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A 400,000-year-old Acheulean assemblage associated with the Aroeira-3 human cranium (Gruta da Aroeira, Almonda karst system, Portugal)

Industrie acheuléenne datée de 400 000 ans associée au crâne humain Aroeira-3 (Gruta da Aroeira, système karstique de l'Almonda, Portugal)

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ABSTRACT

Bifaces dominate the Acheulean stone tools recovered during the archaeological excavation of layer X of Gruta da Aroeira, dated to 389–436 ka. Faunal remains and a human cranium were found in association with this lithic assemblage. The raw materials used are mostly quartz and quartzite cobbles available in the vicinity of the site. Technological and systematic analysis shows that there are no Levallois elements and suggests that on-site knapping consisted of the reduction of centripetal cores. Flake cleavers are absent. Use-wear analysis indicates the processing of hard materials, mainly wood. Gruta da Aroeira represents one of the few Middle Pleistocene sites that provide securely dated diagnostic human remains and associated Acheulean lithics, thus representing a major step forward in our understanding of the variability of westernmost Europe's Acheulean and of the human populations that made it.

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RÉSUMÉ

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La description de l'industrie lithique acheuléenne issue de la couche X de la Gruta da Aroeira, datée de 389–436 ka, révèle un pourcentage élevé de bifaces. Les fouilles archéologiques ont mis au jour un crâne humain associé aux vestiges lithiques et fauniques. L'approvisionnement en matières premières est dominé par le quartz et le quartzite. Les analyses typo-technologiques révèlent des séquences de production à partir de nucléus centripètes. Aucun élément diagnostique Levallois n'a été identifié. Les bifaces dominent l'outillage, alors que les hachereaux sont absents. Les analyses tracéologiques ont permis d'identifier une activité principale liée à la transformation du bois et d'autres types de matériaux durs. La Gruta da Aroeira est l'un des rares sites du Pléistocène moyen à fournir à la fois des restes humains diagnostiques et une industrie datés de manière fiable. Elle signifie donc un apport important à la compréhension de la variabilité des industries acheuléennes et des populations du Pléistocène moyen dans la partie la plus occidentale de l'Europe.

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1. Introduction

The Acheulean technocomplex has long been characterized by the occurrence of large tools such as bifaces (or handaxes), the index fossil, as well as cleavers, picks, and knives (Beyene et al., 2013; Gowlett, 1988). Recent research, however, has shown that the tradition features much variability, including a facies characterized by the production of very large (> 10 cm-long) flake blanks (de la Torre, 2016; Lycett and Gowlett, 2008; Nicoud, 2013). Some studies have stressed that the technology of the Acheulean implies both increased motor skills and advanced hierarchical cognition (Hodgson, 2009; Semaw et al., 2009; Uomini and Meyer, 2013; Wynn, 2002). From a functional perspective, it has also been shown that Acheulean bifaces were used for a large variety of tasks, such as woodworking and butchery (Dominguez-Rodrigo et al., 2001; Machin et al., 2007; Solodenko et al., 2015), which is usually interpreted as signalling an advanced subsistence strategy coincident with the emergence of complex behaviours.

Appearing first in eastern and southern Africa 1.7 Ma ago (Beyene et al., 2013; Lepre et al., 2011), the Acheulean culture spread into Eurasia around the early to middle Pleistocene boundary (Goren-Inbar, 2000; Lycett and von Cramon-Taubadel, 2008; Lycett, 2009a; Pappu et al., 2011). In Europe, the earliest occurrences are at Boxgrove, in England, La Noira and Caune de l'Arago, in France, Notarchirico, in Italy, and Galería-Atapuerca, in Spain (Barsky, 2013; Falguères et al., 2010, 2015; García-Medrano et al., 2015; Lefevre et al., 2010; Moncel et al., 2016. Pereira et al., 2015; Santonja and Villa, 2006; Stout et al., 2014). Even though, at La Noira, the chronology is based on cosmogenic (Shen et al., 2012) and electron spin resonance dating (Moncel et al., 2013, 2016) with large uncertainty intervals (Despriée et al., 2017), at Notarchirico and in several fluvial deposits of the UK (Voinchet et al., 2015), the Acheulean is more securely dated to 550–650 ka. These sites therefore attest to biface technology in both the southern and northern latitudes of Europe minimally by Marine Isotope Stage (MIS) 15.

With regard to western Europe specifically, the circumstances surrounding the emergence of the Acheulean culture have recently come under debate. Some authors argue for an earlier, sporadic, and intermittent presence of the technology, based primarily on the presence of handaxes and other bifacial tools in certain southern Iberian contexts (Moncel et al., 2013, 2016; Scott and Gibert, 2009; Vallverdú et al., 2014). At present, however, the data are insufficient to validate this hypothesis. For example, the lithic assemblage recovered at Barranc de la Boella is sparse and only two of its artefacts can potentially be classified as Acheulean tools (Saladié et al., 2016; Vallverdú et al., 2014); in addition, the interpretation of its assemblage as "Early Acheulean" has been questioned (e.g., Santonja et al., 2016). Similar problems affect two other Spanish sites, Cueva Negra and Solana del Zamborino (Scott and Gibert, 2009), whose chronology is strongly disputed (Álvarez-Posada et al., 2017; Jiménez-Arenas et al., 2011).

In short, the most widely accepted hypothesis is that, in Europe, the Acheulean appeared around ~550–650 ka. It seems likely that the expansion of the Acheulean into the continent occurred in parallel with that of the controlled use of fire (Roebroeks and Villa, 2011). Evidence of fire before MIS 11 (374–424 ka) is extremely scarce and controversial, a possible exception being the pyrotechnical evidence reported from Cueva Negra del Estrecho del Rio Quípar, in Murcia (Rhodes et al., 2016; Walker et al., 2016). Between MIS 11 and MIS 9 (300~337 ka), however, evidence of fire activity is found at several European open-air sites (Roebroeks and Villa, 2011).

The middle Pleistocene is increasingly recognized as an important epoch for both the cultural and biological evolution of humans. Some authors have suggested that a speciation-associated "out-of-Africa" event occurred at this time (Carbonell et al., 1999; Hublin, 2009). Based on the archaeological record, namely the lithic assemblages, others (e.g., Villa, 2001), however, fail to find any support for a link between the spread of the Acheulean culture and the appearance of *Homo heidelbergensis*, while the morphology of European middle Pleistocene human fossils (Rightmire, 1998; Stringer, 2012) suggests a rather more complex human population scenario. Indeed, the recently discovered Gruta da Aroeira cranium (Aroeira-3) (Daura et al., 2017), clearly associated with Acheulean bifaces, points to significant variation among Eurasian humans of the period. The cranium preserves most of the right half of the calvarium (with the exception of the occipital bone), as well as a portion of the left side of the frontal squama and supraorbital torus. Its complex mosaic of features is illustrated, among others, by the combination of a continuous and thick supraorbital torus with a short mastoid process and a large, triangular postglenoid process (Daura et al., 2017).

In an attempt to shed further light on this scenario, we present the Acheulean stone tools from layer Xb/c of Gruta da Aroeira, from which the Aroeira-3 cranium was recovered. Even though not among the earliest Acheulean contexts of western Europe, the site provides precisely dated information on the technology, raw material procurement and function of the lithic assemblages from the critical time frame between 400 and 500 ka, during which the Neanderthal lineage began to emerge and evidence for the use of fire became widespread.

2. The Gruta da Aroeira site

Gruta da Aroeira (39° 30' 20" N; 08° 36' 57" W) is located in the Central Limestone Massif of Estremadura (municipality of Torres Novas, Santarém, Portugal) (Fig. 1.1–1.2). The cave forms part of the Almonda karst system, a labyrinthine network of passages excavated at different elevations and featuring a number of former entrances with Pleistocene sedimentary infills sealed by roof collapse. The intersections of these entrances with the 70-m-high escarpment that rises above the extant spring of the Almonda River (a tributary of the Tagus) correspond to fossil outlets of its subterranean course (Fig. 1.3).

The site was discovered in 1991 by STEA (*Sociedade Torrejana de Espeleologia e Arqueologia*). They identified a network of passages sealed by a cone of sediments containing middle Pleistocene faunal remains and quartz artefacts (Zilhão et al., 1993). The location of the entrance (Fig. 1.5) was established from the surface by means of electromagnetic survey equipment, after which the site was reopened and excavated. A first phase of fieldwork was carried out between 1997 and 2002. In publications arising from this phase, the site was designated as "Galerias Pesadas" (Marks et al., 2002; Trinkaus et al., 2003). This designation, however, corresponds to the interior conduits of the karst system; the 1997–2002 work was carried out over some 60 m^2 in an external area in which erosion had already exposed the cave's sedimentary infill (the Brecha das Lascas *locus*) and in the porch of the reopened cave entrance (the Gruta da Aroeira *senso strictu*).

Archaeological excavation resumed in 2013 in an area of 6 m^2 at the back of the cave (Fig. 1.7), with the aim of reaching bedrock and investigate the chronological range of the archaeological deposit, for which speleothem samples collected and dated between 2006 and 2011 had provided a minimum age of ~400 ka (Hoffmann et al., 2013). In this part of the site, the stratigraphic sequence spans a thickness of 4 m and comprises three major stratigraphic units (Figs. 1.5–1.6). Uppermost Unit 1 is a brecciated infill capped by flowstone dated to 44.8 ± 2.0 ka (2σ). Unit 2 is a 2.2-m thick mud-supported breccia, rich in angular and sub-rounded clasts, corresponding to Acheulean levels X and Xb/c (which are the upper and lower parts of a single unit, excavated 1997–2002 and 2013–2015, respectively) and capped by a second flowstone dated to 418/+37/−27 ka (2σ). Basal Unit 3 is an endokarst fluvial deposit comprising two layers: layer XI is a 0.4 m-thick silty sand with scattered gravel and faunal remains but no artifacts, and layer XII is a 0.5 m-thick, archaeologically sterile, slightly gravelly sand. The external layer of a stalagmite column buried by the subsequent accumulation of Units 1 and 2 and that, based on available cross-sectional views, seems to have grown from the top of layer XII, has been dated to 406 ± 30 ka (2σ). This result represents a maximum age for layer Xb/c, whose deposition can therefore be placed within the 389–436 ka interval.

