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Cut marks made with quartz tools: An experimental framework for understanding cut mark morphology, and its use at the Middle Palaeolithic site of the Navalmaíllo Rock Shelter (Pinilla del Valle, Madrid, Spain)

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A B S T R A C T

The study of cut marks in archaeological contexts is of great importance for understanding the subsistence strategies of past human groups. Many authors have indicated differences to exist between the cut marks produced by different tools and when the same types of tool have been made from different raw materials. The present work examines the cut marks made during the experimental butchering of a red deer (*Cervus elaphus*) using simple quartz flakes, with those found on fossilised animal remains at the Navalmaíllo Rock Shelter site (Pinilla del Valle, Madrid, Spain) likely to have been made with similar flakes. The methodology followed was that of Domínguez-Rodrigo et al. (2009), which was originally designed to differentiate between cut marks and trampling marks, but which here was tested as a method of distinguishing between the raw materials from which cutting tools were made. The results were also compared to those made with other types of tool/raw material reported in the literature. The present results confirm the above ideas: the marks made experimentally by the quartz flakes are very similar to those seen on the faunal remains from the level F of Navalmaíllo Rock Shelter site, but different to those made by other tools or by flakes made from other materials. They also show, however, that different cut mark morphologies are largely independent of the size of the animal butchered, and of the anatomical element on which they appear.

1. Introduction

The study of cut marks has been of great importance in understanding the way in which different human groups - from those of the Lower Palaeolithic in Africa to others living elsewhere in more modern times - have processed animal carcasses. Interest in these marks first appeared in the late 19th/early 20th centuries, when Lartet (1860) and Martin (1910a, 1910b, 1909a, 1909b) discussed the relationship between them and the stone tools found at sites. However, detailed studies did not begin until the 1970s when different authors entered into the hunting-scavenging debate regarding Pleistocene assemblages, and who tried to understand and define the cut marks they saw (Andrews and Cook, 1985; Binford, 1981; Bunn, 1982, 1981; Bromage and Boyde, 1984; Bunn et al., 1986; Olsen and Shipman, 1988; Shipman and Rose, 1983).

Interest in defining the characteristics of cut marks was born out of

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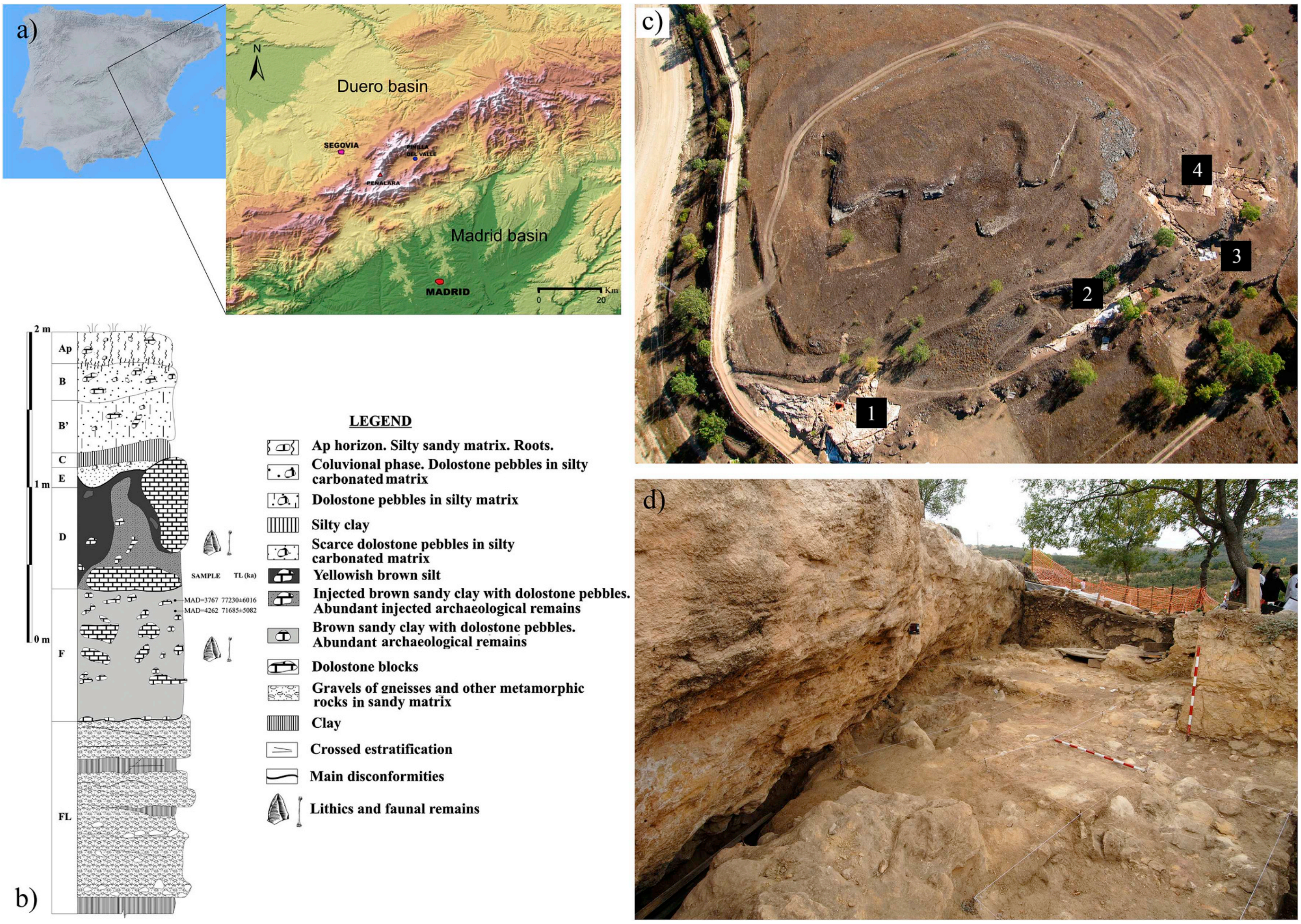

Fig. 1. a) Location of the Valle del Lozoya in the Iberian Peninsula; b) Stratigraphic column of the Navalmaíllo Rock Shelter; c) Calvero de la Higuera hill from the air: 1) Cueva del Camino site; 2) Navalmaíllo Rock Shelter site; 3) Cueva de la Buena Pinta site; 4) Cueva Des-Cubierta site; and d) the Navalmaíllo Rock Shelter site from the north.

the need to differentiate them from the non-anthropogenic alterations caused, for example, by trampling, and to overcome problems of equifinality (Andrews and Cook, 1985; Behrensmeyer et al., 1986; Domínguez-Rodrigo et al., 2009; Olsen and Shipman, 1988; Pineda et al., 2014). Cut marks are defined as alterations caused by the cutting edges of tools (made of stone or other materials) on the surface of bones during the skinning, defleshing, evisceration and dismembering of animals. The most common are slicing marks, and most studies on cut marks have focused on these. However, types of scrape mark, chop mark and sawing mark, etc., were also made depending on the cutting action employed. In general, cutting marks have a V-type shape in cross section, and may contain microstriations in their interior. Other elements may also be present, such as hertzian cones, or the so-called shoulder effect (Andrews and Cook, 1985; Bromage and Boyde, 1984; Bunn, 1981; Bunn et al., 1986; Greenfield, 1999; Shipman and Rose, 1983).

