



HAL
open science

Contributions and Limitations of a Technomorphometric Approach for Cleavers: The Case of Lanne-Darré (Hautes-Pyrénées)

Juliette Capdevielle, David Colonge

► To cite this version:

Juliette Capdevielle, David Colonge. Contributions and Limitations of a Technomorphometric Approach for Cleavers: The Case of Lanne-Darré (Hautes-Pyrénées). *Lithic Technology*, 2023, pp.1-26. 10.1080/01977261.2023.2279350 . hal-04283937v2

HAL Id: hal-04283937

<https://hal.science/hal-04283937v2>

Submitted on 5 Apr 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Contributions and limitations of a technomorphometric approach for cleavers: the case of Lanne-Darré (Hautes-Pyrénées)

Juliette Capdevielle ^a & David Colonge ^{a, b}

^a Archaeological Work and Research on Cultures, Spaces and Societies, UMR 5608 TRACES

^b Institut national de recherches archéologiques préventives, INRAP

Abstract

Research relating to cleavers can help to characterize the Middle Pleistocene European technocultural landscape, via a technomorphometric approach that provides insights into this tool's composite involvement. In this study, a sample of 47 cleavers from the Lanne-Darré site were observed through two scales of technomorphometric analyses, using 3D scans for morphometric data acquisition and exploitation. When the studied entities are the entire tools, technomorphometric links are rarely perceptible; moreover, attributing them to specific usage is impossible given the current state of knowledge. Edge-scale analysis, however, is able to highlight significant relations between technical choices and shape. The transversal cutting edge specific to cleavers, directly resulting from the blank's debitage, revealed recurrent morphologic and morphometric similarities, though differences remained in the nature and organization of other edges appearing on the cleaver's circumference. In total, four technico-structural tools groups were determined from these heterogeneous organizations. The proposed classification differs from J. Tixier's technotypology, still considered as one of the most robust for cleaver studies. Finally, this technomorphometric approach provides essential elements for understanding the structural place of cleavers in the technical systems of this period.

Keywords

Lower Palaeolithic; lithic technology; cleavers; Lanne-Darré; structural analysis; geometric morphometry; angle measurements

Introduction

The debitage of large flakes used as blanks of characteristic macro-tools may have played an important role in the technical changes specific to Lower Palaeolithic industries (Isaac, 1969; Mourre, 2003, 2006; Mourre and Colonge, 2007, 2010; Sharon, 2010; Sharon and Barsky, 2016). One of the resulting tools, in particular, makes an interesting research topic when attempting to clarify the variability of European Middle Pleistocene technical systems: the cleaver. In Europe, the cleaver is predominantly represented in the Iberian Acheulean industries, correlating to MIS 9 to 7, and is concentrated in the south-west of the Continent, throughout the Iberian peninsula up to the southern Aquitaine Basin (Santonja and Villa, 2006; Mourre and Colonge, 2007; Oosterbeek et al., 2010; Jarry, 2010; Turq et al., 2010; Santonja and Pérez-González, 2010; Mosquera et al., 2013; Colonge et al., 2014; Gallotti and Peretto 2015; Rubio-Jara et al., 2016; Santonja et al., 2016). In contrast, the Early Palaeolithic industries of the north and east Continent have an almost total absence of cleavers and other macro-tools on flakes (Sharon, 2010; Tuffreau, 2012; Ravon, 2017, 2019; Moncel et al., 2015, 2018; Moncel and Ashton, 2018). The question of the impact of available raw materials on the ability to produce large flakes and related tools has been ongoing for decades (Isaac, 1969; Villa, 1981; Roche and Texier, 1990; Santonja and Villa, 2006; Sharon, 2008). The resources needed to produce them are indeed generally grained and tenacious; nevertheless, the multiplicity of coarse-grained stones exploited by industries containing cleavers is undeniable, and the availability of these raw materials in certain regions does not necessarily correlate with the presence of this tool type. Environmental constraints may still have played a limiting role in these productions, however (Mourre, 2003).

The cleaver's cultural involvement

The definition of the cleaver has been the subject of numerous debates since its identification in the 1950s (Tixier, 1956), creating scientific competition between different technotypologies (Bleicher, 1875; Mourre, 2003; Deschamps, 2014). From these, we shall retain the two main definitions: that of Jacques Tixier (op. cit.), who defined it as a tool made on a flake that must contain a transversal cutting edge directly taken from the blank's debitage, with retouched lateral and base parts; and that of François Bordes, who described it as a bifacial piece with a shaped transversal edge (1961). If the presence of a transversal cutting edge is a converging point, the fundamental discordance between these two schools of thought lies in the technical nature of this edge, with both expressing divergent views of the technocultural meaning of the cleaver.

This debate is part of a wider polemic on the diversity of this period's technical systems, more fully developed in V. Mourre's doctoral thesis (2003, tome 1). Indeed, it is only the definition of Tixier that makes it possible to clearly identify a technical phenomenon through the production of the cleaver, which requires the anticipation of technical gestures, a mental representation of the method applied and therefore the mastery of a specific conceptual scheme (Roche and Tixier, 1990). The resulting technotypology (Tixier, 1956; Balout and Biberson, 1967), enhanced by J. Zuate y Zuber (in Alimen 1978), distinguishes six types of cleavers according to the predetermination level of the transversal cutting edge (number and organization of predetermined removals), as well as the importance and specificity of the preparation of the core (methods of debitage) correlated to the intensity of the arrangement of the other edges (Fig. 1). Tixier's approach, therefore,

makes it possible to specify the diversity of the cleaver's production mode and to seek potential technical links between different industries of the European Early Palaeolithic.

How to capture this cleaver's individuality?

However, technological bias alone cannot define the individuality of a tool or be reliably interpreted in terms of possible technocultural links, unless the contribution of all possible determinisms is assessed. The cultural value of the cleaver must be questioned according to several reading grids. An important point to address in this regard is the tool's place within the mental templates of human groups. In particular, the objectives behind their production should be kept in mind, as a complement to any technical information (Mourre, 2003; Nicoud, 2013; Herzlinger et al., 2017).

Morphometric approaches in lithic technology were developed precisely with this in mind, considering the relationship between form and function as a point of attack in understanding the functional place of artefacts. The stylistic and functional variability of handaxes was at the heart of initial research (Alimen and Vignal, 1952; Bordes, 1961; Roe, 1964; Crompton and Gowlett, 1993), particularly contour analysis (Gero and Mazzullo, 1984; Dibble and Chase, 1981; Saragusti and Sharon, 1998; Saragusti et al., 2005; Iovita, 2009; Borel, 2010). However, while the general shape of a lithic object can in some cases inform the knapper's objectives (Grosman et al., 2011; Gowlett, 2011; Iovita and McPherron, 2011; Herzlinger and Grosman, 2018), the study of particularly representative areas is still often preferred (Mester and Moncel, 2006; Lycett et al., 2010; Archer et al., 2021; Li et al., 2021). And while the standardization of certain parts of the tool does not always correlate with the homogeneity of its general morphometry (Porraz et al., 2014), the development of digital technology has greatly improved the reliability and objectivity of morphometric studies (Grosman et al., 2008; Shipton and Clarkson, 2015; Grosman, 2016; Delpiano and Uthmeier, 2020; Garcia-Medrano et al., 2020; Li et al., 2021).

Furthermore, the Techno-Morpho-Functional (TMF) approach, which appeared in the 1990s, combined the observation of forms and production modes and was able to characterize the functional objectives behind technical gestures (Lepot, 1993; Brenet, 1996; Boëda, 1997; Soriano, 2000; Nicoud, 2013; Viallet, 2016; Rocca, 2016). The focus of this approach was not on the function of the pieces but on their functional potential. The determination of possible functional entities is made through the characterization of areas with technical, morphological and morphometrical convergences: the Techno-Functional Units (TFU), defined by Boëda as "a set of elements and/or technical characters coexisting in a synergy of effects" (1997). The tool is divided into several subparts, according to the type of action that their volumetric properties make it possible to envisage: Transformative Contact (TC) with the work material to be transformed, Receptive Contact (RC) or energy transmitter, and Prehensive Contact (PC) (Lepot, 1993; Boëda, 1997; Viallet, 2016). This new way of approaching lithic objects, also known as the "structural approach" (Nicoud, 2013), offers a greater flexibility of application and can be adapted to each individual problem.

The specific case of Lanne-Darré

For this study, we chose the case of Lanne-Darré (Colonge and Texier, 2005; Colonge et al., 2012a, 2014), which is an open-air site located in the Pyrenean Piedmont in south-western France. Although no absolute dating has been achieved, the technotypological trends of the industry suggest an attribution to the Iberian Acheulean, with a large amount of macro-tools almost exclusively on flakes, dominated by bifacial pieces and cleavers. It constitutes an important reference for the industries attesting to Acheulean traditions with Iberian tendencies in south-western France (Mourre and Colonge, 2007; Colonge et al., 2012a and 2014). Among the important references of this ensemble, the Duclos site excavated in 2008 presents a relatively reliable chronostratigraphic context: a date of 169 +/- 19 ka was notably obtained by thermoluminescence suggesting that this type of industry would have lasted later in this region than in the Iberian Peninsula (Colonge et al., 2012b and 2014; Hernandez et al., 2012). In contrast to the majority of the sites in south-western Europe (Santonja and Villa, 2006; Santonja et al., 2016; Capdevielle and Ravon, 2021), the Lanne-Darré cleavers show a greater diversity in their degree of predetermination, making them a particularly suitable corpus for our study (Mourre, 2003; Colonge and Texier, 2005).

The site is located on an important Mio-Pliocene detritic cone containing only one archaeological level. Here, lithic remains are mixed with natural coarse fraction in solifluction slides, dating from the LGM (last glacial maximum), and are covered by nearly 1.30 m of removed aeolian sandy silts. The entire stratigraphy is affected by a Late Glacial pedogenesis that reaches the Mio-Pliocene substrate. The assemblage consists of about 3100 artefacts from 100 m² excavated between 1997 and 2003. The deposit has been strongly impacted by taphonomical processes linked to solifluction: elements less than 2 cm are uncommonly rare and remains are worn. However, a technotypological study of macro-tools remains relevant because they have not been impacted by granulometric sorting.

	Nr	%
Raw pebble	2	0,1
Hammer stone	7	0,2
Pebble fragment	13	0,4
Tested pebble	56	1,8
Debris	583	18,8
Flake fragment	1424	46,0
Flake	586	18,9
Core fragment	23	0,7
Core	72	2,3
Pebble tool	2	0,1
Bifacial tool draft	17	0,5
Bifacial tool	102	3,3
Cleaver	116	3,7
Undefined heavy-duty tool on great blank	94	3,0
Total	3097	100

Table 1: Counts and proportion of technical categories represented in the Lanne-Darré industry

This series was mostly focused on flake production, 84% (including 2.5% cores), with 8% untransformed elements and 8% macro-tools. The debitage was primarily small- and medium-sized flakes with only 5.5% of large calibre ones (including 2.2% cores), which are almost exclusively macro-tool blanks (Tab. 1). This

category was divided mostly between handaxes and cleavers, about 4% each, supplemented by several large undefined retouched flakes. The raw materials consisted of more than 99% blue-grey metaquartzites, mainly from the local environment and within a radius of 0 to 2 km from the site. Only some of these came from the Neste River, 7 to 8 km to the south-east, with some flints indicating procurement from around 50 to 100 km. The blue-grey metaquartzites can only be distinguished by their (neo)cortex: some have been affected by a strong chemical alteration to the cortex typical of the Mio-Pliocene deposits; a second group shows this same cortex thinned by several hydric processes; others have a true brown fluvatile neocortex, polished by rounding in local rivers saturated with ferrous oxides (Colonge and Texier, 2005; Colonge et al., 2012a). A sample of 47 cleavers – representing almost half of the whole category – was isolated from the material excavated over the last three years, 2001 to 2003. This assemblage is representative of both the whole assemblage and the site, as the cleavers came from all the different areas excavated and is therefore sufficient to address the present, primarily methodological, study.

A targeted study on cleavers to test analytical procedures

As mentioned in previous studies (Mourre, 2003; Nicoud, 2013; Herzlinger et al., 2017), morphometric analysis of the cleaver's transversal cutting edge, considered as its main transformative part, could help to better define its role. The functional convergence of this part of the tool has already been assumed following the study of hundreds of European and African cleavers, all with a low degree of variation in the mean values of its angle (Mourre, 2003). Moreover, separate investigations into this tool suggest that the invariable shape of its cutting edge, resulting directly from the debitage of the blank, may best reflect the knapper's original intentions (Nicoud, 2013; Herzlinger et al., 2017). The TFUs of the cleaver would be therefore "integrated" (Nicoud, 2013), with the specific morphology of the transversal edge being the main objective of the knapper and the functional condition of the tool (Herzlinger et al., 2017). According to this point of view, the cleaver offers a unique conceptual reality. Nevertheless, all the edges of the cleaver, whether the result of debitage, previous removals or retouching action, must be considered as constituent parts of the artefact. Here, the choice of the cleaver as a unique object of study, as well as the small size of the corpus, made it possible to explore a multitude of analytical processes.

The current study aims to see if different ways of combining technologic and morphometric observations can help to clarify the identity of these objects: We propose to test different ways of applying technomorphometric analyses to the specific case of the cleaver, with a view to establishing the most suitable methodology possible.² A multi-scalar and evolutionary method

In order to test several possibilities in the search for relationships between technical and morphological or morphometrical properties, two scales of analysis were carried out. Firstly, the entire cleaver was observed for potential links between overall shape and technical choices. The study then targeted specific parts of the tool separately, with a view to conducting structural analysis in line with the TMF approach. The technical groups defined according to these two levels of analysis were thus confronted at the expense of their morphometric and/or morphologic characteristics.

