation (Cerveira, 1951). The cream to white microquartz and chalcedony variety (J7), and brown/yellow variety of microquartz and chalcedony (J1), called “jasper” in the mining literature, is noted in two distinct areas of the region surveyed (right bank of the Douro valley and Côa valley), as well as euhedral and anhedral smoky quartz (J8 and J17). These quartz forms, generally spatially associated, are related to the presence of uranium. Macroscopical binocular observations and comparison with archaeological remains of the Côa Valley assemblages indicate higher degree of similarity between J1 types used in the Côa valley archaeological sites and sources located along the

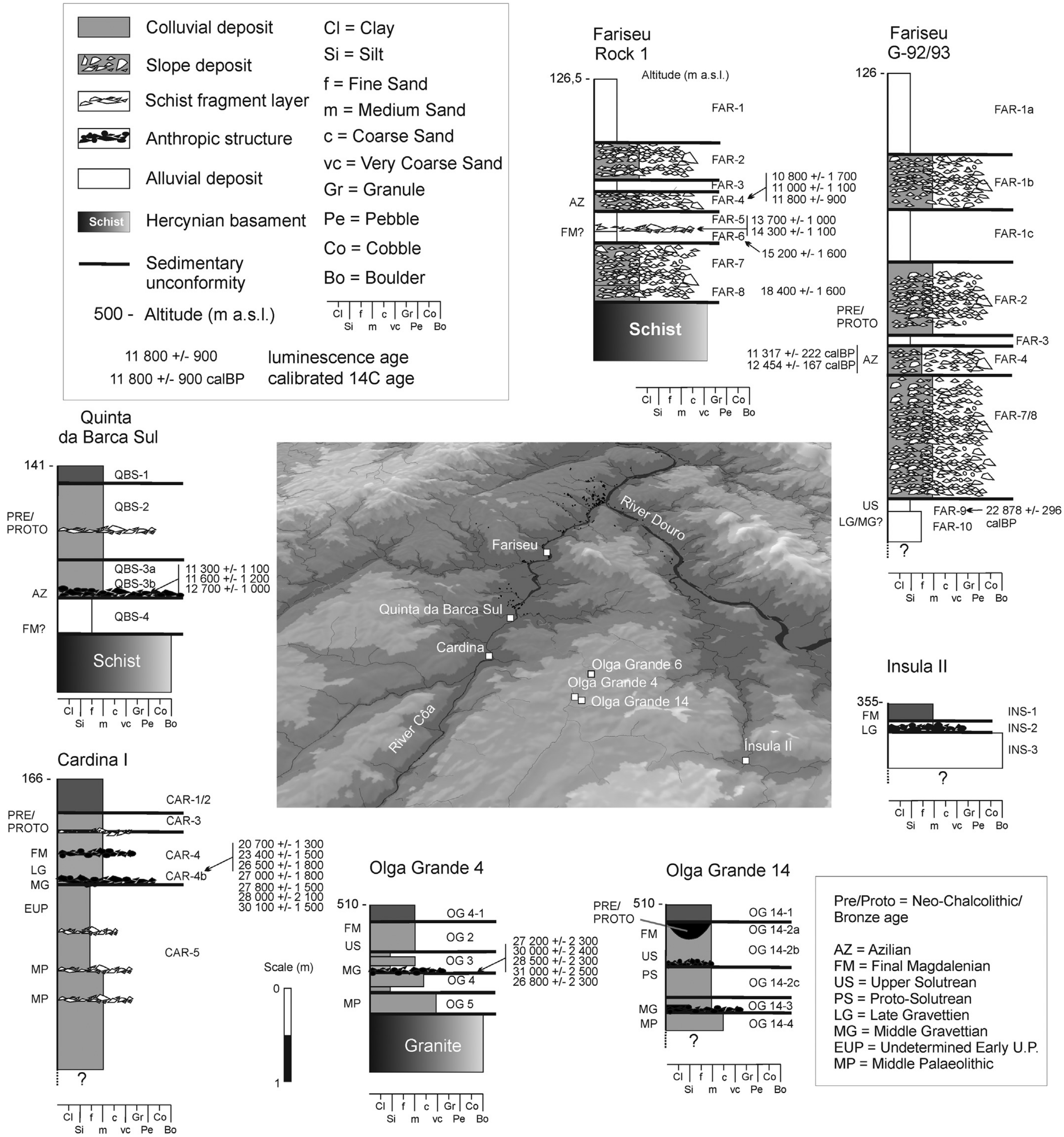

Fig. 1. Upper Palaeolithic settlement in the study area and stratigraphical units defined at Fariseu, Quinta da Barca Sul, Olga Grande 4, 14, Ínsula II and Cardina sites. Calibrated radiocarbon ages are calculated by using CalPal with the Calcurve CalPal_2007_HULU (www.calpal-online.de), and luminescence ages are from Valladas et al. (2001), Mercier et al. (2001, 2006) and Aubry (2009).

same river valley (Fig. 2). Geochemical analyses will be developed in order to test this hypothesis.

The green translucent microquartz and chalcedony (J2), attested in all the Upper Palaeolithic (Aubry, 2009) and Mesolithic (Monteiro-Rodrigues, 2011) sites, until now only attested by small veins fragments recovered in slope deposits (Aubry, 2009), has been observed in primary position and in considerable quantities, along a major fault (Fig. 2).

Euhedral milky quartz (J14) is frequently associated with anhedral milky quartz (J9), composing the largest quartz veins of the region with a NW–SE direction. Translucent to clear euhedral quartz (J13) has been also observed inside joint-fractures that have

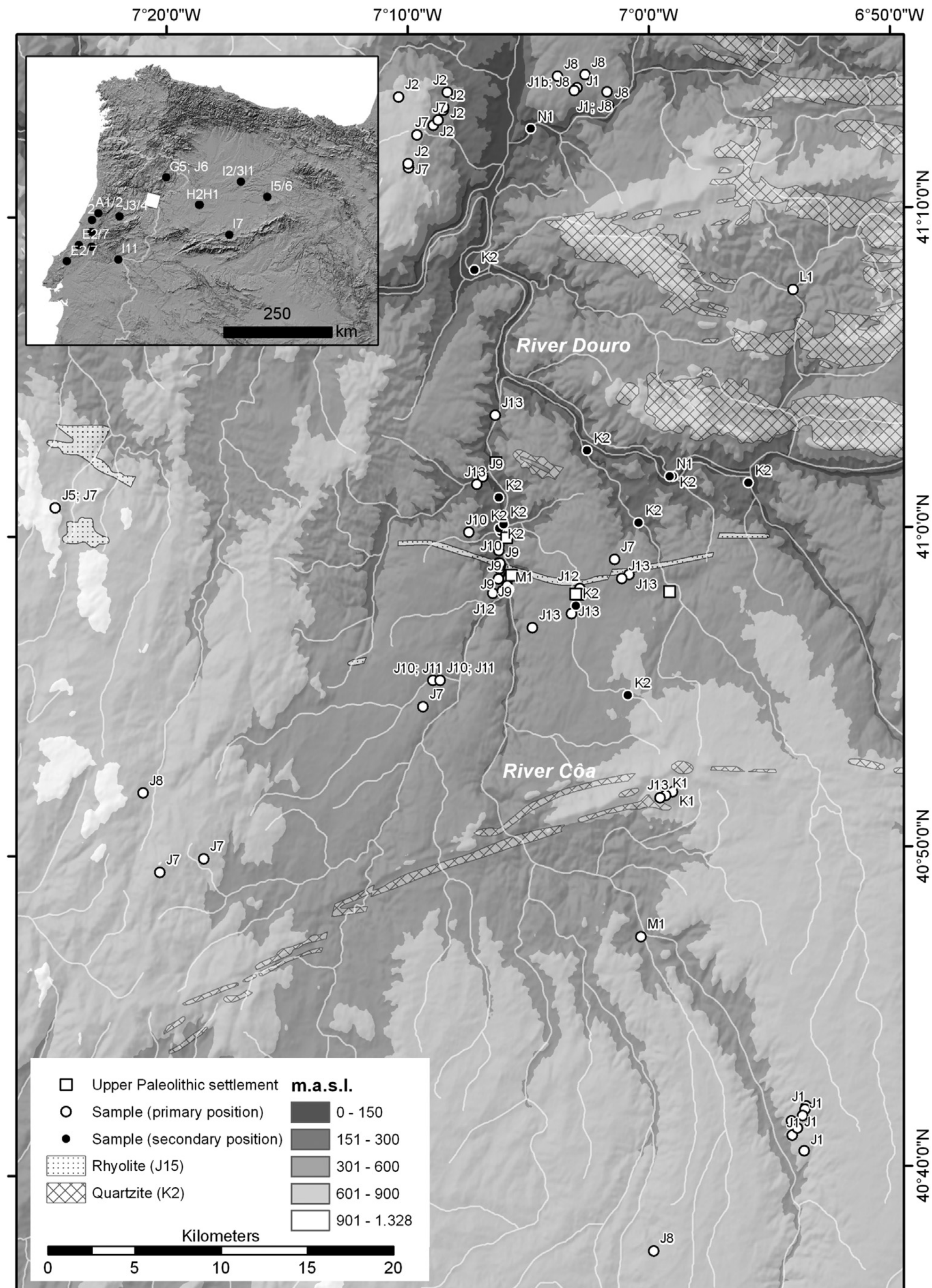

Fig. 2. Siliceous raw materials detected during the survey following the raw material codes defined in Table 1.

affected these main quartz veins and in other fractures in the lower Côa Valley metamorphic rocks. However, the equivalent in size and transparency of some of the euhedral quartz used during the Middle Gravettian of Olga Grande 4 layer 3 remains to be located.