Research has shown that the morphology of a cut mark depends on the type of tool that produced it and the material from which the tool was made. For example, retouched tools, such as bifaces, leave a characteristic mark (de Juana et al., 2010; Domínguez-Rodrigo et al., 2009; Schick and Toth, 1998; Yravedra et al., 2010), but the material from which they are made, e.g., metal (Greenfield, 2006, 1999; Olsen, 1988), shell (Choi and Driwantoro, 2007; Toth and Woods, 1989) or bamboo (Spennerman, 1990; West and Louys, 2007) can also influence the mark's final morphology (Buccheri et al., 2016; Dewbury and Russell, 2007; Fernández-Jalvo and Cáceres, 2010; Fernandez-Jalvo and Andrews, 2016; Maté González et al., 2015; Walker and Long, 1977).

The main aim of the present work is to characterise the morphology of the cut marks made by simple quartz flakes on bone during experimental butchering. Faunal remains at the Navalmaíllo Rock Shelter (Pinilla del Valle, Madrid) were then examined to determine whether the cut marks they bear were also made with the same type of quartz flake; this is likely since 78.4% of all tools found at the site are simple flakes of this material (Márquez et al., 2017). Both sets of cut marks were also compared with those made by other tools/raw materials.

Archaeological research has largely overlooked quartz as a raw material. Much more attention has been paid to other materials, the fracture dynamics of which make them apparently more amenable to knapping (Callahan, 1987; Driscoll, 2011; Márquez, 2016). However, there are many large geographic areas in which quartz is the most common material, and therefore sites of different age in which it is the most frequently found raw material. This is usually the case when quartz is available nearby. Different studies are now underway investigating the features of the management of this material. In Iberian Peninsula there are several sites of such characteristics apart from those of Pinilla del Valle, including Cova 120 (Girona) (Agustí et al., 1991), the Maltravieso and Santa Ana Caves (Cáceres) (Peña et al., 2008), Cova Eirós (Lugo) (Lazuén et al., 2011), and Arbreda (Girona) (Bracco, 1997).

The interest in quartz as a raw material derives from its physical properties, since it does not behave like other raw materials (e.g. flint).

Quartz crystals join together with no need of cement, but the way in which this occurs influences its cutting properties (Clemente Conte et al., 2015). The absence of concoidal fractures in quartz renders the natural edges of flakes little uniform compared to materials such as obsidian, flint or certain types of quartzite. Thus, cut marks made by quartz tools should have their own morphology.

2. The Navalmaíllo Rock Shelter

The Navalmaíllo Rock Shelter, one of the Middle Palaeolithic sites of the Pinilla del Valle archaeopalaeontological complex (Madrid, Spain) occupies some 300 m^2 (Análisis y Gestión del Subsuelo S.L. [AGS], 2006; Pérez-González et al., 2010) and is among the largest karst-setting sites of the Iberian Plateau. Discovered in 2002, it has since been excavated without interruption (Fig. 1).

The site is both karstic and fluvial in origin. The Valmaíllo Stream opened up the cavity by erosion but also helped fill it with a silt-clay infill, the dissolution product of the Cretaceous dolomite rock of the Calvero de la Higuera hill. The infill also contains clastic elements fallen from the shelter's ceiling and walls.

The fossil material examined in the present work comes from Level F, which has been dated twice by thermoluminiscence to the end of MIS 5e (77.2 ± 6.0 ky and 71.6 ± 5.0 ky) (Fig. 1). According to the pollen analysis, level F shows an open-habitat ecosystem (Ruiz Zapata et al., 2015). Level F has been interpreted as a camp used by groups of Neanderthals (Arsuaga et al., 2011; Baquedano et al., 2012; Huguet et al., 2010; Márquez et al., 2016a,b; Pérez-González et al., 2010). The presence of abundant remains of Mousterian lithic industry (Márquez et al., 2017, 2016a, 2013), anthropised faunal remains (Huguet et al., 2010), and the presence of hearths, all attest to Neanderthal use (Baquedano et al., 2012).

Of the lithic elements examined up until the excavation campaign of 2015, some 78.4% were recorded as being made from local quartz (Fig. 2). Flint elements were a distant second most common (10.49%), although the origin of this raw material is already unknown (Márquez et al., 2017) (Table 1). The study of the raw materials used at the site is, however, underway (Abrunhosa et al., 2014).

Some 66.5% of the site's quartz cores are in the last phase of exploitation. Centripetal and orthogonal knapping strategies appear to have been the most commonly used. Operative chains are complete for all the materials recorded, though simple flakes are more common (63.51%) than retouched elements (6.8%) and other products. Among the retouched elements, denticulates are the most common, followed by scrapers.

The lithic industry of the Navalmaíllo Rock Shelter shows a trend towards the production of microlithics, an apparently intentional choice, at least for those tools made of quartz. The presence of anvils near the cores, along with bipolar products, indicate bipolar knapping to be the best way of managing this type of raw material, especially for small format products (Márquez, 2016; Márquez et al., 2016a, 2013).

Functional studies undertaken with the tools collected from Level F suggest them to have a certain versatility, although their identified uses mostly involve butchery and the working of wood (Márquez et al., 2017, 2016a).

The remains of animals of different size and taxa have been recovered from Level F (Table 2; 3) (Arriaza et al., 2017a; Arsuaga et al., 2011; Huguet et al., 2010; Moclán et al., 2017). The remains of very large and large mammals, such as rhinoceroses, bovids, and equids, all show evidence of anthropic activity, such as cut marks, percussion marks, and anthropic fracture patterns. Also, the remains of medium-sized animals (as cervids) show clear anthropogenic modifications. The fossils of carnivores and very small-sized animals such as tortoises and rabbits of the level F of the site are not the result of anthropic activity. The rabbits, for example, were almost certainly brought into the shelter by lynxes (Arriaza et al., 2017a). Taphonomical alterations produced by carnivores are not common in the faunal assemblage, and it would appear that Neanderthals were the main drivers of bone accumulation at the site (Huguet et al., 2010).