Methods

Overall shape analysis

Initially, the raw material and technical criteria were noted to determine qualitative groups of cleavers: type and percentage (on the superior face) of natural surfaces; type of flake-blank ((neo)cortical, Kombewa, undetermined); debitage direction of the flake-blank (taken from the superior face along the morphological axis of the piece); technotypes *sensu* J. Tixier / J. Zuate y Zuber (Tixier, 1956; Balout and Biberson, 1967; Zuate y Zuber in Alimen 1978; Fig. 1). In addition, 3D models were made using an EinScan SP scanner and EinScan-S software, simplified and homogenized with the Meshlab software, in order to access morphometric and shape information.

Description	Type	Drawing	Section	Blank	Debitage
The transversal cutting edge results from the intersection of the flake-blank's ventral face and a natural surface (1)	0				
The transversal cutting edge results from the intersection of flake-blank's ventral face and one preparation removal prior to debitage (1)	I				
The transversal cutting edge results from the intersection of flake-blank's ventral face and several preparation removals prior to debitage (1)	II				
The flake-blank and the transversal cutting edge are obtained by Levallois debitage method (1)	IIIa				
The flake-blank is obtained by Levallois debitage method, with only two prior removals on the transversal cutting edge, giving it a broken line delineation (2)	IIIb				
The flake-blank is obtained by Levallois debitage method, with only one prior removal on the transversal cutting edge, which gives it a linear delineation perpendicular to the tool's morphological axis (2)	IIIc				
The flake-blank is obtained by the Tabelbala-Tachenghit method, prepared by prior removals on all circumference. The transversal cutting edge intersects the two faces and other edges result from oblique removals (1)	IVa				
The flake-blank is obtained by Tabelbala Tachenghit method and is a Kombewa flake (2)	IVb				
Removals made after the debitage of the blank are so invasive that it is not possible to determine the debitage method and the nature of prior removals making the transversal cutting edge (1)	V				
The flake-blank is obtained by the Kombewa debitage method, made from another flake and presenting two ventral faces (3)	VIa				
The flake-blank is obtained by Kombewa debitage method, with preparation removals prior to debitage (2)	VIb				

Figure 1: J. Tixier's cleaver types (1959). Type VI was created later (Balout and Biberson, 1967) and types 3b, 3c, 4b and 6b were defined by J. Zuate y Zuber (in Alimen, 1978)

Traditional morphometric measurements were then collected: length (along the morphological axis), width (perpendicular to the morphological axis), thickness, and mass. These data, except for mass, were extracted from the 3D models with AGMT-3D software (Herzlinger and Grosman, 2018). The tools were objectively positioned through their symmetrical axis by digital processes and then manually according to specific qualitative aspects, such as the transversal edge being localized at the top (Dauvois, 1976; Mourre, 2003) or the position of the ventral face on the flake-blank. Comparisons between the previously determined raw material and technical groups of cleavers were carried out with non-parametric statistical analyses generated by R and Past software. The Mann-Whitney U test (Mann and Whitney, 1947) with a significance level (α) of 0.05 was used to confirm the graphical results. The Shapiro-Wilk test (Shapiro and Wilk, 1965) with a significance level (α) of 0.05 allowed us to check distribution normality, which made it possible to statistically verify the over-representation of certain dimensional classes. Indeed, a set of measurements that are not normally distributed implies that not all the factors influencing them have had the same impact: at least one factor, potentially a deliberate choice by the knapper, thus dominated the others (Chenorkian, 1996; Poinso, 2008).

In contrast, shape variability between these qualitative groups of cleavers was analyzed using a geometric morphometry approach with AGMT-3D software (Herzlinger and Grosman, *op-cit.*). Type III semilandmarks, as defined by Bookstein (1991; Lycett et al., 2010; Métairies, 2014; Pelletier, 2018), were positioned in a 50/50 grid, adapted to each tool's dimensions and projected onto their 3D surfaces (Herzlinger and Grosman, *op. cit.*). The semilandmark coordinates were initially linked to the objects position, size, and orientation. Generalized Procrustes Analysis (GPA) (Rohlf and Slice, 1990; Bookstein, *op. cit.*) excludes these parameters by superimposing the models through translation, scaling, and rotation. The new coordinates inform only about shape (Pelletier, *op. cit.*). Principal Component Analysis (PCA) from Procrustes coordinates enabled us to grasp the localization and intensity of shape variations and the morphological variability inside the whole sample and between groups (Métairies, *op. cit.*; Doyon, 2017; Herzlinger and Grosman, *op. cit.*; Pelletier, *op. cit.*; Garcia-Medrano et al., 2020). The Mann-Whitney U test was applied to check the statistical reliability of the results (Herzlinger and Grosman, *op. cit.*).

Structural analysis

Structural analysis was undertaken on the peripheral edges of the cleaver, as well as its particular transversal edge. While this part of the study integrates the TMF approach, as it fully follows its main procedures and ideas, some variations in possible interpretations were allowed. Contrary to the classical TMF approach, no interpretation of the functional potential of the edges was established: the notions of TC, RC and PC were considered too hypothetical, a fortiori for this type of tool. Indeed, in the case of edged tools with a particularly open angle, the inference between active transformative, receptive and prehensive parts is delicate (Viallet, 2016). Moreover, a purely productive or functional purpose cannot be certified with removal negatives that may also reflect a flake production objective. The present study only aimed to assemble pieces that had a similar functional and/or productive potential and which could thus have occupied a similar place in the artefact panel of past societies. In this respect, TFUs, within the classical TMF approach, were considered here as

"structural parts" of the artefacts, with the cleavers being sorted into "technico-structural" groups, as they only concern the structural organization without any functional or production interpretation.

First, the areas with technical continuity, called Technical Units (TUs), were individualized by technological analysis. Their chronological position towards the blank's debitage was especially noted to define technotypes. Phenomena affecting the ridges was also documented: spontaneous, recent, taphonomical or macro removals, fractures, etc. Except for fractured or naturally flattened edges, morphological and morphometrical criteria were documented (Lepot, 1993; Nicoud, 2013; Viallet, 2016; Rocca, 2016). Frontal and sagittal delineations were analyzed according to two different degrees: a large scale for deviations greater than 10 mm, and a thin scale for deviations between 2 and 10 mm. The section was determined by deviations that exceeded 5 mm across the height of the TU. Height and width were measured manually on the 3D models using Meshlab software. The average angle was calculated with Artefact-3D software, which scans the TU's surface according to several heights from their intersection, after a process limiting the impact of irregularities (Grosman et al., 2008, 2014; Grosman, 2016; Valletta et al., 2020a, b). The analyzed area corresponds to all the 3D apices that appear in the cylinder of radius h , whose axis is located between two points along the intersection line. This h -value was determined manually and corresponds to the maximal height considered for each angle measurement. The two points chosen as the extremities were also picked for each angle acquisition. The software permitted the same process with a combination of several segments for non-linear ridges (Valletta et al., 2020a and b). Here, h is 5, 10 and 20 mm, towards several precision levels (Fig. 2).

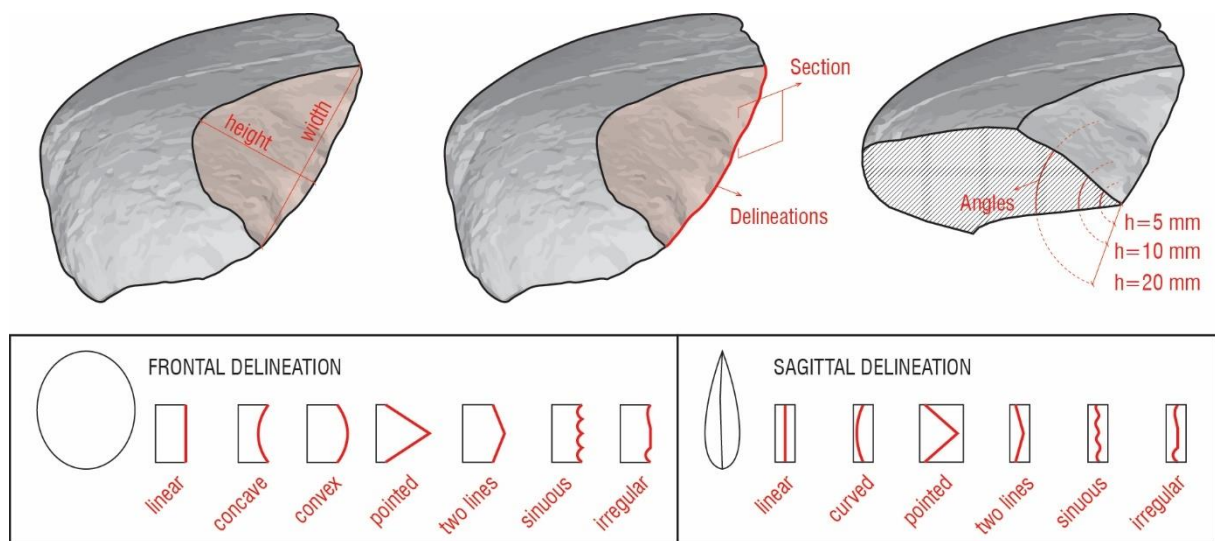


Figure 2: Morphological and morphometrical TU criteria

The metric variables were statistically checked using the Shapiro-Wilk test, with the same significant level and objective as for the global measures (cf. 2.1), for the whole sample and for each TU technotype. Moreover, inter-technotype comparisons of the TUs according to the metric and morphological variables were carried out and verified with the Mann-Whitney U test with a significance level (α) of 0.05. The trends emerging from these comparisons made it possible to isolate the most relevant criteria to characterize structural parts of the artefacts. Analysis of the interrelationships of these areas on each piece was then focused towards discerning several technico-structural groups within the series.

Results

Global shape and production links

All the cleavers are made from metaquartzites. The only differentiation is the nature of their (neo)cortex (cf. introduction): most present a thinned cortex, followed by pieces with a strong cortex, a fluvial neocortex and without natural surface. The flake-blank is mostly (neo)cortical, mainly in low proportions and knapped from various directions. Four technotypes of cleavers *sensu* Tixier/Zuate y Zuber were determined (Fig. 1): type 0, with an unprepared edge at the intersection of (neo)cortical surface and the flake-blank ventral face; type 1, with a pre-determined cutting edge due to a single removal; type 2, with several negatives of removals prior to the debitage of the blank; type 6, made on a Kombewa flake. Most of them are related to type II and 0 (Fig. 3). In terms of morphometry, the lower length, width, weight, and volume classes are overrepresented (Fig. 4). This was confirmed by the Shapiro-Wilk test results with p-values less than 0.05 or 0.01, which exclude a normal distribution for all these variables except thickness (Tab. 2). The volume was globally elongated and flat (Fig. 4-5).

