
Upper Palaeolithic lithic raw material sourcing in Central and Northern Portugal as an aid to reconstructing hunter-gatherer societies

Thierry Aubry¹, Cristina Gameiro², Javier Mangado Llach³, Luís Luís¹,
Henrique Matias², Tiago do Pereiro⁴

1. Fundação Côa Parque. Rua do Museu, 5150-610 Vila Nova de Foz Côa, Portugal.

Email: Aubry: thaubry@sapo.pt; Luís: lsimoest@hotmail.com

2. UNIARQ, Centro de Arqueologia Universidade de Lisboa, Faculdade de Letras. Alameda da Universidade, 1600-214 Lisboa, Portugal. Email: Gameiro: gameiro.cristina@gmail.com; Matias: hamatias@gmail.com

3. Departament de Prehistòria, i Arqueologia. 1er pis. Facultat de Geografia i Història. Universitat de Barcelona. C/Montalegre 6-8. 08001 BCN, Spain. Email: mangado@ub.edu

4. Era Arqueologia, S.A. Calçada de Santa Catarina, 9c, 1495-705 Cruz Quebrada, Portugal.
Email: tiagodopereiro@gmail.com

Abstract:

We present the results of the study of lithic raw materials used in Upper Palaeolithic occupations preserved in caves, rockshelters and open-air sites from two different geological environments in Portugal. For the sites located in the Lusitanian Basin, flint or silcrete sources are easily available in close vicinity. The Côa Valley sites, located in the Iberian Massif, are within a geological environment where restricted fine-grained vein quartz and siliceous metamorphic rocks are available, but no flint or silcrete, even though both are present in the archaeological assemblages. Data from the two clusters of sites are compared with a third newly located site in the Lower Vouga valley, at the limit of the Iberian Massif with the Lusitanian Basin, where quartz vein raw material types are locally available and flint is about 40 kilometres distant. This study reveals prehistoric adaptations to these different geological contexts, with shorter networks for the Lusitanian basin sites contrasting with the long distance ones for the Côa Valley, and the Vouga site at an intermediary position. Finally, we propose that lithic raw material supply networks, defined by a GIS least-cost algorithm, could be used as a proxy not only for territoriality in the case of local and regional lithic raw material sources, but also to infer long-distance social networks between different Palaeolithic human groups, created and maintained to promote the access to asymmetrically distributed resources.

Keywords: Côa Valley; Upper Palaeolithic; lithic raw material sourcing; social networks; archaeological GIS

1. Introduction

Upper Palaeolithic settlement in Portugal was until recently almost entirely restricted to the Meso-Cenozoic deposits of the Western Iberian margin, notably inside caves, as is the



case in almost all of southwestern Europe. Some open-air sites for this period were also known primarily in the vicinity of flint sources (Zilhão 1997b). This image of the Upper Palaeolithic settlement of Central and Northern Portugal changed radically with the discovery of the Côa Valley open-air rock art and the settlement sites associated with it (Aubry 2009; Zilhão *et al.* 1995;). These remains are located deep in the middle of the Iberian Massif, far away from karstic caves, rockshelters or flint sources (Figure 1).

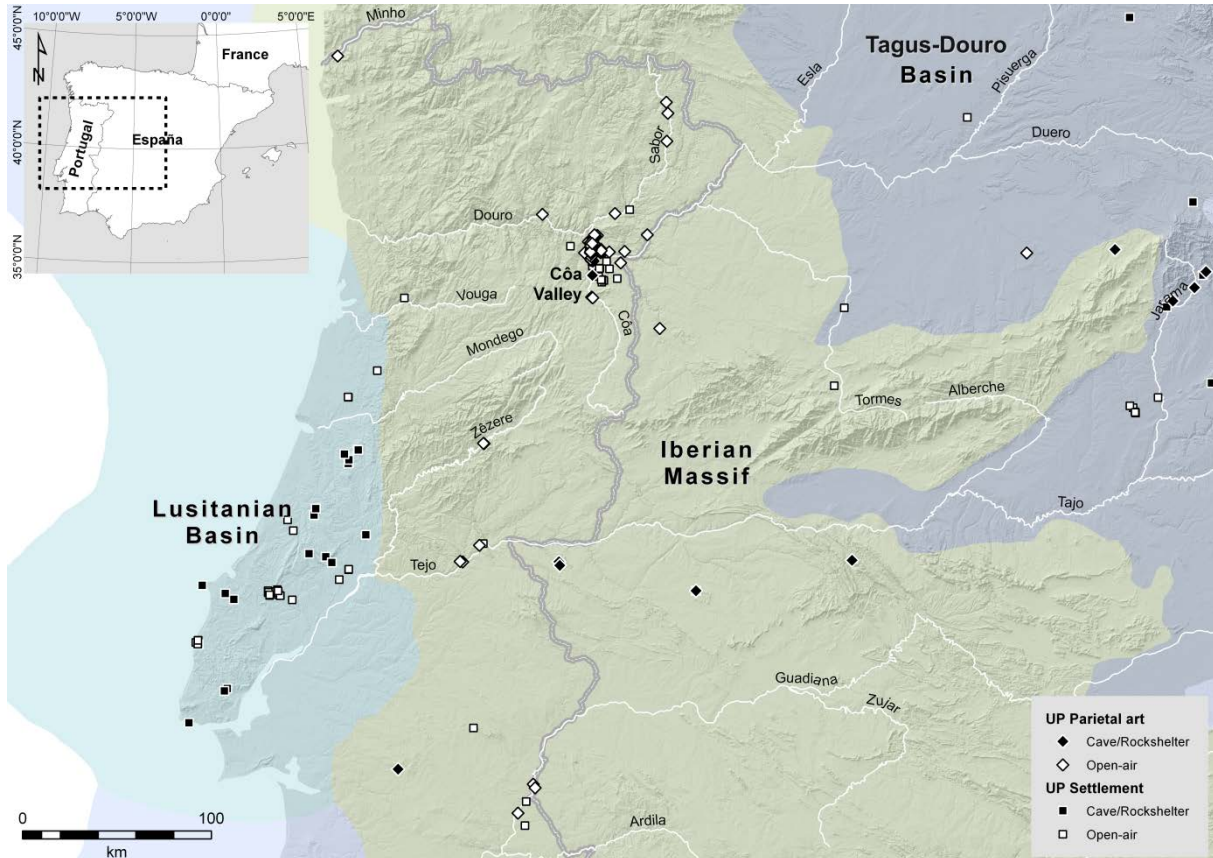


Figure 1. Upper Palaeolithic settlement and rock art in Central and Western Iberia.

The Lusitanian basin occupies the central western area of the Iberian Peninsula and is defined by sedimentary rocks with rare volcanic intrusions (Kullberg *et al.* 2013). On the other hand, the Hercynian Iberian Massif is composed of Precambrian and Palaeozoic metamorphic and plutonic rocks, intruded by hydrothermal veins (Ribeiro 2013; Ribeiro *et al.* 1979). Further to the east, lies the Tagus-Douro Basin, a Tertiary inland basin (Friend & Dabrio 1996), occupying most of the Iberian Meseta, which is divided by the Central Mountain System which is part of the Hercynian basement.

Until the early 1990's, most of the known settlement sites were found close to flint and other lithic sources in the Lusitanian basin and therefore the study of raw material sourcing wasn't perceived as a priority, as opposed to the need to define the chrono-stratigraphic sequence of the Portuguese Upper Palaeolithic (Zilhão 1997b).

Since the beginning of the study of the Côa Valley and the identification of allochthonous flint in the assemblages, it became clear that the development of a large scale geological survey was not only needed, but also provided a real opportunity to establish the relationships with areas where these raw materials are naturally available and to reconstruct territories and human mobility. During the last twenty years, guided by archaeological data, we have developed a methodology of study based on geological field work and laboratory analyses applied to lithic raw material sources of Central and Northern Portugal, as well as the

Spanish Meseta (Aubry *et al.* 2012; 2013). The purpose of this study is to 1) define lithic raw material displacement, management and use by the Late Pleistocene hunter-gatherer societies, 2) to study the use of these materials through time, and 3) to compare the patterns with Holocene human groups' management of the same lithic materials, in order 4) to derive inferences about the social organization of different human groups (Aubry & Mangado Llach 2003; Aubry *et al.* 2012; Aubry *et al.* 2013; Mangado Llach 2005).

In previous works we have demonstrated that during Upper Palaeolithic in the Côa Valley long-distance raw-material frequencies cannot be directly related with specific site function (Aubry 2009). Moreover, a comparison between ethnographic foragers' annual land-use range and the territories defined by the Côa Valley raw-material sources reveals that exotic materials could not be interpreted as the result of direct procurement and are a proxy of long-distance contacts (Aubry *et al.* 2012).

In this paper we focus on Upper Palaeolithic assemblages dating from the middle Gravettian to the Azilian (30,000 to 12,000 calBP) recovered from several sites located within different geological environments and therefore with distinct locally available knappable lithic raw materials. Considering that Solutrean assemblages recovered in the Côa Valley have been systematically affected by erosion processes and could be mixed with other assemblages (Aubry *et al.* 2010), we have excluded them from this analysis. To avoid these taphonomy questions we have recently published the results on Solutrean raw materials based exclusively on diagnostic lithic points and their shaping flakes from the Côa Valley and central Portugal (Aubry *et al.* 2015).

New data recovered during the 2014 excavation campaign at Cardina (4/1 to 4/4 and 5/1-5/12) and unpublished data from the Vau site are included in this study (Table 1). This site was recently identified in the context of the construction of a hydroelectric project. It is still unpublished and no radiometric dating is available. We base our study on data from the results of the first test pits and a preliminary technological and typological characterization of the stone tools.

Besides the date from this newly discovered site in an area previously devoided of known Upper Palaeolithic settlement and in a particular geologic context, we also integrate fine-grained raw materials data with quartzite and quartz varieties.

The aim of this study is to establish a lithological framework, distinguishing between local and non-local raw materials, and to discuss the significance of the presence or absence of raw materials in the different regions, in order to reconstruct past supply strategies and possible social networks. Finally, new guidelines are proposed for future geological and archaeological surveys.

2. Materials and Methods

To compare lithic raw material supply, we have selected twelve open-air, rockshelter and cave Upper Palaeolithic sites from different geographical contexts (Table 1, Figure 2). The first group, located in the Hercynian Iberian Massif, at the western limit of the northern Iberian Meseta, consists on the lower Côa Valley open-air sites, well known for the exceptional concentration of open-air Upper Palaeolithic rock art, engraved on metamorphic rocks and granite (Aubry 2009; Baptista 2009; Zilhão 1997a) (Figure 3).