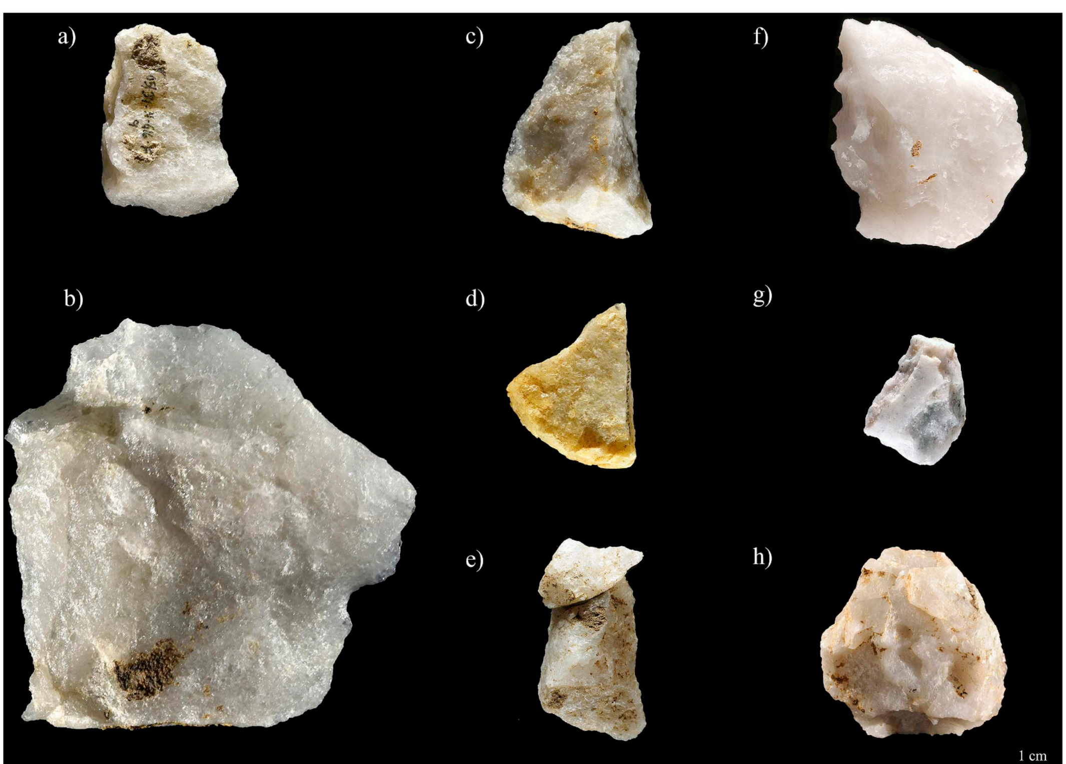

Fig. 2. Examples of lithic industry from the Navalmaíllo Rock Shelter: a) b) and e) simple quartz flakes; c) and d) simple quartz flake with a Siret fracture; f) quartz denticulate; g) quartz side scraper; h) a quartz core. Photos: Museo Arqueológico Regional/M. Torquemada.

Table 1
Lithic remains by tool type (according to the Analytical Logic System (Carbonell et al., 1999, 1992, 1983; Rodríguez, 2004), and raw material recovered from Level F of the Navalmaíllo Rock Shelter (Márquez, 2016).

	Quartz	%	Chert	%	Quartzite	%	Porphyry	%	Rock crystal	%	Sandstone	%	Other	%
Bna	3	0.03	0	0	1	0.35	2	0.97	0	0	3	3.61	15	2.20
BNb	5	0.05	0	0	2	0.69	3	1.45	0	0	0	0	8	1.17
BNc/d	16	0.14	0	0	4	1.39	6	2.90	0	0	0	0	27	3.96
BN1GE	325	2.94	26	1.77	11	3.82	6	2.90	1	0.44	1	1.20	13	1.91
BN2GE	117	1.06	17	1.16	5	1.74	3	1.45	2	0.88	0	0	3	0.44
BN1GC	11	0.10	1	0.07	1	0.35	0	0	0	0	0	0	0	0
BN2GC	635	5.74	122	8.29	21	7.29	15	7.25	26	11.50	3	3.61	11	1.62
BP	3709	33.54	606	41.20	126	43.75	86	41.55	61	26.99	34	40.96	108	15.86
BPF	2180	19.71	225	15.30	68	23.61	39	18.84	41	18.14	9	10.84	46	6.75
FBP	1135	10.26	166	11.28	23	7.99	12	5.80	35	15.49	7	8.43	19	2.79
Frags	2886	26.10	240	16.32	26	9.03	25	12.08	58	25.66	8	9.64	317	46.55
Indet	37	0.33	68	4.62	0	0	10	4.83	2	0.88	18	21.69	114	16.74
Total	**11059**	**78.91**	**1471**	**10.49**	**288**	**2.05**	**207**	**1.48**	**226**	**1.61**	**83**	**0.59**	**681**	**4.86**

Table 2
Animal species recovered from Level F of the Navalmaíllo Rock Shelter (Arriaza et al. 2017a,b; Arsuaga et al., 2011; Huguet et al., 2010; Moclán et al., 2017).

Order	Species
Artiodactyla	*Cervus elaphus*
	Dama dama
	Capreolus capreolus
	Bos primigenius/Bison priscus
Perissodactyla	*Equus ferus*
	Stephanorhinus hemitoechus
Carnivora	*Ursus arctos*
	Canis lupus
	Crocuta crocuta
	Vulpes vulpes
	Mustela cf. *nivalis*
Rodentia	*Arvicola* cf. *sapidus*
	Microtus arvalis
	Microtus agrestis
	Microtus gr. duodecimcostatus
	Pliomys lenki
	Apodemus sylvaticus
	Allocricetus bursae
	Eliomys quercinus
	Castor fiber
Soricomorpha	*Sorex gr. araneus*
	Talpa europaea
Lagomorpha	*Oryctolagus cuniculus*
	Lepus sp.
Testudines	
	Chelonia indet.

3. Materials and methods

The present work characterises the morphology of cut marks made experimentally using quartz tools, and compares these with cut marks found on faunal remains recovered from Level F of the Navalmaíllo Rock Shelter. All the marks examined were slicing marks.

The experimental work was performed on the carcass of an adult female red deer (*Cervus elaphus*) in the Boumort National Hunting Reserve (Lleida, Spain) (Fig. 3), and involved the use of 12 simple flakes prepared from quartz collected near the rock shelter in the Valle del Lozoya (Fig. 4). The size and shape of these flakes were very similar to those recovered from the site. All cutting edges are dihedral and present an average edge angle of 58° and an average length of 40.1 mm. Retouched flakes were not used in this experiment considering their scarcity in the Navalmaíllo Rock Shelter (6.8%).

Once the experiment began, 3 of the pieces were discarded due to their lack of effectiveness. These pieces were used for at least a few seconds (< 30″). The animal was skinned, eviscerated, dismembered, and the meat removed from all areas except the skull. The average working time of each cutting edge has been recorded at 11 min.

Since the aims of our experimentation were to reproduce the whole butchery process, these activities were performed by both a high-qualified and a low-qualified butcher. Throughout the experiment the second butcher was following the instructions of the more experienced individual. The carcass was then transported to the Zooarchaeology Laboratory of the *Institut Català de Paleoecologia Humana i Evolució Social de Tarragona* (IPHES) for cleaning and analysis. The bones were cleaned by boiling them in water with pH-neutral soap (the use of any more aggressive agents was avoided for fear they might alter the morphology of the cut marks) until sufficiently clean, and then left to dry.

A total of 238 cut marks were identified on 48 archaeological remains. These marks present the highest degree of preservation from the studied sample (specimens = 2747), as observed through previous taphonomic analysis presented by Moclán et al. (2017). Specimens have been grouped into size categories (Table 3).

Both the experimental and archaeological cut marks were examined using an Olympus SZX12 and an Olympus SZ1144TR (15–40x) binocular microscope and hand lenses (15x – 18x), plus a HIROX KH-8700 digital microscope when precision viewing was required. All marks were analysed following the method of Domínguez-Rodrigo et al. (2009), using the 14 variables they suggest to define cut mark morphology (Table 4).

To determine whether quartz flakes make cut marks different to those produced by flakes and other tools of different material, the experimentally made quartz flake cut marks were compared to the experimental cut marks made by Domínguez-Rodrigo et al. (2009). In the latter work, two sets of different experimental cut marks were made, 246 with simple flakes, and 105 with retouched flakes, made of quartzite and flint. The biggest handicap presented here is that the marks made with flint cannot be differentiated from those made with quartzite.

The present experimental cut marks were also compared to those left by trampling as recorded by Domínguez-Rodrigo et al. (2009) and Pineda et al. (2014). The former work characterises 251 trampling marks made on experimental bones in different sediments, and in the second one 53 trampling marks on archaeological remains from the La Mina site (Barranc de la Boella, Tarragona, Spain).

The normality of the results was tested using the Shapiro-Wilk test. Pearson correlation coefficients were determined between normally distributed variables, and Spearman correlation coefficients were determined when they were not normally distributed. All correlation calculations were made using R statistic software (R Core Team, 2015).

Fig. 3. Different phases of the butchering process: a) and b) skinning; c) finishing of the process of skinning and eviscerating; and d) defleshing of an upper limb. Photos: F. J. Luengo.