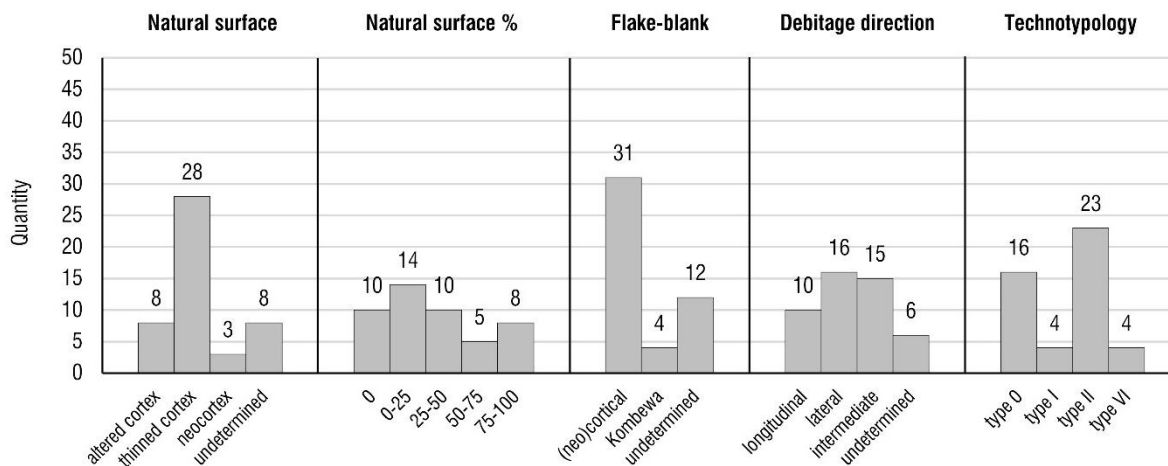


Figure 1: Quantity of cleavers according to qualitative criteria

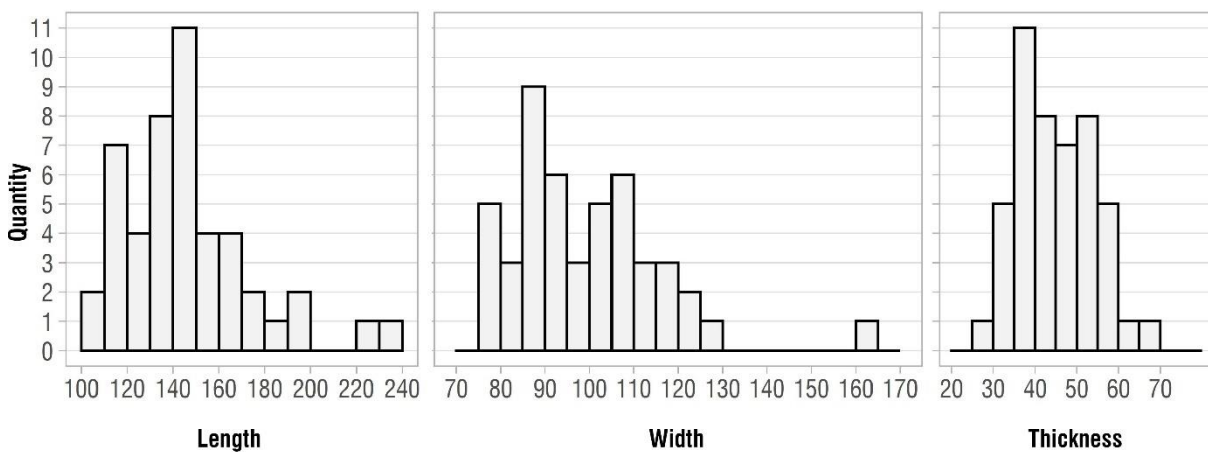


Figure 4: Histogram of the cleaver principal measurements

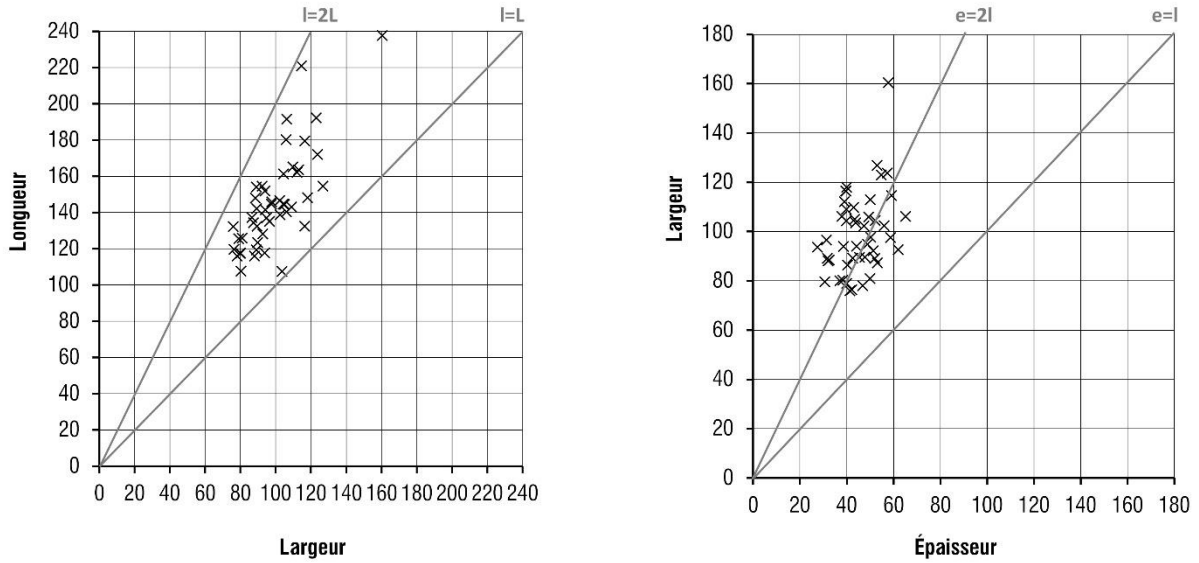


Figure 5: Elongation and flattening cleaver modules

	length (mm)	width (mm)	thickness (mm)	mass (g)	volume (mm ³)
median	142	97	44	656	244 652
minimum	107	76	27	274	108 924
maximum	238	160	65	1 962	760 968
amplitude	130	85	38	1 688	652 044
Shapiro-Wilk p-value	0.0007438	0.004252	0.626	8.783e-05	6.373e-05

	p-value < 0,01: rejected hypothesis / abnormal distribution
	p-value < 0,05: rejected hypothesis / abnormal distribution
	p-value > 0,05: verified hypothesis / normal distribution

H0 = data are distributed according to a normal law

Table 2: Cleaver measurements and Shapiro-Wilk test results

Comparing morphometrical variables between the raw material and the technical groups of cleavers, it appears that the nature and percentage of (neo)cortical surfaces, the type of blank, the debitage direction of the blank, and the technotype *sensu* Tixier/Zuate y Zuber do not have a significant impact on size and mass (Fig. 6). The Mann-Whitney U test results confirm this: p-values greater than 0.01 or 0.05 for most combinations of these criteria indicate that the differences between these groups, according to the morphometric variables tested, are not statistically significant (Tab. 3-7). Only a few differences observed in the graphical results and median values were statistically reliable: cleavers made on quartzite with a fluvial neocortex (152x94x40 mm, 569 g) are smaller than those with an altered cortex (158x105x51 mm, 772 g) (p-value<0.05 for length and mass, <0.01 for thickness) or thinned cortex (142x96x45 mm, 674g) (p-value<0.05 for length and mass); cleavers made on undetermined flakes (125x92x41 mm, 451 g) are smaller than those made on (neo)cortical ones (145x98x47 mm, 611g) (p-value<0.05 for length, thickness and mass); type 1 cleavers are smaller in width (84mm) than type 0 (102 mm) (p-value<0.01 mm). However, the small number of fluvial neocortex pieces (n=3), including those made on Kombewa flakes (n=4) and those of type I (n=4) and VI (n=4), did not allow most of these differences to be considered accurately.

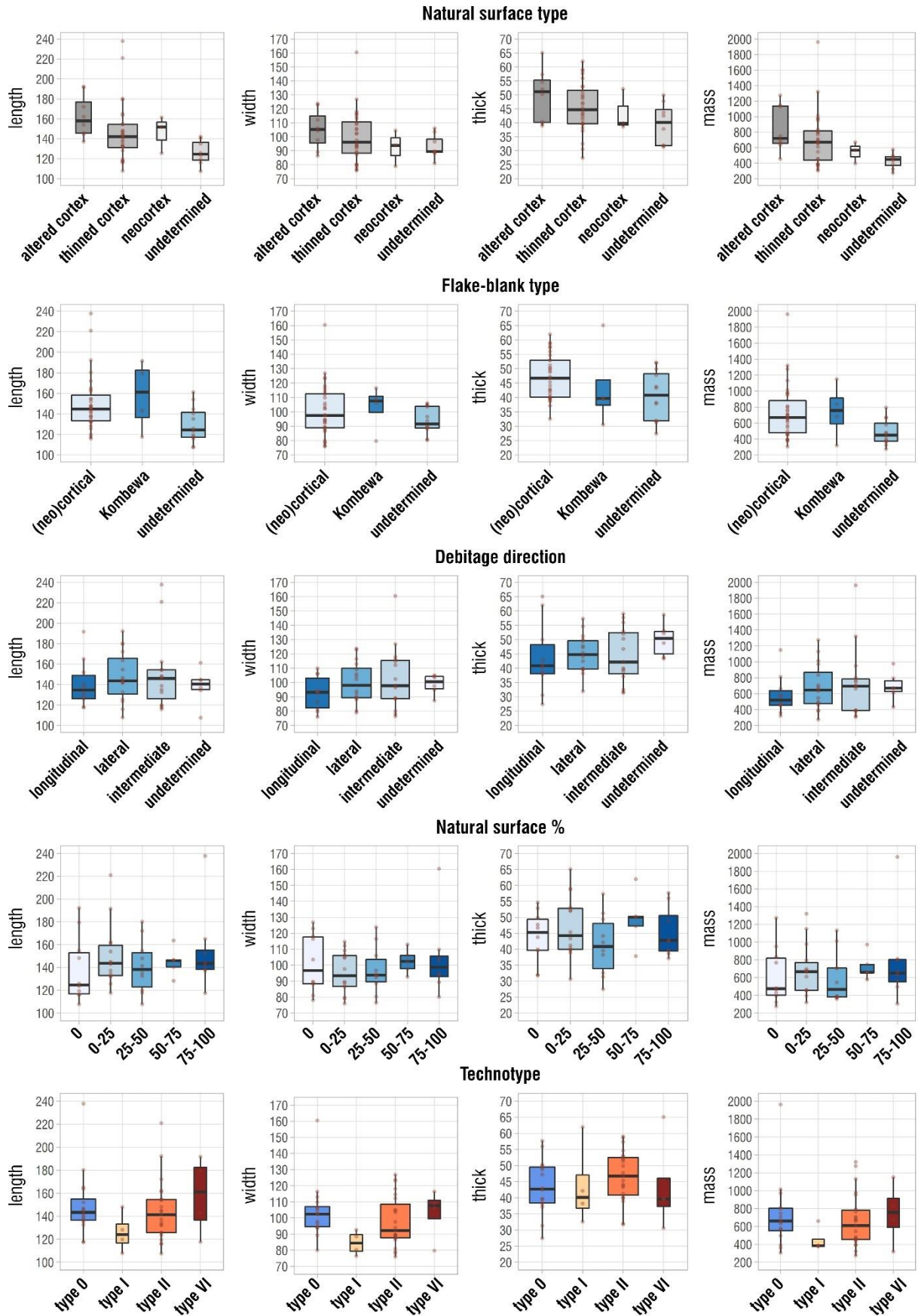





Figure 2: Boxplot of cleaver measurements according to qualitative criteria (red points: individual data; thick line: median; box: 1st and 3rd quartiles; whiskers: 1st and 9th deciles)

Natural surface type															
variables	length			width			thickness			mass			main shape		
groups	thinned cortex	neocortex	undetermined	thinned cortex	neocortex	undetermined	thinned cortex	neocortex	undetermined	thinned cortex	neocortex	undetermined	thinned cortex	neocortex	undetermined
altered cortex	0,055	0,002	0,358	0,332	0,104	0,262	0,351	0,041	0,358	0,262	0,004	0,126	>0,05	<0,01	0,040
thinned cortex		0,038	0,713		0,371	0,526		0,114	0,616		0,024	0,483		0,010	>0,05
neocortex			0,126			0,919			0,475			0,279			>0,05

 p-value < 0,01: rejected hypothesis / significant difference
 p-value < 0,05: rejected hypothesis / significant difference
 p-value > 0,05: verified hypothesis / insignificant difference

H0 = all data belong to a common population

Table 3: Mann-Whitney U test results, realized on principal measurements of cleaver groups depending on their natural surface type

Natural surface %																				
variables	length				width				thickness				mass				mean shape			
groups	0-25	25-50	50-75	75-100	0-25	25-50	50-75	75-100	0-25	25-50	50-75	75-100	0-25	25-50	50-75	75-100	0-25	25-50	50-75	75-100
0	0,208	0,678	0,426	0,307	0,364	0,762	0,854	0,894	0,578	0,521	0,298	0,894	0,539	0,791	0,358	0,450	>0,05	>0,05	>0,05	>0,05
0-25		0,578	0,817	0,811		0,792	0,331	0,562		0,151	0,817	0,517		0,364	0,817	0,865		>0,05	>0,05	>0,05
25-50			0,759	0,505			0,298	0,564			0,198	0,399			0,297	0,450			>0,05	>0,05
50-75				0,942				0,714				0,421				0,714				>0,05

Table 4: Mann-Whitney U test results, realized on principal measurements of cleaver groups depending on their natural surface proportion

Flake-blank type										
variables	length		width		thickness		mass		mean shape	
groups	Kombewa	undetermined	Kombewa	undetermined	Kombewa	undetermined	Kombewa	undetermined	Kombewa	undetermined
(neo)cortical	0,659	0,011	0,641	0,336	0,288	0,041	0,776	0,011	0,020	>0,05
Kombewa		0,170		0,163		0,952		0,163		>0,05

Table 5: Mann-Whitney U test results, realized on principal measurements of cleaver groups depending on their flake-blank type

Debitage direction															
variables	length			width			thickness			mass			mean shape		
groups	lateral	intermediate	undetermined	lateral	intermediate	undetermined	lateral	intermediate	undetermined	lateral	intermediate	undetermined	lateral	intermediate	undetermined
longitudinal	0,385	0,598	0,871	0,304	0,233	0,357	0,477	0,760	0,116	0,330	0,560	0,212	0,010	>0,05	>0,05
lateral		0,859	0,484		1,000	0,971		0,890	0,131		0,874	0,796		>0,05	0,020
intermediate			0,559			0,907			0,199			0,726			<0,01

Table 6: Mann-Whitney U test results, realized on principal measurements of cleaver groups depending on their blank debitage direction