The second group of sites is located in the Meso-Cenozoic deposits of the Western Iberian margin, named Lusitanian basin between the Early Triassic and Early Cretaceous. This group comprises open-air sites, rockshelters and caves (Aubry *et al.* 2001; Aubry *et al.* 2011; Gameiro 2012; Zilhão 1997b) (Table 1, Figure 2).

Table 1. Sites and occupation levels studied (site number corresponds to figure 2). Abbreviations: OA - open air, RS - rockshelter.

N.	Site	Context	Province	Lithological context	Archaeological levels	Cultural attribution	References
1	Fariseu	OA	Iberian Massif	Cambrian phyllites	4	Azilian	Aubry 2009; Mercier <i>et al.</i> 2006
2	Cardina	OA	Iberian Massif	Precambrian phyllites	4/1 to 4/4	Upper Magdalenian to Azilian	Aubry 2009; Valladas <i>et al.</i> 2001
					4/10	Late Gravettian	
					4B	Middle Gravettian	
					5/1-5/12	Early Upper Palaeolithic	
					9 & 10	Gravettian to Solutrean	
3	Quinta da Barca Sul	OA	Iberian Massif	Precambrian phyllites	3	Azilian	Aubry 2009; Valladas <i>et al.</i> 2001
4	Olga Grande 14	OA	Iberian Massif	Hercynian granitoids	2c	Proto-Solutrean	Aubry 2009
					3	Middle Gravettian	
5	Olga Grande 4	OA	Iberian Massif	Hercynian granitoids	3	Middle Gravettian	Aubry 2009; Valladas <i>et al.</i> 2001
6	Ínsula 2	OA	Iberian Massif	Precambrian phyllites	2	Late Gravettian	Aubry 2009
7	Vau	OA	Iberian Massif	Cambrian phyllites	Total	Upper Magdalenian (?)	Pereiro 2015
8	Vale das Buracas	OA	Lusitanian Basin	Middle Jurassic limestone	3b, 3/4	Upper Magdalenian	Aubry <i>et al.</i> 2008
9	Vale dos Covões	RS	Lusitanian Basin	Middle Jurassic limestone	3 & 4	Final Magdalenian	Aubry <i>et al.</i> 2008; Klaric <i>et al.</i> 2009
					5 to 8	Upper Magdalenian	
10	Buraca Escura	Cave	Lusitanian Basin	Middle Jurassic limestone	2ab	Late Gravettian to Proto-Solutrean	Aubry <i>et al.</i> 2001
11	Lapa dos Coelhos	Cave	Lusitanian Basin	Middle Jurassic limestone	3	Final Magdalenian	Almeida <i>et al.</i> 2004
					4	Upper Magdalenian	
12	Terra do Manuel	OA	Lusitanian Basin	Upper Jurassic limestone	Total	Late Gravettian to Proto-Solutrean	Zilhão 1997b

Finally, the Vau site, on the lower Vouga Valley (Pereiro 2015), is located in an intermediate area, still within the Iberian Massif but close to the Lusitanian basin and its flint sources (Figure 4).

The lithic raw material potential of Meso-Cenozoic deposits is well known, based on a long tradition of geological fieldwork and, since the early 1990s, a number of focused surveys and studies developed for the analysis of archaeological lithic assemblages (for complete references see Aubry *et al.* 2013) (Figures 2 and 4). The methodology used, already described in detail in previous publications (Aubry *et al.* 2012; Mangado Llach 2005), relies on the identification of raw material sources present in the archaeological assemblages and on

geological field surveys, followed by systematic macroscopic analysis with a stereomicroscope (2.4x-240x) and microscopic examination of selected thin sections of both archaeological and geological samples. Geochemical analyses are under progress in order to determine the possibility to chemically assigning raw material categories to specific sources, namely in the case of the Iberian Massif quartz vein types.

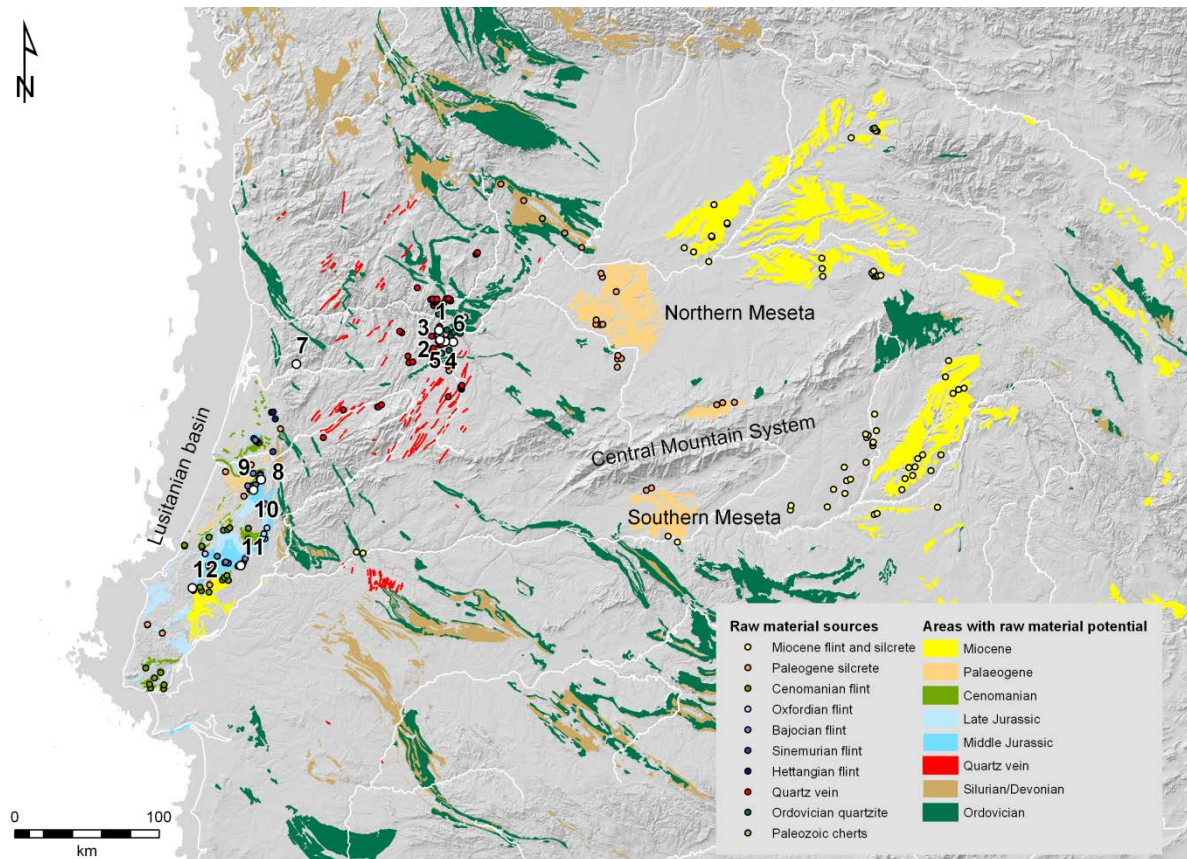


Figure 2. Sites analyzed for this study in the context of raw material sources (sampled or described) and raw material potential, based on equivalent lithofacies areas. Numbers correspond to table 1. Geological information based on Caride de Liñán 1995 and Oliveira *et al.* 1992 (Quartz vein data is only available for the Portuguese territory).

In the Meso-Cenozoic marine deposits of the Western Iberian margin, syn-sedimentary flints formed in continental platform contexts are known from the Early Jurassic to the Late Cretaceous (Aubry *et al.* 2013), and silcrete formation is attested at a large scale during specific phases of the Late Cretaceous and Cenozoic (Cunha 2000). Flint nodules and fragments from beds within these formations are frequent in secondary position, affected by weathering processes, especially in some Miocene siliciclastic deposits (Figure 4).

The analysis of detailed geologic bedrock mapping permits a preliminary assessment of the lithic potential of the Iberian Massif. Quartzite is a common lithology in the Ordovician formations. It is also common, in secondary position, in the Cenozoic siliciclastic deposits (Figure 2 and 3). Anhedral milky to clear quartz varieties occur in hydrothermal veins filling the Hercynian fracture network. Both of these categories are widespread throughout the region (Aubry *et al. in press*). However, focused surveys are needed to fully characterize the lithic raw material potential of most of this area, which remains unknown regarding some locally restricted microquartz and chalcedony sources, sometimes at the scale of individual veins that tend to elude general bedrock mapping.