3.2. Differential use of quartz

The Levallois and Discoidal lithic assemblage recovered in layer 5 of the Cardina sequence (551 pieces, Table 2, 5.13–32) is almost exclusively composed by anhedral translucent, milky or zoned quartz (Fig. 5). Few pieces (3) are made of rhyolite, available near the site as a large vein, and euhedral translucent quartz (10) (Fig. 3). The majority of the raw materials used in this layer could be found in the slope deposits surrounding the site and in the present-day alluvial deposits. The euhedral translucent to clear and milky quartz is found at less than 5 km. Comparatively to the Upper Palaeolithic lithic assemblages recovered at the same site in the top of the layer 5 (5.1–12), layer 4b and 4, it is noteworthy that quartzite is completely absent (Table 2). Only a flake and a blade were retouched as notches (Table 3). The survey of the present-day alluvial deposits near the site has not revealed quartzite cobbles similar to the archaeological blanks. Quartzite from the Ordovician

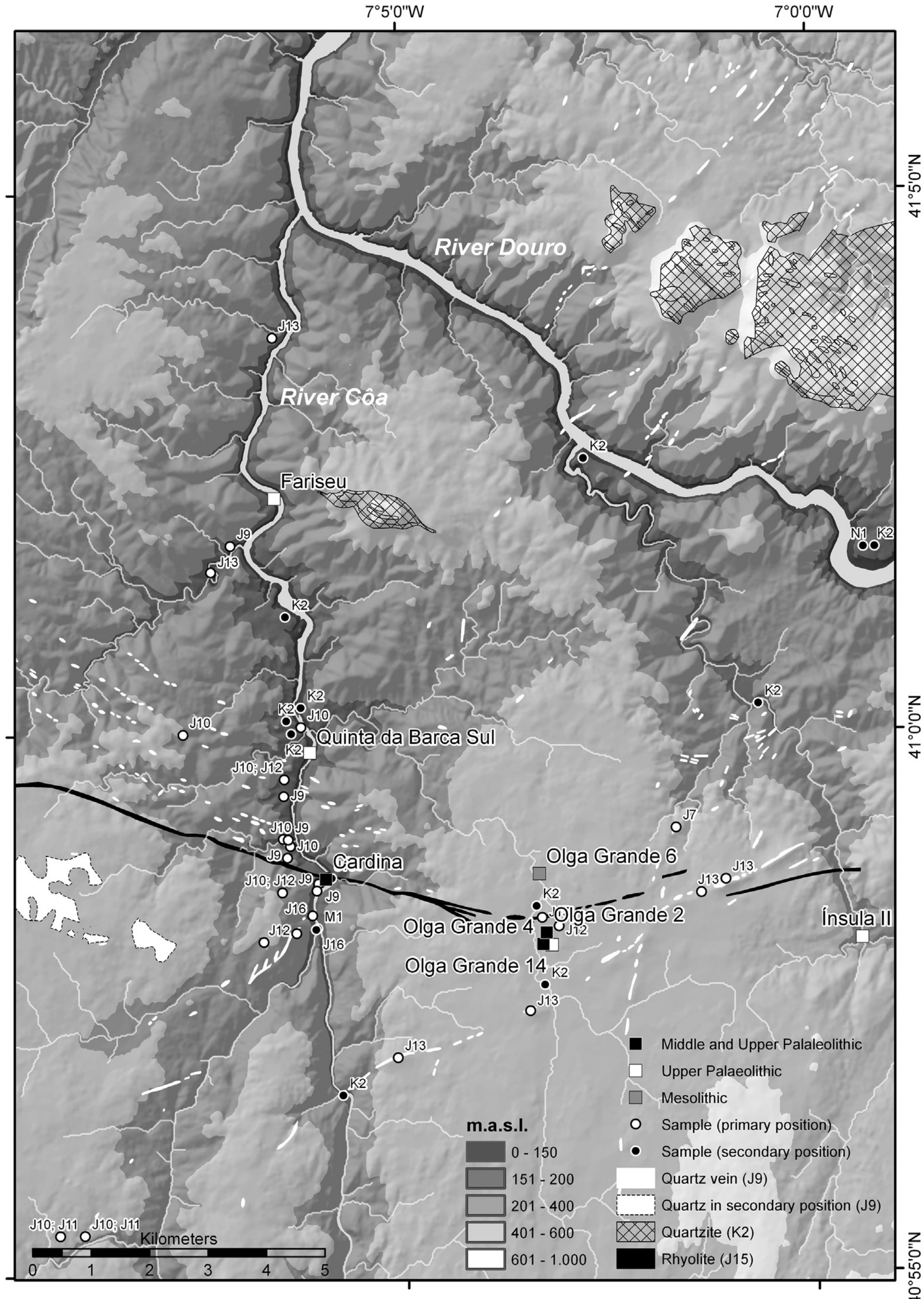

Fig. 3. Local lithic raw materials in the context of the Côa valley Upper and Middle Palaeolithic sites studied.

relief located 15 km upstream is attested as intensively rounded cobbles in Raña Pliocenic deposits, locally preserved on the Meseta surface (Fig. 2), in the Quinta da Barca Eemian terraces, and in the present-day alluvial deposit of the Penascosa/Quinta da Barca and Mouchão da Faia fluvial terraces, respectively located 3 km downstream and upstream (Fig. 3).

A quartzite Levallois flake was discovered in Olga Grande 4 layer 5, associated with local anhedral grey quartz non-diagnostic pieces (Fig. 6, nº 3 and 4), underlying Middle Gravettian occupation level, intercalated by a sterile layer (Fig. 1). Quartzite is locally available in the Ribeirinha alluvial deposits. The flakes obtained by a Levallois technology discovered in layer 2 of Olga Grande 2, are made from rhyolite (Fig. 6, nº 1 and 2) which is available in a thick vein a few metres from the site (Figs. 2 and 3).

The undetermined lithic assemblage from the Fariseu layer 10, the Middle Gravettian occupation of the bottom of the Côa valley (Cardina I, layer 4b), of the granitic plateau (Olga Grande 4 and 14, layer 3), and the Late Gravettian occupation attested at Cardina I (layer 4/10) and Ínsula II show the highest proportion of quartzite known for the Upper Palaeolithic sites of the region (Table 2). The Gravettian assemblages are also characterized by a direct

Table 1
Fine-grained siliceous rock categories identified in the Côa Valley series and code convention used to describe quartz vein categories in this study. Types follow the code convention proposed in Aubry et al. (2012) and gytological types defined by Fernandes et al. (2008) as follows: 0) in situ outcrop; 1) sub-primary outcrops; 2) colluvial gathering; 3) recent river deposits; 4) old alluvial deposits.

Genetic	Code	Gytology	Description
Flint	A1	0/1/2	Hettangian/Sinemurian red marmorean flint with geode
	C1/2	0/1/2/4	Bajocian/Bathonian grey to brown zoned flint (type 1)
	C3/4	0/1/2/4	Bajocian/Bathonian grey to brown zoned flint (type 2)
	D1/2	0/1/2	Oxfordian black/grey marmorean flint
	E2/7	0/1/2/4	Cenomanian brown/red flint
	I1	0/1/2/4	Indiferentiated Miocene flint
	I2/3	0/1/2/4	Miocene Mucientes black/grey flint
	I11	4	Miocene flint in old alluvial terraces
Silcrete	I7	0/1/2/4	Oligocene/Miocene translucent silcrete with black inclusions
	G5	0/1	Oligocene/Miocene green to grey opal with detrital quartz
	H1	0/1/2	Paleocene orange/yellow to cream opal with detrital quartz
	H2	0/1/2	Paleocene grey/yellow to orange sandstone with opal matrix
Hydrothermal veins	J1	0/1	Brown/yellow microquartz/chalcedony
	J2	0/1	Grey/Green translucent microquartz/chalcedony
	J3	0/1	Red microquartz and chalcedony
	J4	2/3/4	Red microquartz and chalcedony in secondary position
	J5	0/1	Yellow to orange opal
	J6	0/1	Peridotite red and translucent opal and chalcedony
	J7	0/1	White/cream/grey microquartz/chalcedony
	J8	0/1/2/3/4	Euhedral smoky and morion quartz
	J9	0/1/2/3/4	Anhedral milky and grey quartz
	J10	0/1/2/3/4	Anhedral translucent to clear quartz
	J11	0/1/2/3/4	Anhedral zoned translucent to clear quartz
	J12	0/1/2/3/4	Anhedral grey zoned quartz
	J13	0/1/2/3/4	Euhedral translucent to clear quartz
	J14	0/1/2/3/4	Euhedral milky quartz
	J15	0/1/2/3/4	Rhyolite
	J16	0/1/2/3/4	Micro-gabbro and basalte
	J17	0/1	Anhedral smoky quartz
Metasediment	K1	0/1/2	Ordovician brown iron siltstone
	K2	0/1/2/3/4	Ordovician quartzite
	L1	0/1	Silurian grey zoned chert
	M1	0/1/2/3/4	Cambrian black fine hornfels
	N1	0/1/2/3/4	Silurian lydite/Phtanite