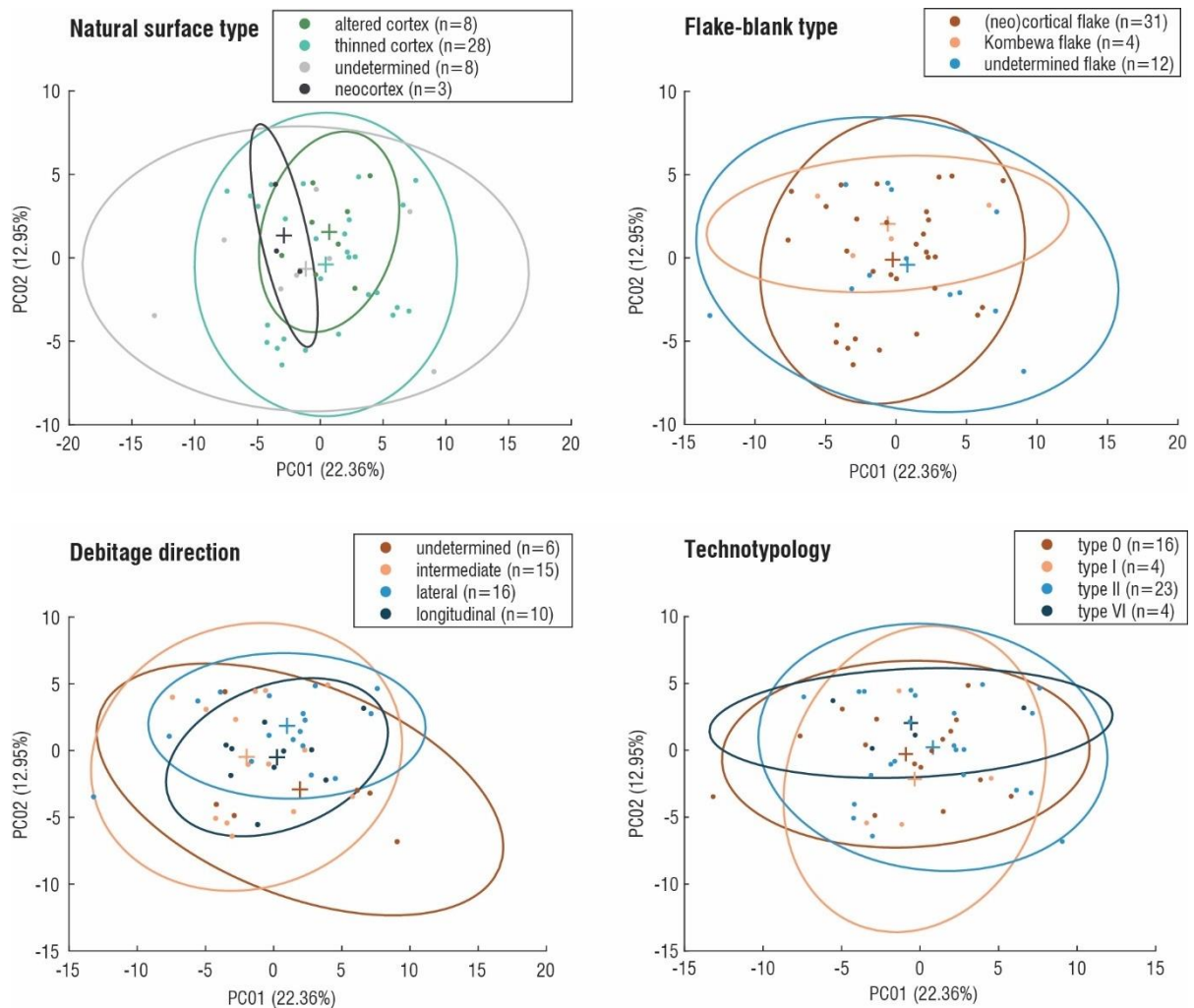


Figure 8: Scatterplots of the first two PC item scores. Each point represents an item; crosses represent group centroids; ellipses are 90% confidence ellipses (Herzlinger and Grosman, 2018)

Edge shape and production links

The technological study individualized 247 TUs from the sample (Fig. 9), with a superior face mainly retouched or coming from removals prior to the blank's debitage, and an inferior face mostly constituted of the flake-blank's ventral surface or retouched. Five ridge technotypes were identified: anterior to the debitage; coming from the debitage (unretouched and unprepared, with a natural superior face); prepared before the debitage (unretouched, with one or several scars on the superior face testifying to prior removals); retouched (with one or several scars from actions posterior to the blank's production, at least on one face); indeterminate (with scars whose chronological position relating to the blank's debitage cannot be determined). They were mostly blunt and one-third presented taphonomical or macro removals. Frontal and sagittal delineations were mainly sinuous in thin observation and straight in broad observation. The section varied without particular tendency (Fig. 10). The Shapiro-Wilk test results invalidated the hypothesis of a normal distribution for both height and width ($p\text{-value} < 0.01$): the smaller measurement ranks were overrepresented and high values were marginal. Similar results were obtained for the average angle at $h=20$ mm, with rank measurements between 35 and 45° being overrepresented (Fig. 11). Moreover, average angles tended to decrease when the h -value increased (Tab. 8).

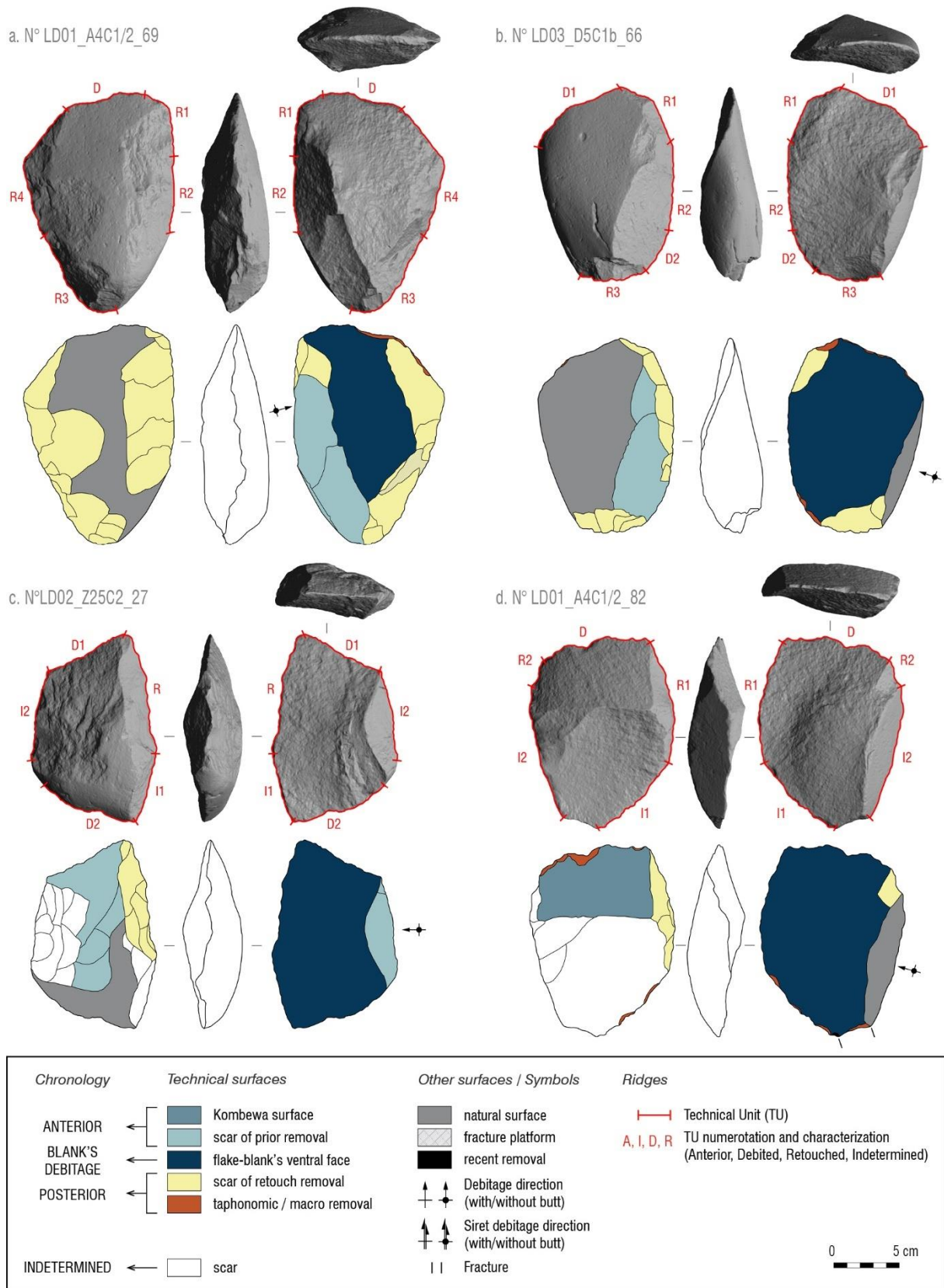


Figure 9: Diacritical drawings of cleavers and TU identification

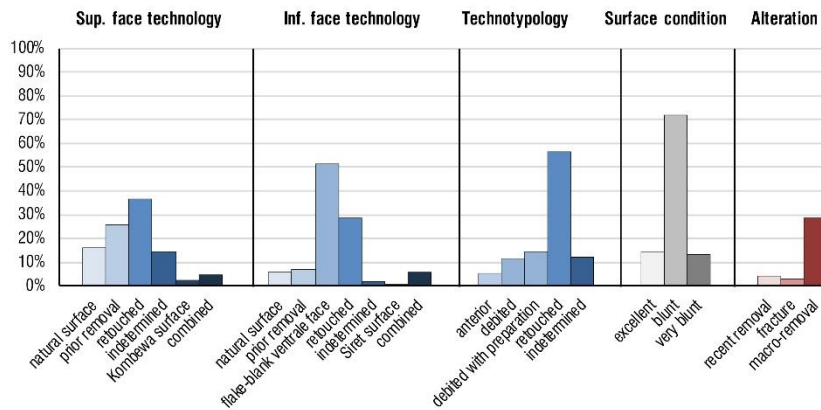


Figure 10: Proportion of TUs (total n=247) according to technical and morphological criteria

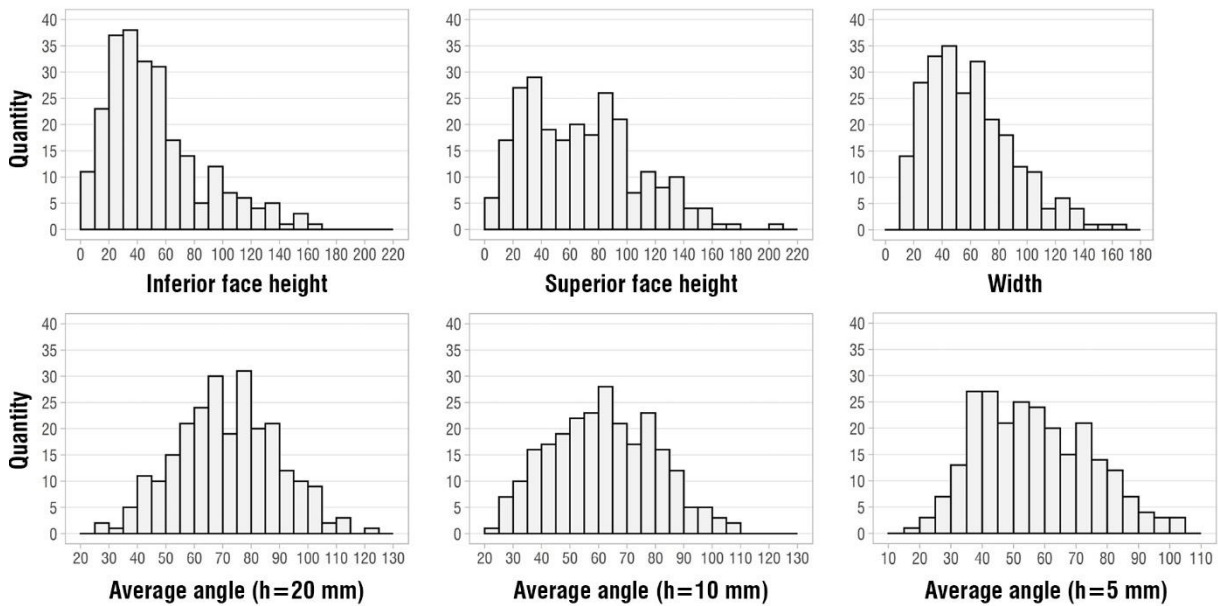


Figure 11: Histogram of TU principal measurements

	height		width (mm)	mean angle		
	sup. face (mm)	inf. face (mm)		h=5 mm	h=10 mm	h=20 mm
median	46	64	56	72	63	55
minimum	5	7	14	27	21	17
maximum	163	202	167	120	109	103
amplitude	158	195	153	93	89	86
Shapiro-Wilk p-value	4.705e-11	2.415e-06	1.854e-07	0.8338	0.0851	0.00192

p-value < 0,01: rejected hypothesis / abnormal distribution
 p-value < 0,05: rejected hypothesis / abnormal distribution
 p-value > 0,05: verified hypothesis / normal distribution

H0 = data are distributed according to a normal law

Table 8: TU measurements and Shapiro-Wilk test results

Links were perceptible between the TUs' morphology and their production modes: section was mainly convex or plane for those coming from the debitage or anterior, and mainly irregular when retouched; delineations were mostly straight or curved for those arising from the debitage or anterior to it, and mostly sinuous or irregular when retouched (Tab. 9). Likewise, taphonomical or macro removals were identified on 66% of the TUs directly debited and on 58% of TUs prepared before debitage, against less than 21% for the rest. Links between ridge morphometry and technotypes also appeared, confirmed by the Mann-Whitney U test: TUs coming from the debitage and anterior to it were higher on both faces than retouched (p -value <0.01 for superior face height; p -value <0.05 for inferior face height) or undetermined (p -value <0.01 for both faces); TUs coming just from the debitage showed more acute angles than retouched (p -value <0.01), indeterminate (p -value <0.01 except for the average angle with $h=5$ mm) and anterior (p -value <0.01 except for the average angle with $h=5$ mm). The angle classes of directly debited ridges were mostly concentrated between 30 and 45° where there was preparation before the debitage, and between 20 and 80° in the absence of preparation (Fig. 12-13; Tab. 10-11). Furthermore, as confirmed by the Shapiro-Wilk test, only TU angles coming from the debitage, with or without preparation, were not shared according to a normal distribution (p -value <0.01 for the average angle with $h=20$ mm of directly debited TUs and for all average angles of the TUs debited with preparation; p -value <0.05 for the average angle with $h=10$ mm of the directly debited TUs) (Tab. 12).