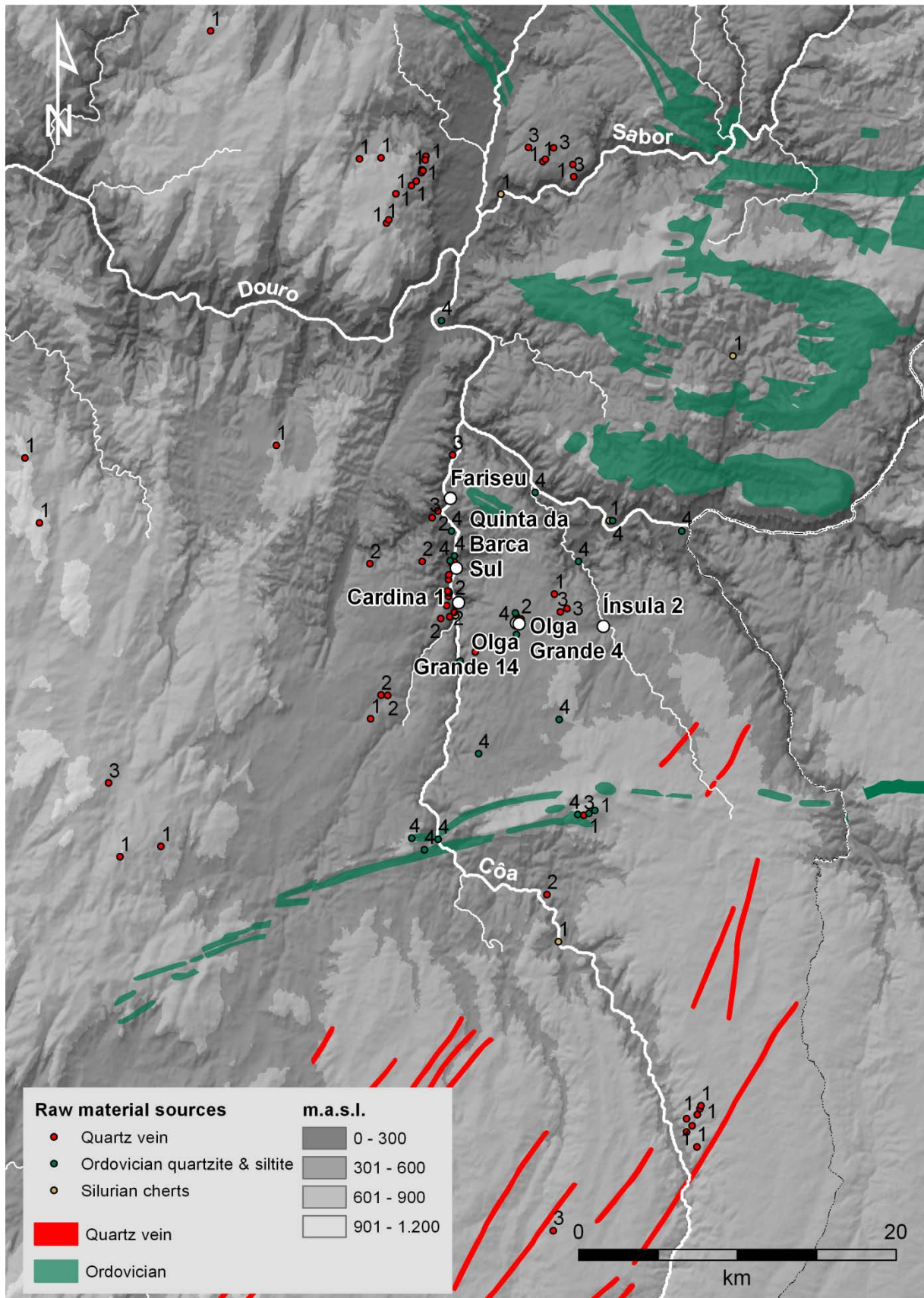


Figure 3. The Côa Valley sites and the associated regional lithic raw material sources. 1) Fine-grained siliceous raw materials (quartz and chalcedony vein varieties, hornfels, rhyolite siltstone and lydite); 2) Anhedral quartz; 3) Euhedral quartz; 4) Quartzite. (m.a.s.l. - meters above sea level).

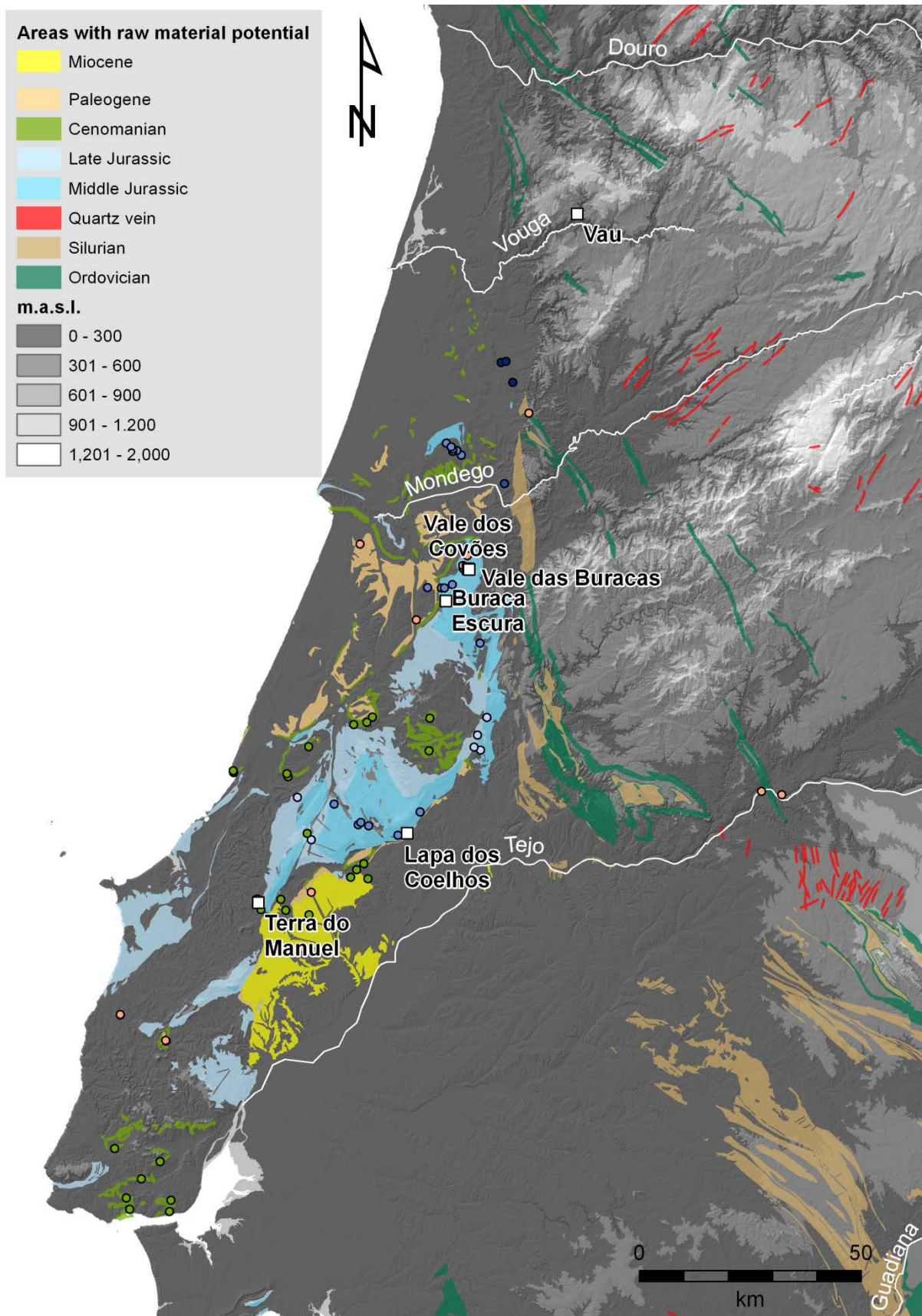


Figure 4. The Western Iberian margin sites and the associated regional lithic raw material sources. Coloured dots represent analysed flint and silcrete samples. (m.a.s.l. - meters above sea level).

In the Côa Valley region, besides quartzite and anhedral quartz, systematic surveys have revealed the existence of several euhedral quartz varieties, available in all of the Iberian Massif. It has also made possible the identification of very restricted fine-grained varieties of vein silica in paragenesis with gold and uranium mineralization, as well as banded silicifications, existing in the Palaeozoic formations or associated with contact metamorphism around the Hercynian granitic intrusion phases (hornfels) (Aubry *et al. in press*).

Geological study and recent surveys developed for the study of the Côa Valley sites have also revealed the potential of Miocene age lacustrine deposits containing flint (evaporitic silcrete) in the Douro and Tagus basin and the existence of Palaeogene pedogenic and groundwater silcrettes (Armenteros Armenteros 1986; Aubry *et al.* 2012; Blanco *et al.* 2008; Fuertes Prieto *et al.* 2014) (Figure 3).

We have used a GIS least-cost path analysis on SRTM 90 DEM (Jarvis *et al.* 2008), in order to define the links between potential raw material sources and the sites where they were recovered. Despite discussions on the advantages and disadvantages of the use of different algorithms (Herzog 2010), we believe that least-cost paths are a better approximation of distance travelled than simple linear distances (Aubry *et al.* 2012; Prieto *et al.* 2016). In the present work we have used the National Park Service Travel Time Cost Surface Model (TTCSM), a script created to define least-cost paths for hikers (Frakes *et al.* 2014), transforming cost paths into time. We have previously used other procedures (Aubry *et al.* 2012; 2015) to define least-cost paths, all based on Tobler's hiking function (Tobler 1993). In this study we've used TTCSM, also based on the same function, since newer ArcGIS's versions became incompatible with Tripcevich's method (2007) for large areas and TTCSM is more user-friendly than Matsumoto's procedure (2008). We've compared the different cost-paths produced and the differences are negligible taking into account the large range of the territory analysed and since we are not trying to determine precise routes but to have an approximation to the total amount of time spent for getting these long-distance raw materials.

In the present study we've used a velocity of 3.1 miles per hour as the maximum walking speed and 31 degrees as the maximum crossable slope. Streams and landcover were not accounted for as travel limitations, because we have no precise information on Pleistocene landcover or fords. Linear vertical factors, which consider the direction of movement, distinguishing upslope from downslope velocity, were also not taken into account since we do not know the direction of movement. The same path may be walked on in different directions if we admit that exchange was involved in these long-distance raw material displacements. Regarding the data we have available, namely the distances involved, and the information we hoped to obtain from the analyses, we used the archaeological sites as a source (point of origin) and the raw material sources as destinations.

In the case where several sources for the same raw material are available, we have used the closest source to the site. For the Côa Valley sites, least-cost paths were defined from a mean centre. In the case of Vale das Buracas, located 300 metres from Vale dos Covões, the path source used is the latter. Finally, a different path was created for each raw material source in order to define distances in kilometres and time distance to each raw material source.

3. Results

The analysis of raw material types and sources in the studied sites (Table 2) reveals that quartz vein varieties and quartzite were systematically used in all of the assemblages considered.

Table 2. Primary raw material groups present on the studied sites and layers of all the core, debitage and retouched tools (Cardina data based on layer sampling).

Site	Level	Lusitanian flint & silcrete		Tagus-Douro flint & silcrete		Other fine-grained siliceous		Anhedral quartz		Euhedral quartz		Quartzite		Total
Cardina	4/1 to 4/4	67	0.6%	146	1.3%	415	3.6%	8,839	76.1%	409	3.5%	1,736	15.0%	11,612
Cardina	4.10	165	0.6%	640	2.3%	36	0.1%	9,817	34.9%	5,564	19.8%	11,875	42.3%	28,097
Cardina	4B	138	0.7%	514	2.6%	92	0.5%	7,247	36.0%	3,507	17.4%	8,608	42.8%	20,106
Cardina	5/1 to 5/12	8	0.8%	23	2.3%	32	3.2%	821	82.3%	40	4.0%	73	7.3%	997
Fariseu	9 & 10	5	1.4%	4	1.1%	0		195	54.2%	0		156	43.3%	360
Fariseu	4	22	0.4%	14	0.2%	45	0.7%	4,974	81.3%	237	3.9%	825	13.5%	6,117
Ínsula 2	2	15	1.2%	26	2.1%	5	0.4%	836	66.0%	142	11.2%	242	19.1%	1,266
Olga Grande 14	2c	33	2.1%	26	1.6%	60	3.8%	1,316	82.4%	92	5.8%	71	4.4%	1,598
Olga Grande 14	3	7	2.0%	25	7.0%	17	4.8%	25	7.0%	108	30.3%	174	48.9%	356
Olga Grande 4	3	53	0.5%	177	1.8%	70	0.7%	7,557	77.1%	968	9.9%	971	9.9%	9,796
Quinta da Barca Sul	3	6	0.6%	17	1.7%	65	6.5%	774	77.7%	16	1.6%	118	11.8%	996
Vau	Total	77	4.2%	0		112	6.1%	1,563	84.5%	92	5.0%	6	0.3%	1,85
Buraca Escura	2ab	23	30.3%	0		0		48	63.2%	1	1.3%	5	6.6%	76
Lapa dos Coelho	3	4,011	63.8%	0		0		1,022	16.3%	26	0.4%	1,225	19.5%	6,284
Lapa dos Coelho	4	605	37.8%	0		0		729	45.5%	72	4.5%	195	12.2%	1,601
Terra do Manuel	Total	9,349	56.7%	0		0		5,998*		36.4%		1,139	6.9%	16,486
Vale das Buracas	3b. 3/4	86	30.3%	0		0		125	44.0%	0		73	25.7%	284
Vale dos Covões	3 and 4	1,853	70.2%	0		0		607	23.0%	2	0.1%	178	6.7%	2,64
Vale de Covões	5 to 8	3,684	69.8%	0		0		1,108	21.0%	0		485	9.2%	5,277

* Even though both are present, anhedral and euhedral quartz were not distinguished.