relationship between the milky and translucent anhedral quartz to produce large endscrapers (Cardina I and Olga Grande 14), and by retouched flakes on quartzite flakes (Cardina I) or slabs (Olga Grande 4 and 14) transformed into inverse denticulate and large scrapers (Aubry, 2009). Olga Grande 4's layer 3 and Cardina I's 4b retouched bladelets were produced on extra-regional flint and silcrete, microquartz vein (J1, J2), fine-grained black hornfels (M1), iron siltstone (K1) and euhedral translucent to clear quartz (J13) (Aubry, 2009; Klaric, 2009; Klaric et al., 2009). Prismatic, unipolar and bipolar, truncated burin cores and anvil bipolar percussion reduction sequences were applied to euhedral translucent to clear quartz to produce bladelets (Fig. 7), using the same reduction sequence as used for flint, silcrete and the fine-grained quartz varieties (Aubry, 2009; Klaric, 2009).

During the Late Gravettian (Cardina 4/10 and Ínsula II), anhedral quartz economy and tool types reveal strong similarities with the Middle Gravettian assemblage, but the economy of euhedral translucent to clear quartz is quite distinct. Bladelets from this material are only transformed by marginal retouch and the diagnostic backed, truncated or bitruncated bladelets are made from black hornfels (M1), brown/yellow microquartz (J1), and long distance flint and silcrete sources (Aubry, 2009).

The Proto-Solutrean phase, characterized in Portugal by an intensive use of quartz (Table 2) for the production of bladelets from carinated or thick muzzled endscraper cores in the sites located nearby flint sources of Central Portugal (Zilhão, 1997a; Almeida, 2000) is attested in layer 2c of Olga Grande 14 (Fig. 1). Large flakes removed from discoidal cores and used as blanks for thick muzzled endscraper core for bladelet production, are made from the local anhedral quartz. This lithic assemblage presents the highest proportion of quartz and the lowest of quartzite of all the Upper Palaeolithic units, even though both are locally available (Table 2).

Of the 24 Solutrean shouldered points recovered from Olga Grande 4 and 14, 20 are made from Central Portugal and Meseta flint and only 2 from the brown/yellow microquartz (J1) we attribute to the Côa Valley sources (Fig. 2). The formation process of the bottom of layer 2 of these sites, bearing the Solutrean diagnostically lithic artefacts, is complex, and these remains are mixed with others ascribed to the Magdalenian occupation of the site. Therefore taphonomy does not indicate if some of the non-diagnostic quartz and quartzite tools of layer 2 of the two sequences are contemporary with the Solutrean points.

The final Magdalenian lithic assemblage from Cardina I (layer 4.2 to 4.4) site reveals some differences with the Middle and Late Gravettian assemblages (Tables 2 and 3, Fig. 8). Quartzite proportion decreases and milky anhedral quartz is dominant. A large variety of exotic flint (from Central Portugal and Central Iberia) and regional microquartz and chalcedony veins (J1, J2, J7 and M1) are used for the production of the blanks of the backed bladelets. However, in contrast to the Middle Gravettian industry, where all the fine-grained raw materials are used to produce the same bladelet tool types, during the Final Magdalenian, as during the Late Gravettian, euhedral translucent to clear quartz is only used to produce small marginal retouched bladelet blanks.

Assemblages of Fariseu's layer 4 and Quinta da Barca's layer 3, both slightly younger than Cardina I Final Magdalenian occupation, confirm the trend observed in this last assemblage. In both those

Fig. 4. Quartz samples recovered during the raw material survey and categories defined. J1) Brown/yellow micro-quartz; J2) Green/gray micro-quartz; J5) Yellow opal; J7) Gray micro-quartz; J8) Euhedral smoky quartz; J9) Anhedral milky quartz; J10) Anhedral translucent to clear quartz; J11) Anhedral zoned translucent to clear quartz; J12) Anhedral grey zoned quartz; J13) Euhedral translucent-clear quartz; J14) Euhedral milky quartz.

occupations, located nearby the bottom of the Côa Valley, anhedral quartz veins, milky and translucent to clear quartz are intensively used (Table 2). In Fariseu layer 4, most of these materials are not retouched. A very small proportion is transformed into notches, denticulates, scrapers and endscrapers (Tables 2 and 4). The Azilian points are made from long distance flint sources, brown/yellow (J1), green translucent quartz (J2) and black hornfels (M1), the last probably recovered in the Côa Valley alluvial deposits. At Quinta da Barca Sul, the sources used for the Azilian points are also used for the small circular endscrapers, profiting from the subproducts of the preparation of bladelet cores. Euhedral translucent to clear quartz is not used for the Azilian points, but, as in the Final Magdalenian, to produce marginal bladelet blanks, using soft hammer percussion or anvil bipolar percussion, as on other fine-grained raw materials (Gameiro, 2009).

4. Discussion

The technologically Middle Palaeolithic lithic assemblage from the Cardina I, recovered in the 2 square metres excavated, indicates a selection of the raw materials presenting the finest textures among the local anhedral milky, translucent and zoned quartz varieties to produce flakes using Discoidal and Levallois reduction sequences (Fig. 5). The Olga Grande 4 layer 5 and Olga Grande 2 layer 2 data also indicates the choice of the local raw materials available (namely rhyolite, quartzite and anhedral grey quartz). It

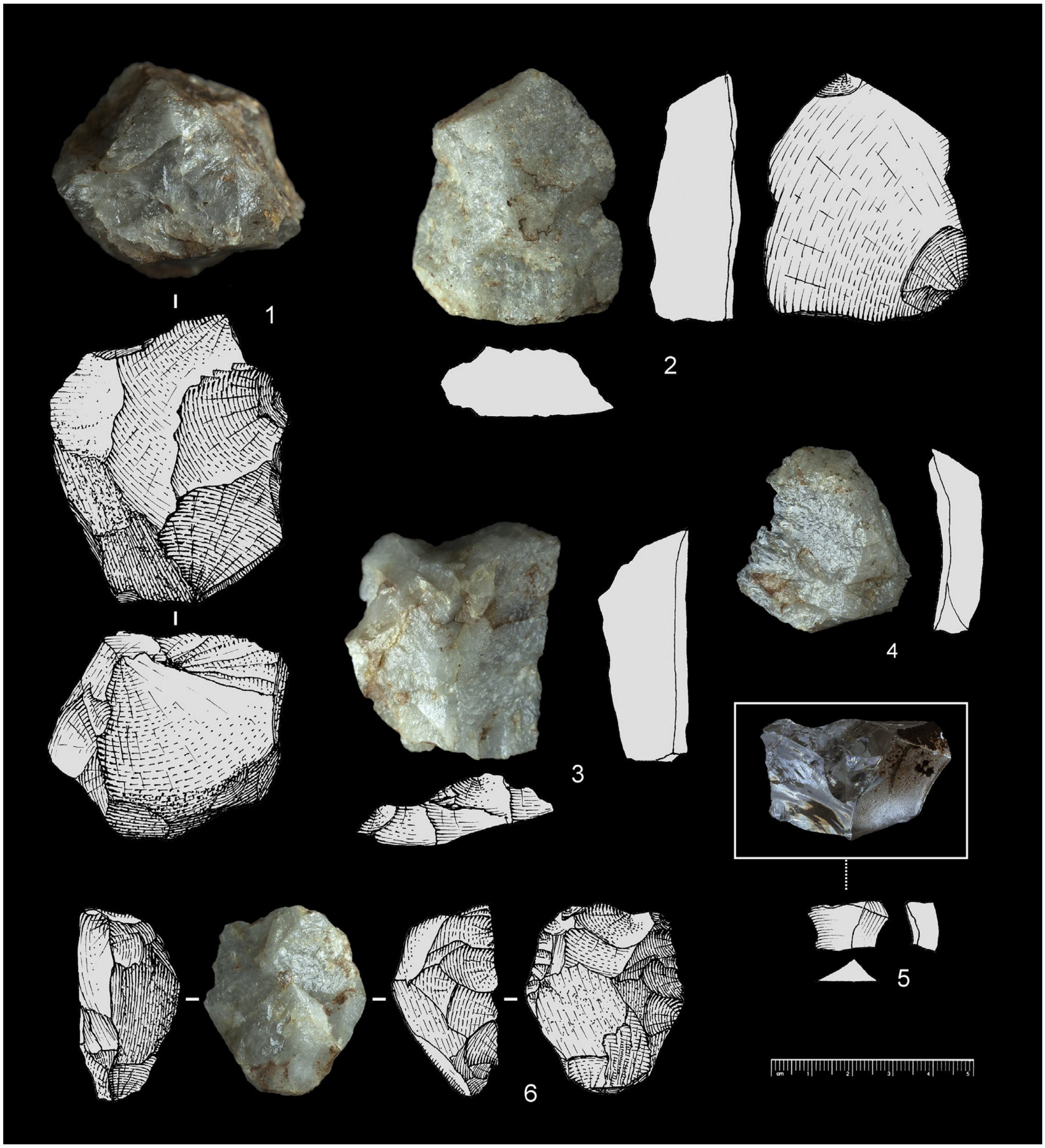

Fig. 5. Middle Palaeolithic Levallois and Discoidal technology and quartz varieties used in the Cardina I layer 5: 1 and 2) I′17 layer 5.25; 3) I′17 layer 5,23; 4) I′17 layer 5.21; 5) I′17 layer 5.18; 6) I′17 layer 5.26.