		Ridge technotype									
		anterior		debited		debited with preparation		retouched		indeterminate	
		Eff.	%	Eff.	%	Eff.	%	Eff.	%	Eff.	%
Thin frontal delineation	linear	6	50,0	7	21,9	14	38,9	11	8,0	6	20,7
	concave	1	8,3	1	3,1	0	0,0	10	7,2	1	3,4
	convex	5	41,7	7	21,9	4	11,1	10	7,2	7	24,1
	sinuous	0	0,0	7	21,9	12	33,3	65	47,1	6	20,7
	irregular	0	0,0	10	31,3	6	16,7	38	27,5	9	31,0
	pointed	0	0,0	0	0,0	0	0,0	2	1,4	0	0,0
	two lines	0	0,0	0	0,0	0	0,0	2	1,4	0	0,0
Total	12	100	32	100	36	100	138	100	29	100	
Thin sagittal delineation	linear	7	58,3	13	40,6	15	41,7	24	17,4	9	31,0
	curved	1	8,3	7	21,9	3	8,3	33	23,9	5	17,2
	sinuous	0	0,0	4	12,5	7	19,4	65	47,1	10	34,5
	irregular	4	33,3	8	25,0	11	30,6	15	10,9	5	17,2
	pointed	0	0,0	0	0,0	0	0,0	1	0,7	0	0,0
Total	12	100	32	100	36	100	138	100	29	100	
Section	plane	4	33,3	0	0,0	1	2,8	2	1,4	3	10,3
	concave	1	8,3	0	0,0	0	0,0	1	0,7	0	0,0
	convex	2	16,7	13	40,6	3	8,3	0	0,0	1	3,4
	irregular	1	8,3	4	12,5	2	5,6	51	37,0	8	27,6
	plano-concave	1	8,3	0	0,0	2	5,6	4	2,9	2	6,9
	plano-convex	1	8,3	4	12,5	11	30,6	4	2,9	3	10,3
	plano-irregular	0	0,0	3	9,4	3	8,3	18	13,0	4	13,8
	concave-convex	1	8,3	2	6,3	8	22,2	4	2,9	0	0,0
	concave-irregular	1	8,3	1	3,1	2	5,6	22	15,9	6	20,7
	convex-irregular	0	0,0	5	15,6	4	11,1	32	23,2	2	6,9
Total	12	100	32	100	36	100	138	100	29	100	

Table 9: Quantity and proportion of TUs depending on morphological criteria for each technotype

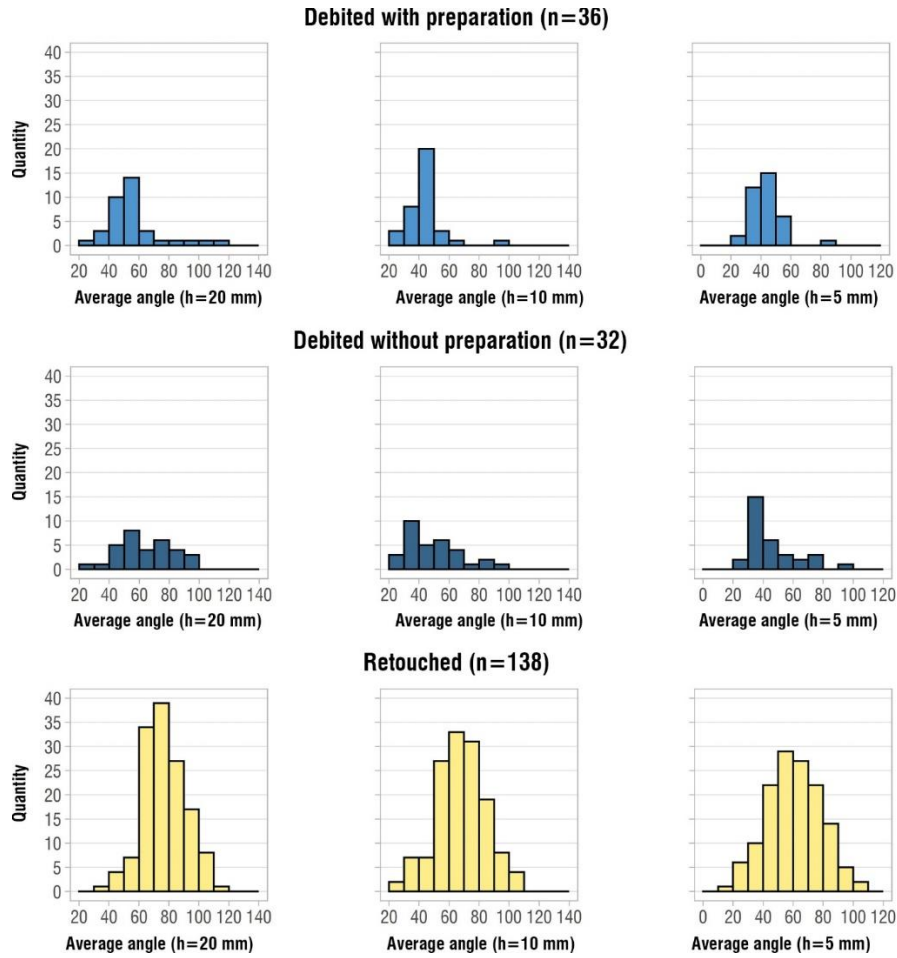


Figure 12: Histogram of TU angles depending on their technotype

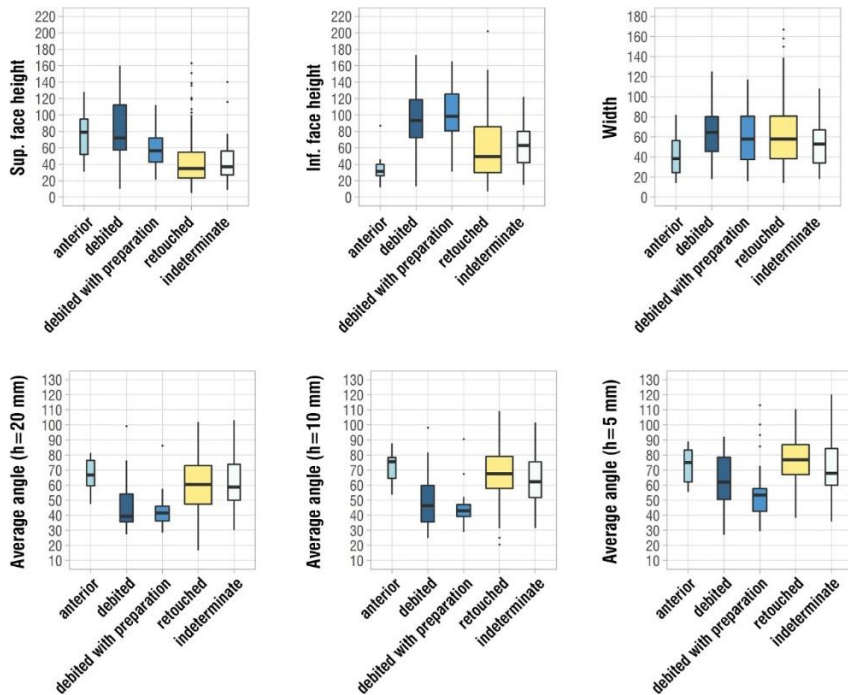


Figure 13: Boxplot of TU measurements according to petrographical and technical criteria (red points: individual data; thick line: median; box: 1st and 3rd quartiles; whiskers: 1st and 9th deciles; the boxes width changes according to number of items)

Technotype												
variables	superior face height				inferior face height				width			
groups	debited	debited with preparation	retouched	indeterminate	debited	debited with preparation	retouched	indeterminate	debited	debited with preparation	retouched	indeterminate
anterior	0,536	0,105	0,004	0,002	0,000	0,000	0,025	0,006	0,023	0,105	0,026	0,178
debited		0,007	0,000	0,000		0,407	0,000	0,000		0,288	0,460	0,110
debited with preparation			0,000	0,004			0,000	0,000			0,567	0,570
retouched				0,694				0,523				0,235

	p-value < 0,01: rejected hypothesis / significant difference
	p-value < 0,05: rejected hypothesis / significant difference
	p-value > 0,05: verified hypothesis / insignificant difference

H0 = all data belong to a common population

Table 10: Mann-Whitney U test results, realized on principal measurements of TUs technotypological groups

Technotype												
variables	Angle (h=5 mm)				Angle (h=10 mm)				Angle (h=20 mm)			
groups	debited	debited with preparation	retouched	indeterminate	debited	debited with preparation	retouched	indeterminate	debited	debited with preparation	retouched	indeterminate
anterior	0,071	0,000	0,396	0,576	0,001	0,000	0,404	0,780	0,000	0,000	0,151	0,183
debited		0,041	0,000	0,163		0,386	0,000	0,002		0,966	0,000	0,001
debited with preparation			0,000	0,000			0,006	0,000			0,000	0,000
retouched				0,031				0,121				0,981

Table 11: Mann-Whitney U test results, realized on mean angles of TUs technotypological groups

	anterior	debited	debited with preparation	retouched	indeterminate
superior face height (mm)	79	72	57	35	37
inferior face height (mm)	32	94	99	50	63
width (mm)	39	65	58	58	53
angle (h=5 mm)					
(°)	75	62	53	77	68
Shapiro-Wilk p-value	0.2521	0.3473	0.000142	0.539	0.1761
angle (h=10 mm)					
(°)	76	46	43	68	62
Shapiro-Wilk p-value	0.3641	0.02587	1.668e-05	0.8527	0.7981
angle (h=20 mm)					
(°)	67	39	42	60	59
Shapiro-Wilk p-value	0.4807	0.0001913	0.0001368	0.881	0.7492

	p-value < 0,01: rejected hypothesis / abnormal distribution
	p-value < 0,05: rejected hypothesis / abnormal distribution
	p-value > 0,05: verified hypothesis / normal distribution

H0 = data are distributed according to a normal law

Table 12: TU measurements and Shapiro-Wilk test results depending on technotype

The most relevant morphological and morphometrical criteria for determining the structural parts of artefacts are sections, delineations, and average angles for h=10 mm. Height and width are not discriminant, highly variable or without significant tendency: average angles for h=5 mm showed less marked tendencies related

to technotypes, and average angles for $h=20$ mm were more often impacted by irregularities on the measured surfaces. Five principal edge morphotypes were thus identified, whose morphological and morphometrical characteristics are the consequence of technical actions realized during different stages of production: these perceptible links between morphotypes and technical characteristics make it possible to identify different types of structural parts (Fig. 14).

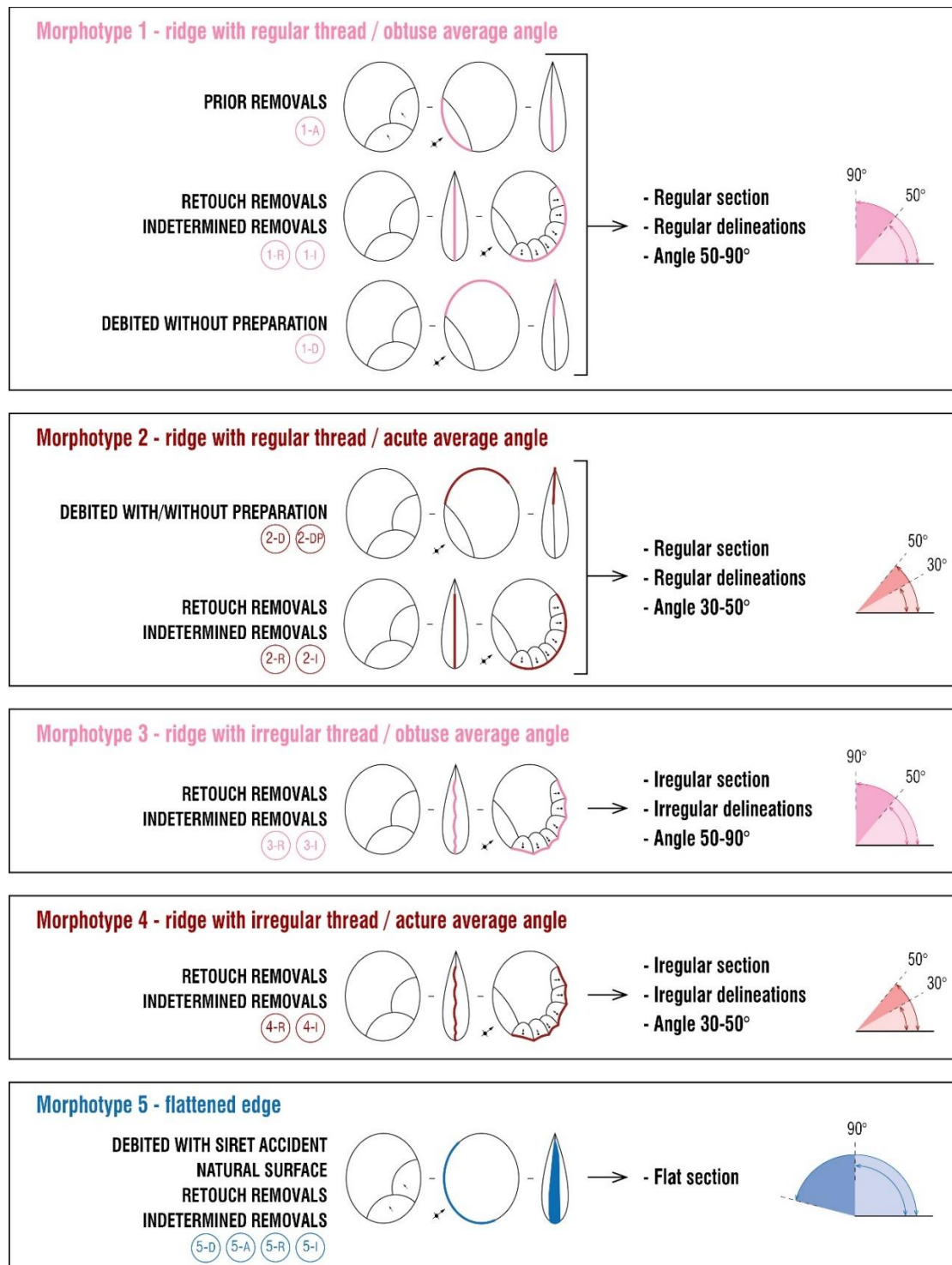


Figure 14: Edge morphotypes identified and their potential modes of production, allowing for structural parts characterization

Technico-structural groups

The structural parts identified in the sample were mostly related to the 3-R (retouched irregular thread with obtuse angle), 2-DP (debited/cut with preparation), 2-D (cut without preparation, regular thread with acute angle), 1-R (retouched regular thread with acute angle) or 3-I (indeterminate irregular thread with obtuse angle) types. Their organizations highlight four principal technico-structural groups sharing the essential transversal edge related to 2-D or 2-DP part types (Fig. 15-16).

