



## The large flake Acheulean with spheroids from Santa Ana Cave (Cáceres, Spain)

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### ABSTRACT

The Acheulean of the Iberian Peninsula is considered a homogeneous technocomplex within the Large Flake Acheulean (LFA) of northern African origin. In this work, we describe the lithic industry of Santa Ana Cave, interpret the territorial functions of the site and search for its technological parallels. Our results place the lithic industry of Santa Ana within the LFA. This assemblage is characterised by: 1) an association of spheroids and large cutting tools (LCTs), 2) the systematic shaping of handaxes on flakes, and 3) quartz knapping. The lithic industry of Santa Ana is unique in the Iberian Peninsula within a region of broad technological variability masked by the apparent homogeneity derived from the extensive presence of handaxes and cleavers. Outside Africa, the technological features observed in the Santa Ana assemblage have only been documented at a few sites in the eastern Mediterranean, China and India. These features illustrate the homeostasis of the Acheulean technocomplex and the expansion of African groups, including northern African groups, towards the Iberian Peninsula.

### 1. Introduction

The Acheulean in the Iberian Peninsula has been considered a homogeneous technocomplex of northern African origin (Santonja and Villa, 2006; Sharon, 2011; Sharon and Barsky, 2016). This idea has been supported by the recovery of numerous handaxes and cleavers, mainly documented in the fluvial terraces of Atlantic rivers (Santonja and Pérez-González, 2001), and also by the lithic industry of Santa Ana Cave, located in the southwestern Iberian Peninsula (Fig. 1) (Carbonell et al., 2005; Peña et al., 2008). The view of Iberian Peninsula Acheulean as resulting from cultural links has highlighted the similarities between these sites and northern African assemblages such as Errayah and Ternifine (Algeria) (Derradji, 2006; Geraads et al., 1986; Sharon, 2011). The identification of the Large Flake Acheulean (LFA) in the Iberian Peninsula has reinforced these considerations (Sharon, 2010; Sharon and Barsky, 2016).

In spite of the assumed homogeneity of the Acheulean of the Iberian Peninsula, the identification of the Large Flake Acheulean represents a

glimpse at the variability among these assemblages. Furthermore, chronological and techno-cultural data indicate differences compared to the early Acheulean of northern Africa identified at Thomas Quarry-Unit L (1.4–1.2 Myr) (Casablanca-Morocco) (Raynal et al., 2001). Population hiatuses occurred following the first possible evidence of Acheulean in the Iberian Peninsula (Ollé et al., 2016), located in La Boella (960–781 ka) (Vallverdú et al., 2014). The widespread presence of Acheulean in the second half of the Middle Pleistocene is confirmed in sites such as Galería, Aroeira and the middle fluvial terraces of Atlantic rivers. However, these assemblages do not contain typological associations with spheroids, handaxes, picks and cleavers like those of Casablanca (Fig. 1) (Daura et al., 2018; García-Medrano et al., 2014; Santonja and Pérez-González, 2001).

The LFA of the Iberian Peninsula shows variability based on shape standardisation in large cutting tools (LCTs). Not all the assemblages with handaxes contain cleavers like in Aroeira (Daura et al., 2018). Moreover, the importance and technical use of large flakes (>100 mm) varies. The structure of the operational sequence for the production of

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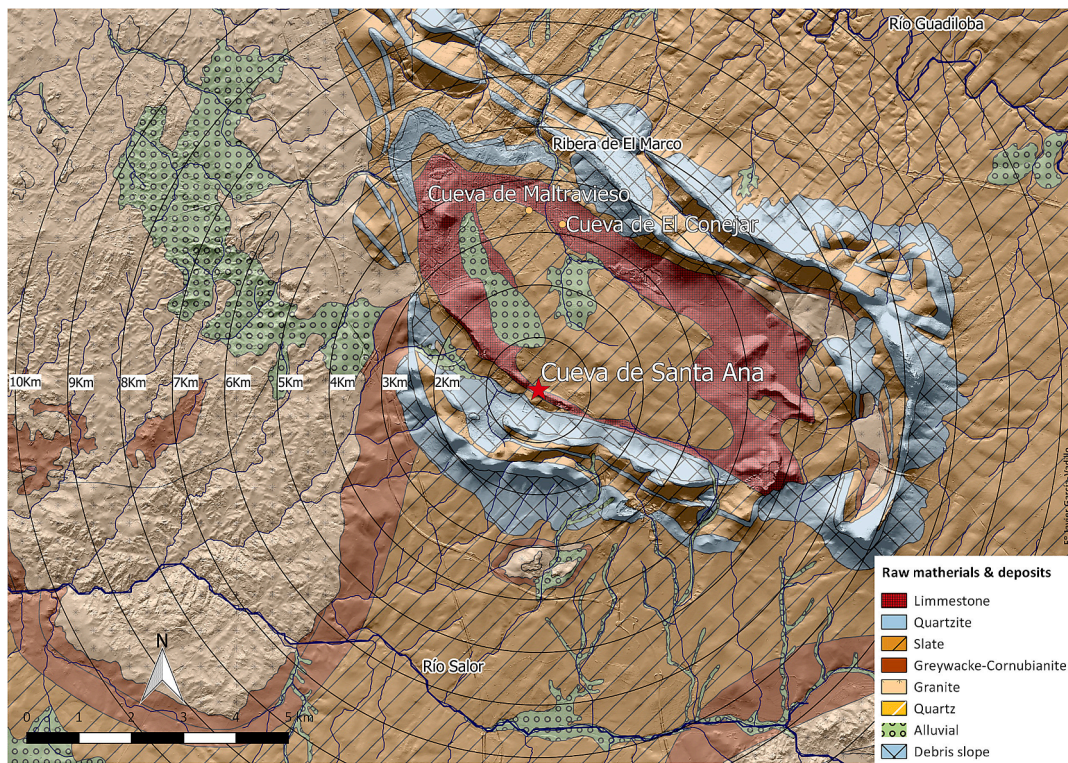


Fig. 2. Potential procurement areas for lithic resources in the Penillanura de Cáceres and their distances from Santa Ana.

materials available in the territory. Within a 0–5 km radius of Santa Ana a wide morphological and petrological variability of raw materials can be found.

### 2.1. Stratigraphy and materials

Santa Ana Cave contains sedimentary deposits inside and in the current entrance area (Fig. 4, Fig. 5). This entrance is the main entry point for sediments and has an excavated area of about 20 m<sup>2</sup> with a depth of 13 m. The lowest area of the cavity is situated to the south, inside, where there is a 2 m<sup>2</sup> test pit and a 30 m<sup>2</sup> excavation area, where a sedimentary sequence containing both faunal and lithic remains has been documented.

The units identified at the entrance are the Pleistocene breccias, dated prior to the MIS 5 (Ur/Th 112 ± 8 Ka) (Carbonell et al., 2005), the cut-and-fill sediment and Unit 8 (Fig. 4C, Fig. 5). Unit 8 is located at the top of the sequence. These are breccias with non-Acheulean archaeological materials. The *Pleistocene breccias* are at least 7 m thick. It is a huge unit of carbonated sediment with blocks, limestone and quartz gravel in a clay matrix. They also contain part of the lithic industry of Acheulean, the subject of this work. These breccias have vertical and horizontal fractures produced after the erosive-depositional process of the *cut and fill* (Fig. 5). This process affected the Pleistocene breccias by eroding and transporting sedimentary materials and blocks of breccias through cracks and dissolved spaces. Faunal remains and lithic industry from the Pleistocene breccias are found among these sediments.

The faunal record of the Pleistocene *breccias/cut-and-fill* (N = 440 approximately) include taxa of cervidae, equidae, hyaenidae, rhinocerotidae and mammals of different sizes. The osseous material shows scarce anthropic modifications. The fracturing of bones through percussion is practically non-existent (2 remains out of a total of 150, campaigns 2001–2007 (Rodríguez-Hidalgo, 2008)).

The lithic assemblage analysed in this work comes from the Pleistocene breccias and cut-and-fill units (defined above) including 578 objects recovered through test pits and the meticulous excavation of

concentrations of materials in the breccias. The handaxes, cleavers and spheroids were located at the same sedimentary units and were identified in parts of the sedimentary sequence not affected by the cut and fill process (Fig. 5, Fig. 6).

### 3. Methods

The analysis of the lithic industry of Santa Ana took into consideration the techno-typological objectives of the operational sequences and their structure: raw materials and blanks (flakes or pebbles) (Table 1) (Carbonell et al., 1983; Carbonell et al., 1992). The raw materials were classified into large groups: quartz, quartzite and ‘other rocks’ (greywackes/metagreywackes/metaquartzites). The potential procurement areas were established through the roundness (rounded or angular) and the sphericity (high or low) of the cortical surfaces (Fig. 3b) (Powers, 1953). The dimensions were described, parametrised and classified as large (>100 mm), medium-sized (61–99 mm) and small (0–60 mm).

The unknapped stones were grouped according to their possible link to a percussion activity (percussive material) or to the supply of raw materials (manuports). The percussive material includes items with marks consistent with this activity (stigmas, strikes and flake scars) and objects with morphological similarities. Observations of the percussive material included the morphologies and surfaces used; aspects that could be related to different potential uses (Chavaillon, 1979; Sánchez Yustos et al., 2015).

The flakes include complete products, fractured and fragmented flakes. The percentages of dorsal corticality were described, linking them to the operational sequences. The butts exhibited differences between cortical and non-cortical surfaces. Faceting and delineation were described for the butts with non-cortical surfaces in order to observe possible preparation and the morphology of the hammered surfaces.