can be argued that the Middle Palaeolithic data of Cardina I is not sufficiently representative to infer behavioural patterns. However, when compared with the superposed Early Upper Palaeolithic layers (5.1–12), excavated in the same area, where regional and extra-regional microquartz and flint where found and quartzite is systematically present, it reveals a clear difference. If the use of quartz vein blanks locally available at Cardina can be perceived as a technological constraint, the absence of quartzite must be explained by the reduced lithic exploitation territory of the site. Quartzite is available less than 3 km upstream and downstream and was used in Olga Grande 4, where it is available at less than 200 m (Fig. 3).

Besides stratigraphy and technology, no other chronological data is currently available to date Cardina's Middle Palaeolithic and Early Upper Palaeolithic occupation. From these early stages of Upper Palaeolithic, all the local, regional and extra-regional raw materials are present in Cardina I assemblages (Fig. 8 and Table 3). Even though the different raw materials vary in proportion, quartzite (metasediment in Fig. 8) and anhedral quartz are largely dominant in the production of tools from flakes. This situation differs from the blade and bladelet tool production, where flint, silcrete, euhedral quartz and microquartz vein are dominant.

In terms of morphometrics and considering length/width ratio of all the bladelet tools from the Côa valley sites, regardless chronology and typology, different raw materials present slightly different trends (Fig. 9). Euhedral quartz and flint and silcrete correspond to the thinnest bladelets, along with anhedral quartz, which was unexpected. Metasediment (exclusively hornfels),

Table 2

Raw material categories effectives as defined in Table 1 used in the Côa Valley assemblages located in Fig. 1. Middle Palaeolithic (MP), Early Upper Palaeolithic (EUP), Middle Gravettian (MG), Late Gravettian (LG), Proto-Solutrean (PS), Final Magdalenian (FM), Azilian (AZ), Mesolithic (M) and Undetermined Upper Palaeolithic (?).

	Site	Olga Grande 4	Olga Grande 14		Cardina											Ínsula II	Quinta da Barca Sul	Fariseu		Olga Grande 6
	Layer	*3*	*2c*	*3*	*4.1*	*4.2*	*4.3*	*4.4*	*4.5*	*4.6*	*4.10*	*4B*	*4B*	*5.1–12*	*5.13–32*	*2*	*3*	*4*	*9, 10*	*2*
	Cultural attribution	MG	PS	MG	AZ	FM	FM	FM	?	?	LG	MG	MG	EUP	MP	LG	AZ	AZ	?	M
	sq.m excavated	75	12	12	18						12	4	12	2	2	11	28	36	1	10
Flint	A1	–	2	–	–	–	–	–	–	–	8	–	2	–	–	–	1	–	–	–
	C1/2	8	6	2	–	–	5	4	3	1	45	3	24	1	–	4	2	–	5	2
	C3/4				–	–	–	–	–	–		–		–	–					
	D1/2	31	17	–	–	4	4	6	1	1	16	–	9	–	–	–	–	3	–	–
	E2/7	14	8	5	7	10	21	6	17	6	96	19	81	7	–	11	3	19	–	–
	I1	144	16	16	6	32	40	34	14	7	402	39	331	15	–	15	6	10	2	2
	I2/3	–	4	5	3	5	3	2	3	–	134	5	85	3	–	2	7	–	–	1
	I5/6	–	–	–	–	–	–	–	–	–	32	–	9	–	–	–	–	–	–	–
	I11	–	1	–	1	–	–	–	–	–	–	2	–	–	–	–	2	4	–	–
	Not determined	–	2	–	5	13	10	6	5	1	96	7	62	4	–	–	–	–	–	–
	Burnt	–	2	–	9	4	11	7	2	–	20	3	81	2	–	2	–	7	–	–
Silcrete	I7	7	3	4	2	1	8	3	2	1	49	2	30	1	–	9	2	–	–	–
	H1	2	–	–	1	1	–	1	–	–	1	–	–	3	–	–	–	–	–	–
	H2	6	2	–	1	2	–	–	1	–	22	1	10	1	–	–	–	–	2	–
Hydrothermal veins	J1	21	–	8	2	3	12	14	7	5	11	10	12	11	–	–	32	–	–	–
	J2	3	–	–	1	–	–	1	2	–	5	1	–	–	–	1	22	26	–	–
	J3/4	–	–	–	–	–	1	–	–	–	11	–	9	–	–	1	–	15	–	–
	J5	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–
	J7	–	–	–	4	2	2	–	1	–	–	2	–	1	–	–	–	–	–	1
	J9	7557	1316	25	1336	1751	1979	1617	765	306	9817	966	5967	616	465	836	774	3882	195	361
	J10				333	441	664	552	260	129		283		170	35			1082		
	J11				33	28	32	47	15	4		28		34	38					
	J12				7	4	7	8	2	1		3		1	–			20		
	J8	968	92	108	–	–	2	2	41	–	5564	1	3411	1	–	142	16	237	–	170
	J13				56	87	102	121	61	20		90		38	*10*					
	J14				5	17	9	8	–	2		5		1	-					
Siltstone	K1	26	16	5	–	1	5	6	4	–	7	6	3	1	–	2	–	–	–	–
Quartzite	K2	971	71	174	284	511	472	469	187	64	11,875	357	8251	73	-	242	118	830	156	384
Hornfels	M1	1	25	3	4	17	29	20	5	2	2	–	6	7	–	1	8	2	–	3
Rhyolite	J15	19	19	1	29	40	76	75	40	11	?	28	?	9	3	-	3	4	–	10
Micro-gabbro	J16	–	–	–	14	17	16	23	10	2	–	15	–	3	–	–	–	1	–	4
Lydite	N1	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–

Table 3
Retouched tools on flake, blade and bladelets per raw material categories. Anhedral quartz (J9–12), Euhedral quartz (J13–14), micro-quartz vein (J1–2, 7), flint and silcrete (A1-I11, I7, H1–2), Rhyolite (J15), Metasediments (K1, K2, M1), micro-gabbro (J16), along the Cardina I archaeo-stratigraphic sequence sequence: Azilian (4.1), Final Magdalenian (4.2 to 4.5), Magdalenian to Gravettian (4.6 to 4.8), Middle Gravettian (4b), Early Upper Palaeolithic (EUP), Middle Palaeolithic (MP).

Layers	Flakes							Blades & bladelets							Total
	Anhedral quartz	Euhedral quartz	Micro-quartz vein	Flint & silcrete	Rhyolite	Meta-sediment	Micro-gabbro	Anhedral quartz	Euhedral quartz	Micro-quartz vein	Flint & silcrete	Rhyolite	Meta-sediment	Micro-gabbro	
Recent	1	–	–	–	–	–	–	–	–	–	–	–	–	–	**1**
Neolithic	17	1	–	3	–	6	1	4	3	1	7	1	1	–	**45**
4/1	4	–	–	3	–	1	–	2	4	3	2	–	–	–	**19**
4/2	12	2	–	3	–	4	–	3	7	–	6	–	2	–	**39**
4/3	15	–	1	3	1	4	–	–	5	–	8	–	–	–	**37**
4/4	18	3	1	–	–	4	–	6	6	2	7	1	4	–	**52**
4/5	11	1	1	1	–	39	–	1	1	1	7	–	–	–	**63**
4/6	8	2	1	3	1	–	–	2	2	1	3	–	–	–	**23**
4/7	7	–	–	1	–	3	–	1	–	1	1	–	–	–	**14**
4/8	4	–	–	1	–	4	–	1	1	1	8	–	–	–	**20**
4b	2	1	–	2	–	3	1	–	5	1	3	–	1	1	**20**
EUP	11	1	–	3	–	2	–	2	5	2	6	–	–	–	**32**
MP	1	–	–	–	–	–	–	1	–	–	–	–	–	–	**2**
Total	**111**	**11**	**4**	**23**	**2**	**70**	**2**	**23**	**39**	**13**	**58**	**2**	**8**	**1**	***367***

rhyolite and, to a lesser degree, microquartz vein show thicker bladelets. The different raw material textures, which is petrologically determined, is dominant, regardless of technology and use.