These raw materials (quartz and quartzite) are present even on sites that are located in close proximity to flint sources (*e.g.*, Terra do Manuel, Vale dos Covões, Buraca Escura and Vale das Buracas). However, in contrast to the Iberian Massif where there is direct access to primary sources of quartz and quartzite, in the Lusitanian Basin sites these raw materials are only available in secondary deposits and in Cenozoic siliciclastic deposits which are all less than 5 kilometres from the sites. This fact may account for the absence of euhedral quartz in some of the sites, since is less abundant in siliciclastic deposits. The availability and the abundance of sources in primary bedrock outcrops explains why Iberian Massif sites present always more than 90% of quartz and quartzite pieces, and Lusitanian Basin sites range from 70% to 30% (Figure 5 and 6).

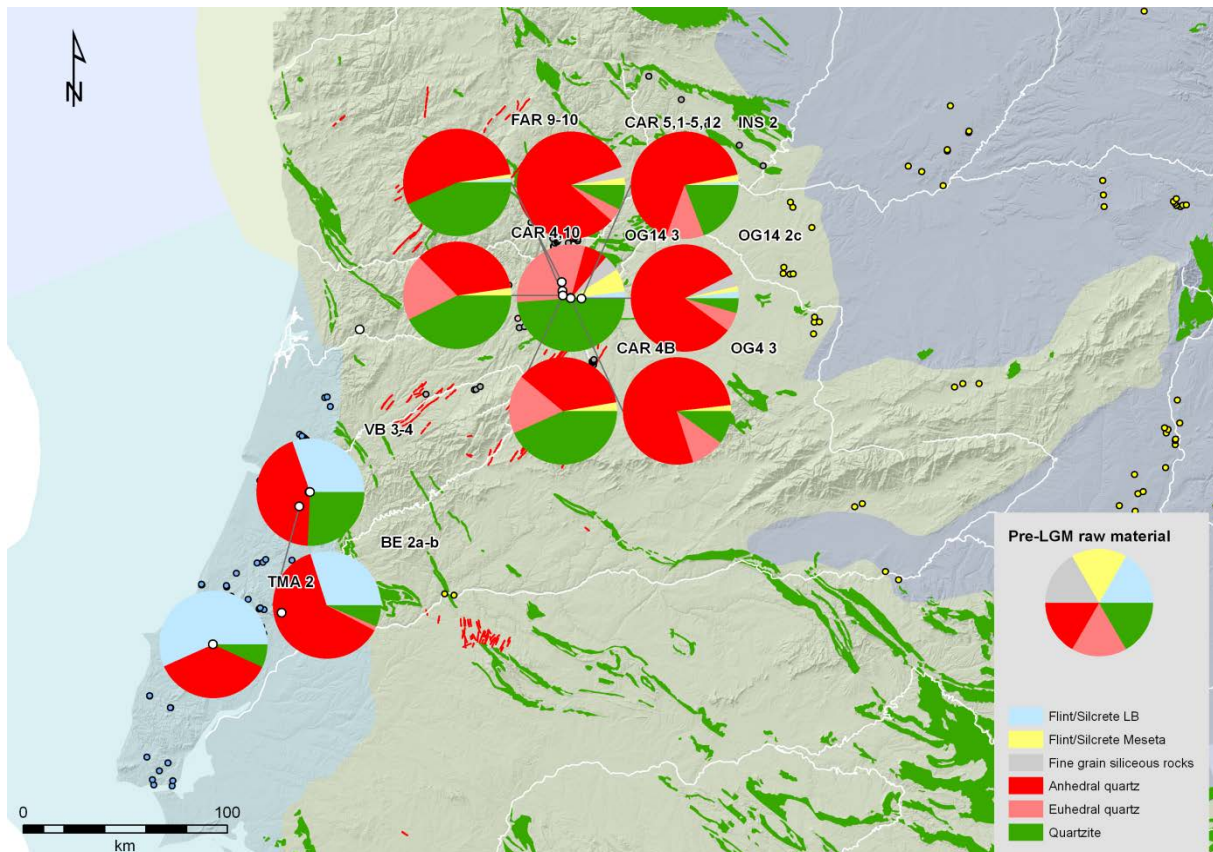


Figure 5. Pre-LGM assemblages according to raw material litho-geographic groups (see Table 2). Abbreviations: FAR - Fariseu; CAR - Cardina; INS - Ínsula; OG - Olga Grande; VB - Vale das Buracas; BE - Buraca Escura; TMA - Terra do Manuel. (The site names in the map are offset to the right.)

Vau follows the tendency of Iberian Massif sites in its massive use of quartz. However, its assemblage presents very few quartzite pieces, which can be explained by the fact that primary Ordovician quartzite formations are located more than 10 kilometres away (Gomes 2008) and by the local availability of other coarse-grained rock pebbles.

Flint and silcrete are present in all the sites and assemblages studied, regardless of the distance from each site to its sources (Figure 5, 6 and 7). The differences in lithic raw materials origin and frequency between each region seem to be related to the geological environment. Therefore, flint is more frequently used in sites located in the Lusitanian Basin and less frequently in the Côa Valley, more than 150 kilometres away from the flint sources. However, distance from the source is not the only variable at play. The Vau assemblage, located in an intermediary position and 40 kilometres from the nearest Hettangian flint source and 60 kilometres from the Bajocian, presents overall flint percentages similar to the Côa

Valley sites (4.2%). However, at Vau only Lusitanian flint sources are present, while in the Côa Valley sites Lusitanian flints represent from 0.4 to 2% and are associated to lacustrine flint and silcretes from the Douro basin, roughly at the same geographic distance as the Lusitanian Basin. These Douro basin sources are absent from the Vouga and all the Lusitanian Basin sites.

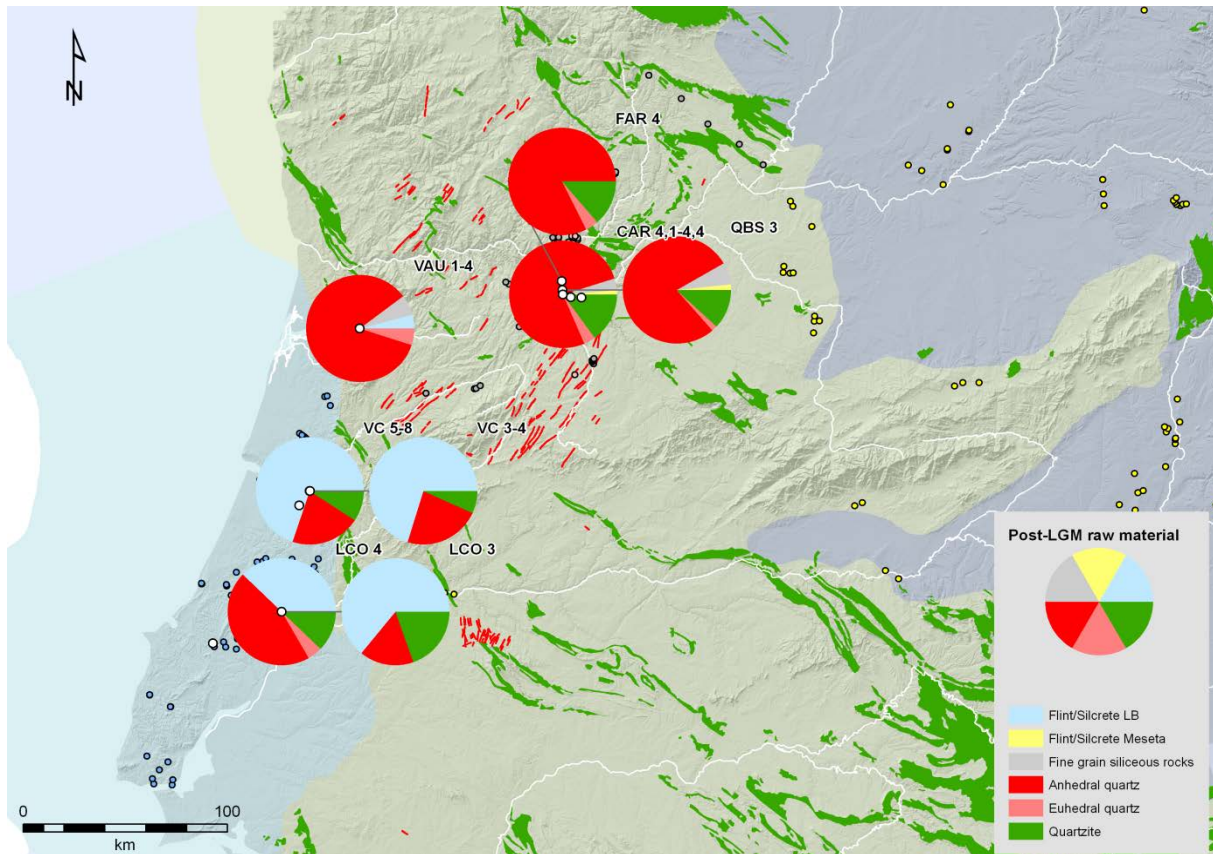


Figure 6. Post-LGM assemblages according to raw material litho-geographic groups (see Table 2) Abbreviations: FAR - Fariseu; CAR - Cardina; QBS - Quinta da Barca Sul; VAU - Vau; VC - Vale dos Covões; LCO - Lapa dos Coelhoos).