As no extant stratigraphic profiles link the different *loci*, the stratigraphic relationship between the 1997–2002 and 2013–2015 excavations is tentative, and establishing the position of the finds from the earlier phase of work relative to the flowstone capping layer X requires an in-depth analysis of spatial distributions that lies beyond the scope of this paper. Thus, our analysis and conclusions are based on the sample retrieved from the area at back of the cave in which we excavated the lower part of Unit 2 ("layer Xb/c") beyond the elevation reached in 2002: grid units H/I/J-6/7/8. In this area of the site, Unit 2 is fully sealed by the flowstone (Fig. 1.5), and, therefore, there can be no question that the stone tool assemblage we describe is securely dated.

Besides the stone tools and the human cranium Aroeira-3, layer Xb/c yielded faunal remains: highly fragmented, and consisting primarily of isolated teeth, phalanges, carpal/tarsal bones, and antler fragments. Among the 209 piece-plotted faunal remains, cervids [Number of Identified Specimens (NISP) = 58], including both *Dama* and *Cervus*, and equids (NISP = 46) predominate. Rarer species include Rhinocerotidae (NISP = 2) (likely *Stephanorhinus* cf. *hundsheimensis*), and bear (NISP = 4) (*Ursus* sp.), as well as a large bovid (*Bos*/*Bison*), a caprid (Caprinae), and a tortoise (*Testudo* sp.) (NISP = 1 each).

3. Materials and methods

3.1. Excavation methodology

Because the archaeological and palaeontological remains are encased in a hard carbonate breccia, excavation had to be carried out with demolition hammers and sieving was not possible. However, much effort was made to collect all the remains. Stone tools and faunal bones were mapped *in situ* prior to extraction, while small fragments were bagged by 1 m^2 units of provenience. The chunks of sediment extracted with the power tools were collected and then broken into small pieces in a separate area. All the finds were restored during the excavation using a pneumatic microhammer and microchisel (Mod. CTS 178) and a normal air scribe (Mod. W 224). Where necessary, bones were consolidated with an acrylic resin (Paraloïd-B72) dissolved with acetone.

3.2. Raw materials

Archaeological samples were analysed macroscopically using a stereomicroscope (Olympus SZ61 up to ×45

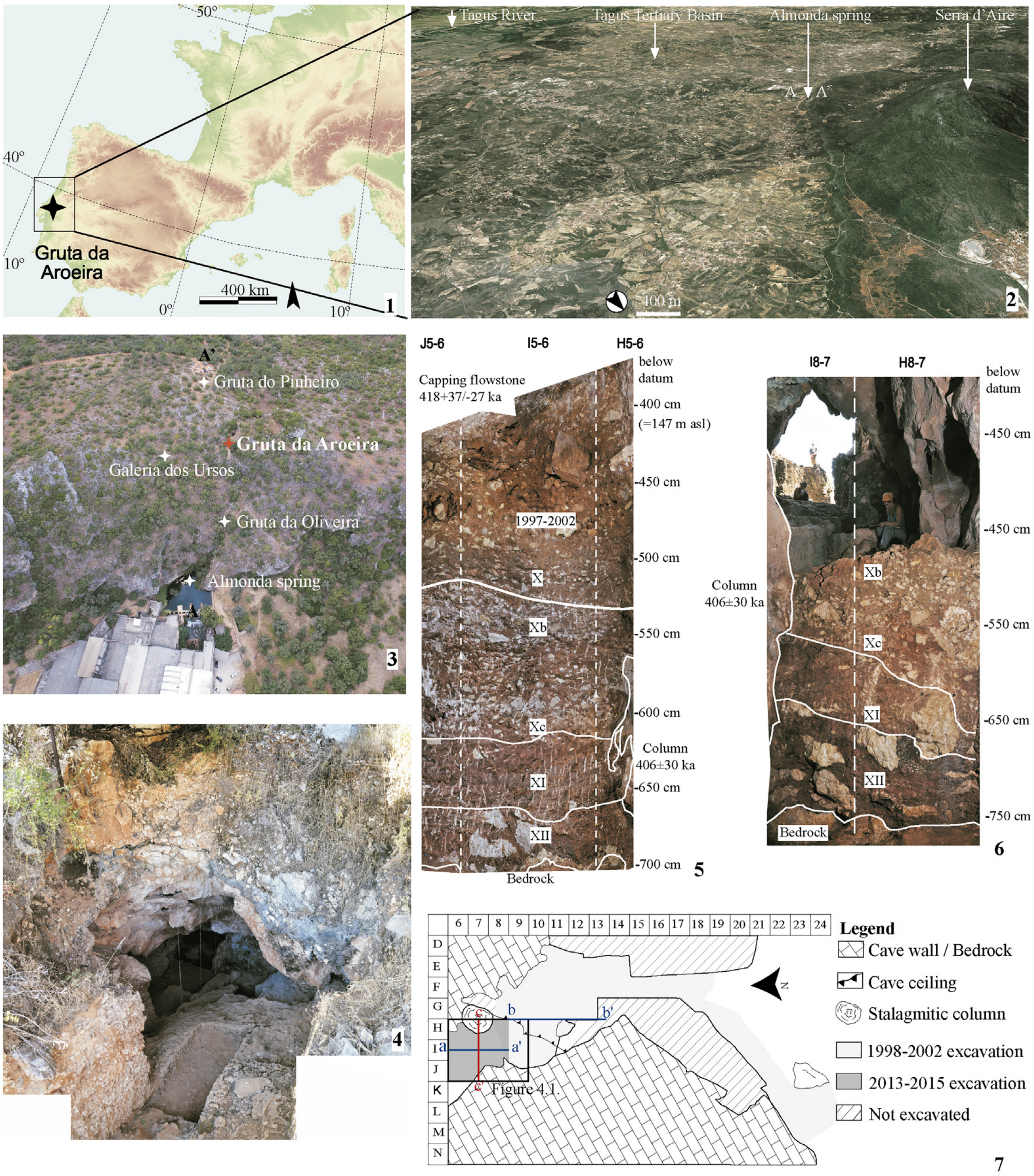

Fig. 1. The site. 1: Geographical location. 2: The southern border of the Estremadura Limestone Massif; the position of the Almonda spring, the Tagus River and the Serra d'Aire are indicated. 3: The Almonda escarpment with the position of known Middle and Lower Palaeolithic sites above the spring of the Almonda River. 4: The reopened Gruta da Aroeira and overview of the excavated area. 5–6: South and North stratigraphic profiles of the 2013–2015 trench. 7: Site plan and grid.

Fig. 1. Le site. 1 : Situation géographique. 2 : Bordure sud du massif calcaire de l'Estrémadure, avec la position de la source de l'Almonda, du fleuve Tage et de la Serra d'Aire. 3 : Escarpement d'Almonda avec la position des sites du Paléolithique moyen et inférieur connus au-dessus la source de l'Almonda. 4 : Vue de l'entrée désobstruée de la Gruta da Aroeira et de la zone de fouille. 5–6 : Coupes stratigraphiques sud et nord de la fouille 2013–2015. 7 : Plan du site et carroyage.

with a coupled photographic camera Olympus SC30), and geological samples were observed under the stereomicroscope and a petrographic microscope (*CARL ZEISS Axiophot Pol* up to 200× with coupled photographic camera *Sony DXF-S500*). Details of the data and methodology used for the analyses of the geological flint and other silicifications collected in the vicinity of the cave have been published elsewhere (Aubry et al., 2016, 2014, 2012; Matias, 2012, 2016). Macroscopic, non-destructive analyses considered the main distinguishing elements, including texture (Dunham, 1962), sedimentary structures, skeletal and other bioclastic elements, porosity and non-skeletal elements, weathering, cortex type, degree of cortex rounding, and knapping quality. Microscopic

Table 1
Raw material.
Tableau 1
Matières premières.

	Artefacts				Manuports			
	n	(%)	Weight (g)	(%)	*n*	(%)	Weight (g)	(%)
Quartzite	159	51.6	12762	67.2	28	32.9	8543	35.3
Quartz	122	39.6	3611	19.0	26	30.6	5446	22.5
Flint	20	6.5	1646	8.7	–	–	–	–
Limestone	4	1.3	777	4.1	–	–	–	–
Lydite	2	0.6	176	0.9	1	1.2	331	1.4
Igneous rock	1	0.3	34	0.2	–	–	–	–
Sandstone	–	–	–	–	6	7.1	2269	9.4
Indeterminate	–	–	–	–	24	28.2	7636	31.5
Total	308	100.0	19006	100.0	85	100.0	24225	100.0

analyses of the geological samples also considered the mineralogical content. Metamorphic rocks and minerals, for example quartzite and quartz, were classified according to their colour, transparency, grain size, weathering, cortex type, degree of cortex rounding, and knapping quality.

3.3. *Taphonomy*

To evaluate the state of preservation of the lithic artefacts, we conducted an analysis of their surfaces and edges with a portable magnifying lens (10×). In order to be as cautious as possible, the analysis of edge preservation only used unretouched flakes of quartzite and flint. Quartz examples were excluded due to the difficulty in clearly discerning between wear-, excavation- and taphonomic-related edge damage.

3.4. *Technology*

A techno-categorical analysis was conducted on the entire lithic assemblage using the operational sequence approach (Barsky and de Lumley, 2010; Boëda et al., 1990; Forestier, 1993; Mourre, 1996, 2004; Tixier, 2012). Unretouched flakes and tool blanks were classified according to technological criteria and retouched tools according to the general characteristics of the retouch. Cores and bifaces were described with the help of diacritical schemes. Cobblestone sites were analysed for the identification of anthropogenic marks (of percussion, heating, etc.).

3.5. *Use wear*

A total of 27 artefacts was selected on the basis of the presence of macroscopic edge damage potentially attributable to tool use (micro scars, fractures, edge rounding) and detectable at low magnification (up to 80×). Because all the artefacts analysed are made of quartzite, high-resolution casts of the tool edges were made to assess their functionality. This method has proved to be highly effective in the analysis of such coarse, highly reflective rocks (Igreja, 2009). The functional interpretation relied on a multi-stranded approach combining the analysis of macroscopic edge damage with high-power microwear analysis, using a standard reflected light microscope (BH Olympus) equipped with differential interference contrast (DIC) at 100×, 200×, and 400× magnification, following standard use-wear analytical procedures (González and Ibáñez, 1994). Photomicrographs of the use-wear traces detected were taken using a digital camera Canon EOS 600D. The patterns observed on the archaeological materials were compared with an experimental reference collection of use-wear traces on a wide range of rocks (e.g., flint, quartzite, quartz).