Technico-structural group 1 (n=20), cleavers with flattened base

Edges from the debitage with a regular thread and angles between 27 and 52° (2-DP, 2-D) are opposed to a flat cortical or retouched edge (5-A, 5-R). The lateral edges have been shaped by retouches or undetermined removals: structural parts with an irregular section and delineations and angles between 52 and 94° (3-R, 3-I) for half the cases, or with similar angles but regular delineations (1-R, 1-I) for the rest, are occasionally accompanied by other structural part types. These cleavers are related to types 0 (n=7), I (n=2), II (n=10) and VI (n=1) *sensu* Tixier/Zuate y Zuber.

Technico-structural group 2 (n=13), cleavers with angular circumference

The entire periphery consists of ridges with angles exceeding 50°, except for the transversal edge which has a regular section and delineations, and an angle between 29 and 53° (2-D, 2-DP). For half the cases, the structural parts with an obtuse angle on the circumference were exclusively retouched, with irregular delineations and an angle between 50 and 89° (3-R). The other half result from an undermined action, despite a similar morphology (3-I). The 3-R structural part type is associated with regular delineated edges (1-A, 1-D, 1-I, 2-R), or with a more acute angle, between 25 and 41° (4-R, 4-I), always when they are adjacent to the 2-D or 2-DP edge. These cleavers are related to type 0 (n=5), I (n=1) and II (n=7) *sensu* Tixier/Zuate y Zuber.

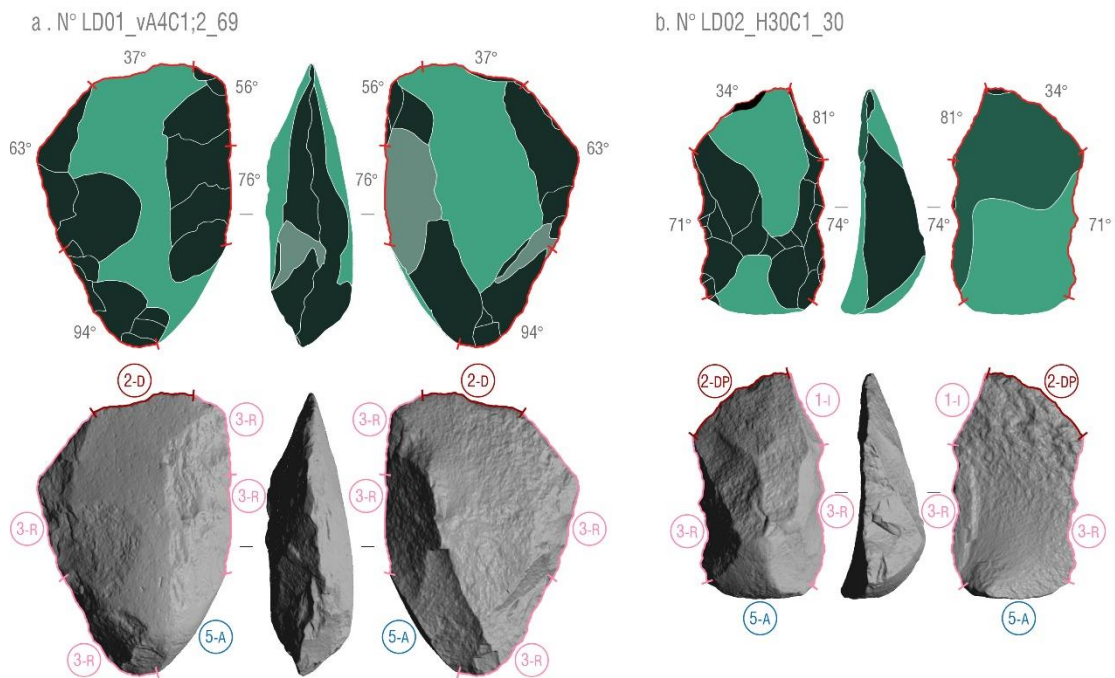
Technico-structural group 3 (n=8), cleavers with a flattened lateral edge

Edges from the debitage that have a regular thread and an angle between 25 and 52° (2-D, 2-DP) are accompanied by an adjacent flattened edge sub-parallel to the tool's morphological axis. It is often cortical, though sometimes is retouched or created by an accidental Siret fracture during debitage (5-A, 5-R, 5-D). The structural parts constituting the rest of the circumference, opposed to the 2-D or 2-DP type and to the flattened lateral one, are mainly retouched with an angle between 54 and 90° (3-R, 1-R), sometimes presenting a similar morphology but resulting from the debitage (1-D) or from a prior action (1-A). These cleavers are related to type 0 (n=5), I (n=1) and II (n=2) *sensu* Tixier/Zuate y Zuber.

Technico-structural group 4 (n=6), cleavers with double transversal cutting extremities

The two cutting edges face each other, sub-perpendicular to the cleaver's morphological axis. At least one of them is directly cut, almost always with prior preparation, with regular delineations and a section and cutting angle between 31 and 50° (2-DP); the rest result from debitage (2-DP), undetermined actions (2-I, 4-I) or retouch (2-R, 4-R). Between these extremities, the post-debitage edges have an irregular thread and angles between 51 and 94° (3-R), accompanied by edges created by anterior or undetermined actions with an obtuse angle and regular delineations (1-A, 1-I) or resulting from an undetermined stage of production creating similar morphologies (3-I). These cleavers correspond to types 0 (n=1), II (n=3) and VI (n=2) *sensu* Tixier/Zuate y Zuber.

Technico-structural group 1 - Cleavers with flattened base



Technico-structural group 2 - Cleavers with whole angular circumference

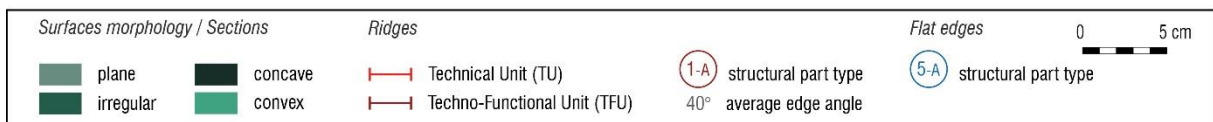
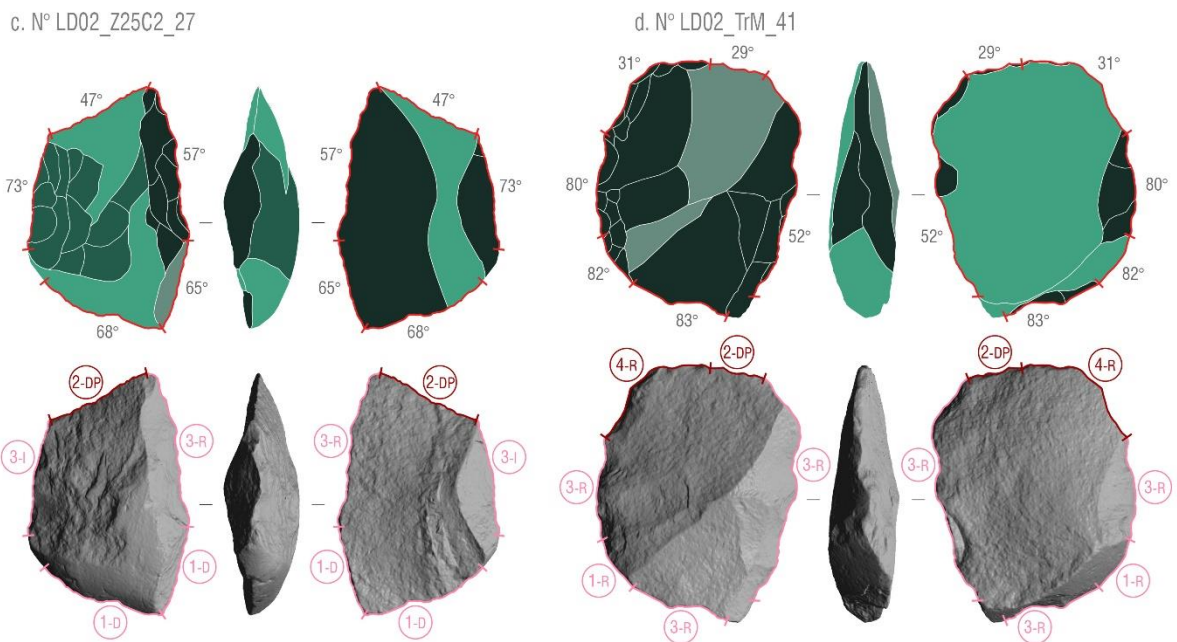
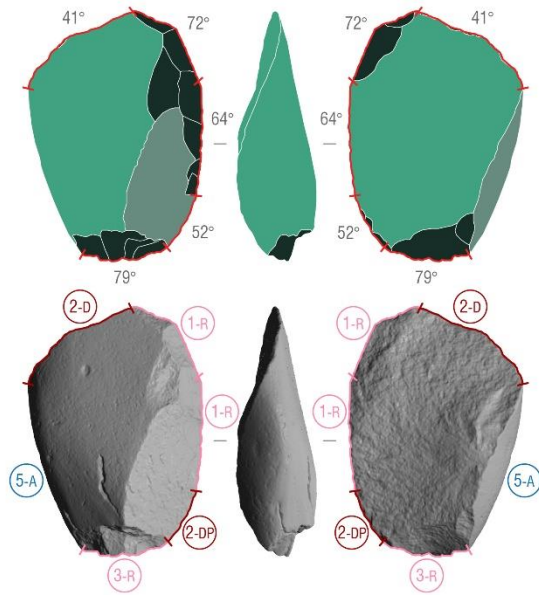


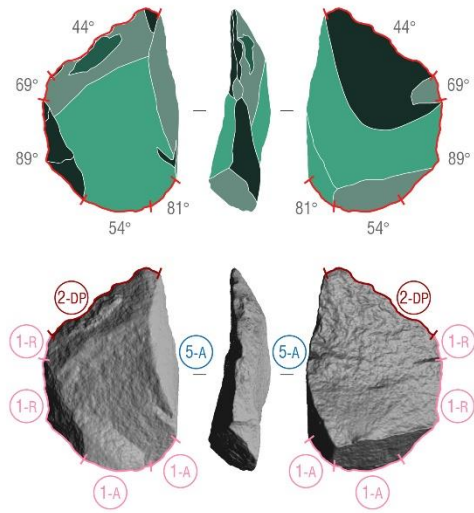
Figure 15: Cleaver drawings with TU morphology and 3D cleaver scans with identification of structural parts; technico-structural groups 1 and 2

Technico-structural group 3 - Cleavers with lateral flattened edge

a. N° LD03_D5C1b_66

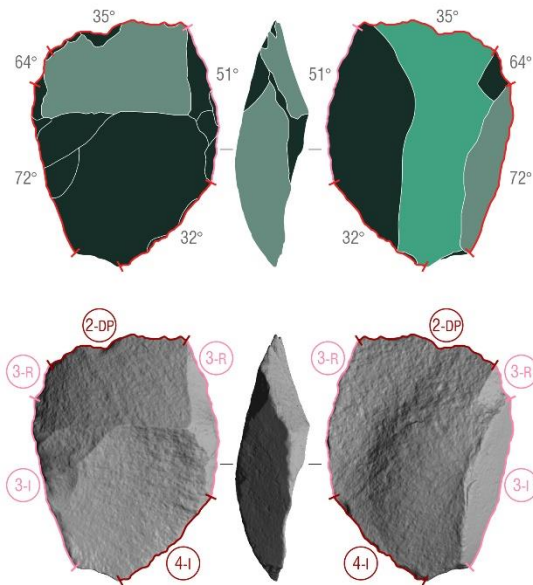


b. N° LD03_F2C2_16

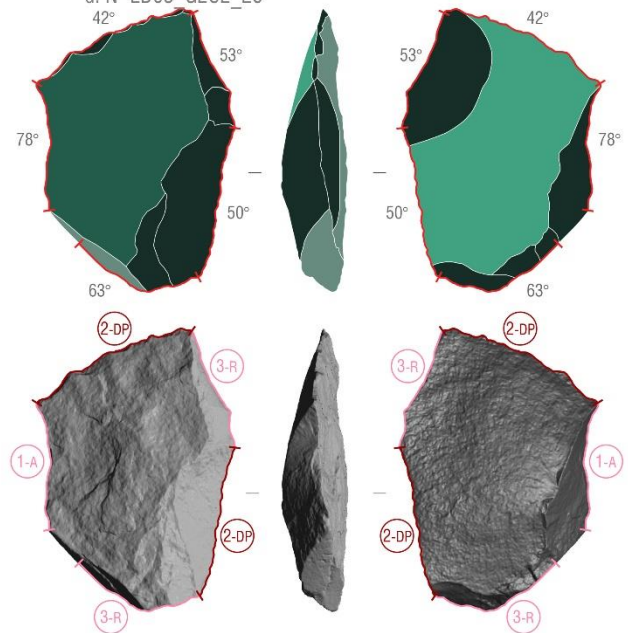


Technico-structural group 4 - Cleavers with double transversal cutting edge

c. N° LD01_A4C1;2_82



d. N° LD03_G2C2_26



Surfaces morphology / Sections		Ridges	Flat edges	0	5 cm
plane	concave	Technical Unit (TU)	structural part type		
irregular	convex	Techno-Functional Unit (TFU)	40° average edge angle		

Figure 16: Cleaver drawings with TUs morphology and 3D cleaver scans with identification of structural parts; technico-structural groups 3 and 4

Discussion

Opportunities and limitations of the tested technomorphometric analyses

The global shape analysis of each tool allowed us to understand the technicomorphometric variability of the sample. A metrical variables study was necessary to address questions regarding size: distribution abnormality can indicate preferential modules choices. Furthermore, geometric configuration analyses enabled us to identify variations within the tool's tridimensional organization. But, although it could partly reflect the goals of their production, the cleaver's global shape has also been strongly impacted by other factors: initial volume of the block of raw materials selected; blank debitage techniques and methods; accidents; unintended but practical opportunities; knapper's experience level; tool's techno-economic status; technical investment; etc. In fact, the degree of a blank's modification is usually low and the involvement of external factors in its shape are difficult to determine – this is the case at Lanne-Darré where no significant link was revealed between technical choices and global measures or geometric configuration.