The core reduction strategies were defined from the faciality (the number of faces or flaking surfaces that have been the subject of exploitation), polarity (location of percussion platforms) and arrangement of the flake scars and their variability: knapping technique

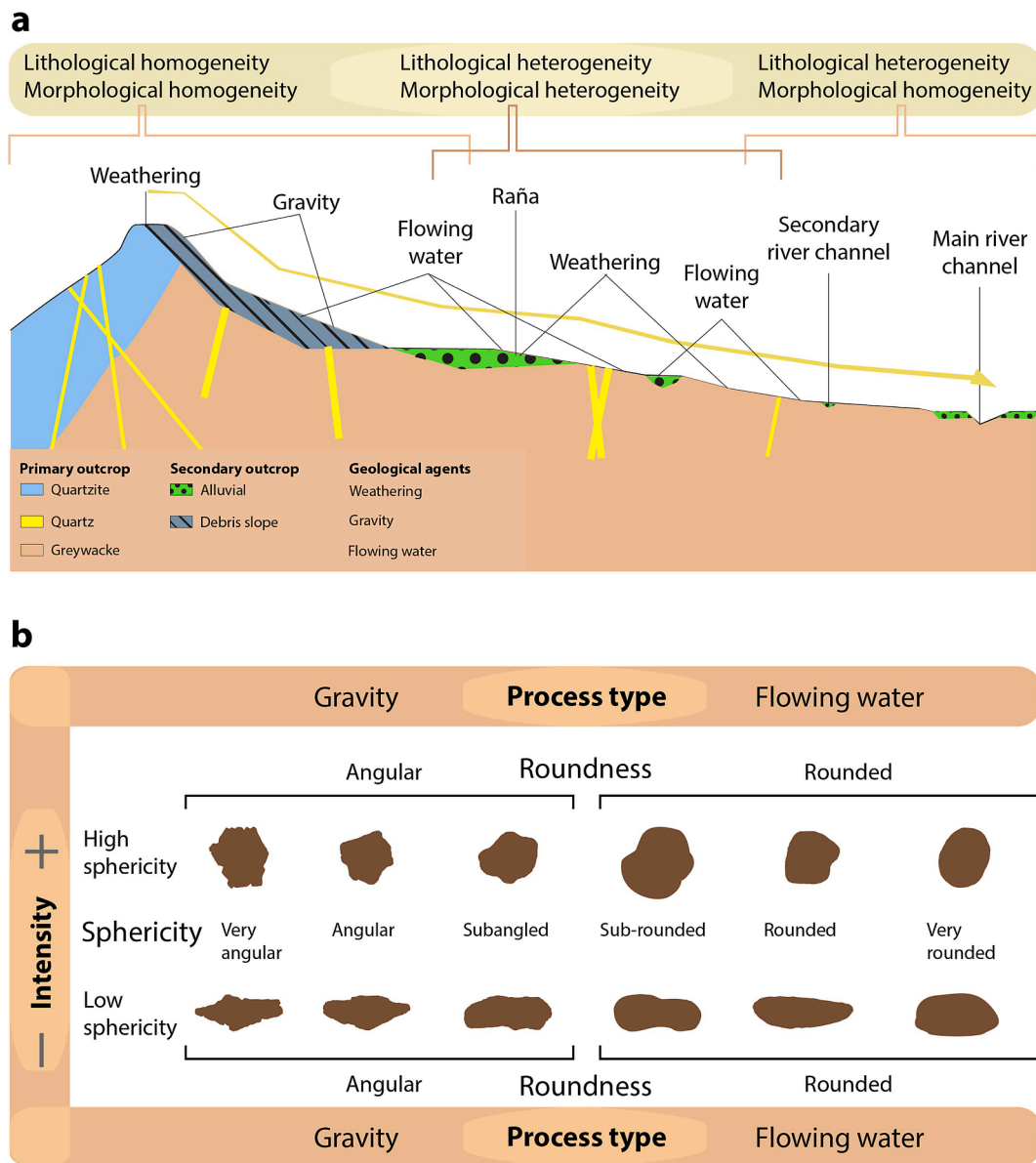


Fig. 3. A: model of the lithological and morphological composition of the blocks in the deposits of the potential lithic resource procurement areas. B: cortical morphologies (sphericity and roundness) (Powers, 1953) relating to the type and intensity of the geological processes involved in the formation of the outcrops.

(freehand or bipolar percussion on anvil technique), knapped perimeter and knapping angles. The development phase of the reduction sequences on cores was also evaluated as initial (opening and cortex removal phase), middle (surface removals without or with a minimum cortex surface) or final (cores with significant volumetric reduction).

The shaped tools were classified into broad techno-typological categories insofar as they comprised objects with technical, shape and morpho-potential similarities. The handaxes (Kleindienst, 1962), picks (Kleindienst, 1962) and cleavers (Tixier, 1956) form the large cutting tools (LCTs) group.

The polyhedrons, subspheroids and spheroids (Leakey, 1971) are grouped into spheroids category. We consider these objects as the result of operational sequences to shape spherical volumes (Sánchez Yustos et al., 2015; Tixier and Roche, 1997). We exclude from this group elements with natural spherical shapes. Their possible involvement in percussion activities and links to operational sequences were described.

The technical attributes of the retouched flakes were analysed, and finally they were classified into large techno-typological groups (Laplace, 1972): denticulate, side scraper, notch, point.

#### 4. Results

The lithic assemblage (N = 578) has a heterogeneous composition (Table 1). Quartz was the most-used raw material (69%). There is no clear polarisation of technical activities according to the distribution of objects in large structural categories (Table 1); flakes are in abundance (36%), albeit with a very low percentage compared to cores (15%) and shaped tools (20%). Percussion tools (24%) are very abundant.

##### 4.1. Raw materials, technical use and potential procurement areas

The presence of manuports suggests raw material was supplied through the transport of blocks (N = 19, 3%, Table 1) with broad dimensional and morphological variability (length 62–185 mm, Fig. 7, Fig. 8). Most manuports are blocks of quartzite (N = 11). Cortical development on the quartz manuports (N = 7) distinguishes these elements from the quartz blocks detached from the calcareous conglomerate of the cave.

The lithic materials have different characteristics and technical uses.

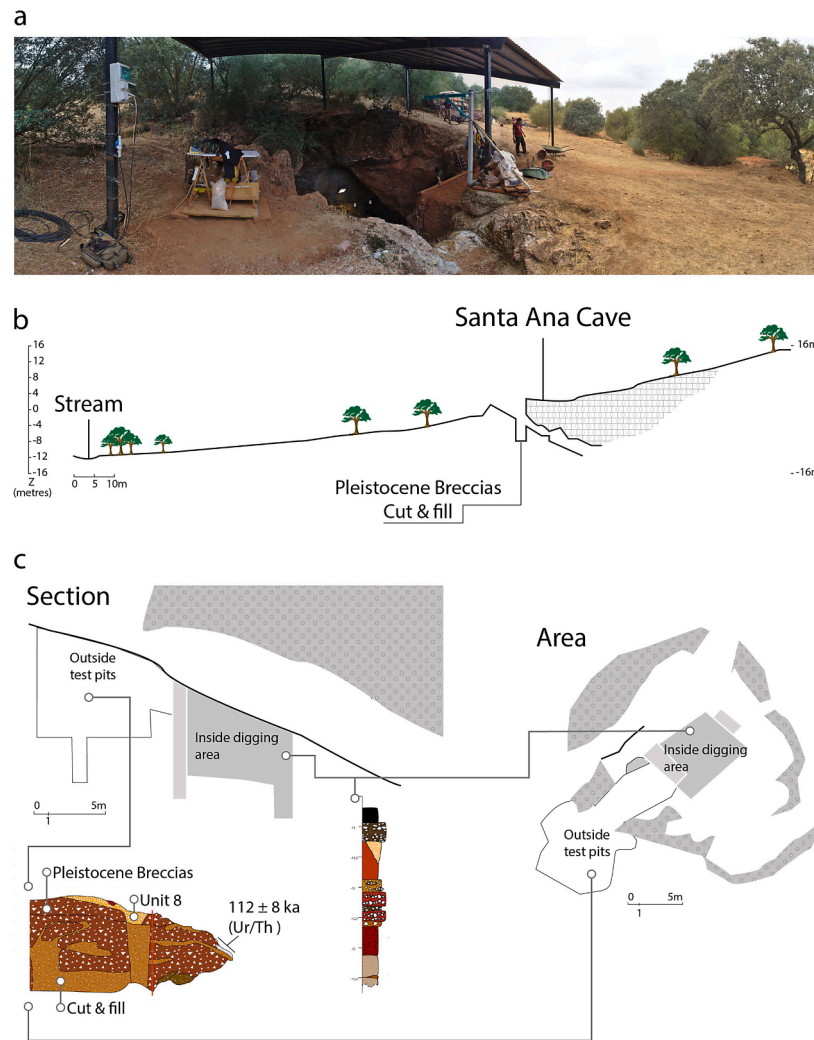


Fig. 4. Entrance to Santa Ana Cave (a), location relative to the stream (b), excavation area and stratigraphic origin of the materials analysed (c). Designed from the topographic work of Raquel Pérez (b and c) and the stratigraphy of Isidoro Campaña (c) (Campaña Lozano et al., 2018).

The roundness and sphericity of cortical surfaces is varied, with differences between materials of a same class and also between quartz and quartzite (Table 2).

In quartz, variation in the size of the crystals, planes of weakness and geodes indicate a high anisotropy and, therefore, a poor aptitude for knapping. In spite of these characteristics, quartz was routinely used, above all for core reduction (flakes 44% and cores 18%) and percussion (22%, Table 1). Quartz with rounded morphologies linked to alluvial environments is rare (34%, Table 2). Angular surfaces with low sphericity dominate (66%,  $N = 192$ ) especially in cores and flakes ( $N = 119$ ). The remains of shale as a host rock indicates a supply close to the primary outcrops, possibly in the vicinity of the cave.

Quartzite (28%) has a good aptitude for knapping. Some present variable proportions of silica and schistosity planes. It was mainly used for shaping (40%, Table 1). Highly spherical rounded elements link the procurement of the quartzite to mainly alluvial environments (67%, Table 2), and above all correspond to percussion items (39 out of 72 cases). Of note is the scarcity of low sphericity items (33%) given the proximity of gravitational deposits (Fig. 2).