4. Results

4.1. *Raw material*

The approximately 6 m^3 of layer Xb/c that we excavated yielded 393 lithic objects, which translates into an artefact density of 65/m^3 (51/m^3 considering the flaked material only); by weight, the corresponding values are, respectively, 7.2 and 3.2 kg/m^3. A total of seven different types of igneous, sedimentary and metamorphic rocks and minerals is present in the sample (Table 1).

Limestone, lydite and an undetermined igneous rock represent less than 2.5% of the artefacts. Although available nearby, flint is relatively scarce in our sample, where it represents 6.5% of the artefacts, against 51.6% for quartzite and 39.6% for quartz. An anhedral milky quartz variety presents varying degrees of translucency, apparently unrelated to knapping quality. A very fine-grained, green or red variety with excellent knapping qualities represents almost 20% of the quartzite assemblage. Quartzite and quartz cobbles derived from the Iberian Hercynian Massif are found in the sedimentary deposits of the Tagus basin ubiquitously present around the Almonda spring, in which this variety is, however, rarely observed (Fig. 2).

Among the unflaked cobbles, quartzite and quartz appear in the same percentage as among the artefacts, flint is absent, and sandstone (which may be either an orthoquartzite or a slightly metamorphosed quartzite) is present. One relevant characteristic of these finds is the recurrent presence of fractures and other imperfections that would make knapping difficult. Although it cannot be excluded that some of these cobbles represent a component of the surrounding soils washed-in by natural processes, most are manuports that bear stigma of use (Table 2).

Due to a high level of desiliconization or necrosis (Bressy, 2003; Masson, 1981), the flint is physically fragile, opaque, and white in colour (Fig. 3.1), with rose-red and

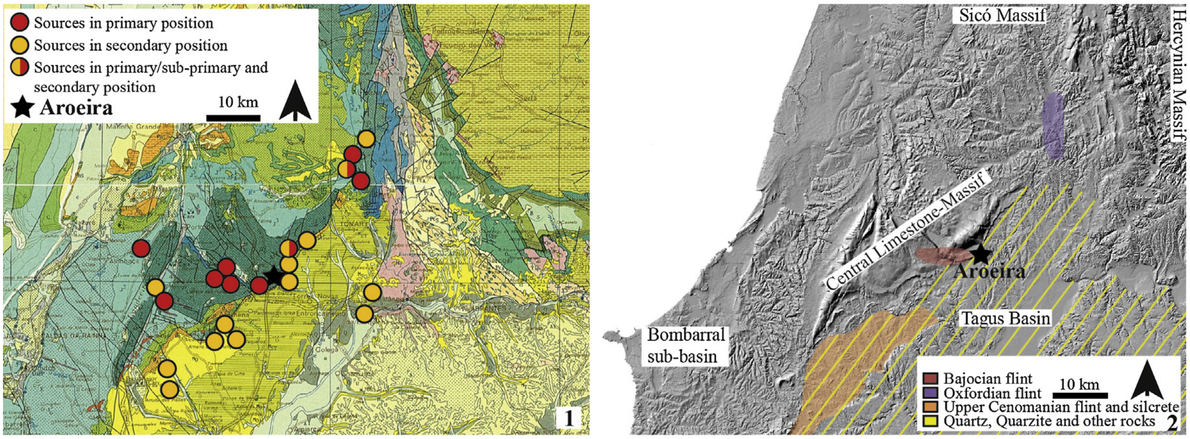

Fig. 2. Raw material provenance. 1: Geological Map (1:500.000, resized) of the Central Limestone Massif and surrounding area of the Tagus sedimentary basin with the location of the sampled geological sources. 2: Digital elevation model (DEM) with the distribution of known raw material sources.
Fig. 2. Sources de matière première. 1: Carte géologique (1 : 500 000, redimensionnée) du massif calcaire et zones environnantes du bassin sédimentaire du Tage avec l'emplacement des sources échantillonnées. 2: Modèle numérique de terrain (MNT) avec localisation des gîtes de silex connus et la répartition des autres matières premières.

Table 2
The lithic assemblage: technology categories per raw material type.
Tableau 2
L'industrie : catégories technologiques selon les types de matière première.

	Quartzite	Quartz	Flint	Sandstone	Limestone	Lidite	Igneous rock	Indeterminate	Total
Flakes	113	82	12	–	–	–	–	–	207
Cores	21	22	3	–	1	–	–	–	47
Bifacial tools	14	0	4	–	–	1	–	–	19
Debris	–	18		–	1	1	1	–	21
Cobbles	39	26	1	6	2	1	–	24	99
Tested cobble	9	9	1	–	2	–	–	–	21
Hammerstones	4	6	–	1	–	–	–	7	18
Anvil?	–	–	–	1	–	–	–	–	1
Unmodified and fragments	26	11	–	4	–	1	–	17	59
Total	187	148	20	6	4	3	1	24	393
%	47.6	37.7	5.1	1.5	1.0	0.8	0.3	6.1	100.0

grey zonations and frequent, isolated iron oxide pellets. When present, the external surface is well-rounded and features a thin (~1 mm) neocortex with iron precipitates (attributable to the iron-enriched soils of the Tagus basin; Fig. 3.2). In a few artefacts, it was possible to identify fossils, which, because of recrystallization, are generally difficult to recognise. Monoaxonic spicules are frequent, as are other undetermined bioclastic fragments; rare and poorly preserved foraminifer, ostracod, algae and bivalves are also present. Euhedral macro-quartz crystals replace the original carbonate of the fossil shells, providing for good contrast with the siliceous, cryptocrystalline sedimentary matrix (Fig. 3.3–3.8). Even though geode formations are frequent in Cenomanian flints, no relevant imperfections were observed in our sample.

Four types of flint have been identified in the vicinity of the Almonda system (Aubry et al., 2014; Matias, 2012, 2016) (Fig. 2). Bajocian (Jurassic) formations < 5 km from the cave contain medium-to-good quality flints in primary and sub-primary positions. More distant Upper Cenomanian (Cretaceous) formations contain very good-to-excellent quality flints, while Tertiary silcrete occurs in secondary position in lower Miocene deposits > 10 km to the SW, alongside Hercynian rock cobbles (quartzite, quartz, etc.). Good quality Oxfordian (Jurassic) flint in primary and sub-primary positions is documented some 20 km to the NE. Our sample, however, only contains Upper Cenomanian flint types. Their nearest known area of occurrence is indicated in Fig. 2.

4.2. *Taphonomy and spatial distribution*

Flint artefacts present an extensive patina, ranging from a whitened exterior surface (36%) to partial or total desiliconization (12%), but quartzite lithics are well preserved: their dorsal ridges show little crushing, while edge damage caused by syn- or post-depositional processes, or resulting from the use of power tools in the excavation process, found on 70% of the pieces, is relatively limited (28% of pieces show some, 19% show more extensive but localized, and only 23% show generalized edge damage). Rolled surfaces suggesting significant displacement or washing-in are found among neither quartzite nor flint pieces. Nine quartzite artefacts (eight cobbles and one flake) have a reddish surface possibly indicative of damage inflicted by thermal alteration; however, naked-eye observation is