In the Iberian Massif sites, where flint and silcrete is naturally unavailable, other fine-grained siliceous rocks systematically complement local and non-local raw materials. These raw materials are very variable, depending on the local geological environments, and their sources are generally restricted. In the Côa Valley, the fine-grained siliceous rocks present naturally are mainly microquartz and chalcedony from veins, hornfels, iron siltstone, microgabbro and rhyolite, all available within a range of up to 50 kilometres from the sites (Figure 3). These raw materials were used along with exogenous flint and silcrete for the production of retouched bladelets. Since the geology of the Iberian Massif is highly variable, the Vau assemblage also depends to a high degree on different types of regional fine-grained siliceous rocks. In this case, the lithic assemblage includes volcanic pebbles available in the Teixeira River, a right bank Vouga tributary, found only a few metres from the site. Another difference from the Côa Valley is that this local fine-grained raw material available as pebbles in the nearby fluvial terrace was not used for the production of bladelets

For the moment it is difficult to define a chronological trend for the raw material use in the sites and regions studied. Differential raw material use through time should be analysed along each site's sequence, since immediate geological environment may condition raw material use. The only site in our database with these characteristics is Cardina, where there is

a slight decrease in flint and silcrete use from the Early Upper Palaeolithic to the Late Glacial assemblages. A major distinction lies in the generalized use of quartzite during the Middle and Late Gravettian, when compared with local anhedral quartz. This trend is confirmed in Quinta da Barca Sul and Fariseu's Azilian occupations, where anhedral quartz is also more frequently used, when compared to quartzite.

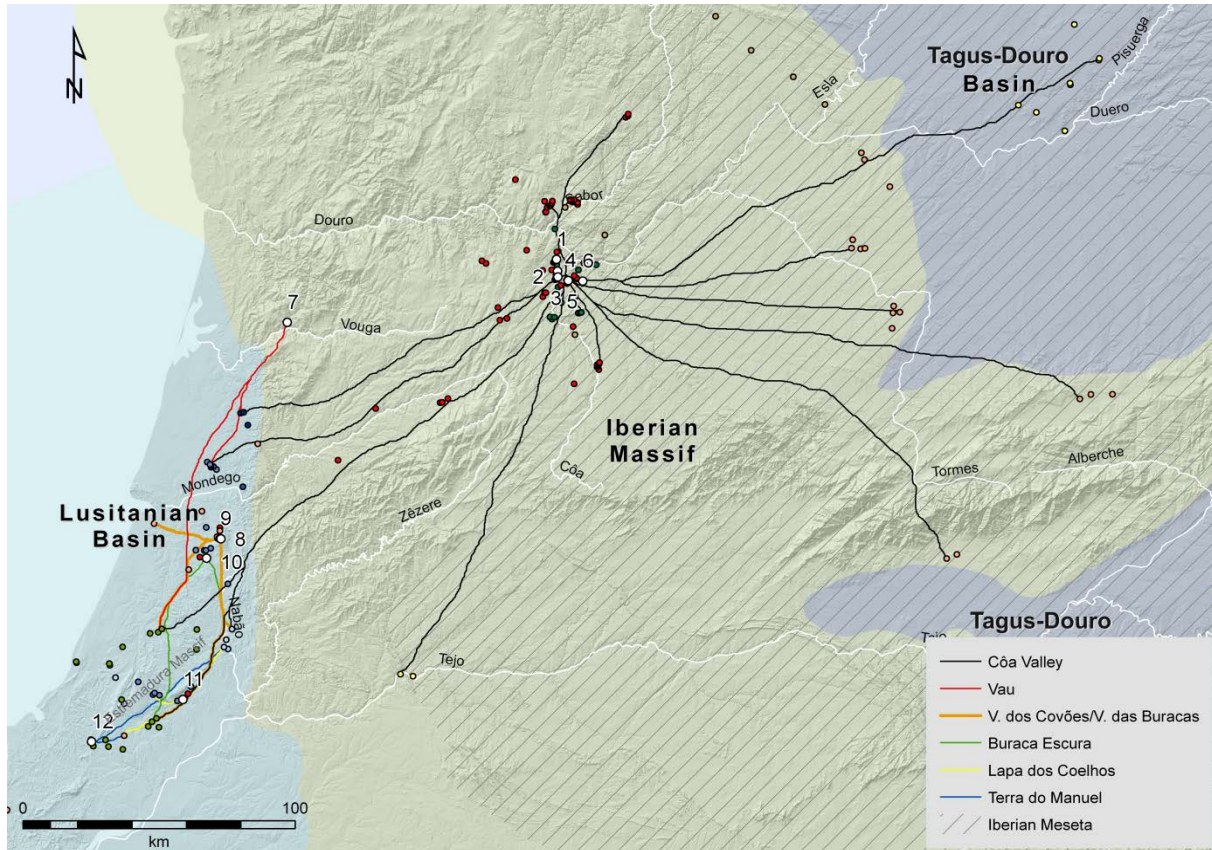


Figure 7. TTCSM least-cost paths from each assemblage to each source present (see Figure 2 for the legend of raw material sources).

The high percentage of anhedral quartz use in layer 2c from Olga Grande 14 may be related with a Proto-Solutrean phase, also characterized in the Lusitanian Basin by the overwhelming importance of quartz use (Zilhão 1997b), which in the present study may be represented by Buraca Escura 2 a-b (Aubry *et al.* 2001).

From the studied data, no Lusitanian Basin site presents a sequence as long as Cardina, ranging from before the Last Glacial Maximum to the Late Glacial. However, with the exception of layer 4 from Lapa dos Coelho, these Lusitanian Basin sites, taken as a whole, seem to become more dependent on flint and less on anhedral quartz over time.

4. Discussion and conclusions

Time and distances defined by least-cost paths reveal lithic raw material networks from the Western Iberian Margin to the centre of the Iberian Meseta throughout the Upper Palaeolithic (Figure 7). In the Lusitanian Basin there are two main North-South routes, one more interior, linking both sides of the Estremadura limestone massif, through the Nabão valley, as already proposed for the Gruta da Oliveira Middle Palaeolithic (Matias 2012), and the second following the western limit of the massif, reaching the northernmost part of this region into the Vouga valley. The route between the Lusitanian Basin and the Côa Valley goes through the Mondego valley. Even though Vau is an intermediary site between these two

regions, topography makes it unlikely that it could work as a passing point between the Côa Valley and the Lusitanian Basin. The Côa Valley is the centre of two major axis, one North-South, linking it to closer regional sources, but extending up to more than 70 kilometres to the north, and 170 kilometres to the south, towards secondary deposits of Tagus Miocene flint. The Côa Valley second axis links the Lusitanian Basin to the Southwest mostly with the eastern Meseta. The available data does not allow us to reconstruct the networks operating in the interior of the Meseta inner since we lack sufficient assemblages.

Following what we have already presented (Aubry *et al.* 2012), the comparison of raw material least cost path analysis for the Côa and Vouga valleys and Lusitanian Basin sites indicates a similar geographic range for the regional supply (roughly up to 50 kilometres, corresponding to a 12 hour direct travel cost) (Figure 8). Therefore, we propose to identify these areas as the minimal band home ranges, where local raw materials were exploited and embedded in a foraging system (Binford 1980), either opportunistically or not, depending on their characteristics, along with other resources, namely biotic.

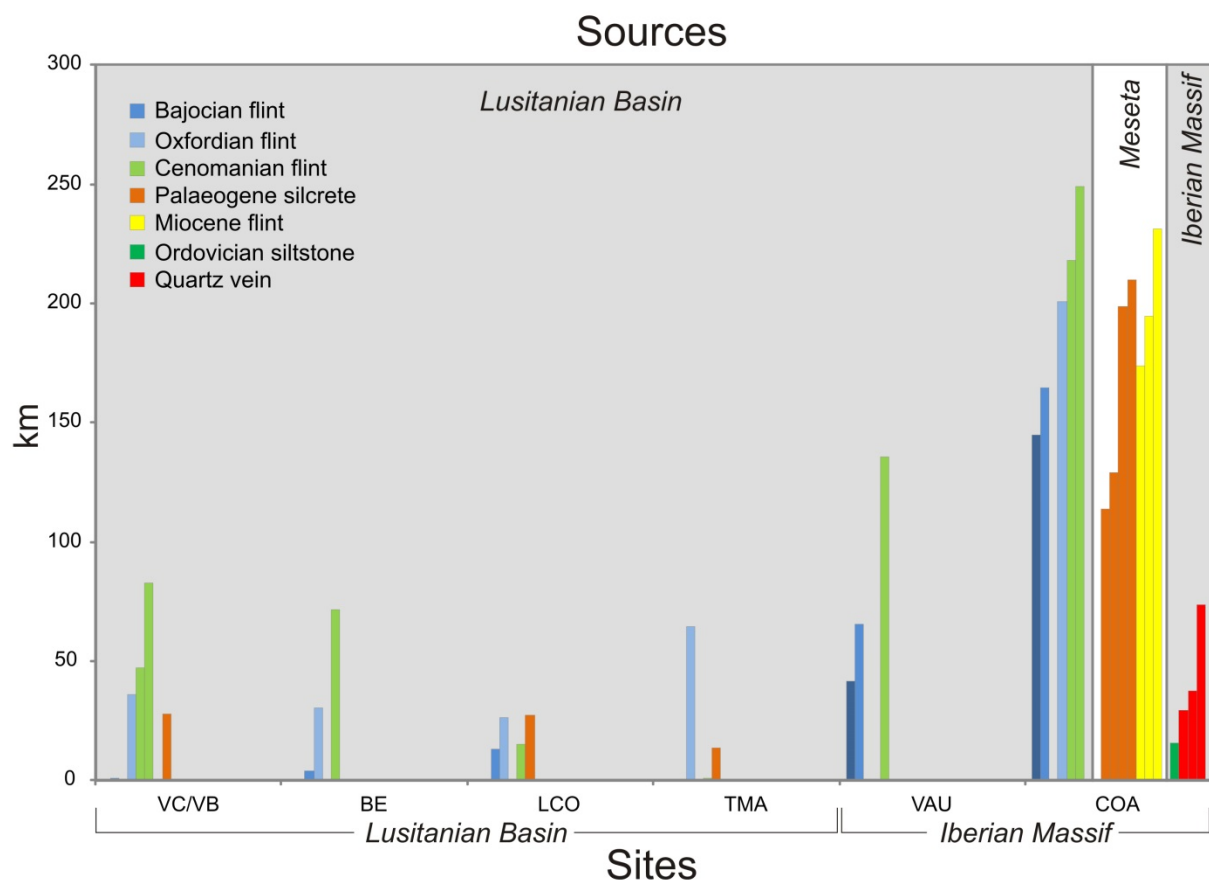


Figure 8. Least -cost distances for raw material sources present in each studied assemblage.

Distances beyond this point, particularly those of the Côa Valley exotic raw material, are incompatible with same territory procurement, either embedded or specially targeted, since the required territory size would be unparalleled in the ethnographic record (Aubry *et al.* 2012). The Côa Valley assemblages document the use of exogenous raw material sources, composed of flint from the Lusitanian Basin, but also from sources located in the Tagus and Douro Basin in the Northern and Southern Meseta (Figure 7). These sources are located from 130 to 225 kilometres, in the case of the Lusitanian basin, and 110 and 205 kilometres for the Northern Meseta, if we consider the closest Miocene sources identified. The Côa Valley sites are located in a region corresponding to the western limit of the Iberian Meseta (Ferreira

1978), the central Iberian plateau, midway between these two large sedimentary areas and their associated sources (Figure 7).