Multiple correspondence analysis was performed using "ca" library (Greenacre and Nenadic, 2006; Nenadic and Greenacre, 2007). Domínguez-Rodrigo et al. (2009) applied a CATPCA (Categorical Principal Components Analysis) to interpret their data, because they used a database that included variables describing each cut mark. In this case we have used a multiple correspondence analysis (MCA) because we lack the corresponding data for each alteration (cut marks and trampling marks), since is presented differently in tables in the other works we have used for comparison (Pineda et al., 2014; Val et al., 2017).

4. Results

4.1. Analysis of the experimental butchering cut marks and those on the faunal remains from the Navalmaíllo Rock Shelter

A total of 199 experimental cut marks were detected on the 21 bones of the axial skeleton, the upper and intermediate appendicular skeleton, and two short bones (Table 5). All the cut marks on the long bones appeared on the diaphysis, both on the metaphysis and central area of the diaphysis. No marks were seen on the epiphysis (Fig. 5).

Fig. 4. Simple quartz flakes used in experimental butchering work. Photos: Museo Arqueológico Regional/A. Dávila.

Table 3
Distribution of taxa of Navalmaíllo Rock Shelter by size weight categories.

Animal size	Weight (kg)	Taxa
Very large-sized	> 800	*Stephanorhinus hemitoechus*
		Bison sp./Bos primigenius
Large-sized	200–800	*Bison sp./Bos primigenius*
		Equus ferus
Medium-sized	50–200	*Cervus elaphus*
		Dama dama
Small-sized	10–50	*Capreolus capreolus*
Very small-sized	< 10	*Oryctolagus cuniculus*
		Lepus sp.
		Chelonia indet

A total of 238 cut marks were identified on 48 archaeological remains. They appeared on the axial (scapula, pelvis and ribs) and appendicular skeleton (humerus, femur, tibia, metacarpals, and metatarsals) of animals of different size, and on 16 remains of indeterminate identity. On the long bones, all the cut marks were found in the midshaft; none were found on the epiphysis. One metatarsal showed a cut mark on its distal metaphysis (Table 6). Archaeological marks appear on a variety of different animal sizes presenting groups of very large-sized (> 800 kg), large-sized (200–800 kg) and medium-sized animals (50–200 kg). Indeterminate sized animals are also present in this assemblage. A series of different cut marks (i.e. experimental and archaeological) can be seen in Fig. 6.

The majority (78.15%) of the experimental cut marks (Table 7) showed a straight trajectory with few barbs (11.76%). No preferential orientation of the marks with respect to the axis of the bones was seen. Some 57.98% of the marks had a wide V shaped groove, while the remainder had narrow a V shaped groove. The morphologies of the marks were mostly symmetrical (75.63%). Some 65.55% showed signs of a shoulder effect, and 59.66% showed flaking at the edges of no preferential length. Overlapping striations were generally absent (76.47%), although internal microstriations were common (65.55%); the latter was neither preferentially continuous nor discontinuous, generally straight (86.3%), and normally appeared on both the walls and floor of the cut mark. Microabrasions were generally absent (83.19%).

The cut marks were practically the same on the long, flat, and short bones, although a few differences should be mentioned. First, on short bone, all the marks appeared to have the same orientation with respect to the bone axis. However, all of these appeared in the same place on two calcaneal bones, making it quite likely that they would have the same orientation. On the flat bones, cut marks parallel with the bone axis were the most common (55.22%), while the most common on the long bones were perpendicular marks (41.46%).

Table 5
Number of cut marks per anatomical element produced during experimental butchering.

Element	Laterality	Cut marks (n)	Location
Scapula	Left	22	Lateral view
Humerus	Left	8	Distal craneal metaphysis (6)
			Lateral diaphysis (2)
Radius - Ulna	Left	6	Craneal diaphysis (2)
			Lateral diaphysis (4)
Pelvis	Left	10	Lateral view (1)
			Ventral view (9)
Femur	Left	3	Proximal lateral metaphysis (1)
			Lateral diaphysis (2)
Tibia	Left	6	Craneal diaphysis
Pelvis	Right	4	Ventral view
Femur	Right	15	Proximal craneal metaphysis (13)
			Craneal diaphysis (2)
Tibia	Right	2	Craneal diaphysis (1)
			Lateral diaphysis (1)
Vertebra	–	8	Transverse process
Vertebra	–	10	Transverse process
Vertebra	–	2	Neural spine
Vertebra	–	3	Neural spine
Calcaneus	Left	5	Lateral view
Calcaneus	Right	5	Lateral view
Rib	–	2	External view
Rib	–	5	External view
Rib	–	2	External view
Rib	–	5	External view
Rib	–	1	External view
Rib	–	11	External view

Flaking at the cut mark edges was more common on flat (70.15%) and short bones (63.64%) than on long bones (41.46%). This might be explained by the greater resistance of the cortical surface of the long bones.

Finally, in the long bones the microstriations were generally discontinuous (72%), as they were in the short bones (62.50%), and less so in flat bones (40%). Again, this might be due to the denser cortical material of first two types.

A number of correlations were sought between the cut marks made on the long, flat and short bones to determine whether they showed similarities. These analyses were performed using the values for the studied variables (Table 7). The normality of the values was first

Table 4
Definition of the variables examined in the present analysis. For more detailed definitions see Domínguez-Rodrigo et al. (2009).

1. Trajectory of the groove.	Straight, curvy or sinuous.
2. Barbs.	Presence or absence.
	It is defined as a shallower end of the groove slightly curved to the side in the form of an open hook.
3. Orientation of the mark.	Longitudinal, parallel or oblique.
4. Shape of the groove.	Narrow V shape (V) or wide V shape (_/).
5. Symmetry of the groove.	Symmetrical or asymmetrical.
6. Shoulder effect.	Presence or absence.
	It is defined as the striae occurring in association with the main groove in a distance no farther than 0.2 mm from the edge of the groove.
7. Flaking on edges of cut mark	Presence or absence.
	It is defined as not a random occurrence of a flaking dent such as those produced in isolated hertzian cones, but as a continuous series of exfoliation of the shoulder edge, which can occur on part of the trajectory of the shoulder or on most of it.
8. Extent of the flaking of the shoulder.	Covering more or less than one third of the trajectory (it can be absent).
9. Overlapping striations	Presence or absence.
10. Internal microstriations.	Presence or absence.
11. Microstriation trajectory.	Continuous or discontinuous.
12. Shape of microstriation trajectory.	Straight or irregular.
13. Location of microstriation.	On the walls of the groove, on the bottom, or on both.
14. Microabrasion.	Presence or absence.
	It is defined as associated shallow striae on the bone specimen away from the main groove. In archaeological context they are usually caused by sediment grains of sandy gritty soils.