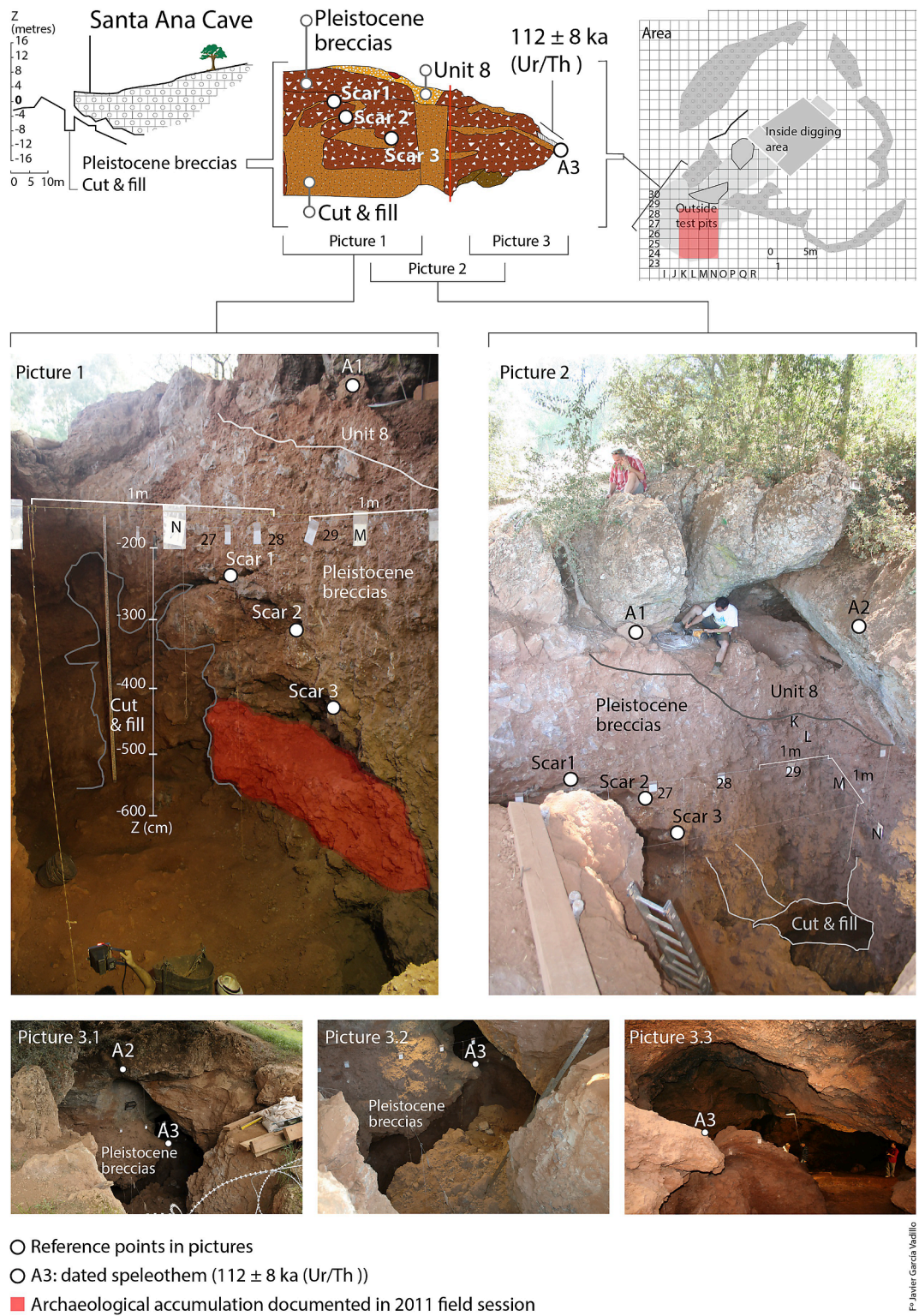
The "other rocks" group (2%) is mainly made up of greywackes. These are fine grain and homogeneous materials. They have a lower proportion of silica than quartzite although their suitability for knapping is good. They appear in the assemblage as percussion items (50%) and shaped flakes (33%, Table 1). The rounded shapes marginally link these materials to alluvial environments (Table 2).

#### 4.2. Percussive material

The most abundant percussion elements are pebbles ( $N = 141$ , Table 1) of highly variable shapes and sizes (Fig. 8, Fig. 7). They have three basic morphologies: parallelepiped, oval and mixed. The parallelepiped and mixed blocks diverge from the oval ( $N = 48$ ), rounded and massive shapes, with regular convexities more suitable for knapping. Quartzite was the most-used material for the oval shapes (50%). The majority of blocks with mixed shapes are angular, and have dihedral and convex edges and partially convex surfaces that mimic the morphology of the oval stones.

A size selection process was detected for these objects, even though the length varies greatly and some objects exceed 5 kg (49–230 mm, Fig. 7). The selected preferences for length limit 50% of these objects to a range between 80 and 105 mm.

This morphological and dimensional diversity reflect a broad range of potential uses and activities in addition to knapping. Most of these objects show percussion marks, fractures and flake scars, indicating abatement actions on rocks. This highlights the absence of use traces in stones transported from alluvial environments ( $N = 31$ , Fig. 8a). This intake of apparently unused stones contrasts with the use of cores and flakes ( $N = 4$ ) as percussive items and the existence of spheroids with percussion marks.



F. Javier García-Vadillo

**Fig. 5.** Location of the sedimentary units and dated speleothem in the entrance area of Santa Ana Cave. Designed from the topographic work of Raquel Pérez (b and c) and the stratigraphy of Isidoro Campaña (c) (Campaña Lozano et al., 2018).

### 4.3. Cores

Reduction activity (N = 87) was mainly carried out using quartz (N = 73). The blanks were mainly pebbles (N = 81) and some flakes (Table 1, Fig. 9). The cores mostly provided small and medium sized flakes (average technical length 68 mm), although they have a broad dimensional range (Fig. 7). Only 16 cores, two of which are on flake,

have a length > 100 mm along the axis of percussion. However, the length and width of the flake scars in no case indicate large format production.

The cores were frequently abandoned during an initial phase of reduction (N = 66, 78%), above all those of quartz (N = 63). Only three of the 14 quartzite cores were recovered in an initial reduction phase. No intensely exploited cores have been documented. This scarce knapping

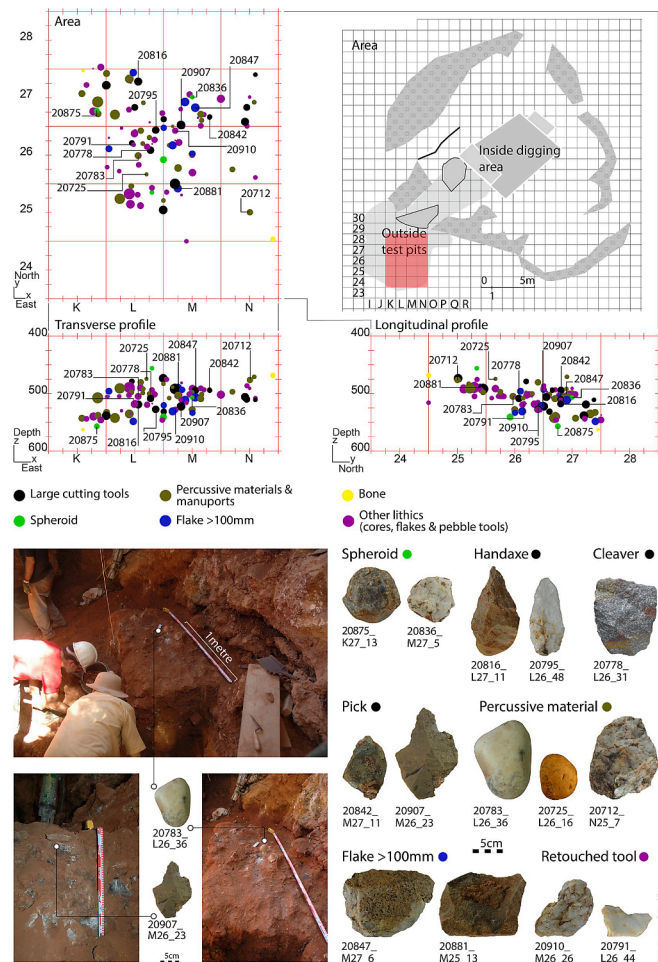


Fig. 6. Accumulation of archaeological elements documented during the 2011 field session. The top shows the spatial distribution of the association spheroids-large cutting tools together with other lithic and bone remains. The numbering corresponds to the items illustrated below.

activity exhibits flake scars arranged in a way intrinsically linked to the orthogonal structure of the natural surfaces of the quartz blocks. The striking platforms are usually completely or nearly completely cortical (80 out of 87 cases).

Three main reduction strategies were identified (Table 3). Freehand knapping was the main technique used, with bipolar percussion on an anvil circumstantial. In longitudinal reduction strategies (N = 42, 48%, Table 3, Fig. 9) the flake scars are parallel and carried out on the transverse surface. Along with unipolar strategies, cores with bipolar unifacial reductions were recovered with two horizontal striking platforms for the reduction of one or two faces.

In another group of cores, we observed an orthogonal volumetric organisation (N = 13, 15%, Fig. 9). The striking and debitage surfaces were used interchangeably and reduced in the same way. These cores may be bifacial or even multifacial, with orthogonal bipolar or multipolar extractions. This orthogonal link between planes could constitute a phase prior to the bifacial volumetric organisation of centripetal tendency. This type of organisation was not found among the quartzite cores.

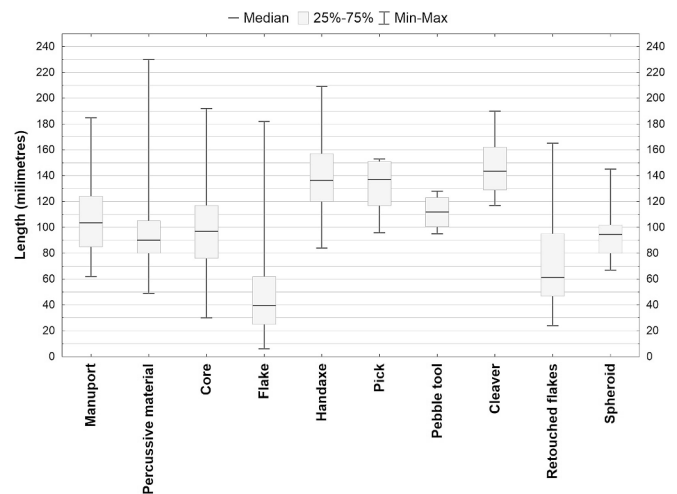


Fig. 7. Length in the typological categories of the lithic industry of Santa Ana.