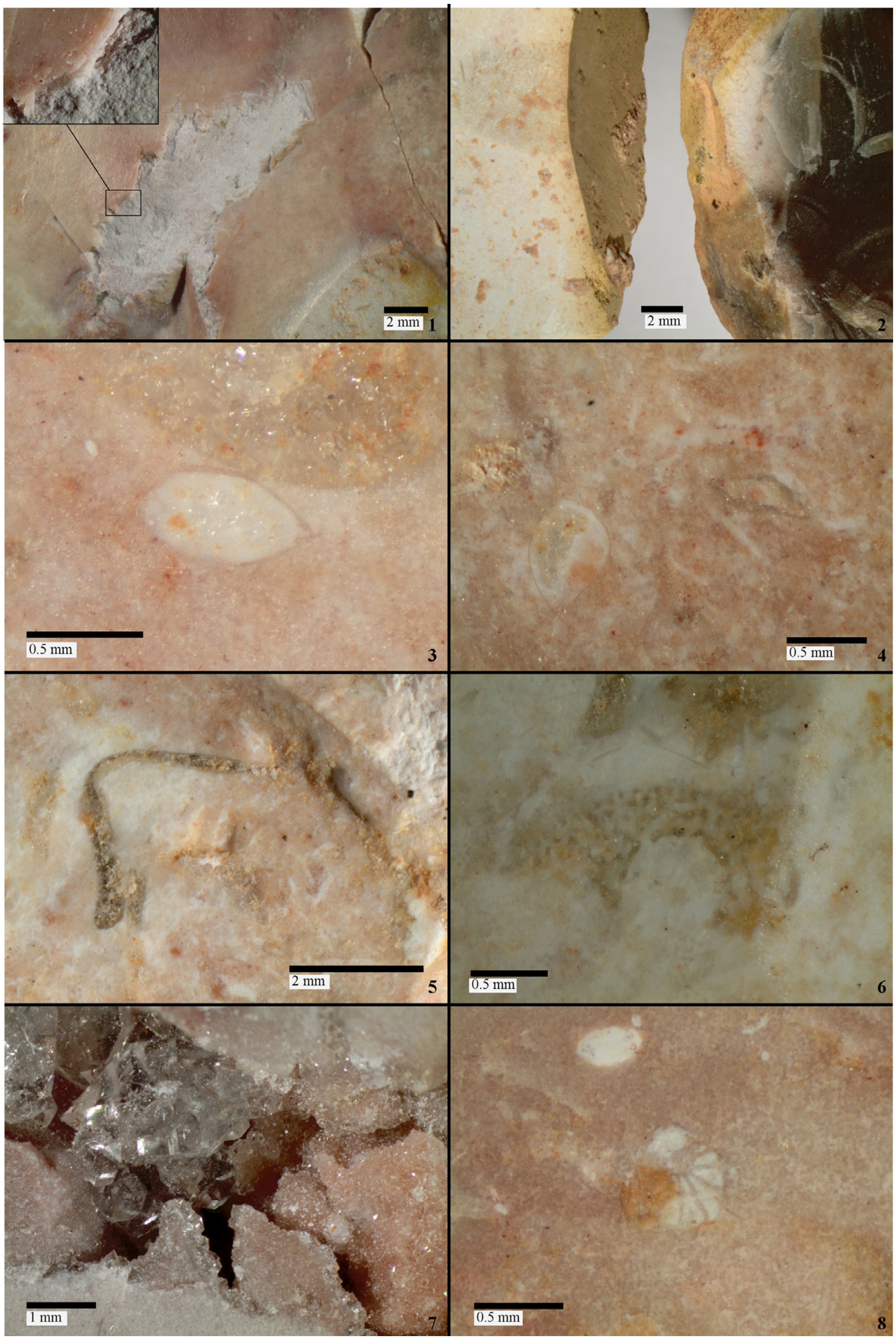

Fig. 3. Raw materials. 1: Detail of excavation breakage (ARO #840) with desilicified interior (whitish area) and shell-like exterior, with conservation of texture, structures and other identifiable elements. 2: On the left, flint flake (ARO #282) with clear weathering of the siliceous matrix (whitening) and cortical impregnation by iron oxide; on the right, Upper Cenomanian flint sample from Azinheira, with the same cortex features. 3–8: Allochem and porosity of the Cretaceous flint artefacts (3–4. Undetermined ostracods; 5. Bivalve section possibly from the Gryphaeidae family, cf. *Rhynchostreon*; 6. Possible section of a Dasycladacea algae; 7. Geode partially filled by euhedral hyaline quartz crystals; 8. Foraminifer section, cf. *Biconcava*.

Fig. 3. Matières premières. 1: Détail d'une cassure récente (ARO #840) avec intérieur déssilicifié (zone blanchâtre) et coquille extérieure avec conservation de la texture, des structures et d'autres éléments identifiables. 2: À gauche, éclat en silex (ARO #282) présentant une altération nette de la matrice siliceuse (blanchiment) et une imprégnation corticale d'oxyde de fer ; à droite, un échantillon de silex du Cénomanien supérieur d'Azinheira, présentant un cortex avec les mêmes caractéristiques. 3–8: Allochème et porosité des artefacts en silex du Crétacé (3–4, ostracodes indéterminés ; 5, section de bivalve appartenant peut-être à la famille des Gryphaeidae, cf. Rhynchostreon ; 6, section possible d'une algue Dasycladacea ; 7, géode partiellement remplie de cristaux de quartz hyalins euhédriques ; 8, section de foraminifère, cf. Biconcava).

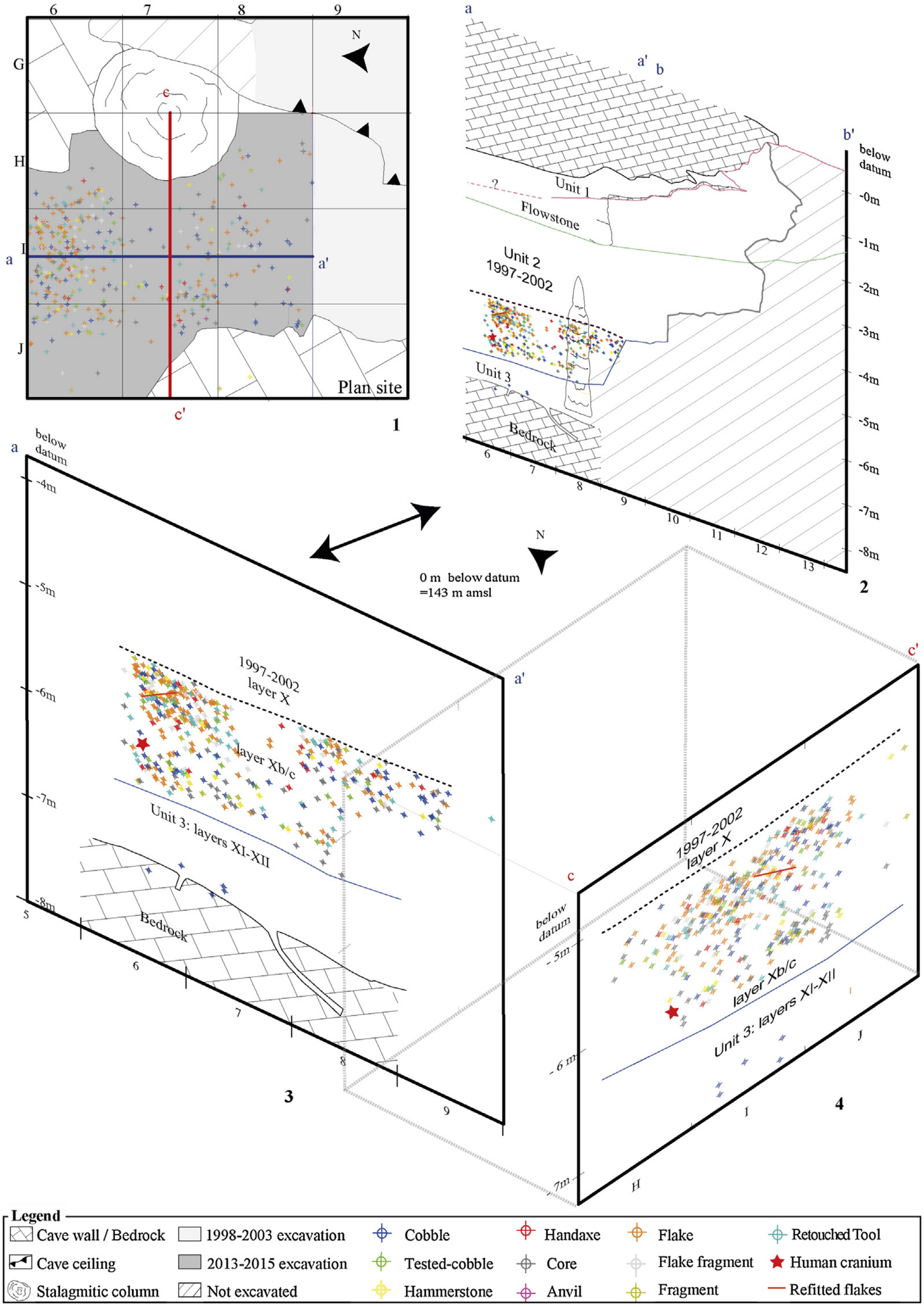

Fig. 4. Vertical distribution of lithic remains from layer Xb/c. Lines a–a'/b–b' (longitudinal) and c–c' (lateral) represent the axis of the vertical projection of the plotted artifacts.

Fig. 4. Distribution verticale des vestiges lithiques du niveau Xb/c. Les lignes a–a'/b–b' (sagittales) et c–c' (transversale) représentent les axes de la projection verticale des vestiges cotés.

Table 3
The cores: mode of reduction per raw material type.
Tableau 3
Les nucléus : mode d'exploitation selon les types de matière première.

	Quartz	Quartzite	Limestone	Flint	Total	%
Limited reduction	7	4	1	–	12	25.5
Discoid–bipyramidal	2	7	–	2	11	23.4
Discoid–unifacial	2	2	–	–	4	8.5
Unipolar	1	4	–	–	5	10.6
Bipolar on anvil	1	4	–	–	5	10.6
Multidirectional	6	–	–	1	7	14.9
Indeterminate	3	–	–	–	3	6.4
Total	22	21	1	3	47	100.0
%	46.8	44.7	2.1	6.4	100.0	

Table 4
Technological classification of the unmodified flake assemblage.
Tableau 4
Classification technologique des éclats non retouchés.

	Quartzite	Quartz	Flint	Total
Cortical flake	21	17		38
Flake > 50% cortical	10	8	1	19
Flake < 50% cortical	16	6	1	23
Naturally backed flake	13	9	–	22
Flake with large convex cortical butt	8	1	–	9
Déordant flake	6	6	–	12
Pseudo-Levallois point	3	–	–	3
Large short flake	3	–	–	3
Elongated flake	4	–	–	4
Secondary Kombewa flake	3	–	–	3
Other flakes	15	26	4	45
Bifacial thinning flake	1	–	4	5
On–anvil bipolar flake	–	1	–	1
Indeterminate flake	10	8	2	20
Total	113	82	12	207
%	54.6	39.6	5.8	100.0

unable to provide definitive confirmation. These observations show that the assemblage did not undergo substantial post-depositional alteration, and this conclusion is supported by the preservation of micro-wear traces (cf. infra).

Bearing in mind the small size of the 2013–2015 trench, the vertical and horizontal plotting of the archaeological remains suggests a random distribution across the total thickness (~1 m) of our excavation of layer Xb/c. This can be clearly seen in Fig. 4: neither the horizontal (Fig. 4.1) nor the vertical plots (Fig. 4.2–4.4) show any signs of discrete accumulations as lenses or patches, even though the lithics seem to be more numerous towards the top and the base of the unit. Only two flakes could be refitted.

4.3. Lithic technology

4.3.1. Operational sequences

Because flint pieces were mostly imported in the form of finished tools, complete operational sequences can be reconstructed for quartz and quartzite only. Based on an analysis of cores and flakes, lithic reduction mostly followed a centripetal scheme (Table 3; Fig. 5.1–5.5, 5.7–5.9). Exhausted cores, whether in quartz or quartzite, most frequently present a bipyramidal organization, although a small percentage are unipolar or bipolar; a few quartz specimens represent bipolar, on-anvil knapping.

A significant number of cores (12, i.e. 25.5%; Table 3) were not much reduced and seem to reflect an opportunistic exploitation: negatives are either disorganized or organized in unipolar or orthogonal manner. Most cores (15, i.e. 31.9%) are discoid and bifacially reduced by centripetal or chordal removals using alternating flaking surfaces, but there are also some unifacial-centripetal ones. Seven cores are multidirectional but the extractions display no apparent organization. They may represent the last stage, using the last convexities available, of more organized reduction sequences. The five unipolar cores display series of removals on only one surface and, contrary to discoid ones, are principally produced on cobbles rather than flakes. The on-anvil, bipolar cores are also made on cobbles and display a clear striking platform opposite another bearing percussion marks.