Data available for Cardina I (layer 4b and 4/10) and Olga Grande 4 (layer 3) indicate that flakes from local quartz and quartzite were seldom retouched (Aubry and Araújo Igreja, 2009). Use-wear marks on retouched and unretouched blanks are underdeveloped, revealing that tools on flakes were not intensively used. The opposite happened with retouched bladelets, shown by the frequency of fractures which morphology diagnoses as projectile impact (Aubry and Araújo Igreja, 2009). The numerical importance of flake production on quartz and quartzite, along with the use-wear data suggests an immediate use and discard of the raw or retouched edges.

To go beyond the raw material limitations we have carried a principal component analysis on the bladelets of the several excavated contexts of the region considering four main types of retouched bladelets (backed bladelets, backed points, marginally retouched bladelets and geometrics, Table 5). For our analysis, we have also included the Olga Grande 6 (OGVI) lithic assemblage, including geometrics (triangular, trapezoid or segment of circle), that could be assigned typologically to the Late Mesolithic, dated c. 7000/7500 BP in the nearby Prazo site (Monteiro-Rodrigues, 2011).

In order to perform a principal component analysis for the Côa Valley sites' blades and bladelets, we defined the assemblage of each type of bladelet from a given phase and a given site as an individual. This resulted in a universe of 44 individuals, which is far less than the desirable minimum number. This problem is amplified by the great number of our variables, the raw material used in the production of bladelets (22). The results are, however, too suggestive to be ignored. The analysis showed a strong contrast between a group composed of raw materials mainly from long distance sources (D1/2, H1, E2/7 and I1) but also some from regional (M1 and J1) and local sources (J15), and another formed essentially by local raw materials (J11, J12 and J13 quartz varieties) some regional (J2

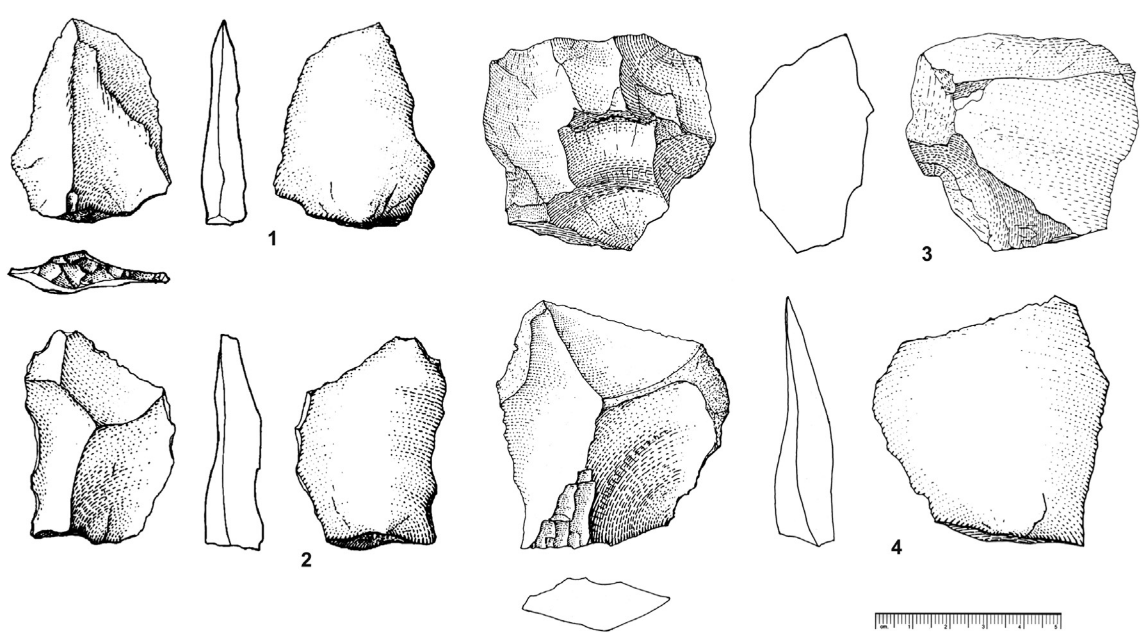

Fig. 6. Levallois material from Olga Grande 2, level 2 (1 and 2) Olga Grande 4, level 5 (3 and 4).

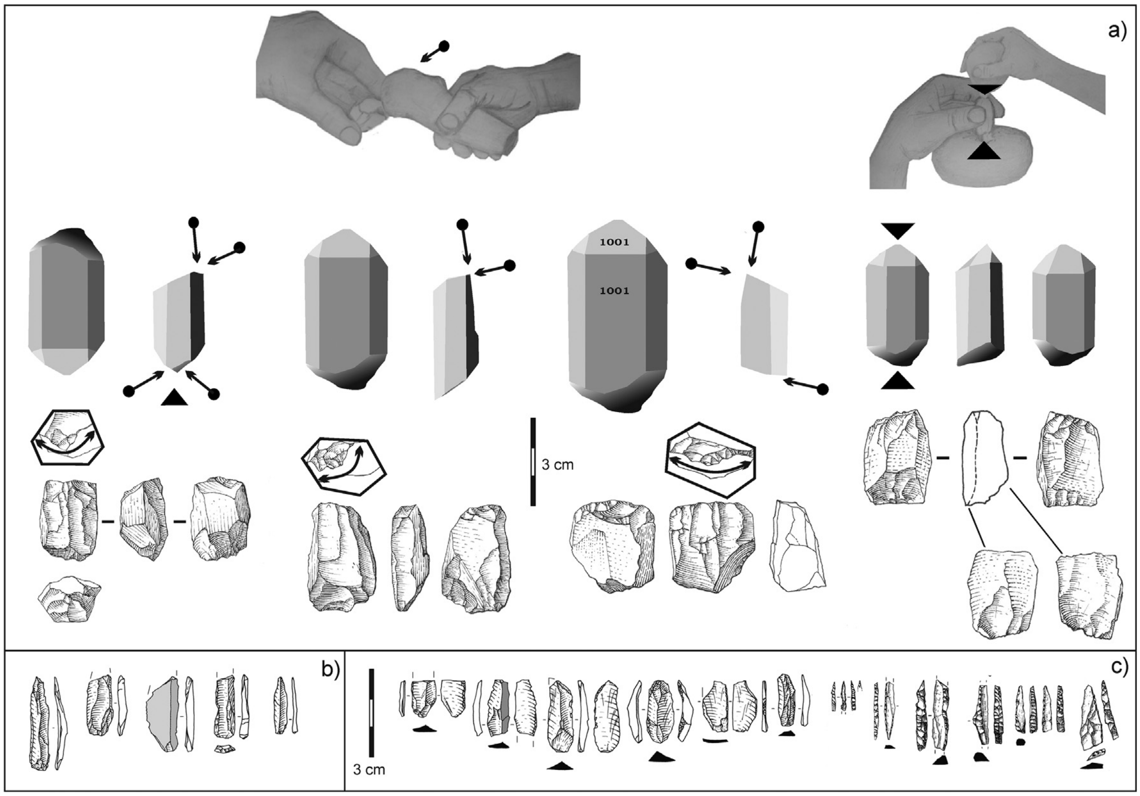

Fig. 7. a) Bladelet operative schemes and removal techniques used on euhedral translucent-clear quartz from the Middle Gravettian layer 3 of Olga Grande 4 site; b) Bladelets; c) Retouched bladelets types (from Aubry (2009) and Klaric (2009) modified).

and K1) and residual long distance sources (I11, I7 and H2). A second less clear difference can be determined based on the presence or absence of J9, J10 and J14 local quartz varieties (Fig. 10). In the cases of absence, there is a subtle association with the presence of A1 flint.

Adding typology as a supplementary qualitative variable to the individual factor map, when we look to the barycentres of the four tool types (Fig. 11) no pattern is clearly distinguished. However, when we analyse the same map, adding phasing as a supplementary qualitative variable (Fig. 12), it is clear that the cultural phases' barycentres are distributed along the first contrast mentioned above, according to a chronological sequence, in which we see clearly the progressive increase of quartz (J11, J12 and J13 varieties) in the production of bladelets through time. There is a reduction of the variety of the raw material of distant sources, although new varieties emerge (I11, I7 and H2). Only the Mesolithic assemblage (geo-OGV[Meso]) is outside this trend, which could suggest a rupture with previous cultures. On the other hand, the line defined by the barycentres of the Upper Palaeolithic cultures suggests that the change of the raw material through time is progressive.