Table 1  
Typological elements, blanks and raw materials of the Pleistocene breccias/cut-and-fill.

	Quartz		Quartzite		Other rocks		Total	%
<b>Manuport</b>	7	1.7%	11	6.8%	1	8.3%	19	3.3%
<b>Percussive material</b>	92	22.8%	43	26.5%	6	50.0%	141	24.4%
<b>Core</b>	73	18.1%	14	8.6%			87	15.1%
On cobble	69	17.1%	12	7.4%			81	14.0%
On flake	4	1.0%	2	1.2%			6	1.0%
<b>Flake</b>	180	44.6%	29	17.9%	1	8.3%	210	36.3%
Flake > 100 mm	9	2.2%	14	8.6%	1	8.3%	24	4.2%
Flake < 100 mm	171	42.3%	15	9.3%			186	32.2%
<b>Handaxe</b>	7	1.7%	38	23.5%	2	16.7%	47	8.1%
On cobble	1	0.2%	4	2.5%			5	0.9%
On flake	6	1.5%	34	21.0%	2	16.7%	42	7.3%
<b>Pick</b>			6	3.7%			6	1.0%
On cobble			3	1.9%			3	0.5%
On flake			3	1.9%			3	0.5%
<b>Cleaver on flake</b>			9	5.6%	1	8.3%	10	1.7%
<b>Pebble tool</b>		0.2%	3	1.9%			4	0.7%
<b>Retouched flake</b>	28	6.9%	7	4.3%	1	8.3%	36	6.2%
Denticulate	19	4.7%	6	3.7%	1	8.3%	26	4.5%
Side scraper	1	0.2%					1	0.2%
Notch	7	1.7%	1	0.6%			8	1.4%
Denticulated point	1	0.2%					1	0.2%
<b>Spheroid on cobble</b>	16	4.0%	2	1.2%			18	3.1%
<b>Total</b>	404	69.9%	162	28.0%	12	2.1%	578	100%



Fig. 8. Percussive material (a-g) and manuports (h-i) from Santa Ana Cave: quartz (a, d-g, i) and quartzite (b-c, h). Percussive material with rounded morphologies (a-b), mixed (c) and parallelepiped with convex edges (e) and dihedral edges (d, g-f).

The overall technical volumetric structure of the *centripetal* cores (N = 32, 37%, Fig. 9) generally resembles discoid strategies (Vaquero, 1999). In the majority of cases there is no clear centripetal tendency. On the bifacial reductions, no significant differences can be observed in the knapped perimeter. The reduced surfaces create a secant angle in relation to an intersection plane which follows the projection of natural

crests. Generally, there is an evident discontinuity among the debitage surfaces. Some cases, including the only trifacial core, evidence alternation and rotation between debitage surfaces.

Taking into account the characteristics of the reduction sequences, the products obtained would have had butts and dorsal faces with great cortical proportions.

**Table 2**  
Roundness and sphericity on the cortical surfaces of lithic objects.

	Quartz		Quartzite		Other rocks		Total	%
Rounded	97	34%	88	67%	3	30%	188	44%
High sphericity	63	22%	72	55%	3	30%	138	32%
Low sphericity	34	12%	16	12%		0%	50	12%
<b>Angular</b>	<b>192</b>	<b>66%</b>	<b>44</b>	<b>33%</b>	<b>7</b>	<b>70%</b>	<b>243</b>	<b>56%</b>
High sphericity	45	16%	5	4%	3	30%	53	12%
Low sphericity	147	51%	39	30%	4	40%	190	44%
<b>Total</b>	<b>289</b>	<b>100%</b>	<b>132</b>	<b>100%</b>	<b>10</b>	<b>100%</b>	<b>431</b>	<b>100%</b>

#### 4.4. Flakes

The assemblage has a low proportion of flakes (N = 210, 36%), mostly of quartzite (Table 1). The unretouched flakes vary greatly in shape and size (length = 6–182 mm, Fig. 7, Fig. 10). Small and medium sizes dominate (N = 186, Table 1), mainly of quartz (N = 171). Traces of bipolar percussion on anvil were detected on 20 flakes.

Of the few large unretouched flakes (N = 24), those of quartzite were most numerous (N = 14), and only one greywacke flake was documented. This scarcity contrasts with the very frequent use of these blanks in shaping activities (N = 60), mainly in quartzite (N = 47).

On all the flakes, even the retouched ones, the percentages of dorsal corticality tended to be polarised compared to the predominantly cortex and non-cortical groups. A large proportion of completely cortical products was recorded in all materials: 35% in quartz and 36% in quartzite.

The dominance of cortical butts (73%) indicates a lack of preparation of the striking platforms. There is a remarkable proportion of non-cortical butts (27%) and non-cortical dorsal faces in quartz considering the characteristics of the cores. The majority of butts with non-cortical portions are unifaceted (N = 63). In only one quartzite flake, measuring > 100 mm in length, is the butt multifaceted. The delineation on the majority of the butts is straight (80%). The scarce uniaxial delineations (3%) indicate very sporadic use of flake scar ridges as a striking platform.

#### 4.5. Shaped tools

Shaping activity (N = 121) was mainly carried out on quartzite (N = 65, Table 1). Flakes were the most-used blanks (N = 91), although selective use of blocks or pebbles was detected according to morpho-technological objectives. A substantial representation of large cutting tools (9.8% of the total, Table 1) was recorded, in addition to chopping tools, shaped tools on flakes and polyhedrons, subspheroids and spheroids (Fig. 10, Fig. 12).

Almost all the *handaxes* (N = 47, Fig. 11) were knapped on flakes (N = 42; 89%), above all in quartzite (N = 38). The occasional use of quartz (N = 7) is significant due to the technical requirements and regular shape achieved. Their lengths span a broad range (84–209 mm, average 140 mm, Fig. 7), and the longest one was knapped on flake (Fig. 11d). The variability of sizes accompanies a wide variety of shapes that include lateral dihedral with convex, concave or straight morphology converging on distal dihedral and trihedral. The majority of handaxes were extensively shaped although there are examples of barely knapped perimeters and discontinuities among the shaped segments. Some flake scars suggest the use of soft hammers (Fig. 11a).

The *picks* (N = 6, Fig. 11) were made of quartzite, using pebbles and flakes (50%). Technical similarities were observed between the picks shaped on flakes and the handaxes (Fig. 12). The picks shaped on pebbles are more similar to chopping tools. In some cases, the distal trihedral is delimited by concave dihedral.

All the *cleavers* (N = 10, Fig. 11) were shaped on flakes exceeding 100 mm in length (Fig. 7). Quartzite was used almost exclusively (N = 9). The shaping of these tools varies greatly. The angles of the retouches are mainly abrupt. They are located on one or two sides (Fig. 11g) and

occasionally on the proximal portion to remove the sharp edges from the prehensile areas on quadrangular flakes (Fig. 11h). Some large, unretouched quadrangular flakes have a morphological structure similar to cleavers (Fig. 10, Fig. 9c).

The *pebble tools* (N = 4, Fig. 12) were occasionally knapped on quartz (N = 1). They exhibit little shape standardisation although some of them share morpho-technical similarities with handaxes and cleavers. They show evidence of the shaping of distal dihedral with sharper angles than the cores and, occasionally, bifacial sequences (chopping tools).

The *retouched flakes* (N = 36, Table 1) exhibit little morphological standardisation and highly variable dimensions (24–165 mm, Fig. 7, Fig. 9). Most of the retouched flakes are of medium and small size (N = 27) with only occasional large artefacts (N = 9) and are mainly on quartz (N = 28). The retouched perimeter of the edges is slight and the flake scars are mostly marginal. Denticulates (n = 27) and notches (n = 8) are the most common types of retouched flakes (Table 1). There is only one side scraper with very marginal bifacial retouch and a point shaped by two converging denticulate edges (Fig. 9e).

All the *polyhedrons, subspheroids and spheroids* (N = 18, Fig. 12) were produced on pebbles, nearly all of them quartz (N = 16). The sizes vary greatly (67–145 mm, Fig. 7). The volume was transformed through shaping or percussion. Some have removals organised to form an overall volumetric structure similar to centripetal cores. As seen in other assemblages, the convexity and the morphology tending towards sphericity makes recurrent volumetric reduction impossible (Tixier and Roche, 1997). Some of these objects show battering marks.

## 5. Discussion

### 5.1. Technical structure, techno-typological composition and territorial functionality of Santa Ana

The lithic industry of Santa Ana exhibits the frequent use of quartz (69.9%) in relation to less complex technical activities: the reduction (62.7%) and shaping of denticulates and notches on flakes with little morphological standardisation. Quartzite and greywacke were mainly used for the shaping of handaxes, picks and cleavers. Pebbles were frequently used for reduction activities and flakes for shaping. These differences indicate some coordinated operational sequences related to the differential and specialised use of raw materials and blanks according to technical and typological objectives.

The low percentage of flakes compared to cores and shaped tools contrasts with the abundant percussive material, the presence of manuports and the local availability of raw materials. The scarce proportion of flakes indicates little knapping activity inside the cave. The largest representation of quartz flakes suggests differences in the territorial location of the technical activities applied to the raw materials. These differences could also be related to procurement areas.

The differences in sphericity/roundness of the cortical surfaces among lithic materials of a same class confirms the provenance from different procurement areas (Akintayo and Canals Salomo, 2019). Our results also show greater links between quartzite and more remote alluvial environments. The alluvial origin of some of the quartz objects shows a repetitive selection of this raw material in multiple environments although the majority of quartz would have come from the



**Fig. 9.** Cores (a-c) of quartz (a-b) and quartzite (c) with orthogonal multifacial multipolar reduction strategies (a), centripetal bifacial (b) and longitudinal unifacial unipolar (c).