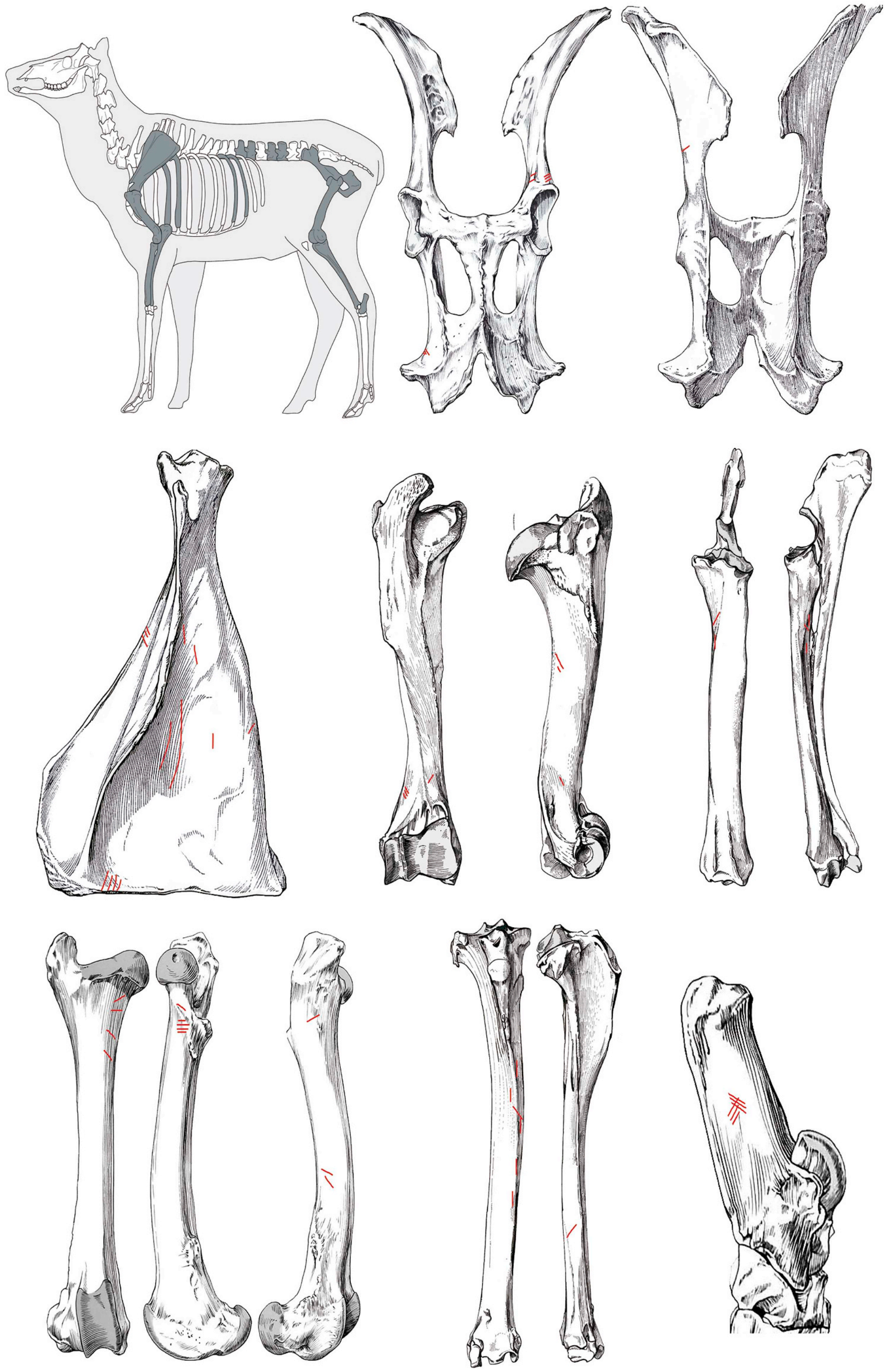

Fig. 5. Distribution of cut marks on the different anatomical elements made during the experimental butchering of the deer.

checked to determine whether to calculate Pearson or Spearman correlation coefficients. Highly significant positive correlations were found, revealing the morphologies of the cut marks made on all these bone types to be very similar (no significant differences) (Table 8).

The marks on the faunal remains from the Navalmaíllo Rock Shelter (Table 9) showed a mostly straight trajectory (86.5%) and an absence of barbs (95.38%). They were more likely to be oblique with respect to the axis of the bone (57.98%) and showed a tendency to have a wide V shaped groove (56.3%). Most marks were symmetrical (81.51%), showed a shoulder effect (63.03%), and their edges were more likely to show no flaking (64.71%), although when they did some 79.76% of the flakes occupied more than one third of the cut mark. Most (71.85%) showed no overlapping striations, and 43.28% showed internal microstriations (more often [54.9%] with a continuous trajectory, straight [96.08%], and affecting both the walls and bottom of the mark [65.05%]; most [83.19%] showed no associated microabrasions).

Generally, faunal remains of different size showed very similar cut marks, although a few exceptions were seen. For example, cut marks

Table 6
Number of cut marks per element on the sample of faunal remains from the Navalmaíllo Rock Shelter.

Bones	Element	Size	Cut marks (n)	Location
Flat	Scapula	Very large-sized	19	–
Flat	–	Very large-sized	1	–
Flat	Rib	Very large-sized	2	External view
Long	Femur	Very large-sized	3	Craneal diaphysis
Long	Humerus	Very large-sized	1	Caudal diaphysis
Long	Femur	Very large-sized	1	–
Long	Femur	Very large-sized	10	Caudal diaphysis/Medial diaphysis
Long	Femur	Large-sized	6	–
Long	Metacarpus	Large-sized	3	Craneal diaphysis
Flat	–	Large-sized	7	–
Long	Metatarsus	Large-sized	2	Distal metaphysis
Long	Tibia	Large-sized	4	Caudal diaphysis
Long	Femur	Large-sized	1	Craneal diaphysis
Long	–	Large-sized	6	–
Long	–	Large-sized	2	–
Long	–	Large-sized	6	–
Long	–	Large-sized	5	–
Long	–	Large-sized	2	–
Long	–	Large-sized	10	–
Long	–	Large-sized	1	–
Flat	–	Large-sized	4	–
Long	–	Large-sized	18	–
Flat	Pelvis	Large-sized	13	–
Long	Tibia	Large-sized	1	–
Long	Tibia	Large-sized	8	Caudal diaphysis/Medial diaphysis
Long	–	Medium-sized	4	–
Long	–	Medium-sized	2	–
Flat	Scapula	Medium-sized	3	–
Long	Femur	Medium-sized	29	–
Long	Tibia	Medium-sized	14	–
Long	–	Medium-sized	1	–
Long	Tibia	Medium-sized	2	–
Long	–	Medium-sized	2	–
Long	–	Medium-sized	2	–
Long	–	Medium-sized	4	–
–	Indeterminate	–	2	–
–	Indeterminate	–	3	–
–	Indeterminate	–	4	–
–	Indeterminate	–	2	–
–	Indeterminate	–	2	–
–	Indeterminate	–	1	–
–	Indeterminate	–	1	–
–	Indeterminate	–	2	–
–	Indeterminate	–	1	–
–	Indeterminate	–	1	–
–	Indeterminate	–	1	–
–	Indeterminate	–	12	–
–	Indeterminate	–	3	–
–	Indeterminate	–	1	–
–	Indeterminate	–	1	–
–	Indeterminate	–	2	–

with wide V cross sections were common (56.30%), except on the remains of medium-sized animals (46.03%). The marks were also generally symmetrical, except for on the remains of large animals, on which they were usually asymmetrical (71.58%). The presence of a shoulder effect distinguished two groups, one composed of very large animal remains and bones of indeterminate identity in which the cut marks showed the shoulder effect, and the other of medium and large animals in which the cut marks showed no shoulder effect. Finally, the trajectory of the microstriations varied: in very large animal remains 50% of the microstriations were continuous and 50% discontinuous, in large sized animal remains 59.52% were discontinuous and the remainder continuous, in medium animals 66.67% were continuous and the remainder discontinuous, and in the bones of indeterminate identity 75% were continuous and the remainder discontinuous.

The difference in size of the experimental red deer and the faunal remains from the Navalmaíllo Rock Shelter site could apparently be a problem when trying to establish analogies between them in terms of the cut marks made. However, Spearman correlation coefficients (required according to the non-normality of the results) calculated between the different archaeological animal sizes (Table 9) showed no significant differences (Table 10).