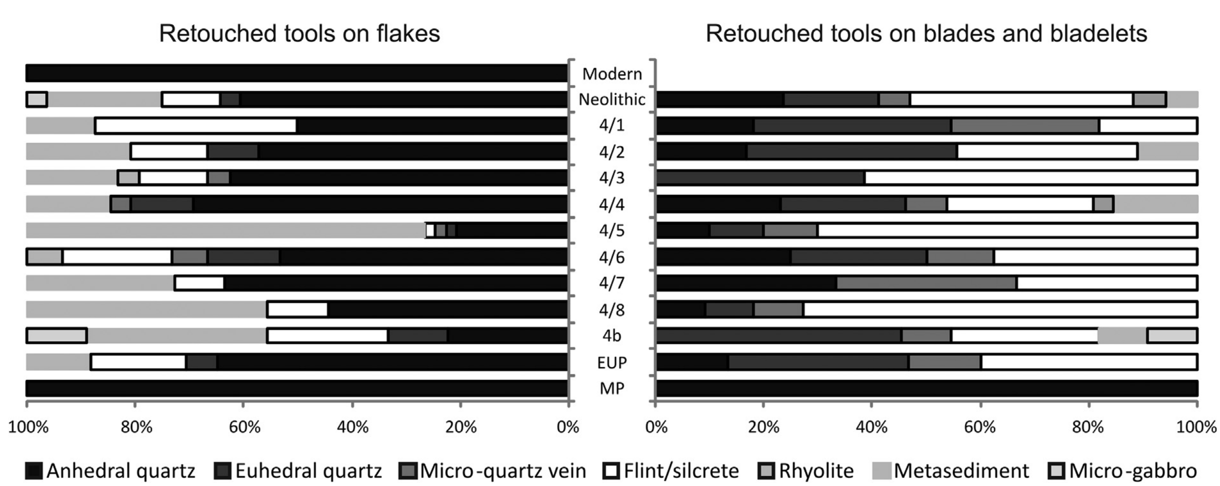

Fig. 8. Retouched tools on flake, blade and bladelets per raw material categories. Anhedral quartz (J9–12), Euhedral quartz (J13–14), micro-quartz vein (J1–2, 7), flint and silcrete (A1-I11, I7, H1–2), Rhyolite (J15), Metasediments (K1, K2, M1), micro-gabbro (J16), along the Cardina I archaeo-stratigraphic sequence: Azilian (4.1), Final Magdalenian (4.2 to 4.5), Magdalenian to Gravettian (4.6 to 4.8), Middle Gravettian (4b), Early Upper Palaeolithic (EUP), Middle Palaeolithic (MP).

Table 4
Fariseu, layer 4 (Azilian) tool types per raw material category.

Type	Flint			Hydrothermal veins					Meta-sediment
	E2/7	I1	Undet.	J2	J9	J10/11	J12	J13/14	K2
Double endscraper	–	–	–	–	–	–	–	–	1
Endscraper on blade	–	–	–	–	1	–	–	–	–
Endscraper on flake	–	–	–	–	–	1	–	–	–
Atypical carinated endscraper	–	–	–	–	1	2	–	–	–
Thick muzzled endscraper	–	–	–	–	1	–	–	–	–
Flat muzzled endscraper	–	–	–	–	1	–	–	–	–
Notched piece	–	–	–	–	1	9	1	1	3
Denticulated piece	–	–	–	–	1	3	–	–	1
Splintered piece	–	–	–	–	8	3	2	9	–
Sidescraper	–	–	–	–	–	1	–	–	–
“Vascas” sidescraper	–	–	–	–	–	1	–	–	–
Segment of a circle	–	–	–	–	–	–	–	1	–
Backed bladelet	–	1	–	–	–	–	–	1	–
Denticulated backed bladelet	–	–	–	–	–	–	–	2	–
“Areeiro” marginally retouched bladelet	–	2	1	–	–	–	–	5	–
Marginally retouched bladelet	1	–	–	–	–	–	1	1	–
Azilian point	–	1	–	1	–	–	1	1	–
Ogival point	–	1	–	–	–	–	–	–	–
Blade, flake and bladelet with discontinuous retouch	1	–	–	–	5	22	–	2	5
Flake or blade fragment with continuous retouch	–	–	–	–	1	7	–	–	–
Total	**2**	**5**	**1**	**1**	**20**	**49**	**5**	**23**	**10**

5. Conclusion

Raw material survey has confirmed that most of the different quartz varieties used in the Côa Valley are available in vein outcrops or slope deposits at the proximity of the sites studied (Fig. 3). The continuation of surveys has also revealed the systematic use of regional geographically restricted categories of fine-grained quartz and chalcedony veins, revealing a deep knowledge of the territory resources, attested by systematic displacements of these varieties, from 20 to 40 km (Fig. 2). A more precise reconstruction of the modalities of exploitation of these sources (gathering quartz vein fragments or core preparation near primary outcrops) could be

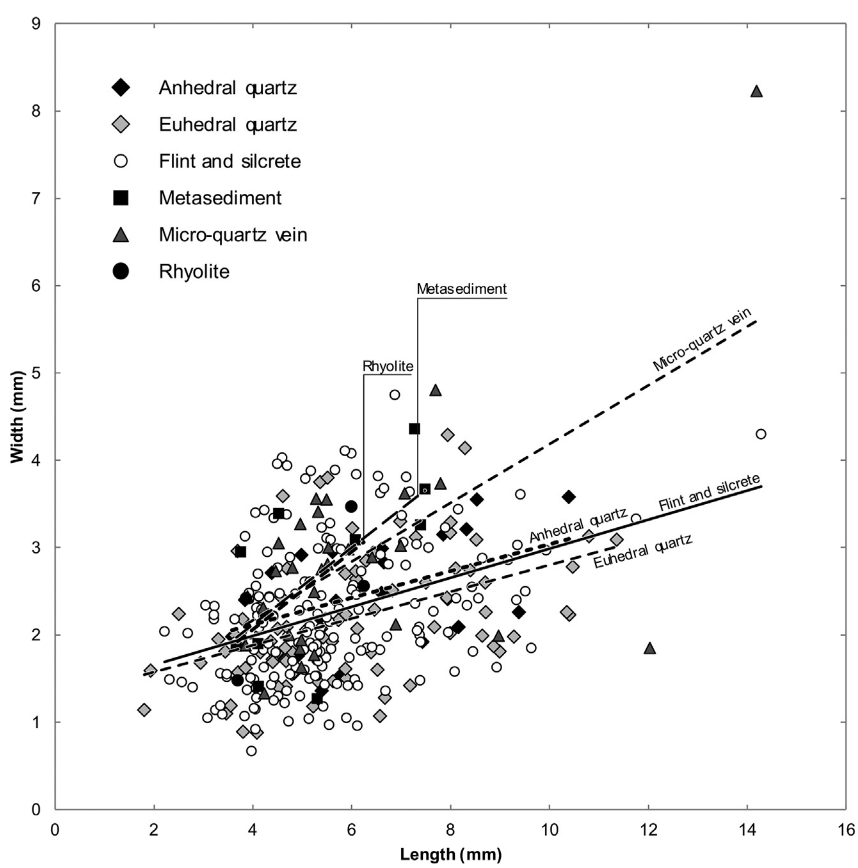

Fig. 9. Length/width ratio for retouched bladelet tools from the Upper Palaeolithic Côa valley occupation.

Table 5

Retouched bladelet tool types per raw material category from the Côa Valley. Code as follows: Backed bladelet (bb), Backed point (bp), Geometric (geo), Marginally retouched bladelet (mr); Cardina (CAR), Fariseu (FAR), Ínsula II (INSII), Olga Grande 4 (OGIV), Olga Grande 6 (OGVI), Olga Grande 14 (OGXIV), Quinta da Barca (QB), Quinta da Barca Sul (QBS); Middle Gravettian (MG), Late Gravettian (LG), Magdalenian (Mag), Azilian (Az), Mesolithic (Meso) and Undetermined Upper Palaeolithic (SM).