On the other hand, structural analyses, which considers each edge as a potential independent functional or productional entity and their interrelations on each tool, enabled interpretations that could not be reached otherwise. Nevertheless, the present study shows that many obstacles still need to be overcome for this level of analysis. Delineation, whether frontal or sagittal, presents different results when observing deviations between 2 and 10 mm or greater than 10 mm. In the same way, intersection surface morphology, which defines the section, is strongly related to the extent of analyzed areas. Some metric criteria are also subject to significant constraints, beyond measurement challenges, evidenced by the recurring relationship between the average angle and height analysis. In addition, angle variations between some different ridge technotypes appeared less significant for the smallest height ($h=5$ mm) than for the others ($h=10$ and 20 mm). Even if an angle measured on large surfaces is more accurate, irregularities are also more numerous. Ridge height is a precious indicator of their functional potential (Soressi, 2002; Viallet, 2016), but it is also tricky to objectify because it is often calculated from an arbitrary technical or morphological continuity. Finally, the nature of taphonomical or macro removals that can modify the ridges is complex to identify.

Within the different analytical processes considered, only the technico-structural analysis seems to establish links between the technicomorphometric properties of cleavers and production intentions. Nevertheless, this method must be applied to other series of cleavers from European Middle Pleistocene in order to refine the chosen criteria, culminating in the study of other industry parts to precise the place of cleavers alongside associated artefacts.

Technico-structural diversity versus J. Tixier's typology

The systematic transversal cutting edge that defines cleavers *sensu* Tixier/Zuate y Zuber already reveals a shared production concept. In this sense, the fact that TUs resulting from the blank's debitage present more taphonomical or macro removals than the other edges could indicate a specific status – further taphonomic analysis is essential to exclude accidental or natural phenomena. Furthermore, the angle distribution of the debited ridges does not follow a normal law, which could indicate a knapper's preferential choice, unlike those of the other TU technotypes. Nevertheless, the variability of the other structural parts interrogates the

exclusivity of the transversal cutting edge as the tool's unique transformative area. In fact, 2-D, 2-DP, 2-I, 4-I, 2R or 4R edges, located on opposite sides of the transversal cutting edge on cleavers of technico-structural group 4, show the same sharp morphological uniformity. Additionally, the changing organization of the other structural parts, opposite or lateral backs, or even obtuse angular circumferences, may reveal different possible intentions of use, such as gripping or fitting. Consequently, the cleaver might represent a plurality of different conceptual realities, with only its transversal cutting edge being an unchanging structural area. But is this variability, intrinsic to the concept of cleaver production, also linked to the method of blank production as suggested by Tixier's typology?

The proposed technico-structural classification differs from Tixier's technotypology, although both are based on technological observations. Indeed, cleavers relating to type 0, I, II and VI *sensu* Tixier/Zuate y Zuber identified in Lanne-Darré's sample are represented indistinctly within the four technico-structural groups. Similarly, neither their principal dimensions nor their geometrical configurations present any links with Tixier's types. This paradox points to a possible weakness in the way cleavers are classified in both cases: on one hand, Tixier's classification appears incomplete, based on the only area considered as transformative, the transversal cutting edge; on the other hand, the rigidity of the technico-structural characterization criteria used here could be reduced in order not to multiply technico-structural classes, and details on the methods of the blank's debitage could be given more consideration. What is certain is that the technico-structural groups highlighted provide a new insight into the possible diversity of this tool's configuration by focusing on its whole perimeter.

Implications of the structural variability of the Lanne-Darré cleavers

In Europe, most of the cleavers are of J. Tixier's type 0 although other types are also represented (Capdevielle et Ravon, 2021). This is the case for the El Sartalejo (Santonja et Villa, 1990 et 2006), Pinedo (Querol et Santonja, 1980; Mourre, 2003) and Porto Maior (Méndez-Quintas et al., 2018) sites in the Iberian Peninsula, and for Lanne-Darré in south-western France. Within the Iberian Acheulean industries at the north of the Pyrenean, Duclos cleavers (n=22) are exclusively Tixier's type 0, and a series of tools from surface collections have also yielded numerous cleavers in the region, such as Géry or Campsas, but this time attributed to Tixier's types 0, I, and II (Tavoso, 1986; Jaubert et Savelle 1996; Mourre, 2003; Jarry, 2010). Tixier raised the question of the chronological scope of his typology: according to him, type 0 would represent the least "evolved" type and therefore the oldest, since the technical and conceptual investment in its development is more limited than for the other types (1956). This perception was later refuted: "the representation of the different types does not seem to have any implication in terms of degree of evolution or chronology" (Mourre, 2003). A certain evolution in the degree of predetermination is, however, highlighted by Mourre, who analyzed the relationships between the direction of the blank debitage and those of the removals predetermining the transversal edge, which tend to come closer with time.

The present preliminary study has already revealed that the place of the cleaver within the mental schemes of human groups cannot be reduced to purely the production of the transversal edge. If this does not call into question the importance of the cleaver as a technico-cultural marker, the potential diversity of the conceptual realities of this tool within the industries in which it appears leads us to better qualify its meaning. With this in

mind, a technico-structural approach adapted to the study of the cleaver, or more broadly to the large tools on flakes characteristic of the Iberian Acheulean industries, need to be carried out on other collections in a wider geographical area, in order to provide new knowledge about the variability of this tool within the region's series and even across the entire south-west Continent and through time.

Conclusion

This article has tested several different ways of approaching the technicomorphometry of the cleaver, retaining the structural analysis as the most adapted to the issues addressed, even though it still needs to be refined. It is a first step towards a better understanding of the status of large tools which are prevalent in many Western European Middle Pleistocene lithic industries. If gaps still remain, regarding their place in technical systems and mental templates, the contribution of an adapted technico-structural analysis attests its relevance.

The analytical tool proposed aims to approach the identity of the artefact differently, without trying to create a new typology. Indeed, any technico-structural groups that could emerge from a larger-scale study are not intended to replace that of Tixier, but rather to provide additional information about the cleaver: an object which remains misunderstood. Clearly, this would only make sense if the study of these objects were later reintegrated into the study of the whole industries from which they originated, or at least into their macro-tool set and large blank production.

Nevertheless, the technotypology of cleavers that is considered as one of the strongest is revealing a circular reasoning in the case of the issues raised in this study. These reflections also encourage us to maintain ongoing exploration into our methodological paradigms, in order to avoid this kind of phenomenon: it will be indispensable when considering the countless subtleties inherent in all lithic industries and the implications that they underlie.

Acknowledgments

We would like to thank Anne-Lyse Ravon and Vincent Mourre for their supervision of Juliette Capdevielle's Master degree, from which this work results. We would also like to thank the entire teaching staff of the ASE2P Master at the Université of Toulouse Jean-Jaurès, as well as all the members of the TRACES laboratory. Special thanks to Thomas Perrin for his help with the statistical analyses, and to Marianne Deschamps for giving us the opportunity to make 3D scans of the Lanne-Darré cleavers and for training us in the AGMT-3D software, as part of the Fyssen Morph-Axe project. Thanks to Paula García-Medrano and Antoine Muller for their help in choosing the best tool for measuring edge angles, and in using the Artefact-3D software. Thanks to Jill Cucchi for the help with the translation, and to the ChroTAll project for the support. We would also like to thank the two reviewers for their pertinent feedback, which helped to improve the article considerably.

References

- Alimen, H., Vignal, A., 1952. Etude statistique de bifaces acheuléens. Essai d'Archéométrie. Bulletin de la Société préhistorique de France 49, 5–72.
- Alimen, M.-H., 1978. L'évolution de l'Acheuléen au Sahara nord-occidental : Saoura, Ougarta, Tabelbala, CNRS. Ed. Meudon.
- Archer, W., Djakovic, I., Brenet, M., Bourguignon, L., Presnyakova, D., Schlager, S., Soressi, M., McPherron, S.P., 2021. Quantifying differences in hominin flaking technologies with 3D shape analysis. *Journal of Human Evolution* 150, 102–912.
- Balout, L., Biberson, P., 1967. L'Acheuléen de Ternifine (Algérie), gisement de l'Atlanthrope. *L'Anthropologie* 71, 217–238.
- Bleicher, D., 1875. Découverte d'armes préhistoriques à Tlemcen. Bulletin de la société en sc. phys. nat. climat. D'Alger t. XII, 58–61.
- Boëda, E., 1997. Technogenèse de systèmes de production lithique au Paléolithique inférieur et moyen en Europe occidentale et au Proche Orient (Habilitation à Diriger des Recherches). Université Paris X.
- Bookstein, F.L., 1991. *Morphometric Tools for Landmark Data: Geometry and Biology*. Cambridge University Press, Cambridge.
- Bordes, F., 1961. *Typologie du Paléolithique ancien et moyen*, 2. éd. ed, Publications de l'Institut de préhistoire de l'Université de Bordeaux 1. ImprDelmas, Bordeaux.
- Borel, A., 2010. *Formes et fonctions au sein des industries lithiques de la fin du Pléistocène et du début de l'Holocène en Asie du Sud-Est : un nouvel apport à la compréhension des comportements humains* (Thèse de doctorat). Paris, Muséum national d'histoire naturelle.
- Brenet, M., 1996. Analyse du façonnage de pièces bifaciales : une méthode appliquée à deux sites acheuléens de Dordogne, Cantalouette et Manestruges (Mémoire de diplôme de l'EHESS de Toulouse), 83.
- Capdevielle, J., Ravon, A.-L., 2021. Analyse technotypologique des hachereaux et autres macro-outils à tranchant transversal de Menez-Dregan I (Plouhinec, Finistère). *Bulletin de la Société préhistorique française* 118, 215–243.
- Chenorkian, R., 1996. *Pratique archéologique statistique et graphique, Méthodes et techniques 1996*. Éd. Errance Association pour la diffusion de l'archéologie méridionale, Paris Lattes.
- Colonge, D., Hernandez, M., Lelouvier, L.-A., Mercier, N., Mourre, V., 2014. Paléolithique ancien et Paléolithique moyen ancien dans le piémont pyrénéen occidental : relations entre chaînes opératoires, continuités et ruptures. *Bulletin de la Société Préhistorique Française* 119–137.
- Colonge, D., Bertran, P., Brenet, M., Busseuil, N., Chalard, P., Claud, É., Chopin, J.-F., Dayrens, O., Galibert, P., Hernandez, M., Lelouvier, L.-A., Mercier, N., Mourre, V., Normand, C., Pasquet, V., Prodeo, F., Réchin, F., Rouzo, P., 2012b. Aquitaine, A65, Pyrénées-Atlantiques, Aurillac, Duclos. Pléistocène moyen et Antiquité en Béarn (Rapport d'opération fouilles archéologiques). INRAP.

- Colonge, D., Lelouvier, L.-A., Normand, C., Mourre, V., 2012a. Approvisionnement et économie des matières premières dans l'Acheuléen du piémont occidental des Pyrénées, in: Actes Du Colloque " Roches et Sociétés de La Préhistoire Entre Massif Cristallins et Bassins Sédimentaires " Du 27 Au 30 Avril 2010, Rennes. Presses universitaires de Rennes, pp. 53–65.
- Colonge, D., Texier, J.-P., 2005. Le gisement acheuléen de Lanne-Darré (Uglas, Haute-Garonne) et perspectives régionales dans le sud-ouest de l'Europe, in: Les Premiers Peuplements En Europe. Presented at the Données récentes sur les modalités de peuplement et sur le cadre chronostratigraphique, géologique et paléogéographique des industries du Paléolithique ancien et moyen en Europe, Rennes, pp. 203–214.
- Crompton, R.H., Gowlett, J.A.J., 1993. Allometry and multidimensional form in Acheulean bifaces from Kilombe, Kenya. *Journal of human evolution* 25, 175–199.
- Dauvois, M., 1976. Précis de dessin dynamique et structural des industries lithiques préhistoriques, P. Fanlac. Ed. Périgueux.
- Delpiano, D., Uthmeier, T., 2020. Techno-functional and 3D shape analysis applied for investigating the variability of backed tools in the Late Middle Paleolithic of Central Europe. *PloS one* 15, 55.
- Deschamps Marianne, 2014. La diversité culturelle au Paléolithique moyen récent: le Vasconien et sa signification au sein des faciès moustériens (Thèse de doctorat). Université Toulouse-Jean Jaurès.
- Dibble, H.L., Chase, P.G., 1981. A New Method for Describing and Analyzing Artifact Shape. *American antiquity* 46, 178–187.
- Doyon, L., 2017. La variabilité technologique et morphométrique des pointes de projectile aurignaciennes en matière osseuse : implications cognitives, sociales et environnementales (Thèse de doctorat). Bordeaux.
- Gallotti, R., Peretto, C., 2015. The Lower/early Middle Pleistocene small débitage productions in Western Europe: New data from Isernia La Pineta t.3c (Upper Volturno Basin, Italy). *Quaternary International, Correlations of Quaternary Fluvial, Eolian, Deltaic and Marine Sequences: SEQS 2013 357*, 264–281.
- García-Medrano, P., Ashton, N., Moncel, M.-H., Ollé, A., 2020. The WEAP Method: a New Age in the Analysis of the Acheulean Handaxes. *Journal of Paleolithic Archaeology*, 756–793.
- Gero, J., Mazzullo, J., 1984. Analysis of Artifact Shape Using Fourier Series in Closed Form. *Journal of field archaeology* 11, 315–322.
- Gowlett, J.A.J., 2011. The Vital Sense of Proportion: Transformation, Golden Section, and 1:2 Preference in Acheulean Bifaces. *PaleoAnthropology* 174–187.
- Grosman, L., 2016. Reaching the Point of No Return: The Computational Revolution in Archaeology. *Annual review of anthropology* 45, 129–145.
- Grosman, L., Goldsmith, Y., Smilansky, U., 2011. Morphological Analysis of Nahal Zihor Handaxes: A Chronological Perspective. *PaleoAnthropology* 203–215.