Most of the cut marks made during the experimental work were parallel to the bone axis (41.8%), whereas in the faunal remain cut marks the most common were oblique 57.98%. Further, 59.66% of the experimental marks showed flaking, while 64.71% of the marks on the faunal remains did not. In the experimental marks, 49.3% of flakings were short and 50.70% long, while 79.76% of the flakings in the faunal remain cut marks were short and the remainder long. Microstriations were present in 65.55% of the experimental cut marks and in 56.72% of those on the faunal remains. Finally, in the experimental cut marks, 49.32% of the microstriations were continuous and 50.68% discontinuous, while in the faunal remain cut marks, 54.9% were continuous and the remainder discontinuous. However, Spearman correlation coefficients calculated between values for the experimental cut marks and those of the fossil material (Table 11) showed them to be so similar as to be almost identical, with an overall correlation between the two sets of samples of $r = 0.89$ (p-value = 7.615^{-11}) (Fig. 6).

4.2. Comparison between cut marks made by quartz and other materials

Despite the statistic similarity between the cut marks made experimentally and those on the faunal remains, comparisons were also made against trampling marks and other sets of cut marks made by retouched flakes and flint or quartzite flakes (Domínguez-Rodrigo et al., 2009; Pineda et al., 2014), to rule out that linear marks could have been made by such tools/materials or discard trampling marks. Table 12 summarises these authors' results (with an error they made with respect to microabrasion values corrected).

Using the data in Table 12, Spearman correlation coefficients were calculated for the different sets of marks (Table 13).

These analyses showed the experimental quartz flake-made cut marks to bear no correlation at all with trampling marks. However, a weak correlation was seen between the former marks and those made by retouched quartzite and flint flakes, and a slightly stronger correlation with the simple quartzite/flint flakes, but both were below $r = 0.63$. Thus, the marks made by the experimental quartz flakes showed similarities to those made by other tools and materials, but that they were certainly different enough to be distinguishable.

The same analyses returned similar results for comparisons between the cut marks on the faunal remains from the Navalmaíllo Rock Shelter and these other materials: $r = 0.65$ with the simple quartzite/flint flakes and under $r = 0.5\%$ with the retouched quartzite/flint flakes. No correlations were seen between the faunal remain cut marks and trampling marks. This provides further evidence that the cut marks made on the fossil faunal remains were indeed made by simple quartz flakes.

Therefore, a positive and significant correlation is shown between the experimental marks and those of the Navalmaíllo Rock Shelter when compared with the samples of Domínguez-Rodrigo and Yravedra (2009). However, this correlation is low (< 70%) and can be explained by the fact that these samples are all composed of cut marks, thus highlighting their similarities. Nevertheless, the correlation between experimental cut marks and those observed in the Navalmaillo Rock Shelter presents a higher significance than with the previously described samples published by Domínguez-Rodrigo et al. (2009).

Multiple correspondence analysis (Fig. 7) confirm that clear

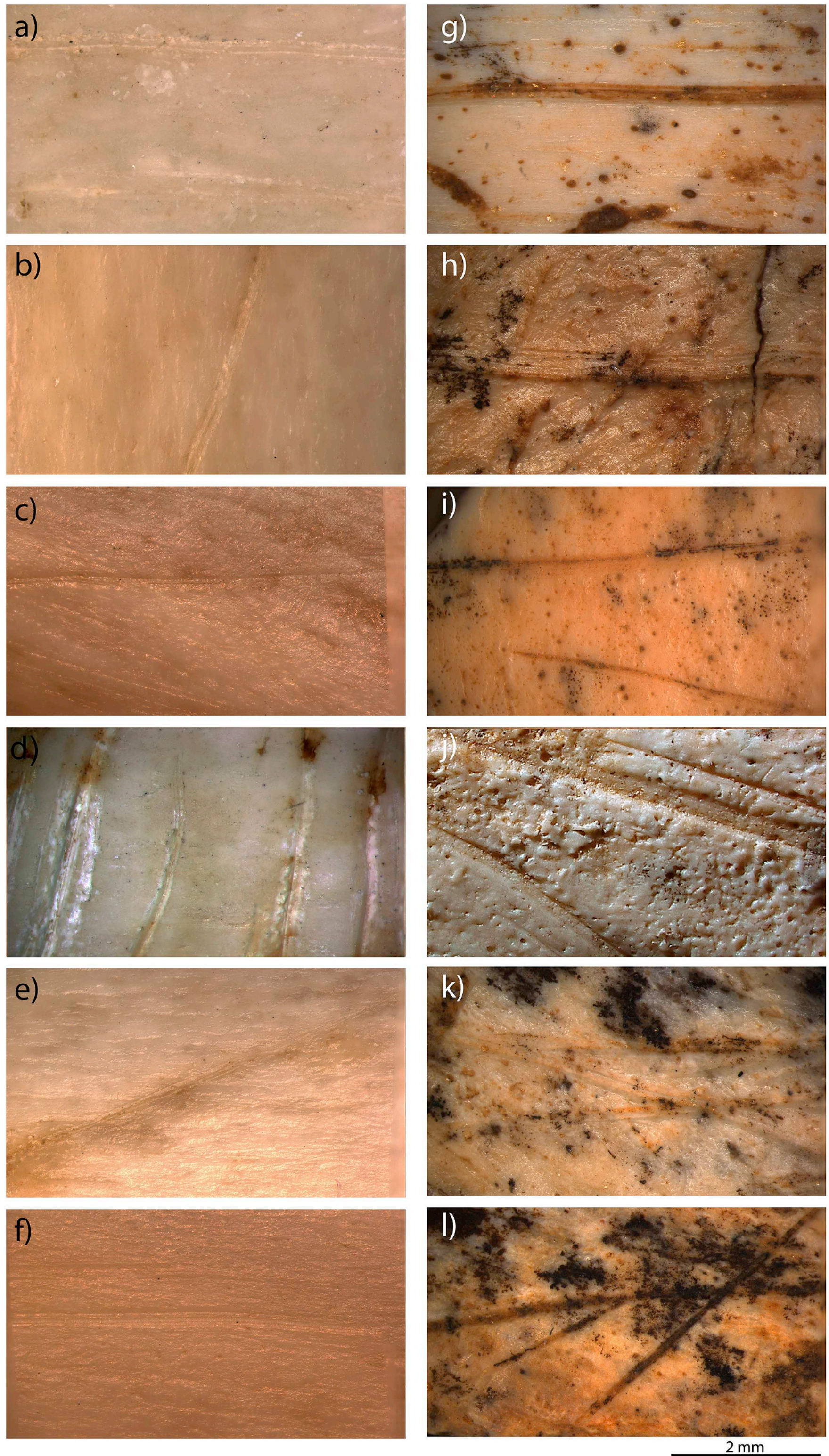

Fig. 6. Experimental (left) and archaeological cut marks (right): a) cut marks in a scapula; b) cut mark in an humerus; c) cut mark in a radius; d) cut marks in a femur; e) and d) cut marks in two different tibiae; g) and h) cut marks in two very large-sized specimens; i) and j)) cut marks in two large-sized specimens; and k) and l), cut marks in two medium-sized animals. All pictures have been photographed by an Olympus SZX12 binocular microscope (20x).

differences exist between the cut marks made by the quartz flakes and those made with other tools/raw materials (Fig. 7a). At the same time, trampling marks were clearly different from all types of cut marks we examined. The different graphs in Fig. 7 have been generated using the information included in Tables 10 and 11.