	Anhedral quartz				Euhedral quartz		Flint and silcrete										Microquartz			Metasediment		Rhyolite
Code	J10	J11	J12	J9	J13	J14	A1	C3/4	D1/2	E2/7	H1	H2	I1	I11	I2/3	I7	J1	J2	J5	K1	M1	J15
bb-CAR(Az)	–	–	–	2	3	–	–	–	–	–	–	1	3	–	–	–	–	1	2	–	1	–
bb-CAR(LG)	–	–	–	–	3	–	–	–	–	3	1	2	6	1	–	2	1	–	–	–	1	1
bb-CAR(Mag)	3	1	–	1	6	–	–	1	2	6	–	–	7	–	1	–	1	1	–	–	–	–
bb-CAR(MG)	–	–	–	–	4	–	–	2	1	7	5	–	–	–	1	–	4	–	–	–	5	1
bb-CAR(SM)	–	1	–	–	4	–	–	4	2	2	–	–	2	–	–	–	3	–	–	–	–	–
bb-FAR(Az)	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–
bb-INSII(LG)	–	–	–	–	–	–	–	–	–	1	–	–	2	–	–	–	1	–	–	–	–	–
bb-OGIV(Mag)	–	–	–	–	1	–	–	–	–	1	–	–	2	2	–	–	–	–	–	–	–	–
bb-OGIV(MG)	–	–	–	–	5	–	–	–	1	–	1	–	2	–	1	–	–	–	–	1	–	–
bb-OGXIV(MG)	–	–	–	–	1	–	–	–	–	–	–	–	2	–	–	–	1	–	–	–	–	–
bb-QB(Mag)	–	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–
bb-QBS(Az)	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–
bp-CAR(Az)	–	–	–	–	–	–	–	1	–	–	–	–	1	–	–	–	–	–	–	–	–	–
bp-CAR(LG)	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
bp-CAR(Mag)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–
bp-CAR(MG)	–	–	–	–	–	–	–	–	–	1	–	–	4	–	1	–	3	–	–	–	–	–
bp-CAR(SM)	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–
bp-FAR(Az)	–	1	1	1	–	–	–	–	–	–	–	–	–	1	–	–	–	1	–	–	–	–
bp-OGIV(Mag)	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–
bp-OGIV(MG)	–	–	–	–	3	–	–	–	–	–	–	–	3	–	–	–	1	–	–	–	–	–
bp-OGXIV(MG)	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–
bp-QB(Mag)	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
bp-QBS(Az)	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	2	–	–	1	–
geo-CAR(Az)	–	–	–	2	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
geo-CAR(Mag)	–	1	–	–	6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
geo-CAR(SM)	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
geo-FAR(Az)	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
geo-OGIV(Mag)	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
geo-OGIV(MG)	–	–	–	–	3	–	–	–	–	–	–	–	1	–	1	–	–	–	–	–	–	–
geo-OGVI(Meso)	–	–	1	–	5	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
geo-QB(Mag)	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
geo-QBS(Az)	–	–	–	–	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
mr-CAR(Az)	–	–	–	–	1	–	–	1	–	–	–	–	1	–	–	–	–	–	–	–	–	–
mr-CAR(LG)	–	–	–	–	4	–	–	–	–	2	–	–	1	–	–	1	–	–	–	–	–	–
mr-CAR(Mag)	–	1	–	–	4	–	–	3	1	8	–	–	4	–	1	–	–	–	–	–	–	1
mr-CAR(MG)	–	–	–	–	9	–	1	–	–	–	–	–	2	–	2	1	–	–	–	–	–	–
mr-CAR(SM)	–	–	–	–	5	–	–	–	–	2	–	–	1	–	–	–	–	–	–	–	–	–
mr-FAR(Az)	–	–	1	–	8	–	–	–	–	–	–	–	–	3	–	–	–	–	–	–	–	–
mr-INSII(LG)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–
mr-OGIV(Mag)	–	–	–	–	–	–	–	–	–	1	–	–	1	–	–	–	–	–	–	–	–	–
mr-OGIV(MG)	–	–	–	–	3	–	–	–	–	1	–	–	2	–	–	–	–	–	–	–	–	–
mr-OGXIV(MG)	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
mr-QB(Mag)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	1	–	–	–	–
mr-QBS(Az)	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

obtained by extending systematic surveys. The distinction between brown/yellow microquartz (J1) of the right margin of the Douro Valley and Côa Valley sources, to the north and the south of the sites, respectively (Fig. 2), and its implication for the social network reconstruction should be determined by geochemical analysis. Although the excavated area is still limited and no chronometric data is available yet, the Middle Palaeolithic lithic assemblages recovered at the Cardina I site and Olga Grande 4 and 2 show the dominant use of raw materials present in the settlement vicinities (anhedral quartz and rhyolite for Cardina, rhyolite and quartzite for Olga Grande 2 and 4) the absence of most of the regional and all of the long distance sources systematically used during all the Upper Palaeolithic.

The Upper Palaeolithic assemblages show a wider source network, including all the local and regional siliceous rocks and extra-regional flint and silcrete. The exploitation of the local quartz varieties in association with other local, regional and extra-regional sources shows a trend though time. During all the phases of the Upper Palaeolithic, retouched flake tools are mainly done on the local quartzite and anhedral varieties of quartz. Frequency of non-retouched blanks of these materials and use-wear analysis suggest immediate use and discard of the raw and retouched quartz and quartzite flakes produced on the Côa valley sites. Retouched bladelet tools are produced on a large variety of raw materials, preferentially extra-regional flint and silcrete, but also euhedral local quartz and anhedral translucent quartz and rhyolite and regional hornfels and iron siltstone. Independently of the chronology, statistical analysis of Upper Palaeolithic retouched bladelets does not reveal a clear relation between typology and the raw material. Nevertheless, statistical analysis indicates slight differences in preferences from the Middle Gravettian to the Azilian, when considering bladelet tool raw materials. If the same large

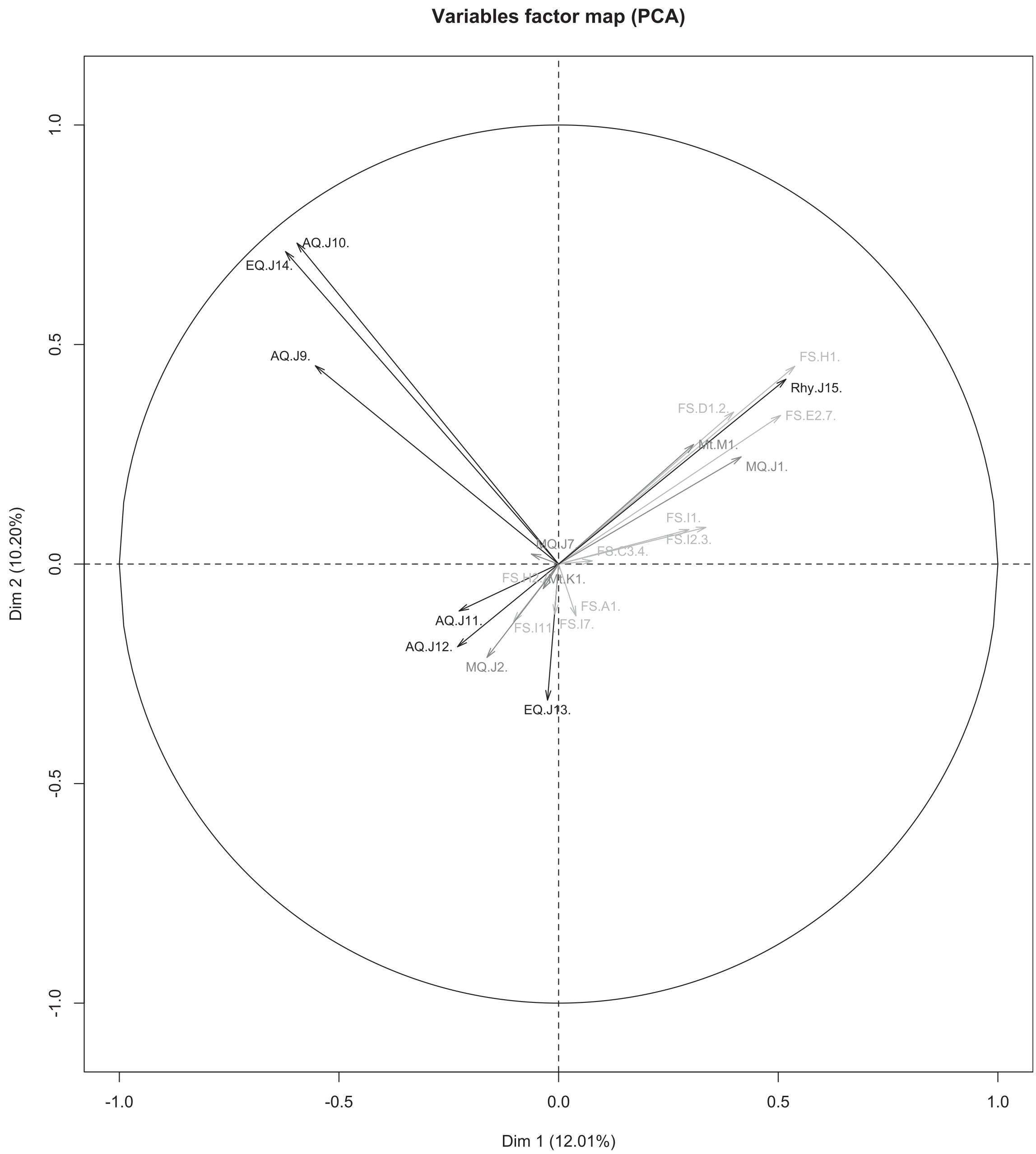

Fig. 10. Variables factor map for the Côa Valley's blades and bladelets. Black arrows represent local raw materials, lighter represent raw materials from regional and long distance sources. (See Table 1 for raw material type).

geographic range and diversity of lithic raw material supply is generally the same throughout the Upper Palaeolithic, over time there is a constriction in the raw material supply range (Aubry et al., 2012). This general trend seems to be confirmed by the known Mesolithic assemblage, essentially focused on local euhedral and anhedral quartz varieties for the production of the bladelets retouched into geometrics tools, even if exotic flint is not completely absent.