Most cores (19%) were set up on flakes, and a few Kombewa-type flakes were identified. Because the initial core morphology could not be determined on the most heavily exploited specimens, that percentage is probably underestimated. This evidence suggests that the core blanks were split cobbles of quartz and quartzite. This volume-reducing operation may have been carried out at the site of acquisition, from where half-cobbles or large flakes were transported to the site, or at Gruta Aroeira itself, into which they could have been introduced whole.

The high percentage of flakes that are either entirely cortical or more than 50% cortical also hints at complete lithic reduction sequences being represented at the site (Table 4). Flake platforms are overwhelmingly neo-cortical and secondarily unfaceted. Centripetal flakes, overshot or naturally backed flakes, and short backed flakes were the targeted products. Certain cores were also recycled as hammerstones (6%) (Thiébaut et al., 2010), while some hammerstones were recycled as cores (6%).

The high percentage of cores ($n = 46$) relative to flakes ($n = 207$) could indicate that reduction sequences were short, each core yielding a small number of flakes, or that the assemblage underwent some sort of spatial redistribution, whether post-depositional or anthropogenic, which could also account for the over-representation of the larger elements (raw cobbles, cores, bifaces). As the present study is based on an area of just 6 m^2, this alternative cannot be resolved.

4.3.2. Bifaces and their manufacturing sequences

Morphologically, the fifteen bifaces in our assemblage are cordiform, lanceolate and amygdaloid (Figs. 6–8). Diacritical analysis of the bifaces permitted partial reconstruction of their manufacturing sequences. In most cases, the original blank used cannot be determined; in a few, it was a flake. A first phase of bifacial shaping was performed alternately on both faces and resulted in the initial shaping of the general morphology into two edges that converged to a point. The edges were then refined with a series of non-invasive unifacial flake removals. Finally, the point was further shaped with a series of smaller removals in continuity with those used to form the edges. On several pieces, removals corresponding to re-shaping or edge re-sharpening were identified. The last stage often was the shaping of the base through bifacial removals. These

Fig. 5. Cores. 1, 3, 5, 7–8: Bipyramidal-centripetal quartzite and flint cores. 2: Unifacial-centripetal core on flake. 4: Bipyramidal-centripetal quartzite core reused as a hammerstone. 6: Unipolar quartz core. 9: Bipyramidal-centripetal flint core. 10: Unipolar quartzite core. The grey dots signal the position of the use-wear traces illustrated in Fig. 9.

Fig. 5. Nucléus. 1,3, 5, 7–8: Nucléus centripètes bipyramidaux en quartzite et silex. 2 : Nucléus centripète unifacial sur éclat. 4: Nucléus centripète bipyramidal en quartzite réutilisé en percuteur. 6: Nucléus unipolaire en quartz. 9: Nucléus centripète bipyramidal en silex. 10: Nucléus unipolaire en quartzite. Les points gris indiquent les traces d'usure illustrées sur la Fig. 9.

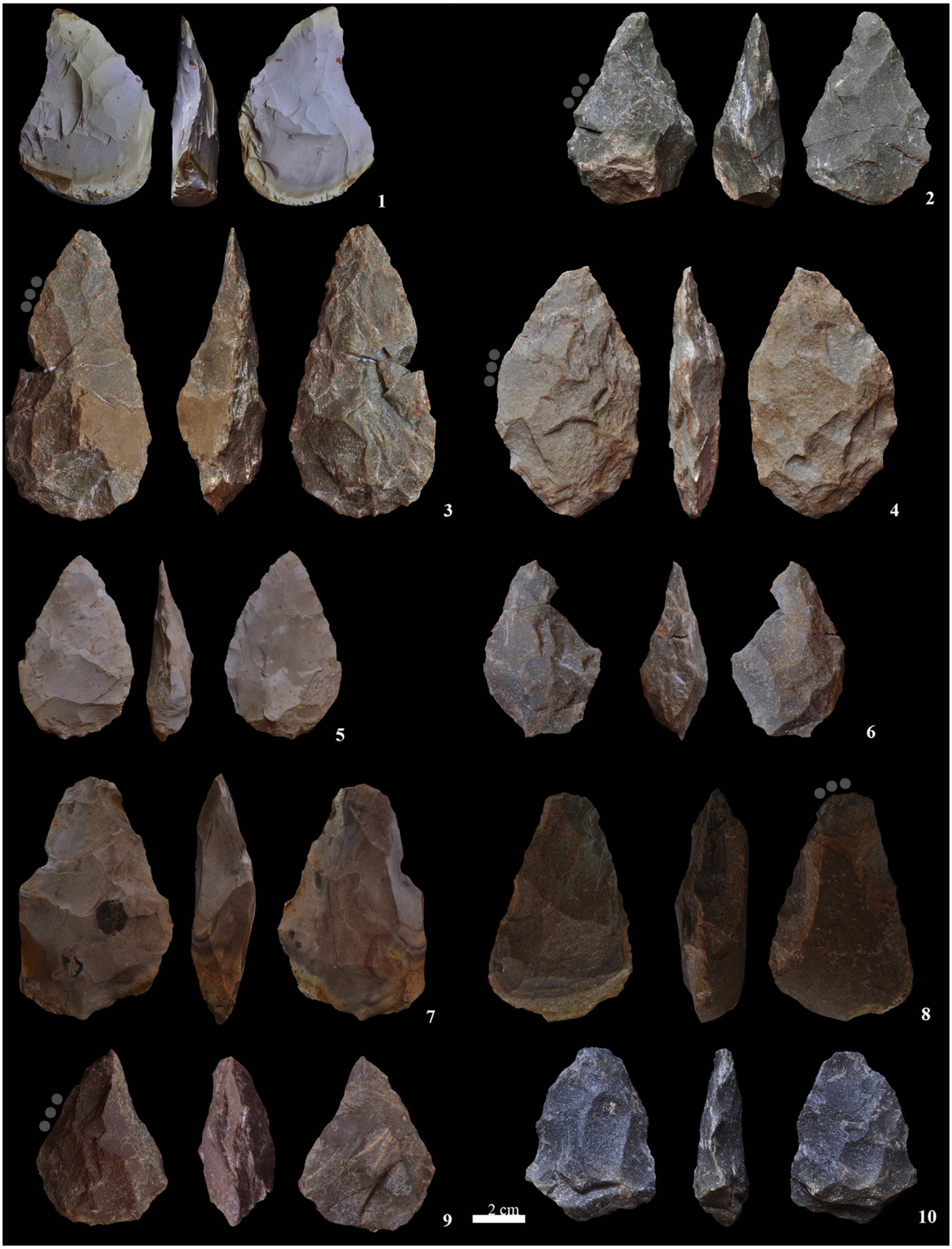

Fig. 6. Bifaces. 1, 5: Flint, cordiform. 2, 4, 6: Quartzite, cordiform. 7: Flint, triangular. 8: Quartzite, triangular, made on large flake. 9–10: Small quartzite bifaces. The grey dots signal the position of the use-wear traces illustrated in Fig. 9.

Fig. 6. Bifaces. 1, 5: Cordiformes en silex. 2, 4, 6: Cordiformes en quartzite. 7: Flint, triangulaire. 8: Quartzite, triangulaire, sur grand éclat. 9–10: Petits bifaces en quartzite. Les points gris indiquent les traces d'usure illustrées sur la Fig. 9.

Fig. 7. Retouched tools. 1: Quartzite biface. 2: Large denticulate with double patina. 3: Large flake with distal edge microwear. 4: Transversal scraper. 5, 9: Lateral sidescraper (#5 with scalariform retouch). 6: Alternate scraper. 7: Retouched pseudo-Levallois point. 8: Flake with use-wear. 10: Transversal scraper with bifacially thinned base. 11: Bifacial tool. 12: Bifacial scraper with double patina. The grey dots signal the position of the use-wear traces illustrated in Fig. 9.

Fig. 7. Outillage retouché. 1: Biface en quartzite. 2: Denticulé présentant une double patine. 3: Grand éclat présentant des macrotraces d'utilisation sur son tranchant distal. 4: Racloir transversal. 5, 9: Racloirs simples latéraux (#5 avec retouche scalariforme). 6 : Racloir à retouche alterne. 7: Pointe pseudo-Levallois retouchée. 8: Éclat avec des traces d'utilisation. 10: Racloir transversal avec base amincie bifacialement. 11: Outil bifacial. 12: Racloir bifacial présentant une double patine. Les points gris indiquent les traces d'usure illustrées sur la Fig. 9.