At this point it is important to make a distinction other than that of local or regional and exotic raw materials, which is the distinction between raw materials of specialized use and those of opportunistic or expedient use. In all assemblages from the Côa Valley, independent of the chronology, retouched flake tools are essentially made on the local quartz and quartzite, and retouched bladelet tools are made on flint, silcrete, euhedral quartz and fine-grained varieties of quartz, using the same reduction sequence (Aubry 2009; Aubry *et al. in press*; Gameiro 2012). The raw material used to produce bladelet tools reveal a large geographic range of supply and retouched bladelets show the same typical impact fractures produced by their use as composite hunting tools (Aubry & Igreja 2009). The energy and social effort of transporting flint and silcrete as raw material into the Côa Valley and Vau sites may be related to its better adaptation to tool production and working efficiency, when used as composite specialized hunting tools. The importance of flint and silcrete for specialized tool use is highlighted by the fact that in the Côa Valley during the Gravettian, assemblages portray technological changes in the *chaîne opératoire* that are adapted to the raw material scarcity (Klaric *et al.* 2009). In this area, other fine-grained siliceous rocks, namely microquartz and vein chalcedony, hornfels and rhyolite were also used in the production of such tools, complementing flint and silcrete, but they don't seem to have been useful or abundant enough to make their way back to the Lusitanian Basin, since up to now these Iberian Massif raw materials are almost completely unknown in Lusitanian Basin assemblages. As discussed above, euhedral and anhedral quartz are not foreign to Lusitanian Basin assemblages, but since they are available in this region in secondary position they can't be traced directly to the Iberian Massif. So far, the single unquestionable exception is an unrounded tested smoky euhedral quartz core, with tourmaline inclusions, from Buraca Escura.

On the other hand, besides the exceptional cases mentioned of quartzite use during the Côa Middle and Late Gravettian, and quartz for the Proto-Solutrean, quartz and quartzite seem to have been object of expedient use, despite being generally highly represented both on Iberian Massif sites and in the Lusitanian Basin. This assertion is justified by two facts. Firstly, most of the studied sites have close access to either primary or secondary sources of these raw materials. Vau's assemblage constitutes an exception that can be justified by the absence of quartzite in the surrounding 10 kilometres area. On the other hand, the technological study of the Côa Valley milky quartz and quartzite revealed a lack of blade production, a low frequency of retouched blanks (mostly endscrapers, notches and sidescrapers), and use-wear traces, both on flake blanks and retouched tools, suggesting use on soft material or short term use, followed by immediate discard (Aubry & Igreja 2009).

In conclusion, raw materials for expedient use originate from the minimal band range, normally from the immediate vicinity of the settlement. Nevertheless, the fact that Hettangian flint is only present in the Iberian Massif assemblages, hints that its lesser knappability did not justify getting it from more than 50 kilometres for the Lusitanian basin sites, but justified less than 40 kilometres trip for Vau. Even if present in reduced quantities, its presence in the Côa Valley should be attributed not only to the absence of flint, but mostly to the network established with the Lusitanian Basin. Within this framework, and contrary to what is presented in Figure 7, Hettangian flint wouldn't arrive directly to the Côa Valley, but along with other Lusitanian Basin flint types through the Mondego valley. The least-cost paths shown in Figure 7 are therefore primarily indicative of the distances between each source and the respective assemblages where they have been recovered. We are aware that in a living and dynamic society, access to different raw material categories in neighbouring regions would have been integrated within a least-cost network (Herzog 2013), a line of enquiry we shall pursue in the future.

We have proposed that, complementing the home range, the Côa Valley exotic raw material network could express the range of the endogamous maximal band (macro-band sensu Wobst 1974) or dialectal tribe (sensu Birdsell 1968). The maximal band is essential as a safety net in times of scarcity, due to resource fluctuations in a forager society (Whallon 2006). It can also be a means to level resources that are unevenly distributed. Lithic raw materials belong to this category, namely those highly sought after for specialized uses, as seems to have been the case of flint.

The safety net is based on sharing and generalized reciprocity, a central rule of the hunter-gatherer way of life (Ingold 1988; Lee & Daly 1999; Sahlins, 1972). This assertion poses a problem however since we know that the Iberian Massif sites received flint and silcrete coming from the Lusitanian and Tagus-Douro Basins, but, as already stated, we are unaware of what was offered in return. This difficulty is caused by the biased nature of the archaeological record, offering plenty of information on lithic resources but very few organic remains.

Reciprocity in hunter-gatherer societies is not a given fact and must be promoted. Marriage rules are a common way to do this, not only to ensure biological survival, but also to promote reciprocal access to resources within the safety net, as exemplified by Australian section and subsection systems (Rose 1968; Yengoyan 1968). Marriage brokering occurs generally during the called “public phase” (Mauss & Beuchat 1905), known in most of the hunter-gatherer societies. Regardless of their ecological setting, these societies evidence a pattern of fusion-fission, seasonally aggregating when and where resources make it possible (Lee & Daly 1999). Even though this phase is resource dependent, its goals are eminently social, defining and maintaining the social networks within the maximal band. Besides marriage arrangements, this is the time for collective singing, dancing, hunting and gathering, to perform rites of passage, but also to exchange long-distance resources, in a context of social intensification and ceremonialisation (Lee 1972). It is in this regard that rock art comes to play an important role, as it can be understood, not only as the result but also as an agent for the definition and maintenance of the safety net, fighting against contradictory forces that could undermine it. It can be seen as the material expression of an ideology of reciprocity, as has been proposed for Southern San rock art (Lewis-Williams 1982).

We have already discussed the different possible contexts in which exotic flint could have arrived to the Côa Valley (Aubry *et al.* 2012, fig.7). Based on exploitation territories, distances travelled, geomorphology, and the archaeological record, namely raw material sourcing and the largest concentration of European Upper Palaeolithic open-air art, we favour a setting where these raw materials arrived in the context of reciprocal exchange at a boundary between different territories, in the context of the aggregation phase typical of most hunter-gatherer societies.

One of the arguments supporting this model was the absence of sites between the Côa Valley and the Lusitanian Basin sources. However, we have also stated that this absence should not be considered as definitive, and that “a mixed hypothesis, such as the existence of intermediate bands that would acquire these raw materials via exchange, and bring it to the Côa Valley in the context of aggregation” could not be discarded (Aubry *et al.* 2012, p.543). The *hxaro* practice by the !Kung San is a perfect ethnographic example of this type of down-the-line long distance exchange performed notably during the public phase (Lee, 1972; Wiessner, 1982).

The newly discovered Vouga site, located in an area between the Lusitanian Basin and the Côa Valley, where no Upper Palaeolithic sites were previously known, could point in this direction. Firstly, the large use of local and regional raw materials in the Vau assemblage suggests its use by a local band, highly knowledgeable of regional sources, but with relations with Lusitanian Basin bands. This is in opposition to its interpretation as the result of a

logistical seasonal system (Binford 1980) extending from the Lusitanian Basin and up the Vouga river valley, as for instance is the case of Upper Palaeolithic French Massif Central sites (Delvigne *et al.* 2014; Fontana *et al.* 2009).

Its raw material use, largely based on regional and local sources is similar to the Côa Valley sites, along with the presence of less than 5% use of flint, which arrives from up to 135 kilometres distant. Besides the lesser use of quartzite, not locally available, there are several major differences between the Côa Valley sites and Vau. The first lies in the absence of Tagus & Douro Basin raw materials and any of the Côa Valley regional fine-grained siliceous rocks. The other lies in the fact that there is no evidence of Oxfordian flint, coming from the south of the Estremadura limestone massif, which is systematically represented in both the Lusitanian and Côa Valley sites.

This and the fact that hunter-gatherer societies are based on face-to-face relationships (Ingold 1988; Lee & Daly 1999), suggests that Lusitanian Basin raw material would have arrived directly to the Côa Valley, through the Mondego valley, and that sites similar to Vau should be discovered in this area, where fine-grained siliceous rocks sources are already known (Figure 7).

The scenario we have presented may appear ahistorical since it seems to lack elements of change. Limited by the low temporal resolution of the archaeological record, we have only presented the “big picture”, particularly emphasizing what remains constant. Zooming in on the archaeological record of the Côa Valley, elements of change become more clear through time, in the rock art (style, location, visibility, inter-visibility), but also the intra site organization of habitats and their structures, with necessary implications for economic and social contexts (Luís *et al.* 2015). Concerning raw material supply networks, the Côa Valley shows the same large-range network between the Gravettian and the Late Glacial, extending from the Spanish Northern Meseta to the Portuguese Western margin. This is not unexpected since the availability of the lithic raw materials depends on geological formations which did not change within the timeframe of this study. Nonetheless, small differences are noted though time, as to the relative importance of specific sources of the main geological groups, with closer sources gaining importance (Aubry *et al.*, 2012, p. 547). This could be related to the slight reduction in flint and silcrete use in the Côa Valley and increased dependence for the Lusitanian Basin sources, already mentioned. These facts suggest that the social network becomes looser, with bands more self-reliant and less mobile or more isolated.

The Côa Valley is a remarkable case in the study of the European Upper Palaeolithic where the conservation and discovery of an ideological manifestation, the open-air rock art – a context overlooked for this period’s rock art in an area where human settlement was not supposed to exist – opened new research avenues for the study of Palaeolithic hunter-gatherer economies and societies.

For the last 20 years, ongoing studies have shed light on hidden and unsuspected areas of scientific research. Geological survey developed for the study of the open-air sites of the Côa Valley revealed the existence of spatially localized veins of fine-grained varieties of microquartz and chalcedony well adapted for the production of retouched bladelets, one of the most frequent tool categories of the Upper Palaeolithic in Portugal. The presence of such varieties of fine-grained quartz in the Hercynian Massif sites suggests that the raw material potential of this province is difficult to detect, but higher than previously thought, and also very variable spatially. The geographic distribution and variability of these raw materials needs to be better established through further surveys and geochemical analysis.

The recent discovery of the Vau site and its assemblages confirms that the distribution map of Upper Palaeolithic settlement is still in progress and some of the inner Iberian Massif regions of Portugal and Spain need specific survey methodologies, undertaken by teams able

to detect the local lithic industries that are adapted to local raw materials and are different from the regions where flint is abundant.