**Table 3**  
Core reduction strategies with regard to the raw materials.

	Quartz		Quartzite		Total	%
Longitudinal	32	44%	10	71%	42	48%
Orthogonal	13	18%			13	15%
Centripetal	28	38%	4	29%	32	37%
<b>Total</b>	<b>73</b>	<b>100%</b>	<b>14</b>	<b>100%</b>	<b>87</b>	<b>100%</b>

immediate surroundings of Santa Ana. The local procurement of quartz was mainly linked to percussion and reduction activities. The differences in the cortical surfaces among objects with the same typology reflect multiple origins, as with the raw materials. Thus, technical activities were reproduced in different environments.

The low percentage of cores on flake, handaxes on pebbles and the variations in the preferred materials indicate a certain flexibility in the coordination of the operational sequences. This flexibility would have been the product of the adaptability of the technical processes used by knappers on the raw materials, as well as blanks variability and constrictions. Moreover, the use of quartz for handaxes ( $N = 7$ ) signifies that this material was incorporated into complex technical operations. The shaping of quartz handaxes on flakes indicates the existence of knappers who overcame the restrictions posed by the planes of weakness and geodes in order to control the knapping process. The versatile use of quartz and the regular shape of the handaxes on quartz flakes suggest the existence of expert knappers.

The lithic materials from Santa Ana assemblage result from different operational sequences that explain their morphology and presence within the cave. These operational sequences comprise the procurement and selection of raw materials, transformation processes through knapping and use, and finally, discard of the tools. However, analyses of the operational sequences employed in the production of Santa Ana assemblage reveals the absence of some of its phases and therefore suggests the fragmentation of the operational sequences. Different aspects suggest a differential fragmentation of operational sequence depending on the raw material. For each raw material, we observed variable proportions among the unretouched flakes, cores, and shaped tools. Furthermore, the differences between the corticality of small and medium-sized flakes in all the raw materials with regard to the reduction phases of the cores suggest the partial fragmentation of some segments of these operational sequences. The numerous cores in the initial phase of reduction and cortical quartz flakes indicate that some reduction sequences began and ended at this point. Quartz flakes with hardly any cortex on the butt and dorsal face suggest the transport of cores in the middle of the reduction phase to and from the cave. In quartzite, the presence of cortical flakes in relation to the limited number of cores during the initial phase indicates the mobility of decorticated cores. The differences between the reduction phases represented on cores and flakes point to the fact that technical activities were carried out within the cave after which the materials were taken outside the cave. The presence of flakes exceeding 100 mm in length in relation to the absence of cores with these production capacities in the cave is evidence of the allochthonous production of large size flakes.

In quartzite and greywacke, unlike quartz, the scarcity of unretouched flakes compared to the shaped flakes and cores suggests the greater fragmentation of the operational sequences. In quartzite, the main link with alluvial procurement environments indicates a certain correlation between distance, mobility and fragmentation of the operational sequences. The numerous quartzite and greywacke percussive elements with oval morphology suggest the possible specialised use of the procurement areas. This use would explain the under-representation of quartzite procured in nearby gravitational deposits.

The abundance of large cutting tools among the quartzite and greywacke objects indicates a specialised use of these raw materials. The systematic use of large blank flakes in the LCTs and the rarity of small and medium-sized products indicate a double fragmentation of these

operational sequences. The production and shaping of these blanks were allochthonous. In addition, the small proportion of large unshaped flakes as opposed to retouched flakes suggests that mobility was a determining factor in the technical use of these blanks. These blanks were considered versatile elements, fundamental to the territorial exploitation and mobility of hominids and their technical activities.

The presence of handaxes with extensive shaping sequences and others with very little shaping indicates a convergence in the cavity of polarised knapping sequences. The morphology of handaxes varies greatly, which shows the extent of this concept. This variability and the similarities between the technical and morphological schemes for picks and pebble tools with handaxes and cleavers indicate the influence of these concepts. In addition, the morphology of the cleavers can be seen in the selection and transport of large quadrangular flakes. The handaxes and cleavers correspond to standards that polarised the morphological variability of many of the objects used in territorial mobility strategies.

The numerous LCTs, hammers and cores documented at Santa Ana were, in most cases, abandoned before the end of their useful lives for reasons such as fracturing or volumetric depletion. The typology of objects and this reiterative pattern of abandonment indicate planned behaviour through transport of tools and the territorial mobility of knapping, versatile technical objects, and raw materials.

The low level of knapping activity in the cave and minimal transformation of the raw materials procured in the immediate environment suggest low impact, short duration occupations. As with other Acheulean sites, the characteristics of Santa Ana indicate that mobility and fragmentation of the operational sequences are structural and recurrent (Gallotti, 2015; Mishra et al., 2010; Sharon, 2006, 2009, 2010). Scarcity of evidence of knapping activity at the site, the importance of the allochthonous technical processes and the different provenance of the raw materials of the technical objects discarded at the cave suggest that Santa Ana was a territorial nodal point. As Isaac (1981) noted, the nodes correspond to points of temporary aggregation of individuals around a certain resource. We do not know what kind of resources attracted the different occupations, however, through the lithic industry of Santa Ana, we can see that different individuals visited this site carrying similar techno-typological elements in different episodes, as indicated by some elements preserved in some of the levels of the Pleistocene breccias (Fig. 6).

The presence of large cutting tools (LCTs), handaxes, picks and cleavers, the differential use of raw materials and frequent employment of flakes in the shaping of the handaxes place this lithic industry within the Large Flake Acheulean (Sharon, 2010). The lithic repertoire of Santa Ana also includes spheroids, pebble tools and non-standardised retouched flakes: denticulates, notches and a point. An analysis of the cores evidences longitudinal, orthogonal and centripetal reductions with discoid features. Levallois cores and products are absent.

### 5.2. The Pleistocene breccias of Santa Ana and Acheulean technology in the Iberian Peninsula

The scarce number of Acheulean sites in karstic environments in the Iberian Peninsula (e.g., Galería, Gruta da Aroeira, Cueva del Angel) make Santa Ana an exceptional site because of its cave location (Fig. 1). The Acheulean of the Iberian Peninsula is rich in open-air deposits, in fluvio-lacustrine environments such as La Boella and Solana del Zamborino, and above all in the middle fluvial terraces of the Atlantic basin with dated sites from the Miño, Tajo and Jarama rivers (dating, context and bibliographic references in Supplementary Material 1).

The frequent associations of handaxes and cleavers in the Acheulean assemblages of the Iberian Peninsula have been considered uniform features related to the expansion of the LFA from a northern African origin (Méndez-Quintas et al., 2020; Santonja and Pérez-González, 2001; Santonja and Villa, 2006; Sharon, 2011; Sharon and Barsky, 2016). However, the Acheulean of this territory exhibits chronological discontinuities and techno-typological differences compared to the



**Fig. 10.** Flakes (a-d) of medium-sized (a-b) and large (c-d) and retouched flakes (e-i). Materials: quartz (b, d-h) and quartzite (a, c, i). Shaped items: denticulate point (e), notch (f), denticulate tool (g, i) and side scraper (h).

earliest northern African Acheulean.

Thomas Quarry Unit L (Casablanca, Morocco) places the initial presence of a Acheulean with LCTs and spheroids at 1.4 Myr at most (Raynal et al., 2005). In the Iberian Peninsula, the first evidence of Acheulean is later – at around 1 Myr in La Boella, although this lithic industry may reflect a possible local development from Oldowan

(Mosquera et al., 2015; Vallverdú et al., 2014). After La Boella, an occupational hiatus seems to have occurred in the Iberian Peninsula (Ollé et al., 2016). Although there are indications of an old Acheulean in the high fluvial terraces of the Tajo and Guadalquivir rivers (Caro Gómez, 2006; Rodríguez del Tembleque et al., 2010), the Acheulean evidence is later than Galería-GIIa (503 ± 95 ka) (Berger et al., 2008;



Fig. 11. Large cutting tools from Santa Ana Cave: handaxes (a-d), picks (e-f) and cleavers (g-h) in quartz (c) and quartzite (a-b, d-h) on pebble (e-f) and flake (a-d, g-h).

García-Medrano et al., 2014), extending to MIS 5 and without spheroids.

The uniformity that the handaxes and cleavers bring to the Acheulean of the Iberian Peninsula masks the behavioural variability of these groups. The use of quartz, the structure of the operational sequences of the handaxes and the techno-typological composition makes it possible to identify similar technical behaviours among human groups and marks

the uniqueness of Santa Ana.