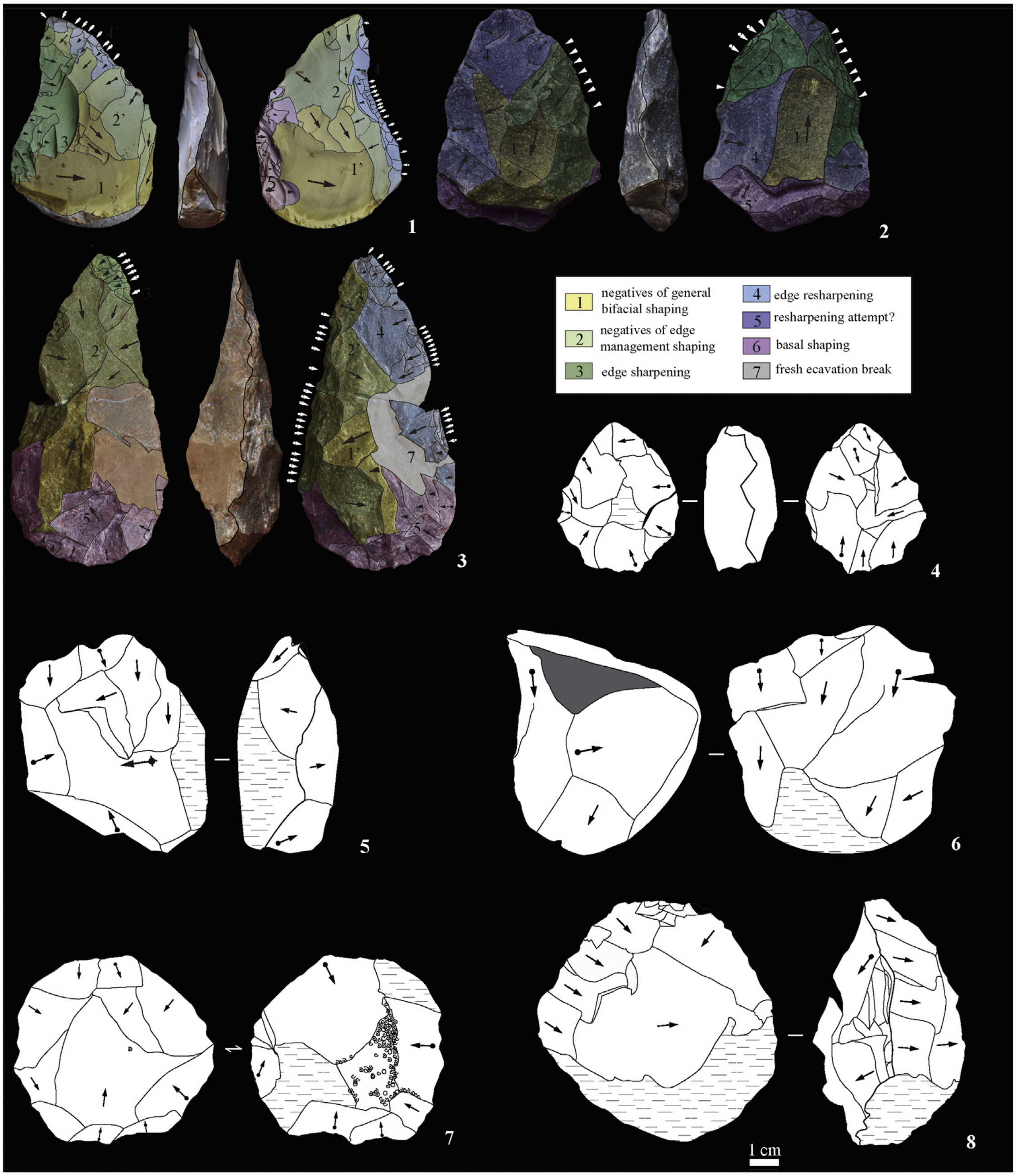

Fig. 8. Technological interpretation of Gruta da Aroeira lithics. 1–3: Bifaces. 4–8: Cores.

Fig. 8. Schémas diacritiques interprétatifs de l'industrie de la Gruta da Aroeira. 1–3: Bifaces. 4–8: Nucleus.

modifications were probably intent on adequating the general morphology of the tool subsequent to episodes of re-shaping or edge re-sharpening.

Most bifaces are small (average length = 90.6 mm), which could be due to one of two factors: (1) they represent the final stage, before discard, in the life of the tool; or (2) they were made small to begin with. Apart from a single flake fragment that might be a by-product of bifacial thinning but whose platform is missing, thus preventing unambiguous identification, no quartzite flakes related to bifacial reduction were identified. The platforms of some flint flakes bear knapping-related stigma indicative of soft percussion. These flakes may well represent by-products of bifacial thinning indicative of on-site re-shaping or re-sharpening. The original manufacture of the bifaces, however, clearly occurred off-site.

4.3.3. *Retouched flake tools*

Flake tools (Table 5; Fig. 7) represent 16% of the total assemblage (but 30% among flint). The majority of these

Table 5
Retouched tools classified by typological category.
Tableau 5
Classification typologique de l'outillage retouché selon les types de matière première.

	Quartzite	Quartz	Flint	Lidite	Total	%
Scrapers	23	5	4	–	32	50.0
Lateral sidescraper, straight	6	2	–	–	8	12.5
Lateral sidescraper, convex	4	1	1	–	6	9.4
Lateral sidescraper, thinned	2	–	–	–	2	3.1
Transversal sidescraper	2	1	–	–	3	4.7
Transversal sidescraper, thinned	1	–	–	–	1	1.6
Bifacial sidescraper	2	–	–	–	2	3.1
Bifacially thinned sidescraper	1	–	2	–	3	4.7
Double sidescraper	1	–	–	–	1	1.6
Double sidescraper, alternate	1	–	–	–	1	1.6
Double sidescraper, convergent	1	1	–	–	2	3.1
Multiple sidescraper	1	–	–	–	1	1.6
Sidescraper–denticulate	–	–	1	–	1	1.6
Sidescraper fragment	1	–	–	–	1	1.6
Denticulates and notches	3	4	1	–	8	12.5
Denticulate	2	4	1	–	7	10.9
Notche	1	–	–	–	1	1.6
Other	3	3	1	–	7	10.9
Endscraper	–	1	1	–	2	3.1
Retouched flake	2	2	–	–	4	6.3
Core–tool	1	–	–	–	1	1.6
Bifacial tools	13	–	3	1	17	26.6
Biface	12	–	3	–	15	23.4
Bifacial tool fragment	1	–	–	–	1	1.6
Cobble tool	–	–	–	1	1	1.6
Total	42	12	9	1	64	100.0
%	65.6	18.8	14.1	1.6	100.0	

tools are single scrapers whose lateral edges have been modified by direct retouch, but five scrapers present bifacial retouch. Several specimens present proximal removals, probably intended to remove the bulb and reduce the thickness of the blank — which may relate to hafting, even though use-wear analysis did not detect direct evidence to that effect. Denticulates are the second most numerous category and the only one in which quartz outnumbers flint and quartzite.

4.4. Use-wear

As a rule, edges and surfaces are well preserved, facilitating use-wear analysis in reliable analytical conditions, in particular with regards to the identification of microscopic use-wear traces. Of the 27 artefacts examined (11 bifaces, 15 flakes and one core), 16 presented recognizable use-wear evidence (Table 6 and Supplementary Figures 1–6). The nature of the worked material can be inferred for five bifaces, four flakes and the core.

In some cases, the degree of development of the use-wear traces and their features were insufficient to securely determine either the nature of the worked materials or that of the working motions. For four bifaces and two flakes we could only make inferences about the hardness of the contact material — these pieces present use-wear associated with work on hard materials, such as wood, antler or bone — and for two bifaces and one flake it was not possible to determine the type of working motion. Where it was possible to identify worked materials and motions, use-wear traces are mostly suggestive of wood processing activities, and of several types of motion: percussion, longitudinal, and transversal.

Table 6
Use-wear analysis results.
Tableau 6
Résultats de l'analyse tracéologique.

	Bifaces	Flakes	Cores	Total
State of preservation				
Good	11	15	1	27
Weathered	–	–	–	–
Use–Wear				
Present	8	7	1	16
Number of utilized zones	9	7	1	17
Wood–working, motions				
Longitudinal	3	1	–	4
Transversal	–	3	1	4
Percussion	2	–	–	2
Indeterminate	–	1	–	1
Hard material, motions				
Longitudinal	1	2	–	3
Percussion	1	–	–	1
Indeterminate	2	–	–	2

Tasks potentially related to percussion on wood are observed on two bifaces (Fig. 6.8, 7.1) in which polish is associated with crushing and abrasion of the used edge (Fig. 9.8 and 9.11–12). A further three bifaces (Fig. 6.2, 6.9) present use-wear on their lateral edges indicative of wood cutting (Fig. 9.3–9.4, 9.9–9.10). Two bifaces (Fig. 6.3–6.4) present evidence of the processing of hard materials; for these two artefacts the working motion remains undetermined (Fig. 9.5–9.7).

Five flakes used for woodworking present numerous scars. Two of them present scars along both