Furthermore, raw material studies of the Côa Valley site assemblages has determined that the flint and silcrete potential of the Douro and Tagus basins (Northern and Southern Meseta) was well known and systematically exploited throughout the Upper Palaeolithic. The rarity of known human settlement in the area, with a few exceptions (Alcaraz-Castaño *et al. in press*; Fabián García 1986; Sánchez Yustos & Díez Martín 2007), including rock art (Alcolea González & Balbín Behrmann 2006; Ripoll López & Municio González 1999), must be attributed to a research bias (Aubry *et al.* 2015). From the proportions of raw material categories in the different sites studied, it is predicted that sites with raw material proportions similar to the Lusitanian basin, but where Miocene flint and Palaeocene silcrete replace Jurassic and Cretaceous flints, should be found in the centre of the Northern Meseta, associated with Miocene flint sources, and at the limit between the Douro and Tagus Basins and the Iberian Massif, similar to Vau, but corresponding to the silcrete formations.

With this study we hope to contribute to overcome persistent research biases that limit the reconstruction of Upper Palaeolithic hunter-gatherer societies and their cultural responses to specific geologic constraints, showing a richer than previously suspected ability to adapt to varied geologic environments.

Acknowledgements

This study is a contribution to the Project PALÆCOA: Neanderthal to Anatomically Modern Human transition in the Côa Valley: Environments, Symbolism and Social networks (PTDC/EPH-ARQ/0326/2014), funded by Fundação Ciência e Tecnologia (FCT) and the Europe 2020 Programme, and the PhD. Scholarship SFRH/BD/108396/2015, funded by FCT. We thank the Fundação Côa Parque for its logistical support and permission to conduct the project on which this study is based, and Era Arqueologia S.A. for its support on the study of Vau lithic assemblage. We also acknowledge the HAR2014-55131 project (Spanish Ministerio de Economía y Competitividad). We thank the reviewers, particularly Adrian Burke, for their careful reading, valuable insights and wording revision. However, we remain fully responsible for any errors.

References

- Alcaraz-Castaño, M., Tapias, F., Cuartero, F. Baena, J, Ruiz-Zapata, B., Morín, J., Pérez-González, A. & Santonja, M. *in press*, The human settlement of Central Iberia during MIS 2: New technological, chronological and environmental data from the Solutrean workshop of Las Delicias (Manzanares River valley, Spain). *Quaternary International*, (Accepted for publication 19 August 2015). doi:10.1016/j.quaint.2015.06.069
- Alcolea González, J.J. & de Balbín Behrmann, R. 2006, *Arte Paleolítico al aire libre: El Yacimiento rupestre de Siega Verde, Salamanca*, Arqueología en Castilla y Leon, Vol. 16, Junta de Castilla y Leon, Valladolid, 422 p.
- Almeida, F, Angelucci, D.E., Gameiro, C., Correia, J. & Pereira, T. 2004, Novos dados para o Paleolítico Superior final da Estremadura Portuguesa: Resultados preliminares dos trabalhos arqueológicos de 1997-2003 na Lapa dos Coelhos (Casais Martanes, Torres Novas). *Promontoria*, 2(2): 157-192. URI: <http://hdl.handle.net/10400.1/7474>
- Armenteros Armenteros, I. 1986, *Estratigrafia y Sedimentologia del Neogeno del Sector Suroriental de la Depression del Duero (Aranda de Duero-Peñafiel)*, Serie Castilla y León Vol. 1. Diputación de Salamanca, Salamanca, 472 p.

- Aubry, T. (Ed.) 2009, *200 séculos da história do Vale do Côa: Incursões na vida quotidiana dos caçadores-artistas do Paleolítico*, Trabalhos de Arqueologia Vol. 52. Igespar, I.P., Lisboa, 512 p.
- Aubry, T., Brugal, J.P., Chauvière, F.X., Figueiral, I., Moura, M.H. & Plisson, H. 2001, Modalités d' occupations au Paléolithique supérieur dans la grotte de Buraca Escura (Redinha, Pombal, Portugal). *Revista Portuguesa de Arqueologia*, 4(2): 19-46.
URL: http://www.patrimoniocultural.pt/media/uploads/revistaportuguesadearqueologia/4_2/3.pdf
- Aubry, T. & Mangado Llach, J. 2003, Modalidades de aprovisionamento em matérias-primas líticas nos sítios do Paleolítico Superior do Vale do Côa: Dos dados à interpretação. In: *Paleoecologia Humana e Arqueociências: Um programa multidisciplinar para a arqueologia sob a tutela da cultura*, (Mateus, J.E. & Moreno-García, M., Eds.), Trabalhos de Arqueologia Vol. 29. Instituto Português de Arqueologia, Lisboa: p. 340-342.
- Aubry, T., Almeida, M., Dimuccio, L.A., Cunha, L. & Neves, M.J. 2008, Archives géoarchéologiques des grottes et abris sous roches du Massif de Sicó (Portugal). In: *Actas do Simpósio Ibero-Americano: Património Geológico, Arqueológico e Mineiro em Regiões Cársicas*, (Brandão, J., Calado, C. & Couto, F.S., Eds.), Sociedad Española para la Defensa del Patrimonio Geológico y Minero (SEDPGYM), Batalha: p. 239-251.
- Aubry, T. & Igreja, M.A. 2009, Economy of Lithic Raw Material during the Upper Paleolithic of the Côa Valley and the Sicó Massif (Portugal): Technological and Functional Perspectives. In: *Proceedings of the Workshop Functional Studies of Non Flint Stone Tools: Methodological Improvements and Archaeological Inferences (Lisbon, 2008)*, (Igreja, M.A. & Clemente Conte, I., Eds.), Padrão dos Descobrimentos, Lisbon. 25 p. CD-ROM. ISBN 978-989-20-1803-4.
- Aubry, T., Dimuccio, L.A., Bergadà, M.M., Sampaio, J.D. & Sellami, F. 2010, Palaeolithic engravings and sedimentary environments in the Côa River Valley (Portugal): Implications for the detection, interpretation and dating of open-air rock art. *Journal of Archaeological Science*, 37: 3306–3319. doi:10.1016/j.jas.2010.07.033
- Aubry, T., Dimuccio, L.A., Almeida, M., Neves, M.J., Angelucci, D.E. & Cunha, L. 2011, Palaeoenvironmental forcing during the Middle-Upper Palaeolithic transition in central-western Portugal. *Quaternary Research*, 75(1): 66-79. doi:10.1016/j.yqres.2010.11.002.
- Aubry, T., Luís, L., Mangado, J. & Matias, H. 2012, We will be known by the tracks we leave behind: Exotic lithic raw materials , mobility and social networking among the Côa Valley foragers (Portugal). *Journal of Anthropological Archaeology*, 31(4): 528-550. doi:10.1016/j.jaa.2012.05.003
- Aubry, T., Mangado, J. & Matias, H. 2013, Matérias-primas das ferramentas em pedra lascada da Pré-história do Centro e Nordeste de Portugal. In: *Proveniências de Materiais geológicos*, (Dinis, P.A., Gomes, A. & Monteiro-Rodrigues, S., Eds.), Associação Portuguesa para o Estudo do Quaternário, Coimbra: p. 165-192.
- Aubry, T., Luís, L., Mangado Llach, J. & Matias, H. 2015, Adaptation to Resources and Environments during the Last Glacial Maximum by Hunter-Gatherer Societies in Atlantic Europe. *Journal of Anthropological Research*, 71(4): 521-544. doi:10.3998/jar.0521004.0071.404

- Aubry, T., Barbosa, A.F., Luís, L., Santos, A.T. & Silvestre, M. *in press*, Quartz use in the absence of flint: Middle and Upper Palaeolithic raw material economy in the Côa Valley (North-Eastern Portugal). *Quaternary International*, (Accepted for publication 15 December 2015). doi:10.1016/j.quaint.2015.11.067
- Baptista, A.M. 2009, *O paradigma perdido: O Vale do Côa e a arte paleolítica de ar livre em Portugal*. Edições Afrontamento/Parque Arqueológico do Vale do Côa, Porto, 254 p.
- Binford, L.R. 1980, Willow Smoke and Dogs' Tails: Hunter-Gatherer Settlement Systems and Archaeological Site Formation. *American Antiquity*, 45(1): 4-20.
URL: <http://www.jstor.org/stable/279653>
- Birdsell, J.B. 1968, Some predictions for the Pleistocene Based on Equilibrium Systems among Recent Hunter-Gatherers. In: *Man the Hunter*, (Lee, R.B. & Devore, I., Eds.), Aldine de Gruyter, New York: p. 229-240
- Blanco, J.A., Armenteros, I. & Huerta, P. 2008, Silcrete and alunite genesis in alluvial palaeosols (late Cretaceous to early Palaeocene, Duero basin, Spain). *Sedimentary Geology*, 211 (1-2): 1-11. doi:10.1016/j.sedgeo.2008.07.005
- Caride de Liñán, C. (Ed.) 1994, *Mapa geológico de la Península Iberica, Baleares y Canarias, 1: 1 000 000*. Instituto Tecnológico Geominero de España, Madrid.
- Cunha, P.P. 2000, Paleoalterações e cimentações nos depósitos continentais terciários de Portugal central: Importância na interpretação de processos antigos. *Ciências da Terra*, 14: 145-154.
- Delvigne, V., Fernandes, P., Piboule, M., Lafarge, A., Geneste, J.-M., Moncel, M.-H. & Raynal, J.-P. 2014, Ressources en silex au Paléolithique supérieur dans le Massif central: Réseaux locaux et approvisionnements lointains revisités. In: *Modes de contacts et de déplacements au Paléolithique eurasiatique*, (Otte, M. & Le Brun-Ricalens, F., Eds.), ERAUL/ArchéoLogiques, Liège & Luxembourg: p. 403-435.
- Fabián García, J.F. 1986, La industria lítica del yacimiento de la Dehesa en El Tejado de Béjar (Salamanca). Una industria de tipología magdalenense en la Meseta. *Numantia*, 2: 101-143.
- de Ferreira, A. de B. 1978, *Planaltos e montanhas do norte da Beira: Estudo de geomorfologia*. Centro de Estudos Geográficos, Lisboa, 374 p.
- Fontana, L., Digan, M., Aubry, T., Mangado Llach, J. & Chauviere, F.-X. 2009, Exploitation des ressources et territoire dans le Massif Central français au Paléolithique supérieur: Approche méthodologique et hypothèses. In: *Le concept de territoire chez les chasseurs-cueilleurs paléolithiques*, (UISPP, XV Congrès, Session C16, Lisbonne 7-8 septembre 2006), (Djindjian, F., Kozłowski, J. & Bicho, N., Eds.), BAR International Series Vol. 1938. Archaeopress, Oxford: p. 201-215.
- Frakes, B., Sherrill, K.R. & Flowe, T. 2014, *Travel Time Cost Surface Model: User Guide*, Natural Resource Report. NPS Inventory and Monitoring. Published Report-2212337, Fort Collins, Colorado. Accessed: 24 February 2016.
URL: <http://irmafiles.nps.gov/reference/holding/496603>
- Friend, P.F. & Dabrio, C.J. (Eds.) 1996, *Tertiary Basins of Spain: The Stratigraphic Record of Crustal Kinematics*. Cambridge University Press, Cambridge, 420 p.