Firstly, Fig. 7a shows a clear difference between cut marks produced by simple (Unretouched Flakes, UF) and retouched flakes (RF) (quartzite and flint) and those produced by simple quartz flakes. The most interesting aspect is that raw materials clearly determine the morphologies of cut marks, since it would be expected to find a clear

Table 7
Number of cut marks (and percentage) of the experimental sample by anatomical elements according to the methodology of Domínguez-Rodrigo et al. (2009). * = significant values reflected in the text.

	CM		CM (long bones)		CM (flat bones)		CM (short bones)	
	n	%	n	%	n	%	n	%
Groove trajectory								
Straight	93	78.15*	31	75.61	51	76.12	11	100
Curvy	18	15.13	5	12.20	13	19.40	0	0
Sinuous	8	6.72	5	12.20	3	4.48	0	0
Barb								
Present	14	11.76*	10	24.39	2	2.99	2	18.18
Absent	105	88.24	31	75.61	65	97.01	9	81.82
Mark Orientation								
Parallel	49	41.18	12	29.27	37	55.22	0	0
Oblique	43	36.13	12	29.27	20	29.85	11	100
Perpendicular	27	22.69	17	41.46	10	14.93	0	0
Groove shape								
V	50	42.02	18	43.90	28	41.79	4	36.36
_/	69	57.98*	23	56.10	39	58.21	7	63.64
Symmetry								
Symmetrical	90	75.63*	30	73.17	51	76.12	9	81.82
Asymmetrical	29	24.37	11	26.83	16	23.88	2	18.18
Shoulder effect								
Present	78	65.55*	22	53.66	48	71.64	8	72.73
Absent	41	34.45	19	46.34	19	28.36	3	27.27
Flaking on shoulder								
Present	71	59.66	17	41.46	47	70.15	7	63.64
Absent	48	40.34	24	58.54	20	29.85	4	36.36
Extent of flaking								
Short	36	30.25	12	29.27	19	28.36	5	45.45
Long	35	29.41	5	12.20	28	41.79	2	18.18
Absent	48	40.34	24	58.54	20	29.85	4	36.36
Overlapping striations								
Present	28	23.53	17	41.46	7	10.45	4	36.36
Absent	91	76.47	24	58.54	60	89.55	7	63.64
Internal microstriation								
Present	78	65.55	25	60.98	40	59.70	8	72.73
Absent	41	34.45	16	39.02	27	40.30	3	27.27
Microstriation trajectory								
Continuous	36	49.32	7	28	24	60.00	3	37.50
Discontinuous	37	50.68	18	72	16	40.00	5	62.50
Shape microstriation trajectory								
Straight	63	86.3*	18	72	37	92.50	8	100
Irregular	10	13.7	7	28	3	7.50	0	0
Location of microstriation								
Walls	15	20.55	4	16	9	21.95	2	25
Bottom	9	12.33	5	20	5	12.20	0	0
Both	49	67.12	16	64	27	65.85	6	75
Microabrasion								
Present	20	16.81	12	38.71	7	10.45	1	9.09
Absent	99	83.19*	19	61.29	60	89.55	10	90.91

Table 8
Correlation between long, flat and short bones from the experimentally butchered deer. The Pearson correlation coefficient was calculated between the flat and long bones since the data were distributed normally; Spearman correlation coefficients were calculated between the short and other bone types since the data were not normally distributed.

	Flat		Short	
	Correlation (r)	p value	Correlation (r)	p value
Long	0.71	5.38E-06	0.73	1.68E-06
Flat	–	–	0.76	5.29E-07

relationship between the two types of cut marks made with simple tools (i.e. quartz and quartzite/flint). When introducing the data from Navalmaíllo Rock Shelter (NV F) in the analysis (Fig. 7b), the archaeological sample directly relates to the experimental cut marks made with quartz simple flakes (Q). Cut mark assemblages cluster in their own Euclidean space, showing a marked difference to the rest of the dataset, with the exception of those marks produced by experimental quartz flakes and the archaeological marks from Navalmaíllo Rock Shelter, which appear in the same Euclidean space.

On the other hand, the introduction of the trampling samples (Trampling, and Tramp. Boella) in the analysis provides a new interesting model: the samples of cut marks appear in the negative part of the X-axis (Fig. 7c and d), while the trampling marks cluster in the positive part of the axis. This distribution shows that with a complete analysis of the different marks, trampling and cut marks can be clearly differentiated using this methodology as other authors have proposed previously (Domínguez-Rodrigo et al., 2009; Pineda et al., 2014). Moreover, cut mark samples show differences in Fig. (7c and d) along the Y-axis (i.e. simple quartzite/flint flakes appear in the positive part of the axis and the rest of them in the negative part of the axis).

The distribution of the cut mark samples along the Y-axis can be interpreted as follows. Cut marks produced with simple quartz flakes, those produced by retouched quartzite/flint flakes and the archaeological sample are clearly joined in the graphs. This does not mean that both types of marks are indistinguishable as we have explained above (Fig. 7a and b), but they share more similarities between each

Table 9
Number of cut marks (and percentage) of the archaeological sample by size weight categories according to the methodology of Domínguez-Rodrigo et al. (2009). CM = cut mark VLS = very large sized; LS = large sized; MS = medium size; Indet = indeterminate bones. * = significant values reflected in the text.

	CM		CM (VLS)		CM (LS)		CM (MS)		CM (Indet.)	
	n	%	n	%	n	%	n	%	n	%
Groove trajectory										
Straight	205	86.5*	32	86.49	83	87.37	52	82.54	38	90.48
Curvy	17	7.17	2	5.41	7	7.37	6	9.52	2	4.76
Sinuous	15	6.33	3	8.11	5	5.26	5	7.94	2	4.76
Barb										
Present	11	4.62	4	10.81	3	3.16	4	6.35	0	0
Absent	227	95.38*	33	89.19	92	96.84	59	93.65	42	100
Mark Orientation										
Parallel	56	23.53	4	10.81	30	31.58	15	23.81	7	16.67
Oblique	138	57.98*	21	56.76	49	51.58	42	66.67	26	61.90
Perpendicular	44	18.49	12	32.43	16	16.84	6	9.52	9	21.43
Groove shape										
V	104	43.7	18	48.65	35	36.84	34	53.97	16	38.10
_/	134	56.3*	19	51.35	60	63.16	29	46.03	26	61.90
Symmetry										
Symmetrical	194	81.51*	32	86.49	27	28.42	56	88.89	37	88.10
Asymmetrical	44	18.49	5	13.51	68	71.58	7	11.11	5	11.90
Shoulder effect										
Present	150	63.03*	24	64.86	31	32.63	14	22.22	19	45.24
Absent	88	36.97	13	35.14	64	67.37	49	77.78	23	54.76
Flaking on shoulder										
Present	84	35.29	16	43.24	45	47.37	11	17.46	12	28.57
Absent	154	64.71	21	56.76	50	52.63	52	82.54	30	71.43
Extent of flaking										
Short	67	28.15	13	35.14	37	38.95	8	12.70	9	21.43
Long	17	7.14	3	8.11	8	8.42	3	4.76	3	7.14
Absent	154	64.71	21	56.76	50	52.63	52	82.54	30	71.43
Overlapping striations										
Present	67	28.15	6	16.22	30	31.58	27	42.86	4	9.52
Absent	171	71.85*	31	83.78	65	68.42	36	57.14	38	90.48
Internal microstriation										
Present	103	43.28*	16	43.24	42	44.21	24	38.10	20	47.62
Absent	135	56.72	21	56.76	53	55.79	39	61.90	22	52.38
Microstriation trajectory										
Continuous	56	54.9*	8	50	17	40.48	16	66.67	15	75
Discontinuous	46	45.1	8	50	25	59.52	8	33.33	5	25
Shape microstriation trajectory										
Straight	98	96.08*	16	100	38	90.48	24	100	20	100
Irregular	4	3.92	0	0	4	9.52	0	0	0	0
Location of microstriation										
Walls	16	15.53	0	0	8	19.05	4	16	4	20
Bottom	20	19.42	4	25	10	23.81	6	24	0	0
Both	67	65.05*	12	75	24	57.14	15	60	16	80
Microabrasion										
Present	40	16.81	5	12.5	16	17.98	12	19.05	6	14.29
Absent	198	83.19*	35	87.5	73	82.02	51	80.95	36	85.71

Table 10
Spearman correlation coefficients between the faunal remains of different size from the Navalmaíllo Rock Shelter.