In the Iberian Peninsula, quartz served a marginal use although it is a raw material that is available across the region (Fig. 13). This limited use of quartz has been related to its low quality (Marks et al., 2002), but this was not the case in all assemblages, including Santa Ana. The frequent use of quartz in Cau del Duc de Torroella de Montgrí (70.6%) and in Puig



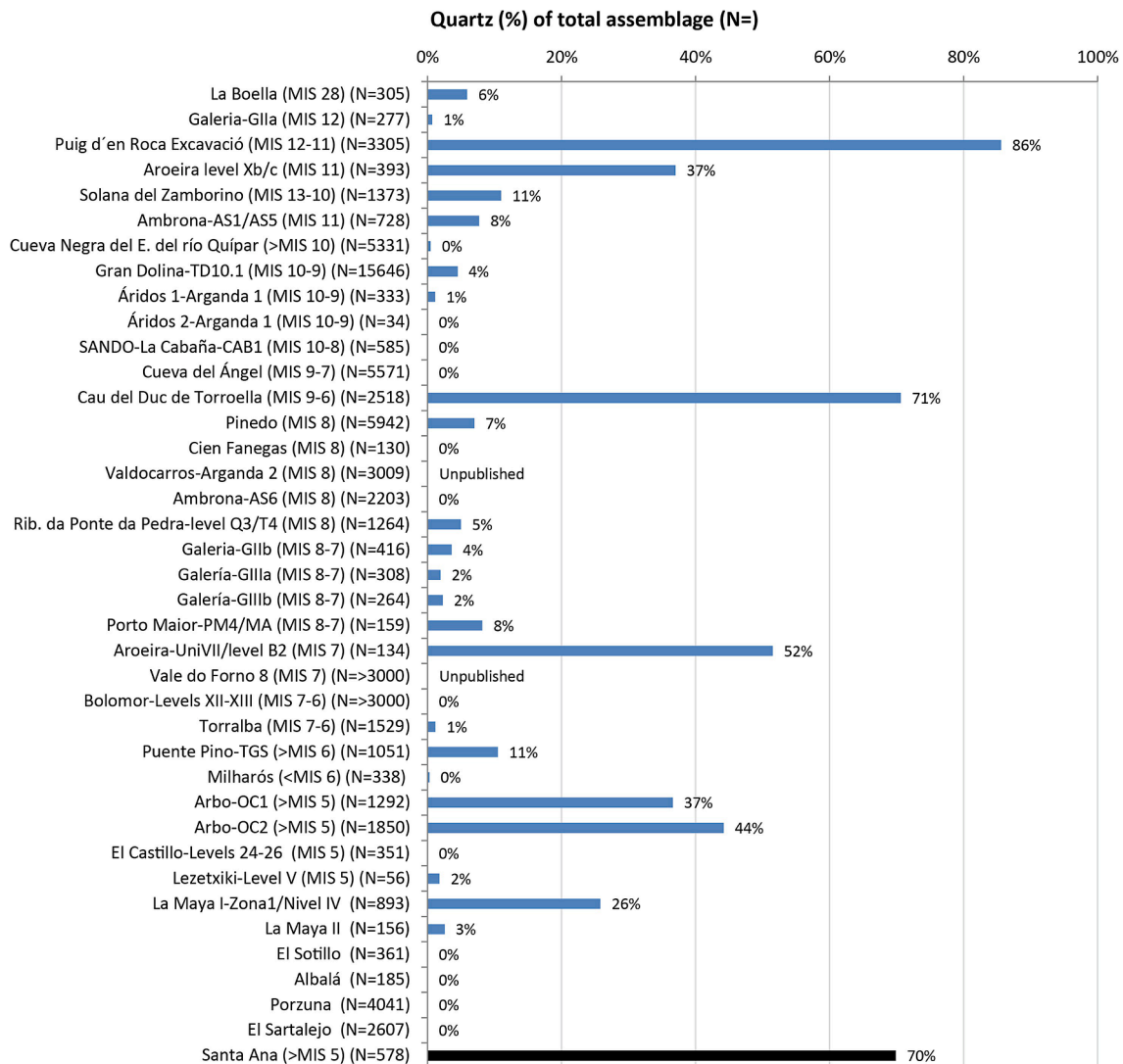
Fig. 12. Pebble tools (a-b) and spheroids (c-d) from Santa Ana Cave in quartz (b-d) and quartzite (a) on pebble (a-d).

d'en Roca (85.6%), both in the north-eastern Iberian Peninsula, has been linked to a local supply in environments where it dominates and with a differential technical pattern of use. Quartz was intended, above all, for reduction (Rodríguez-Álvarez, 2016).

This differential use of quartz has been related to perfect knowledge and the adaptation of operational schemes to the mechanical characteristics and properties of this raw material (Rodríguez-Álvarez, 2016).

Based on this interpretation, the quality of quartz would have limited its use for complex technical operations and operational schemes would have had to be adapted. Although the majority of assemblages respond to this differential pattern of use, some sites in which quartz exceeds 30% of the raw materials used confirm the incorporation of quartz into more complex technical activities (Fig. 13).

The increased use of quartz in Aroeira-level B2 (52%) compared to



**Fig. 13.** Use of quartz at sites with Acheulean technologies of the Iberian Peninsula. The percentages were calculated in relation to the total number of objects in the assemblage (N = ). Dating, context and bibliographical references available in Supplementary Material 1.

level Xb/c (37%) may correlate to a greater degree of adaptation to this raw material. This adaptation consists of the versatile use of quartz in more complex technical operations such as the shaping of handaxes and large-sized objects (Daura et al., 2018; Marks et al., 2002). In addition to the handaxes, the production of large quartz flakes has also been discovered in Arbo (Méndez-Quintas et al., 2019) and in Puig d'en Roca (Rodríguez-Álvarez, 2016).

The use of quartz in Santa Ana would have responded to a local supply and differential use model. Unlike other assemblages, quartz was even selected in more remote alluvial environments where quartzite was available too. In addition, the supply of quartz was bolstered by local procurement despite the proximity of quartzite. The quality of the quartz was not always a limiting factor and was used to produce large flakes in the knapping of handaxes and extensively in the shaping of flakes. The technical skills needed to master knapping on quartz suggests the existence of expert knappers at these sites.

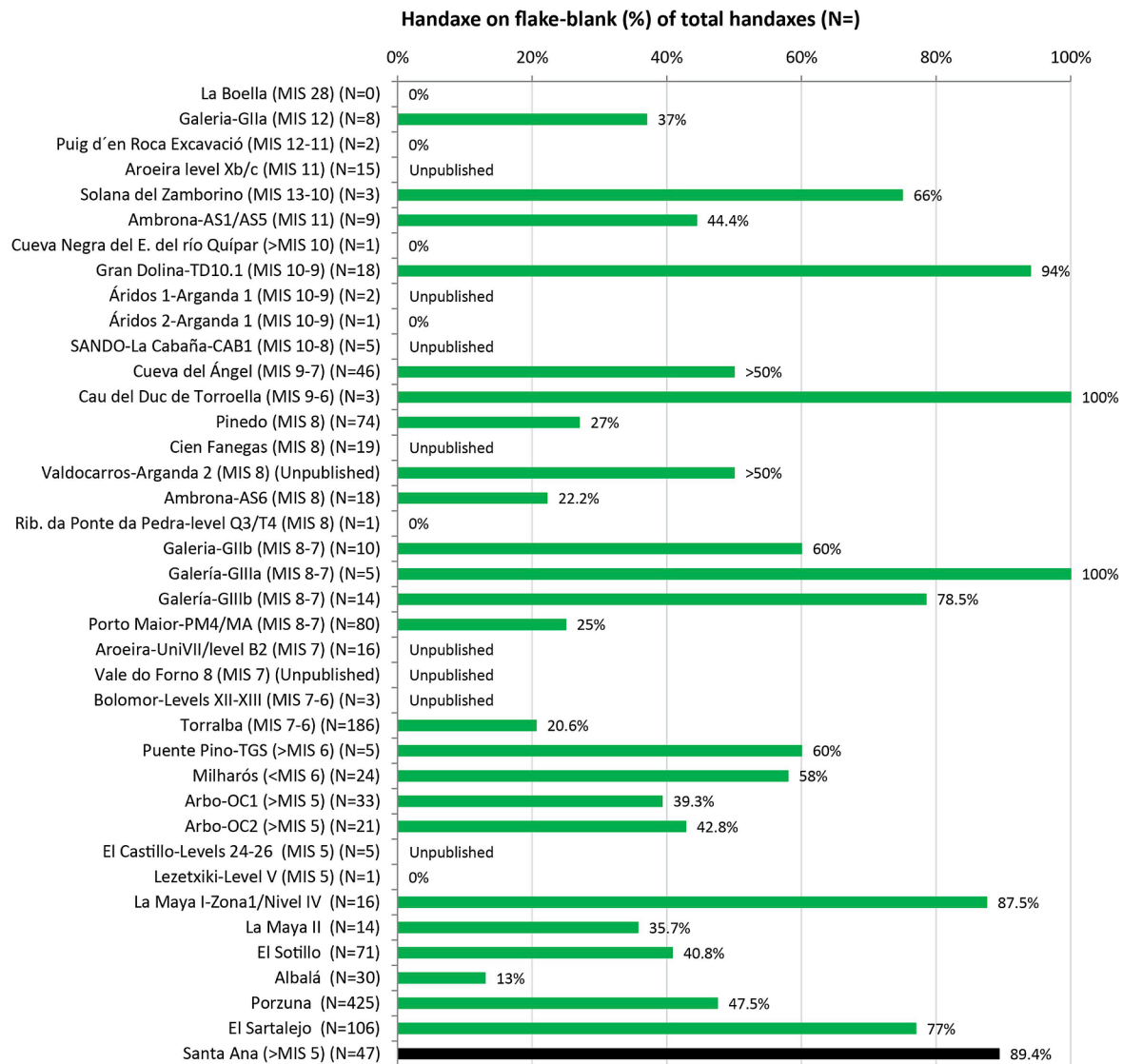
The Acheulean assemblages of the Iberian Peninsula show significant variation with regard to the importance of large blank flakes in the structure of the operational sequences of the handaxes (Fig. 14). The use of the flakes is important because 1) the large flakes and cleavers substantiate the characterisation of the LFA (Sharon, 2010); 2) the LFA has been related to the oldest manifestations of Acheulean outside Africa and 3) the presence of Acheulean in the Iberian Peninsula has been

linked to this expansion from Africa (Méndez-Quintas et al., 2020; Sharon, 2011; Sharon and Barsky, 2016).

From a chronological perspective, different phenomena have been documented in the Iberian Peninsula in terms of the blanks used for the knapping of handaxes: the coexistence in the use of pebbles or flakes as blanks, the endurance of the use of large flakes, and changes in the preferred blanks for some sequences (Fig. 14). The changes in Galería from level GIIb, with a preferential use of flakes as blanks for the making of handaxes, contrast with the preferred use of pebbles in Pinedo and Torralba in a similar chronological range (250 ka).

Some assemblages with numerous handaxes (e.g., Cueva del Ángel, Arbo, Milharós, El Sotillo and Porzuna) show great flexibility in preferences for blank selection (40–60% of the handaxes knapped on flakes) (Fig. 14). On the other hand, very little flexibility has been recorded in other assemblages and the preferred option exceeds 70%, like at Solana del Zamborino. The use of flakes even reaches 100% at sites with few handaxes, like Galería-GIIb, or even with just a small proportion of handaxes, like at Gran Dolina-TD10.1. Assemblages with abundant handaxes, such as Porto Maior, Pinedo and Torralba, evidence a clear preference for pebbles compared with El Sartalejo.