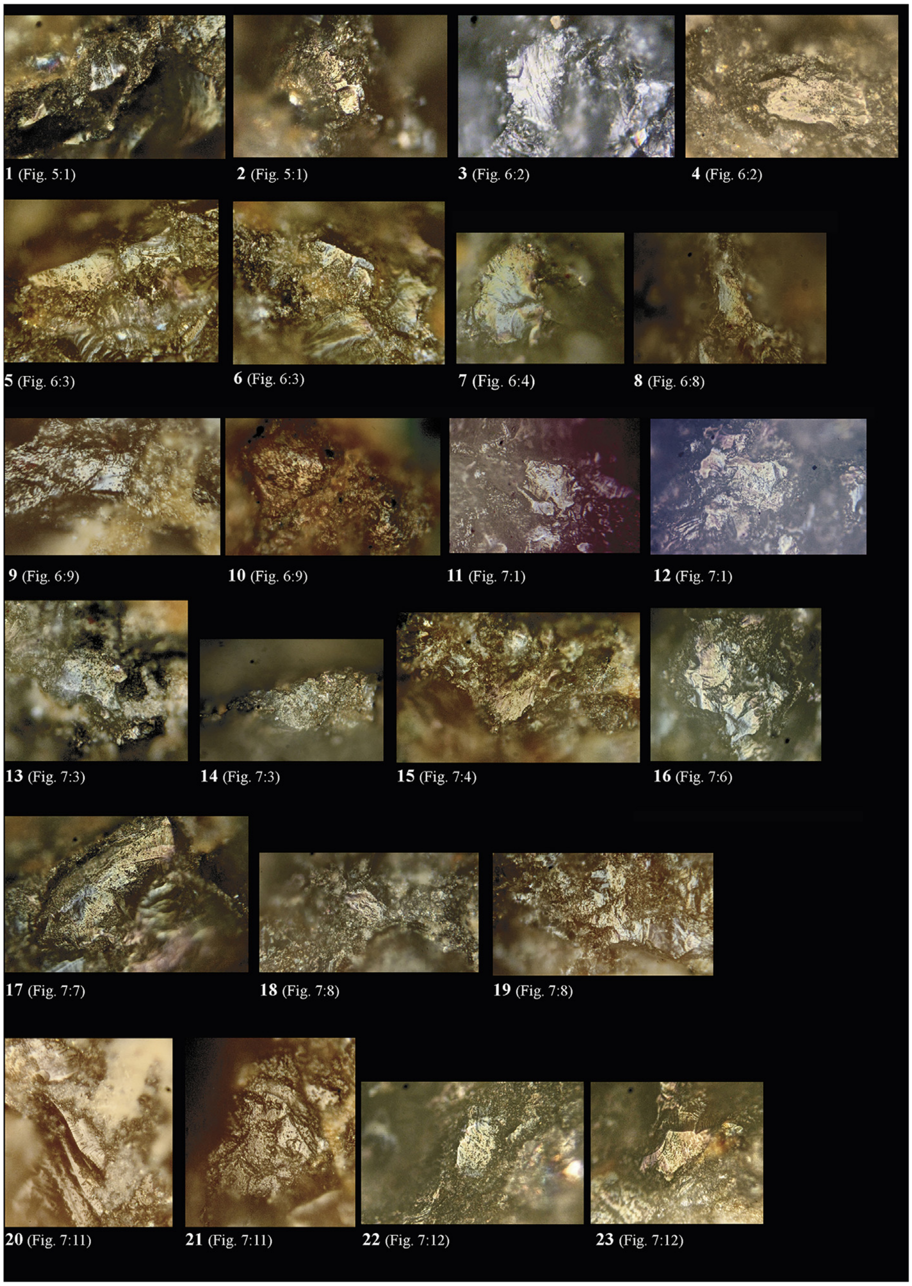

Fig. 9. Microscopic detail of use-wear evidence (images at 200× magnification). 1–2: Core with evidence of use-wear resulting from wood scraping. 8, 11–12: Evidence of wood polish resulting from a percussion motion. 3–4, 9–10: Bifaces with evidence of wood sawing. 5–7: Bifaces with use-wear from working of hard materials with undetermined motion. 15, 17: Flake and retouched flake used to scrape wood. 16: Retouched flake used to saw wood. 18–19: Flake with evidence of wood scraping. 22–23: Flake with wood polish made resulting from an undetermined motion. 13–14, 20–21: Flakes showing polishes associated with numerous scars on both sides of the active edges, indicating work on hard materials with a cutting motion.

Fig. 9. Détail microscopique des traces d'usure (images à un grossissement de 200×). 1–2: Nucléus présentant des traces de raclage de bois. 8, 11–12: Exemple d'un poli de bois résultant d'une utilisation en percussion. 3–4, 9–10: Bifaces avec des traces de sciage de bois. 5–7: Bifaces portant des traces d'utilisation liée à un mouvement indéterminé sur des matériaux durs. 15, 17: Éclat et éclat retouché utilisés pour racler du bois. 16: Éclat retouché utilisé pour scier du bois. 18–19: Éclats avec traces de raclage de bois. 22–23: Éclat portant un poli de bois résultant d'un mouvement indéterminé. 13–14, 20–21: Éclats portant des polis associés avec de nombreuses stries sur les deux côtés des tranchants actifs, indiquant des mouvements de découpe sur des matériaux durs.

sides of the active edge, consistent with longitudinal motions such as cutting/sawing (Fig. 9.16). Three other present scars along just one side of the used edge (Fig. 7.4, 7.7–7.8), typical of a transversal motion such as scraping (Fig. 9.15, 9.17–9.19). For one flake presenting wood polish (Fig. 7.12), the nature of the gesture could not be inferred (Fig. 9.22–9.23). Two flakes (Fig. 6.7.3, 7.11) presenting scars on both sides of the used edges were employed to cut hard materials (Fig. 9.13–14 and 9.20–9.21).

One core (Fig. 5.1) was examined to determine whether it would also have been used as a tool. On a section of the edge, it revealed evidence of contact with wood in a scraping motion (Fig. 9.1–9.2). This evidence suggests that cores could have been opportunistically used as tools.

With the exception of one biface, which presents evidence of use on various edges, only one edge was used per tool. Rots and Van Peer (2006) and Beyries (1987a) have reported hafting in late middle Pleistocene and Middle Palaeolithic contexts but, given the size of the stone tools in our assemblage and the fact that no traces of the practice were found, it seems most likely that they were hand-held.

5. Discussion

5.1. Industrial context

Gruta da Aroeira is one of the few middle Pleistocene cave sites known in Europe that contain a well-preserved and *in situ* Acheulean toolkit as well as faunal and human remains. All other Acheulean sites in the Atlantic façade of Iberia are found in fluvial or lacustrine contexts, mostly river terraces and palaeolakes (Cunha-Ribeiro, 1999; Méndez-Quintas et al., 2008; Raposo and Santonja, 1995; Santonja and Villa, 2006). Most of these open-air sites have not been directly dated, but recent studies conducted on the terraces of the Tagus and Douro rivers have begun to provide a reliable chronological framework (Cunha et al., 2017; Silva et al., 2017).

In other parts of the Iberian Peninsula, most sites are also found in fluvial contexts with varying degrees of preservation. Some of the better preserved sites are located in low energy deposits. This is, for example, the case with Torralba, Ambrona and Áridos (Santonja and Pérez-González, 2006; Santonja and Querol, 1980; Santonja and Villa, 2006; Villa, 1990). Karst sites containing industries of a similar age are rare in SW Europe: Galería and Gran Dolina in Atapuerca (García-Medrano et al., 2015), Cueva de Santa Ana (Carbonell et al., 2005), Cueva del Angel (Barroso Ruíz et al., 2011), and Caune de l'Arago (Barsky, 2013). While Arago, Santa Ana and Cueva del Angel functioned as living spaces, Galería is a natural trap accessed by both humans and carnivores to exploit herbivore carcasses.

The Gruta da Aroeira lithic assemblage is broadly in line with those reported from other Iberian middle Pleistocene industries (Santonja and Pérez-González, 2010). The provision of raw materials is local in the case of quartz and quartzite, while flint artefacts come from > 10 km away and were imported as retouched tools or bifaces. Centripetal cores with a bipyramidal organization, sometimes set-up on flake blanks, and the unipolar, on-anvil reduction are also found at coeval sites (Barsky, 2013; García-Medrano et al., 2015). As elsewhere, we found no Levallois flakes or cores. Whether the small size of the bifaces relates to functional considerations, raw-material economy, or deliberate choice, remains to be clarified, but suffices to exclude comparison with the LFA (Large Flake Acheulean) facies as recently described in Galicia (Méndez-Quintas et al., 2018).

A particular aspect of the Gruta da Aroeira assemblage, rarely documented in middle Pleistocene industries, is the proximal thinning of scrapers. Marks et al. (2002) also provide examples of bifacial preparation or sharpening of scrapers, following a method well-known in the *Keilmesser-gruppen* of central Europe, but we found no comparable items in our much smaller excavation. Given the limited number (eight) of such items and bearing in mind the difference in the size of the excavated areas (60 m^2 in 1997–2002 vs. 6 m^2 in 2013–2015), sampling bias is the parsimonious explanation for this discrepancy.

García-Medrano et al. (2015) have recently proposed an evolutionary scheme for the technological characteristics of lithic industries at the site of Galería (Atapuerca). By comparison, the Gruta da Aroeira industry would seem to be most similar to that in Galería's level GIIIa, in which, however, a smaller proportion of bifacial tools (< 5% of the artefacts) is observed. In both contexts, the bifaces are imported as finished tools. However, there is one striking difference: neither in our sample nor in that from the 1997–2002 work (Chabai et al., 2001; Marks et al., 2002) have flake cleavers been found at Gruta da Aroeira.

In the Caune de l'Arago sequence, technological change through time differs from that described in Galería. For example, bifaces, numerous and finely worked in level P (assigned to MIS 14), are absent from levels K–H, and reappear in level G, but with more irregular forms (Barsky, 2013). Centripetal and Clactonian flaking increase in level G, which also sees a diversification of tool types. With a mean age estimate of 438 ± 31 ka, this Caune de l'Arago level G is broadly coeval with Gruta da Aroeira.

In the Iberian Acheulean, the use of large flakes as blanks for bifaces and cleavers has been interpreted as representing diffusion from the North African Acheulean via the Strait of Gibraltar (Santonja and Pérez-González, 2010; Sharon, 2011). However, that use is variable, as can be seen in the Galería sequence, in the basal levels of which bifacial tools are exclusively made from cobbles. According to García-Medrano et al. (2015), the use of large flakes as blanks in the upper levels can be considered a successful adaptation to local raw materials. The technological decisions taken by Acheulean populations would certainly have been the result of multiple environmental, functional, and cultural factors, and examples of local adaptation to a specific mineral environment are documented at Grotte de l'Observatoire, where the large flake technology is recorded (Porraz et al., 2014). Indeed, technological convergence rather than diffusion has been proposed to explain aspects of the recently described reduction sequences of Victoria West and Tabelbala-Tachenghit (Lycett, 2009b; Mourre et al., 2016; Sharon and Marder, 2016).

The absence of flake cleavers in the Gruta da Aroeira assemblage is remarkable given that their distribution usually coincides with that of bifaces. Santonja and Villa (2006) claim, however, that their presence is more common in regions with abundant large quartzite cobbles, while Santonja and Pérez-González (2010) and Sharon (2011) argue that their distribution in Europe may be related to migrations from Africa. Flake clavers are present in the fluvial terraces of the Tagus (Cunha-Ribeiro, 1999), and they are found in the late MIS 5, Middle Palaeolithic levels of

Gruta da Oliveira, another site of the Almonda karst system (Deschamps and Zilhão, 2018). The absence of flake cleavers in the Gruta da Aroeira assemblage thus cannot be explained by raw material constraints and, given the area and volume of the Gruta da Aroeira excavation, it cannot be explained by sampling bias either.

It has been suggested that cleavers were manufactured for a specific function (Freeman, 1966, 1969), while other authors propose that they were used in a wide range of activities (de la Torre et al., 2014; Rios-Garaizar, 2012). The few use-wear analyses of cleavers point to power-hitting and chopping actions in the case of Acheulean specimens (García-Medrano et al., 2014; Ollé, 2003), and to cutting or percussion in heavy-duty activities in the case of Middle Palaeolithic ones. Experimental analyses have shown that cleavers are likely to have been hafted and used to fell trees and split carcasses (Claud et al., 2015). Since the overall features of the archaeological context suggest that Gruta da Aroeira was a living place, it is unlikely that such kinds of activities were not carried out in the context of the occupation of the site. Hence, the lack of cleavers in the stone tool assemblage can hardly be explained by functional factors either.

At this stage of our research, the parsimonious explanation would therefore seem to be that cleavers were not in use during the phase of the Acheulean tradition represented in the Gruta da Aroeira assemblage. This hypothesis is in line with the fact that recent dating work conducted at Galería suggests that its Acheulean industries are more recent (between ~363 and 220 ka) (Demuro et al., 2014; Falguères et al., 2013) than Aroeira's.