- Fuertes Prieto, M.N., Neira-Campos, A., Fernández-Martínez, E., Gómez-Fernández, F. & Alonso-Herrero, E. 2014, "Mucientes chert" in the Northern Iberian Plateau (Spain). *Journal of Lithic Studies*, 1(1): 117-135. doi:10.2218/jls.v1i1.785
- Gameiro, C. 2012, *La variabilidade regional das indústrias liticas de la fin du Paléolithique supérieur au Portugal*. PhD Thesis at the U.F.R. d'Histoire de l'Art et d'Archéologie, Université Paris I, Panthéon-Sorbonne, 490 p.
- Gomes, A.A.T. 2008, *Evolução Geomorfológica da Plataforma Litoral entre Espinho e Águeda*. PhD thesis at the Faculdade de Letras, Universidade do Porto, 338 p.
- Herzog, I. 2010, Theory and Practice of Cost Functions. In: *Fusion of Cultures. Abstracts of the XXXVIII Conference on Computer Applications and Quantitative Methods in Archaeology, CAA 2010 (Granada 2010)*, (Contreras, F., Farjas, M. & Melero, F.J., Eds.), BAR International Series Vol. 2494. Archaeopress, Oxford: p. 431-434.
- Herzog, I. 2013, Least-cost networks. In: *Archaeology In The Digital Era: Papers from The 40th Annual Conference of Computer Applications and Quantitative Methods in Archaeology (CAA), Southampton, 26-29 March 2012*, (Earl, G., Sly, T., Chrysanthi, A., Murrieta-Flores, P., Papadopoulos, C., Romanowska, I. & Wheatley, D., Eds.), Amsterdam University Press, Amsterdam: p. 240-251.
- Ingold, T. 1988, Notes on the foraging mode of production. In: *Hunthers and Gatherers. Volume 1. History, Evolution and Social Change*, (Ingold, T., Riches, D. & Woodburn J., Eds.). Berg, Oxford: p. 269-285.
- Jarvis, A., Reuter, H.I., Nelson, A. & Guevara, E. 2008, *Hole-filled SRTM for the globe, Version 4, available from the CGIAR-CSI SRTM 90m Database*. Accessed: 24 February 2016. URL: <http://srtm.csi.cgiar.org>
- Klaric, L., Guillermin, P. & Aubry, T. 2009, Des armatures variées et des modes de productions variables: Réflexions à partir de quelques exemples issus du Gravettien d'Europe occidentale (France, Portugal, Allemagne). *Gallia Préhistoire*, 51: 113-154.
- Kullberg, J.C., Rocha, R.B., Soares, A.F., Rey, J., Terrinha, P., Azerêdo, A.C., Callapez, P., Duarte, L.V., Kullberg, M.C., Martins, L., Miranda, R., Alves, C., Mata, J., Madeira, J., Mateus, O., Moreira, M. & Nogueira, C.R 2013, A Bacia Lusitaniana: Estratigrafia, Paleogeografia e Tectónica. In: *Geologia de Portugal. Volume 2*, (Dias, R., Araújo, A., Terrinha, P. & Kullberg, J.C., Eds.), Escolar Editora, Lisboa: p. 195-347.
- Lee, R.B. 1972, The Intensification of Social Life among the !Kung Bushmen. In: *Population growth: Anthropological implications*, (Spooner, B., Ed.), MIT Press, Cambridge, Mass: p. 343-350.
- Lee, R.B. & Daly, R. 1999, Foragers and others. In *The Cambridge Encyclopedia of Hunter-Gatherers*. Cambridge University Press, Cambridge: p. 1-19.
- Lewis-Williams, J.D. 1982, The Economic and Social Context of Southern San Rock Art. *Current Anthropology*, 23(4): 429-438. doi:10.1086/202871
- Luís, L., Aubry, T. & Santos, A.T. 2015, Directing the eye: The Côa Valley Pleistocene rock art in its social context. In: *XIX International Rock Art Conference IFRAO 2015: Symbols in the Landscape: Rock Art and its Context*, (Collado Giraldo, H. & García Arranz, J.J., Eds.), Arkeos Vol. 37, DVD-ROM. Instituto Terra e Memória, Tomar: p. 1341-1348.

- Mangado Llach, J. 2005, *La caracterización y el aprovisionamiento de los recursos abióticos en la Prehistoria de Cataluña: Las materias primas silíceas del Paleolítico Superior Final y el Epipaleolítico*, BAR International Series Vol. 1420. Archaeopress, Oxford, 206 p.
- Matias, H. 2012, *O aprovisionamento de matérias-primas líticas na Gruta da Oliveira (Torres Novas)*. Universidade de Lisboa. Masters thesis at the Faculdade de Ciências, Universidade de Lisboa, 136 p.
- Matsumoto, G. 2008, *Availability of Least-Cost Pathway Analysis for the Study of Inka Road System*. Poster Presented at the 36th Annual Midwest Conference on Andean and Amazonian Archaeology and Ethnohistory, February 23-34th, University of Wisconsin, Madison, WI.
- Mauss, M. & Beuchat, S. 1905, Essai sur les variations saisonnières des sociétés eskimo: Étude de morphologie sociale. *Année Sociologique*, 9: 39-132.
- Mercier, N., Valladas, H., Aubry, T., Zilhão, J., Jorons, J.-L., Reyss, J.-L. & Sellami, F. 2006, Fariseu: First confirmed open-air Palaeolithic parietal art site in the Côa Valley (Portugal). *Antiquity*, 80(310). Accessed: 24 February 2016.
URL: <http://www.antiquity.ac.uk/projgall/mercier/>
- Oliveira, J.T., Pereira, E., Ramalho, M., Antunes, M.T. & Monteiro, J.H. 1992, *Carta Geológica de Portugal, na escala de 1.500 000*. Serviço Geológico de Portugal, Lisboa.
- do Pereiro, T. 2015, *Aproveitamento Hidroeléctrico de Ribeiradio - Ermida: Diagnóstico Arqueológico no sítio nº 214 - Vau: Relatório Final*. Oniknos - Arqueologia Lda., 54 p.
- Prieto, A., García-Rojas, M., Sánchez, A., Calvo, A., Dominguez-Ballesteros, E., Ordoño, J. & García-Collado, M. I. 2016, Stones in Motion: Cost units to understand flint procurement strategies during the Upper Palaeolithic in the south-western Pyrenees using GIS. *Journal of Lithic Studies*, 3(1): 0-28. doi:10.2218/jls.v3i1.1310
- Ribeiro, A. 2013, Evolução geodinâmica de Portugal: Os ciclos ante-mesozóicos. In: *Geologia de Portugal*. Volume 2, (Dias, R., Araújo, A., Terrinha, P. & Kullberg, J.C., Eds.), Escolar Editora, Lisboa: p. 15-57.
- Ribeiro, A., Antunes, M.T., Ferreira, M.P., Rocha, M.P., Soares, A.F., & Zbyszewski, G. 1979, *Introduction à la géologie générale du Portugal*. Serviços Geológicos de Portugal, Lisboa, 114 p.
- Ripoll López, S. & Municio González, L.J., (Eds.) 1999, *Domingo García: arte rupestre paleolítico al aire libre en la meseta castellana*, Arqueología en Castilla y Leon Vol. 8. Junta de Castilla y Leon, Salamanca, 278 p.
- Rose, F.G.G. 1968, Australian Marriage, Land-Owning Groups, and Initiations In: *Man the Hunter*, (Lee, R.B. & Devore, I., Eds.), Aldine de Gruyter, Hawthorne: p. 200-208.
- Sahlins, M., 1972, *Stone Age Economics*. Aldine Publishing Company, Chicago, 348 p.
- Sánchez Yustos, P. & Díez Martín, F. 2007, Historia de las investigaciones paleolíticas en la provincia de Valladolid: El caso de Mucientes. *Boletín del Seminario de Arte y Arqueología*, 72-73: 7-38. URI: <http://uvadoc.uva.es/handle/10324/9153>

- Tobler, W. 1993, *Three Presentations on Geographical Analysis and Modeling: Non-Isotropic Geographic Modeling; Speculations on the Geometry of Geography; and Global Spatial Analysis (93-1)*. UC Santa Barbara: National Center for Geographic Information and Analysis, 25 p. Accessed: 21 May 2016.
URL: <http://escholarship.org/uc/item/05r820mz>
- Tripevich, N. 2007. *Quarries, Caravans, and Routes to Complexity: Prehispanic Obsidian in the South-Central Andes*. PhD Thesis. UC Santa Barbara Anthropology, 945 p.
Accessed: 21 May 2016. URL: <http://works.bepress.com/tripevich/8>
- Valladas, H., Mercier, N., Froget, L., Jorons, J.-L., Reyss, J.-L. & Aubry, T. 2001, TL dating of Upper Palaeolithic sites in the Coa Valley (Portugal). *Quaternary Science Reviews*, 20(5-9): 939-943. doi:10.1016/S0277-3791(00)00026-3
- Whallon, R. 2006, Social networks and information: Non-“utilitarian” mobility among hunter-gatherers. *Journal of Anthropological Archaeology*, 25(2): 259-270.
doi:10.1016/j.jaa.2005.11.004
- Wiessner, P. 1982, Risk, reciprocity and social influences on !Kung San economics. In: *Politics and History in Band Societies*, (Leacock, E.B. & Lee, R.B. Eds.), Cambridge University Press; Editions de la Maison des Sciences de l’Homme, Cambridge; New York; Paris: p. 61-84.
- Wobst, H.M. 1974, Boundary conditions for Paleolithic social systems: A simulation approach. *American Antiquity*, 39(2): 147-178. doi:10.2307/279579
- Yengoyan, A.A. 1968, Demographic and Ecological Influences on Aboriginal Australian Marriage Sectios. In: *Man the Hunter*, (Lee, R.B. & Devore, I., Eds.), Aldine de Gruyter, Hawthorne: p. 185-199.
- Zilhão, J. (Ed.) 1997a, *Arte rupestre e Pré-história do Vale do Côa: Trabalhos de 1995-1996*. Ministério da Cultura, Lisboa, 454 p.
- Zilhão, J. 1997b, *O Paleolítico Superior da Estremadura Portuguesa*, 2 Vols. Edições Colibri, Lisboa, 1160 p.
- Zilhão, J., Almeida, F., Aubry, T., Carvalho, A.F. & Zambujo, G. 1995, O sítio arqueológico paleolítico do Salto do Boi (Cardina, Santa Comba, Vila Nova de Foz Côa). *Trabalhos de Antropologia e Etnologia*, 35(4): 471-497.