The heterogeneity in the organisational structure of the operational sequences for the making of handaxes denotes diversity. The use of flakes implies the territorial dispersion of large cores and the mobility of



**Fig. 14.** Use of flakes for handaxes in Acheulean assemblages of the Iberian Peninsula. The percentages were calculated in relation to the total number of handaxes (N = ). The data from Torralba was estimated from the study of the Cerralbo collection after [Sánchez-Cervera et al. \(2015\)](#). Dating, context and bibliographical references available in the Supplementary Material 1.

the operational sequences ([Sharon, 2009](#)). The use of flakes with long and regular edges simplifies the shaping sequences as well as the morphological selection of pebbles. Moreover, the use of flakes would have optimised the size/weight ratio of the handaxes ([Sharon, 2011](#)). However, in Albalá and El Sotillo the differences in the size of the blanks are insignificant ([Arroyo and de la Torre, 2013](#)).

Using flakes would have increased the complexity of the operational sequences, introducing intermediary steps and uncertainty regarding the dimensional limitations of the cobbles for extracting them ([Santonja and Villa, 2006](#)). The wide variety in the size of the cobbles in alluvial environments does not explain why Sartalejo, on a terrace of the Alagón River, exhibits evidence of a strong preference for flakes (77%) when it also includes those shaped on smaller pebbles ([Mejías, 2009](#); [Moloney, 1992](#)). In Galería, the changes to the LCT blanks ([García-Medrano et al., 2015](#)) occurred in a similar raw material procurement environment and would not have been related to their availability.

In the absence of apparent advantages relating to the handaxe blanks, cultural factors may have been a determining factor in the preferred option, without ruling out a certain influence from other factors, such as the quality and availability of raw materials. In Santa Ana, flake blank selection was systematic and took place within the

different procurement environments and from among the different raw materials available, including quartz.

The frequent presence of cleavers in Acheulean assemblages, especially in the western area of the Iberian Peninsula, has been linked to the influence of the LFA ([Méndez-Quintas et al., 2020](#); [Santonja and Villa, 2006](#); [Sharon, 2011](#)). However, the frequency of cleavers in this area is irregular and would have been influenced by different factors. The presence of cleavers in Áridos 2 and their absence in Áridos 1 ([Santonja and Querol, 1980a, b](#)) must be linked to the functionality of these instruments, as these sites are only a few metres apart.

In Aroeira, the absence of cleavers in the entire sedimentary sequence is structural and has been used to propose a non-African origin of this Acheulean ([Daura et al., 2018](#)). This absence could be related to an adaptation of the Acheulean like the one documented at La Noira and at Cueva del Ángel, where there are also no cleavers in the typological sense ([Barroso et al., 2012](#); [Moncel et al., 2020b](#)). This adaptation would mean a loss in the typological diversity of Acheulean related to cultural factors.

The presence or absence of cleavers in Cueva del Ángel, Aroeira and Galería is independent of large flakes and their technical use. In Aroeira-level X/bc they were used frequently in the reduction scheme and as

blanks for some handaxes (Daura et al., 2018). In Cueva del Ángel, the majority of handaxes were knapped on flakes and fractured stones, and the quartzite side scrapers were knapped on large flakes (Barroso et al., 2012). Galería, from level GIIb, has yielded evidence of the frequent use of flakes for shaping LCTs and as cores (García-Medrano et al., 2015). In Santa Ana, the selective use of blanks dissociates the flakes from the reduction scheme and links them with shaping.

In the Iberian Peninsula, the consideration of Acheulean assemblages as accumulations of handaxes and cleavers whose intensity marks their affinity with the African Acheulean must be redefined (Méndez-Quintas et al., 2019). The evidence from Santa Ana and Galería indicates that, along with handaxes and cleavers, there was an accumulation of manuports and percussive material that contrasts the importance of allochthonous knapping. The abundance of hammers in Galería (Galería-GIIa: 18%; GIIb: 11%) suggests that they were versatile elements, essential in roaming strategies (García-Medrano et al., 2015). Accumulations of pebbles like these are documented in habitat areas in which high bone fragmentation has been recorded, like in Aroeira-level Xb/c (21%) (Daura et al., 2018). In Cueva del Ángel, however, the virtual absence of hammers contrasts with the intense knapping activity evident at the site (Barroso et al., 2012). The morphological and dimensional diversity of the percussive material of Santa Ana indicates a broad range of activities whose execution was implemented by means of spheroids.

In Santa Ana the association of LCTs and spheroids marks an important singularity. These associations have still not been documented in the Iberian Peninsula. Although there are references to spheroids and LCTs in the Cantabrian area (Rodríguez Asensio, 1976), they are surface assemblages, with no stratigraphic correlation, like in Bañugues (Álvarez-Alonso et al., 2014). The presence of stone balls in Porzuna (Vallespí et al., 1980) and in the Martín Aguado collection with materials from Pinedo (López-Recio et al., 2013) is also mentioned, but they are lithic materials selected from surface assemblages, without stratigraphic references and could be spherical natural shapes. The stone balls documented in the Acheulean assemblages of the Manzanares River, Arenero de Hermanos and Arenero de Arriaga, Arenero de Nicomedes, Manuel Soto, Jesús Fernández and Arenero de la carretera de San Martín de la Vega (Rubio Jara, 2011), coincide with natural unshaped morphologies (this stone balls are shown at CERES (2021), Red Digital de Colecciones de Museos de España web page). Until now the only spheroids of Pleistocene contexts are in Barranco León (1.3 Myr) and correspond to Oldowan technology (Titton et al., 2020).

The differences detected regarding the presence of handaxes and cleavers and the role of large flakes allows us to consider the Acheulean of the Iberian Peninsula as a conglomeration of characters. Bearing in mind that the dating of the peninsular Acheulean focuses on the second half of the Middle Pleistocene, mainly after MIS 9, these characters would have been a product of the influx and adaptation of technologies preceding MIS 12, as suggested by some researchers (Moncel et al., 2020a). MIS 9 is fundamental in the emergence of Mousterian in Europe: Changes in the mobility strategies and management of raw materials, procured in more remote environments, led to the incorporation of innovations like Levallois knapping (Moncel et al., 2020a; Moncel et al., 2020b).

Between 350 and 300 ka, Mousterian appeared in the Iberian Peninsula, where it coexisted with Acheulean until 150 ka ago (Rodríguez, 2004; Santonja et al., 2016). The initial Mousterian technologies, such as that seen at Gran Dolina-TD10.1, Bolomor, Cueva Negra del río Quípar, Ribera da Ponte da Pedra-Q3 level, and Ambrona-AS6, have very diverse reduction methods and include some handaxes (Cura, 2014; de Lombera-Hermida et al., 2020; Fernández Peris et al., 2000; García-Medrano et al., 2015; Santonja and Pérez-González, 2006; Walker et al., 2013).

Handaxes, cleavers and some innovations have been documented at Acheulean sites posterior to MIS 9. Galería, from level GIIb (237–269 ka, MIS 7–MIS 8) evidences the gradual appearance of Mousterian features which could be related to population and cultural displacement on top of

adaptation to the environment (García-Medrano et al., 2015). The economisation of raw materials, centripetal knapping and hierarchical cores accompany changes to the materials of LCTs and the increase in flakes used in shaping and cores (García-Medrano et al., 2014).

The technological comparison between Gran Dolina-TD10.1 and Galería reveals different spatial behaviours (García-Medrano et al., 2015). This spatial adaptation of the technical behaviours possibly favoured the adoption of Mousterian technological innovations. The Acheulean assemblages contain Levallois cores and products, occasionally made of the highest quality raw materials, are less abundant, and clustered in remote environments. Although the presence of these elements is occasional, it has been noted at many sites, such as Áridos 1, Ambrona-AS1/AS5, Pinedo and Milharós (Querol and Santonja, 1980; Raposo, 1996; Santonja and Querol, 1980b; Santonja et al., 2018).

Cueva del Ángel lacks Levallois elements. However, it evidences innovative technical behaviour that may be linked to Mousterian: centripetal reductions with flake scars that point to recurrence, the dimensional standardisation of the medium-sized flakes and the morphological standardisation of retouched flakes. In addition, the quartzite was procured >40 km away. Santa Ana also lacks Levallois cores and products, and Mousterian technological features have not been recorded there. Raw material procurement is local and the mobility of large flakes and LCTs largely supported the territorial activity of these groups.

### 5.3. Santa Ana and its technological parallels

In the Acheulean assemblages of northern Africa, the associations of handaxes and cleavers without spheroids, and the frequent use of flakes for the making of handaxes define assemblages such as Ternifine (700 ka) and Errayah (Algeria) (Fig. 1) (Derradji, 2006; Geraads et al., 1986; Sharon, 2011). In Sidi Zin (Tunisia), the almost exclusive use of flakes for handaxes has been recorded in some levels (Marnaoui, 2017). These characters have been observed in multiple sites in the Iberian Peninsula. However, the particularities of Santa Ana, such as the shaping of handaxes on flakes and the spheroids, may modify previously assumed connections between the Iberian Peninsula and northern Africa (Méndez-Quintas et al., 2020; Santonja and Pérez-González, 2010; Santonja and Villa, 2006; Sharon, 2011; Sharon and Barsky, 2016).

The sequences of Casablanca (Morocco), Thomas Quarry Unit L, Sidi Abderrahmane and Rhinoceros Cave, have LCTs associated with spheroids from between 1.2/1.4 Myr and 0.4 Myr (Geraads et al., 2004; Raynal et al., 2016; Raynal et al., 2005; Raynal et al., 2002; Raynal et al., 2001; Rhodes et al., 2006). Unlike Santa Ana, in Casablanca pebbles were the preferred blanks for the handaxes, although in the Sidi Abderrahmane Extension, the frequent use of flakes was suggested but not specified (Raynal et al., 2004).