5.2. *Behavioural inferences*

The Gruta da Aroeira assemblage features a level of raw material diversity comparable to that seen in the Middle and Upper Palaeolithic sites of the Almonda karst system (Aubry et al., 2016, 2014; Gameiro et al., 2008; Matias, 2016). This diversity mirrors the petrographic composition of the siliciclastic deposits of the Tagus basin, from where raw material was procured, as clearly illustrated by the well-rounded cortex surfaces associated with an epigenetic mineralization attributable to the basin's iron-rich soils (Fig. 3.2).

However, the exclusive use of Cretaceous flint (and possibly of silcrete, found in the same secondary deposits and, therefore, in the same areas) contrasts with the flint procurement patterns seen in the Middle and Upper Palaeolithic sites of the Almonda system. Both at the Magdalenian site of Lapa dos Coelhos and the Mousterian site of Gruta da Oliveira, local and regional Jurassic flints (Bajocian and Oxfordian), as well as Cretaceous flint, were employed, albeit in different proportions. The same pattern is also observed at the regional level. For instance, at the Gravettian open-air site of Terra do Manuel, located close to Cretaceous flint sources, Jurassic flint sources lying at distances of up to 40 km (Bajocian) and > 60 km (Oxfordian) as the crow flies are also represented (Aubry et al., 2012).

Thus, while the Mousterian and Upper Palaeolithic occupants of the Almonda system procured their flint in both the lowlands of the Tagus basin (containing quartz, quartzite, silcrete and Cretaceous flint) and the highlands of the adjacent Limestone Massif (where the Jurassic flint sources are located), the Gruta da Aroeira Acheuleans only used sources in the former. In Portugal, a pattern of flint being little used and mostly imported in the form of retouched tools tends to be found whenever it occurs neither locally nor regionally and has to be imported from distant territories, as exemplified by a number of Upper Palaeolithic sites (Aubry and Mangado Llach, 2003a, 2003b; Aubry and Mangado, 2006; Aubry et al., 2016, 2012, 2004). This is not the case with Gruta da Aroeira. Here, given the site-to-source distances involved (< 10 km), the pattern suggests that raw material procurement was embedded in daily subsistence activities and that these activities remained restricted to the lowlands of the Tagus plain (Binford, 1979, 1980).

Lower Palaeolithic heavy-duty tools such as bifaces have frequently been linked with woodworking tasks in which they would have been used as adzes or shaving tools (Anderson-Gerfaud, 1990; Aranda et al., 2014; Beyries, 1987a, 1987b, 1988, 1993; Hardy and Moncel, 2011; Márquez et al., 2001; Ollé and Vergès, 2008; Ollé et al., 2014; Rots, 2013). In the Middle Palaeolithic, however, bifaces were used primarily for butchery (and, occasionally, as retouch hammerstones), as shown at the site of Jonzac (Claud, 2012); in this later period, therefore, bifaces do not seem to have been functionally distinct from unretouched flakes, whose sharp edges have been linked to cutting motions, in particular to the processing of soft materials during butchery (Claud, 2015; Clemente-Conte et al., 2015; Márquez et al., 2016).

Bearing in mind the limited size of the assemblage, our preliminary results for the Gruta da Aroeira bifaces are consistent with the Acheulean rather than the Middle Palaeolithic pattern, even though, dimensions-wise, our sample resembles that latter because of the many small specimens. The Gruta da Aroeira bifaces were also used in woodworking tasks, and the range of activities otherwise identified at Gruta da Aroeira by use-wear analysis is also dominated by wood processing. However, the faunal remains are anthropogenic, so some of the tools for which the material worked on could not be diagnosed beyond "hard" may well have been used on bone.

The fragmentation of the faunal remains, the presence of cut marks in the bone assemblage, the number of stone tools retrieved and the identification of on-site reduction sequences suggest that the cave was used as a residential space and suggest continuous occupation of the area through the time frame represented by the deposit.

5.3. *Human paleontological implications*

The paleoanthropological and archaeological records are inherently noisy: the uncertainty intervals of dating methods are wide, and the units of stratigraphy we work with are for the most part palimpsests compressing unknown amounts of time and unknown amounts of behavioural diversity. This situation complicates any discussion of possible links between human biology, hominin taxa, cognitive capacities, stone tool technology, symbolic behaviour, and the consumption of natural resources. Even so, many scholars have proposed that, at several key-points in the human evolutionary process, the changes or innovations seen in the archaeological record go hand-in-hand with changes in the biology, or the identity, of its makers. Examples thereof concern the emergence of stone tool making in Africa (e.g., Harmand et al., 2015; McPherron et al., 2010), the human taxonomy of the bearers of the Acheulean tradition (McPherron, 2000; Stout et al., 2014, 2015), or the emergence of the Upper Palaeolithic in Europe (Benazzi et al., 2015; Peresani et al., 2016).

Based on current evidence, bifaces did not appear in Europe until 550–650 ka, and widespread, continuous occupation of the European continent probably did not happen until that time. Several hypotheses have been constructed to explain this watershed (Hublin, 2009). For example, Carbonell et al. (1999) suggest that the arrival of the Acheulean in Europe can be related to demographic growth in the Rift Valley regions of Africa. This would imply either the arrival in Europe of populations of African origin making the so-called “Developed Mode 2” industries, or the establishment at this time of regular channels of cultural diffusion linking Europe with Africa. Based on the Italian evidence, Villa (2001), however, argues against two different migration events at the origins of the human settlement of Europe (i.e. initially, by bearers of the Oldowan, later on by bearers of the Acheulean), and claims that the main reason for the variability seen in European Lower Palaeolithic industries lies in the adaptive flexibility of hunter-gatherer populations.

More than 80 years since the migration vs. diffusion dichotomy emerged in the context of attempts to explain the difference between the Lower Palaeolithic industries of central Europe and the Russian Plain (without bifaces) and those of western Europe (with bifaces), the debate is still far from being resolved (Lycett and Bae, 2010, Movius, 1944). Due to the similarities between North African and western Mediterranean assemblages, most authors have supported an African origin for the Acheulean of Europe, leading to the proposition that this technological complex reached southern Europe via the Strait of Gibraltar, despite the absence of any direct evidence that such a crossing was feasible or did occur (Bar-Yosef, 2006; Goren-Inbar and Sharon, 2006; Santonja and Pérez-González, 2010; Santonja and Villa, 2006; Sharon, 2011). Others have argued that the handaxe was reinvented in Europe (Nicoud, 2013; Soriano, 2000; Villa, 2001), and that cross-Mediterranean contacts remain unproven until recent prehistoric times (Derricourt, 2005; Muttoni et al., 2010; Straus, 2001).

The relationship between the Acheulean and the putative dispersal into or local evolution of *H. heidelbergensis* in Europe is another point of contention. The middle Pleistocene archaeological record of Europe gives no indication of major movements of people, let alone of massive African immigration. The physical anthropological evidence suggests that European populations of the period were morphological diverse, or that, at this time, humans from both Africa and Europe formed a single clade (Rightmire, 1998; Stringer, 2012).

The number of European sites in which clearly diagnostic human remains are associated with Acheulean lithics being scarce (Arsuaga et al., 2014; de Lumley, 2015; Falguères et al., 2004; Pereira et al., 2015; Stringer and Hublin, 1999; Stringer et al., 1998; Wolpoff, 1980), this issue remains unsettled. As discussed by Daura et al. (2017), however, it has nonetheless been possible to divide the human fossils of the middle Pleistocene of Europe into two groups: one, represented by Atapuerca/Sima de los Huesos (SH) and Swanscombe, belongs to the Neanderthal clade (Arsuaga et al., 2014; Meyer et al., 2016; Stringer, 2012); the other, represented by the Arago hominins, has been attributed to either an incipient stage of Neanderthal evolution (Dean et al., 1998), to *H. heidelbergensis* (Stringer, 2012), or to *Homo erectus tautavelensis* (de Lumley, 2015).

The Aroeira-3 cranium (Daura et al., 2017) adds complexity to this picture because of its contrasting mosaic of features, suggesting that human variability was at this time significantly greater than envisaged by current models. More to the point, the Acheulean technology is associated with the two groups of middle Pleistocene Europeans represented by the Arago and Sima de los Huesos fossils, as well as with the Gruta da Aroeira specimen. This evidence suggests that the middle Pleistocene technological innovations associated with the Acheulean — controlled use of fire, prepared core reduction, projectile weaponry — spread across the European continent irrespective of human palaeontology’s perceived taxonomic boundaries. In addition, the Acheulean contexts that have been considered to present a seal of African origin (e.g., the Galician sites reported by Méndez-Quintas et al., 2018) are significantly later than Gruta da Aroeira, which predates them by > 100,000 years and lacks the corresponding indicators (large bifaces made on large flake blanks, presence of flake cleavers). The Gruta da Aroeira evidence is therefore inconsistent with models postulating African migration through the Strait of Gibraltar as the explanatory mechanism for the emergence of the Acheulean in Europe.

6. Conclusion

Acheulean layer Xb/c of the Gruta da Aroeira, dated at around 400 ka, provides novel information for the behavioural reconstruction of the Middle Pleistocene populations of western Iberia. The multi-proxy data provide the basis for more accurate reconstructions of the lifeways of middle Pleistocene hunter-gatherers than hitherto possible due to the absence of good-resolution, good-preservation archives such as those found in karst environments.

In short, the results presented here suggest that the territory frequented by the Acheulean occupants of Gruta da Aroeira was limited to the lowlands of the Tagus and its tributaries, with raw-material procurement indicating on-site knapping of immediately available sources and on-site discard of finished items brought in from elsewhere and made on flints available > 10 km away. These tools were used in woodworking and, probably, butchering activities.

The association of this lithic assemblage with a human cranium sheds light on the issue of the links between material culture and human morphology. This association adds support to the notion that the emergence and spread of the Acheulean in Europe cannot be tied to a specific taxonomic entity and that it needs to be understood in its own terms — as a cultural/prehistoric development that cannot be reduced to a simple by-product of the evolution, or expansion, of a specific human type.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.crpv.2018.03.003.

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