In the Côa Valley, quartz and quartzite are dominant in all knapped industries. Our study highlights the importance of the knowledge of local and regional raw material varieties in the study of lithic economy, namely in an area where flint and silcrete are absent, opening new prospects for the survey of similar areas.

A fine-grained study of the raw materials economy shows differences through time. Keeping in mind the constraints related to the Middle Palaeolithic technology, first results from the Côa Valley, where flint is regionally absent, hint different behaviours between Neanderthal and Modern Human societies, concerning territory exploitation and/or raw material choices, and have implications on territoriality and social networks, which future works will enlighten. Further excavation and dating of Middle Palaeolithic occupations at Cardina and other sites will be required, as well as a thinner analysis of both the possible relation between Upper Palaeolithic raw material procurement strategies and cold millennial-scale climate oscillations, and the transition to Holocenic societies.

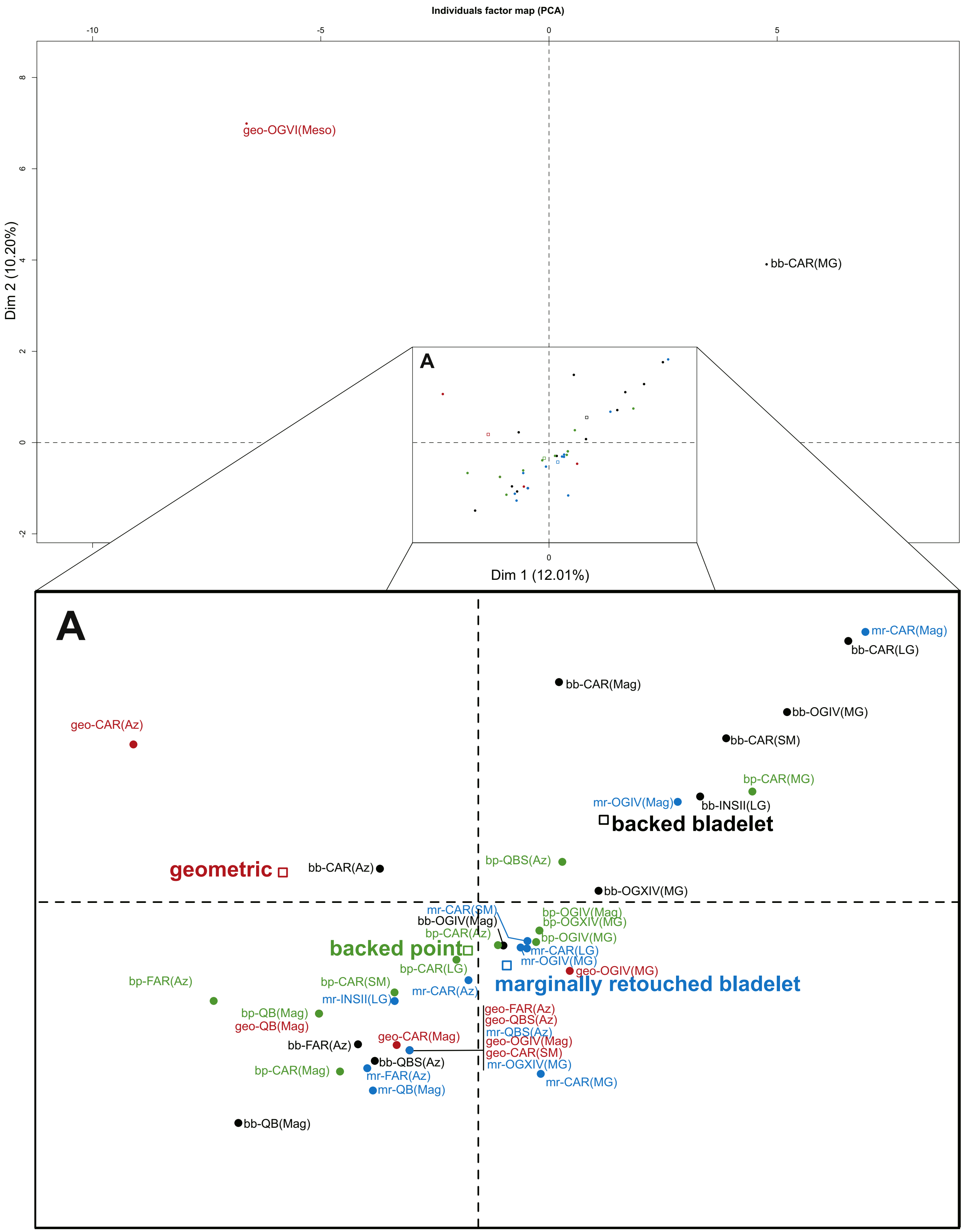

Fig. 11. Individuals factor map of the Côa valley's blades and bladelets by type. Squares represent the barycentres of the supplementary variable, the different blades and bladelets' types. (See Table 5 for abbreviations).

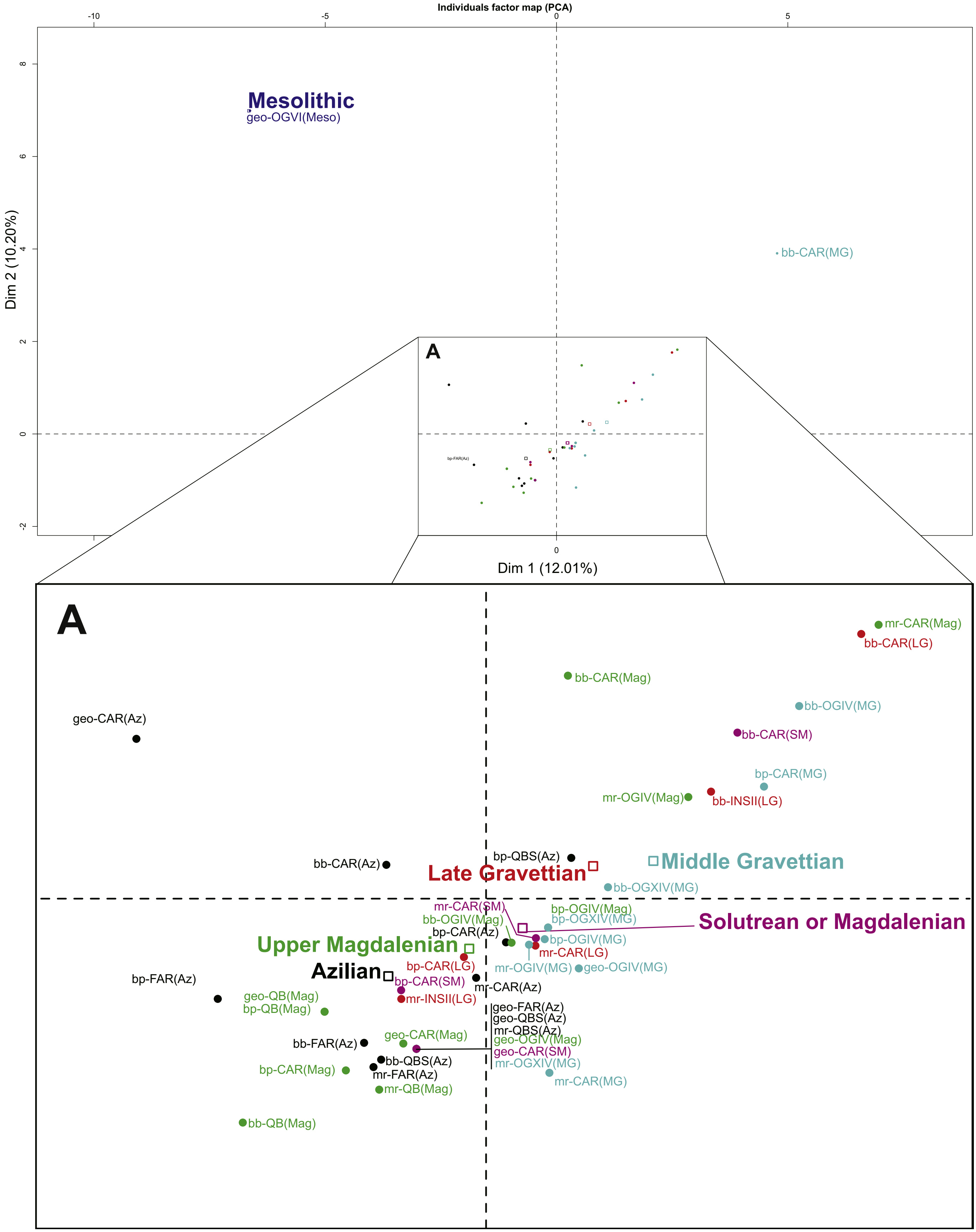

Fig. 12. Individuals factor map of the Côa valley's blades and bladelets by cultural phase. Squares represent the barycentres of the supplementary variable, the different phases of blades and bladelets. (See Table 5 for abbreviations).

Acknowledgements

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