Techno-typological associations like those of Santa Ana are found in eastern Africa in the Olduvai Bed IV formation, Olorgesailie, Isimila and Kalambo Falls (Fig. 1) (Sharon, 2006). Outside of Africa, similar techno-typological parallels to Santa Ana are rare.

In the eastern Mediterranean (Fig. 1), Latamne (Syria), dated to around 1 Myr, presents LCTs and spheroids (Bar-Yosef, 1994). Geshar Benot Ya'aqov (GBY) (790 ka) has presented evidence of the systematic use of flakes for the production of handaxes at around 100 ka (Sharon, 2010; Sharon et al., 2011). All but four of the handaxes in Layer II-6 (N = 323) were knapped on flakes. In GBY, there are cleavers and a great diversity of percussive material, but no spheroids (Goren-Inbar et al., 2018). Close to GBY, the lithic repertoire of the North Bridge Archaeological Site (NBA) (<658 ± 15 ka) is similar to that of Santa Ana, with spheroids, cleavers, large flakes and 93% of the handaxes shaped on flakes (Sharon et al., 2010).

The spheroids of Qesem (N = 16), with Achelo-Yabrudian technology (400–200 ka) (Barkai and Gopher, 2016), were recycled from other sites and used in the extraction of bone marrow (Assaf et al., 2020). Although bone marrow extraction has frequently been recorded at

Pleistocene sites, spheroids do not appear clearly in the Acheulean of the Iberian Peninsula or the rest of Europe. In Western Europe there are two Acheulean lithic assemblages, Dive du Nord locality (Germond, 1982) and Bois-de-Riquet US4 level (Bourguignon et al., 2016), where spheroids are mentioned but their presence is not clear. Dive du Nord is a surface selected lithic ensemble with handaxes, spheroids, and unshaped stone balls. However, Germond (1982) suggests that there could be a mixture of lithic materials from different chronologies. At Bois-de-Riquet US4 level (BDR-US4) there are in the same stratigraphic level polyhedrons associated with a Large Flake Acheulean assemblage without handaxes and cleavers. Nevertheless, “In the case of BDR-US4, for the moment, the aim for such pieces is unclear: to produce flakes or to obtain shaped tools?” (Bourguignon et al., 2016)

Many sites with Large Flake Acheulean technology were located in India, but only a few are comparable to Santa Ana (Fig. 1). Singi-Talav (>390 ka) includes spheroids, picks and cleavers, and the handaxes were knapped mainly on thin plates of quartzite, the schistosity of which prevents it being linked to the production of flakes (Chauhan, 2010; Gaillard et al., 1985). In Yediyapur VI (Hunsgi-Baichbal River Basin), handaxes and related elements were preferably shaped on flakes (65%). Along with LCTs, there are polyhedrons and objects comparable to spheroids (Paddayya and Yogesh, 2008).

Similar assemblages to that of Santa Ana have also been recorded in China, in spite of the general scarcity of LCTs (Li et al., 2014a). The lithic repertoire documented along with the spheroids does not always include cleavers. Among the oldest Acheulean sites in China, the locations of Shuigou-Huixingou in the T4 of the Yellow river (900 ka, MIS 24) are noteworthy. They contain at least 1 spheroid, cleavers and picks, and all the handaxes were knapped on flakes (Li et al., 2017).

The fluvial terraces T4, T3 and T2 of the Han and Dan rivers (Yangtze basin-Danjiangkou Reservoir Region) have also yielded Acheulean assemblages (Fig. 1) (Kuman et al., 2014). In T3, the assemblage of Shuangshu ( $651 \pm 65$  ka– $518 \pm 52$  ka) is similar to that of Santa Ana, although it lacks spheroids; quartz was the most-used material (80–87%), some handaxes were knapped on quartz, and flakes were the preferred blanks for LCTs (58.3%) (Li et al., 2014b).

In the Han-Shui Valley (Hanzhong Basin) the Longgangsi (600 ka) site includes spheroids, picks and handaxes, at least one of which was produced on a flake (Moncel et al., 2018). In the Luonan Basin, the Zhoupo site (500–250 ka) contains spheroids, handaxes, picks and cleavers (Wang, 2005).

The techno-typological associations similar to that of Santa Ana appear in different phases and territories and also evidence the frequent use of flakes in the production of handaxes. Although the LFA includes a wide variability of reduction strategies and materials used to obtain large flakes, the LCTs are uniform (Sharon, 2008, 2009). According to Mishra et al. (2010), this morphological similarity of the LCTs is due to close relations between populations. Bearing in mind the demographic hiatuses in territories such as the Iberian Peninsula (Ollé et al., 2016), and the extensive time–space of the Acheulean, this uniformity of LCTs would indicate great technological conservatism (Andersson, 2011).

The assemblages with technical characteristics comparable to that of Santa Ana confirm this conservatism. The spheroids link these Acheulean assemblages to the cultural substrate of Oldowan (de la Torre and Mora, 2010; Díez-Martín et al., 2016). The proximity between GBY and NBA and its dates indicates that in the Near East handaxes were shaped from flakes for about 200 ka. In Casablanca, the LCT-spheroid associations confirm this for a period of approximately 600 ka. Sites in China, India and the Levantine Corridor show that, outside Africa, the Large Flake Acheulean characterised by handaxe knapping on flakes and the LCT/spheroids association survived between 900 and 300 ka. The wide spatial distribution and temporal persistence of these characteristics and tools indicate a phenomenon of technological stasis. Technological conservatism (Andersson, 2011) would constitute a fundamental explanatory component of this phenomenon.

## 6. Conclusions

Santa Ana Cave is one of the rare karstic deposits excavated in the Iberian Peninsula containing Large Flake Acheulean lithic industry (Sharon, 2010). This industry has three special features: the spheroids/large cutting tools association (handaxes, picks and cleavers), the systematic shaping of handaxes on flakes, and the frequent use of quartz. The Santa Ana record includes cores with longitudinal, orthogonal and centripetal reduction, but Levallois knapping is absent. Furthermore, it contains abundant and diverse percussive material, retouched flakes with little morphological standardisation, denticulates, notches and a point.

This lithic industry is the result of a few coordinated operational sequences from the differential, specialised use of raw materials and blanks according to techno-typological objectives; flakes and quartzite were used in shaping activities, and pebbles and quartz in reduction sequences. The assemblage suggests the possible existence of expert knappers adapted to the use of quartz. The Santa Ana record points to the recurring procurement of quartz in multiple environments and a versatile use that includes the knapping of handaxes on flakes.

Santa Ana was a territorial nodal point. It acted as an attractive focal point frequented during occupational episodes of low impact and short duration. These episodes made the cave a convergence point for raw materials, fragmented operational sequences, and versatile technical objects: handaxes, hammers and large flakes. The technical activity of these groups was essentially allochthonous. The cave and its surroundings were quartz procurement areas. Quartz was used in percussive and reduction activities.

The allochthonous nature of the knapping and the types of objects produced indicate planning and the fulfilment of technical needs through structured transport and mobility strategies. The diverse origin of the artefacts and raw materials indicate a spatial reproduction of similar technical behaviours. Large flakes were obtained from different environments and used as versatile morphotechnical elements essential to mobility. The operational sequences of the LCTs were structured on large flakes, and they were shaped primarily as handaxes. The activities carried out inside or outside of Santa Ana Cave led to the systematic abandonment of the transported objects before the end of their useful lives due to fracturing or volumetric depletion.

The lithic industry of Santa Ana consists of a techno-typological association and singular technical structure unique to the Iberian Peninsula. Hitherto, the spheroid/LCTs association and the systematic use of flakes in the production of handaxes have only been confirmed at this site. This singularity is relevant as the variability detected in the peninsular Acheulean exceeds initial considerations of its homogeneity (Méndez-Quintas et al., 2020; Santonja and Villa, 2006; Sharon and Barsky, 2016). Santa Ana also stands out due to the frequent and versatile use of quartz.

The absence of assemblages similar to Santa Ana in northern Africa, the variability of the peninsular Acheulean and its similarities and differences to northern African assemblages suggest the possible existence of multiple dispersal routes of Acheulean to the Iberian Peninsula. The variability of the peninsular Acheulean would be the result of numerous cultural relations and traditions, their evolution and adaptation mainly from MIS 12.

The spheroid/LCTs association and the systematic shaping of handaxes on flakes in Santa Ana is similar to the Large Flake Acheulean represented at the North Bridge Archaeological Site (Sharon et al., 2010), in Shuigou-Huixingou (Li et al., 2017), Singi-Talav (Gaillard et al., 1985) and in Olorgesailie, Isimila and Kalambo Falls (Sharon, 2006). The extensive spatio-temporal dispersion of the assemblages similar to that of Santa Ana suggests a common African origin. The spheroids prove that the techno-typological diversity of the Oldowan substrate of the Acheulean achieved a wide spatio-temporal dispersion outside Africa, between 1 Myr and 400 ka.

Santa Ana and its technological parallels show that the versatility of

the tools of the Acheulean was operational in multiple ecosystems. The extensive time span represented by the assemblages linked to Santa Ana indicates phenomena of technological homeostasis in the Acheulean. This homeostasis reveals a great technological conservatism that must be understood as an adaptive mechanism. Thanks to the ability to learn, teach and transmit knowledge reliably, this mechanism acted to ensure that these tools were accessible to many individuals (Andersson, 2011).

## 7. Author agreement

All authors have seen and approved the final version of the manuscript being submitted. They warrant that the article is the authors' original work, hasn't received prior publication and isn't under consideration for publication elsewhere.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Conflicts of interest/Competing interests

The authors have no conflicts of interest to disclose.

## Availability of data and material (data transparency)

All relevant data are within the manuscript and its [Electronic Supplementary Materials](#) files. The studied material is preserved in the Museo de Cáceres (Extremadura, Spain) and Institut Català de Paleoecologia Humana i Evolució Social (Catalunya, Spain).

## Code availability

Not applicable

## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jasrep.2021.103265>.

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