- Grosman, L., Karasik, A., Harush, O., Smilansky, U., 2014. Archaeology in Three Dimensions: Computer-Based Methods in Archaeological Research. *Journal of Eastern Mediterranean archaeology & heritage studies* 2, 48–64.
- Grosman, L., Smikt, O., Smilansky, U., 2008. On the application of 3-D scanning technology for the documentation and typology of lithic artifacts. *Journal of archaeological science* 35, 3101–3110.
- Hernandez, M., Mercier, N., Bertran, P., Colonge, D., Lelouvier, L.A., 2012. Premiers éléments de datation des industries du Pléistocène moyen (Acheuléen - Paléolithique moyen ancien) de la région pyrénéo-garonnaise : une approche géochronologique pluri-méthodes (TL, OSL et TT-OSL) des sites de Duclos et Romentères. *PALEO. Revue d'archéologie préhistorique* 155–170.
- Herzlinger, G., Grosman, L., 2018. AGMT3-D: A software for 3-D landmarks-based geometric morphometric shape analysis of archaeological artifacts. *PLOS ONE* 13.
- Herzlinger, G., Wynn, T., Goren-Inbar, N., 2017. Expert cognition in the production sequence of Acheulian cleavers at Gesher Benot Ya'aqov, Israel: A lithic and cognitive analysis. *PloS one* 12.
- Iovita, R., 2009. Ontogenetic scaling and lithic systematics: method and application. *Journal of archaeological science* 36, 1447–1457.
- Iovita, R., McPherron, S.P., 2011. The handaxe reloaded: A morphometric reassessment of Acheulian and Middle Paleolithic handaxes. *Journal of human evolution* 61, 61–74.
- Isaac, G.LI., 1969. Studies of Early Culture in East Africa. *World Archaeology* 1, 1–28.
- Jarry, M., 2010. Les groupes humains du Pléistocène moyen et supérieur en Midi toulousain : contextes, ressources et comportements entre Massif Central et Pyrénées (Thèse de Doctorat). Université Toulouse le Mirail - Toulouse II.
- Jaubert, J., Servelle, C., 1996. L'Acheuléen dans le bassin de la Garonne (région Midi-Pyrénées) : Etat de la question et implications, in: *Publications Du CERP. Presented at the L'Acheuléen dans l'ouest de l'Europe : actes du colloque de Saint-Riquier, 6-10 juin 1989*, pp. 77–108.
- Lepot, M., 1993. Approche techno-fonctionnelle de l'outillage lithique moustérien : Essai de classification des parties actives en termes d'efficacité technique. Application à la couche M2e sagittale du Grand Abri de LA FERRASSIE (Fouille Henri DELPORTE) (Mémoire de maîtrise). Université de Paris X-Nanterre.
- Li, H., Lei, L., Li, D., Lotter, M.G., Kuman, K., 2021. Characterizing the shape of Large Cutting Tools from the Baise Basin (South China) using a 3D geometric morphometric approach. *Journal of archaeological science, reports* 36, 12.
- Lycett, S.J., Cramon-Taubadel, N. von, Gowlett, J.A.J., 2010. A comparative 3D geometric morphometric analysis of Victoria West cores: implications for the origins of Levallois technology. *Journal of Archaeological Science* 37, 1110–1117.
- Mann, H.B., Whitney, D.R., 1947. On a Test of Whether one of Two Random Variables is Stochastically Larger than the Other. *The Annals of mathematical statistics* 18, 50–60.

- Mester, Z., Moncel, M.-H., 2006. Le site Paléolithique moyen d'Erd (Hongrie) : Nouvelles données sur les chaînes opératoires et résultats morpho-fonctionnels de la production. *Anthropologie (Brno)* 44, 221–240.
- Métairie, L., 2014. Apports de la morphométrie géométrique à la paléoanthropologie dentaire (Thèse de doctorat). Université Claude Bernard Lyon 1.
- Moncel, M.-H., Arzarello, M., Boëda, É., Bonilauri, S., Chevrier, B., Gaillard, C., Forestier, H., Yinghua, L., Sémah, F., Zeitoun, V., 2018. The assemblages with bifacial tools in Eurasia (first part). What is going on in the West? Data on western and southern Europe and the Levant. *Comptes Rendus Palevol, Hominins and tools. Expansion from Africa towards Eurasia* 17, 45–60.
- Moncel, M.-H., Ashton, N., 2018. From 800 to 500 ka in Western Europe. The Oldest Evidence of Acheuleans in Their Technological, Chronological, and Geographical Framework, in: *The Emergence of the Acheulean in East Africa and Beyond: Contributions in Honor of Jean Chavaillon, Vertebrate Paleobiology and Paleoanthropology*. Springer International Publishing, pp. 215–235.
- Moncel, M.-H., Ashton, N., Lamotte, A., Tuffreau, A., Cliquet, D., Despriée, J., 2015. The Early Acheulian of north-western Europe. *Journal of Anthropological Archaeology* 40, 302–331.
- Mosquera, M., Ollé, A., Rodríguez, X.P., 2013. From Atapuerca to Europe: Tracing the earliest peopling of Europe. *Quaternary International, East meets West: First settlements and human evolution in Eurasia* 295, 130–137.
- Mourre, V., 2006. Émergence et évolution de la prédétermination au Paléolithique, in: *Normes Techniques et Pratiques Sociales : “De La Simplicité Des Outillages Pré- et Protohistoriques”*, XXVIe Rencontres Internationales d'archéologie et d'histoire d'Antibes. APDCA, Antibes Juan les Pins, pp. 61–74.
- Mourre, V., 2003. Implications culturelles de la technologie des hachereaux (Thèse de doctorat). Université Paris Nanterre.
- Mourre, V., Colonge, D., 2010. La question du débitage de grands éclats à l'Acheuléen. *PALEO. Revue d'archéologie préhistorique* 35–48.
- Mourre, V., Colonge, D., 2007. Et si l'Acheuléen méridional n'était pas là où on l'attendait ?..., in: *Un Siècle de Construction Du Discours Scientifique En Préhistoire - Avignon, 21-25 Septembre 2004, Congrès Du Centenaire de La SPF*. pp. 63–78.
- Nicoud, E., 2013. Le paradoxe acheuléen. Comité des travaux historiques et scientifiques, Paris, France.
- Oosterbeek, L., Grimaldi, S., Rosina, P., Cura, S., Cunha, P.P., Martins, A., 2010. The earliest Pleistocene archaeological sites in western Iberia: Present evidence and research prospects. *Quaternary International, Oldest Human Expansions in Eurasia: Favouring and Limiting Factors* 223–224, 399–407.
- Pelletier, M., 2018. Evolution morphométrique et biogéographie des léporidés dans les environnements méditerranéens au Pléistocène : implications socio-économiques pour les sociétés humaines (Thèse de doctorat). Aix-Marseille.
- Poinsot, D., 2008. *Statistiques pour statophobes*, Inédit.

- Porraz, G., Nicoud, É., Grenet, M., Simon, P., 2014. Les soucoupes de l'Observatoire (Principauté de Monaco) : contribution à l'étude du phénomène des grands éclats au Paléolithique ancien. *Paléo (Les Eyzies de Tayac-Sireuil)* 195–232.
- Ravon, A.-L., 2019. Early human occupations at the westernmost tip of Eurasia: The lithic industries from Menez–Dregan I (Plouhinec, Finistère, France). *Comptes Rendus Palevol* 18, 663–684.
- Ravon, A.-L., 2017. Originalité et développement du Paléolithique inférieur à l'extrémité occidentale de l'Eurasie : le Colombanien de Menez-Dregan (Plouhinec, Finistère) (Thèse de doctorat). Université de Rennes 1, France.
- Rocca, R., 2016. Depuis l'Est ? Nouvelles perspectives sur les premières dynamiques de peuplement en Europe. *Anthropologie (Paris)* 120, 209–236.
- Roche, H., Texier, P.-J., 1991. La notion de complexité dans un ensemble lithique. application aux séries acheuléennes d'Isenya (Kenya). Presented at the XIèmes Rencontres Internationales d'Archéologie et d'Histoire d'Antibes, APDCA, Antibes.
- Roe, D.A., 1964. The British Lower and Middle Palaeolithic: Some Problems, Methods of Study and Preliminary Results. *Proceedings of the Prehistoric Society* 30, 245–267.
- Rohlf, F.J., Slice, D., 1990. Extensions of the Procrustes Method for the Optimal Superimposition of Landmarks. *Systematic zoology* 39, 40–59.
- Rubio-Jara, S., Panera, J., Rodríguez-de-Tembleque, J., Santonja, M., Pérez-González, A., 2016. Large flake Acheulean in the middle of Tagus basin (Spain): Middle stretch of the river Tagus valley and lower stretches of the rivers Jarama and Manzanares valleys. *Quaternary International, The Acheulean in Europe: origins, evolution and dispersal* 411, 349–366.
- Santonja, M., Pérez-González, A., 2010. Mid-Pleistocene Acheulean industrial complex in the Iberian Peninsula. *Quaternary International, Oldest Human Expansions in Eurasia: Favouring and Limiting Factors* 223–224, 154–161.
- Santonja, M., Pérez-González, A., Panera, J., Rubio-Jara, S., Méndez-Quintas, E., 2016. The coexistence of Acheulean and Ancient Middle Palaeolithic techno-complexes in the Middle Pleistocene of the Iberian Peninsula. *Quaternary International, The Acheulean in Europe: origins, evolution and dispersal* 411, 367–377.
- Santonja, M., Villa, P., 2006. The Acheulian of Western Europe. *Axe Age: Acheulian tool-making from quarry to discard* 429–478.
- Saragusti, I., Karasik, A., Sharon, I., Smilansky, U., 2005. Quantitative analysis of shape attributes based on contours and section profiles in artifact analysis. *Journal of archaeological science* 32, 841–853.
- Saragusti, I., Sharon, I., Katzenelson, O., Avnir, D., 1998. Quantitative Analysis of the Symmetry of Artefacts: Lower Paleolithic Handaxes. *Journal of archaeological science* 25, 817–825.
- Shapiro, S.S., Wilk, M.B., 1965. An Analysis of Variance Test for Normality (Complete Samples). *Biometrika* 52, 591–611.

- Sharon, G., 2010. Large flake Acheulian. *Quaternary International, Oldest Human Expansions in Eurasia: Favouing and Limiting Factors* 223–224, 226–233.
- Sharon, G., 2008. The impact of raw material on Acheulian large flake production. *Journal of Archaeological Science* 35, 1329–1344.
- Sharon, G., Barsky, D., 2016. The emergence of the Acheulian in Europe – A look from the east. *Quaternary International, The Acheulean in Europe: origins, evolution and dispersal* 411, 25–33.
- Shipton, C., Clarkson, C., 2015. Flake scar density and handaxe reduction intensity. *Journal of archaeological science, reports* 2, 169–175.
- Soressi, M., 2002. Le Moustérien de tradition acheuléenne du sud-ouest de la France : discussion sur la signification du faciès à partir de l'étude comparée de quatre sites : Pech-de-l'Azé I, Le Moustier, La Rochette et la Grotte XVI (Thèse de doctorat). Bordeaux 1.
- Soriano, S., 2000. Outillage bifacial et outillage sur éclat au paléolithique ancien et moyen : coexistence et interaction (Thèse de doctorat). Paris 10.
- Tavoso, A., 1986. Le paléolithique inférieur et moyen du Haut-Languedoc: gisements des terrasses alluviales du Tarn, du Dadou, de l'Agout, du Sor et du Fresquel. Université de Provence, Éditions du Laboratoire de paléontologie humaine et de préhistoire.
- Tixier, J., 1956. Le hachereau dans l'Acheuléen nord-africain - Notes typologiques, in: *Compte Rendu de La XVème Session Congrès Préhistorique de France. Société Préhistorique Française, Poitiers-Angoulême*, pp. 914–923.
- Tuffreau, A., 2012. Les premières industries lithiques dans le nord de la France, reflet des premiers peuplements dans une région de haute latitude. *État des connaissances. Les nouvelles de l'archéologie* 36–41.
- Turq, A., Brenet, M., Colonge, D., Jarry, M., Lelouvier, L.-A., O'Farrell, M., Jaubert, J., 2010. The first human occupations in southwestern France: A revised summary twenty years after the Abbeville/Saint Riquier colloquium. *Quaternary International, Oldest Human Expansions in Eurasia: Favouing and Limiting Factors* 223–224, 383–398.
- Valletta, F., Grosman, L., Smilansky, U., 2020b. *Angles3-D. Mendeley Data* 1.
- Valletta, F., Smilansky, U., Goring-Morris, A.N., Grosman, L., 2020a. On measuring the mean edge angle of lithic tools based on 3-D models – a case study from the southern Levantine Epipalaeolithic. *Archaeological and Anthropological Sciences* 12, 49.
- Viallet, C., 2016. Potentiel fonctionnel des outils bifaciaux au Pléistocène moyen en contexte méditerranéen. Analyse de la structure et des macro-traces des outils bifaciaux de la Caune de l'Arago, Terra Amata, Orgnac 3 et du Lazaret. (Thèse de doctorat). Perpignan.
- Villa, P., 1981. Matières premières et provinces culturelles dans l'Acheuléen français. *Quaternaria* 23, 19–35.