		Size					
		Large		Medium		Indeterminate	
		Correlation (ρ)	p-value	Correlation (ρ)	p-value	Correlation (ρ)	p-value
Size	Very large	0.79	5.76E-08	0.84	1.51E-10	0.93	5.02E-15
	Large	–	–	0.78	1.27E-07	0.82	8.04E-09
	Medium	-	–	–	–	0.92	2.19E-13

other than to those produced with simple quartzite/flint flakes. From these data, it can be followed that the marks produced by simple quartz flakes are clearly different from those produced with other simple flakes made with other raw materials (i.e. quartzite/flint).

5. Discussion

The study of cut marks has thrown light on the processing of food resources by hominin groups. It allows relationships to be established between sets of faunal remains and human activity, to test butchering strategies, and even allows inferences to be drawn on the work of individual butchers (Bermúdez de Castro et al., 1988; Lozano et al., 2009; Pickering and Hensley-Marschand, 2008). The present work adds to the literature on how the morphology of cut marks is influenced by the different raw materials used in lithic industry (Bello and Soligo, 2008; Buccheri et al., 2016; Fernández-Jalvo and Cáceres, 2010; Greenfield,

Table 11
Comparison of the data recorded for the experimentally obtained cut marks and those on the faunal remains from the Navalmaíllo Rock Shelter.

	Cut marks - Experimental		Cut marks -Navalmaíllo RS	
	n	%	n	%
Groove trajectory				
Straight	93	78.15	205	86.50
Curvy	18	15.13	17	7.17
Sinuous	8	6.72	15	6.33
Barb				
Present	14	11.76	11	4.62
Absent	105	88.24	227	95.38
Mark Orientation				
Parallel	49	41.18	56	23.53
Oblique	43	36.13	138	57.98
Perpendicular	27	22.69	44	18.49
Groove shape				
V	50	42.02	104	43.70
_/	69	57.98	134	56.30
Symmetry				
Symmetrical	90	75.63	194	81.51
Asymmetrical	29	24.37	44	18.49
Shoulder effect				
Present	78	65.55	150	63.03
Absent	41	34.45	88	36.97
Flaking on shoulder				
Present	71	59.66	84	35.29
Absent	48	40.34	154	64.71
Extent of flaking				
Short	36	30.25	67	28.15
Long	35	29.41	17	7.14
Absent	48	40.34	154	64.71
Overlapping striations				
Present	28	23.53	67	28.15
Absent	91	76.47	171	71.85
Internal microstriation				
Present	78	65.55	103	43.28
Absent	41	34.45	135	56.72
Microstriation trajectory				
Continuous	36	49.32	56	54.90
Discontinuous	37	50.68	46	45.10
Shape microstriation trajectory				
Straight	63	86.30	98	96.08
Irregular	10	13.70	4	3.92
Location of microstriation				
Walls	15	20.55	16	15.53
Bottom	9	12.33	20	19.42
Both	49	67.12	67	65.05
Microabrasion				
Present	20	16.81	40	16.81
Absent	99	83.19	198	83.19

2006, 1999; Olsen, 1988; Yravedra et al., 2017, 2009). The Navalmaíllo Rock Shelter has provided a very rich set of Mousterian tools, largely made from quartz. It provides a perfect opportunity, therefore, to examine how this raw material was used in butchering, an activity in which traceological analyses confirm it was involved (Márquez et al., 2016a,b).

5.1. Morphology of the experimentally made cut marks

Experimental work is vital for understanding the archaeological record, and forming analogies is important in taphonomic studies since the equifinality of different processes can lead to misinterpretations (Domínguez-Rodrigo, 2008). The making of analogies must, however, begin with a good comparison of the elements studied, their components, and the contexts in which they appear (Bunge, 1981). By using simple quartz flakes to butcher a medium-sized animal, the present experimental work tried to be as analogous possible with the conditions leading to the cut marks made on the examined faunal remains from Navalmaíllo Rock Shelter.

The present results provide important insights into cut mark morphology. Some of the cut mark characteristics identified could be present or absent, e.g., a symmetrical morphology, the presence of the shoulder effect, flaking, and microstriations were commonly present, while barbs, overlapping microstriations and microabrasions were commonly absent. Other variables such as the orientation of the mark with respect to the bone axis, the shape of the groove, the extent of flaking, and the trajectory of the microstriations, stood out neither for their greater presence nor absence. Although it may seem that some variables are more important than others, this is not the case. The use of multivariate approaches (Fig. 7) allows a better understanding of the variability between these samples, making all the variables relevant in this statistical analysis (Domínguez-Rodrigo and Yravedra, 2009). It is especially important to use a high number of variables since this will allow more complete comparisons with other types of samples.

The variability of the characteristics in the examined experimental cut marks would appear to be a consequence of the physical characteristics of the material (quartz) from which the flakes were made. As presented in the introduction, quartz has its own characteristics that determine the morphology of the flakes, and therefore also consequently condition the morphology of the cut marks.

The present experimental results reveal no relationship to exist between cut mark morphology and the type of bone on which they appear. Indeed, the marks on the long, flat and short bones were very similar, even though these anatomical elements differed in their cortical thickness and compactness (Braun et al., 2016). However, these results were all collected from a medium-sized animal; it remains to be accomplish experimentally other animal size to test whether the same holds true for animals of other size.

An interesting result is that the experimentally made cut marks (NISP = 21, *n* cut marks = 199), and those on the rock shelter's faunal remains (NR = 48; *n* cut marks = 248), show a very different morphology to trampling marks. This shows that problems of equifinality can be overcome via statistical analysis.

5.2. The Navalmaíllo Rock Shelter: an archaeological example of the use of simple quartz flakes in butchering activities

The analysis of the cut marks following the methodology of Domínguez-Rodrigo et al. (2009) revealed the great similarity between those made experimentally using locally sourced quartz, and those archaeological faunal remains. Indeed, it can be concluded that the latter were mainly made with simple quartz flakes. These marks were characterised by their straight trajectory, symmetry of cross section, the presence of a shoulder effect, and an absence of barbs, flaking, overlapping striations and associated microabrasion. No characteristic preferences were seen in terms of the orientation of the marks with respect to the bone axis, the presence of microstriations, or the type of cross section.

These findings support traceological evidence reported by other authors (Márquez et al., 2017, 2016a) which suggests that simple quartz flakes were used intentionally to cut meat at the Navalmaíllo Rock Shelter.

The study of the cut marks on the faunal remains also provides a response to the question left unanswered by the study of the experimentally made cut marks, i.e., whether the size of the animal conditions cut mark morphology. The present results suggest that it does not.

However, other researchers (Bello et al., 2016, 2009; Wallduck and Bello, 2016) have concluded very different ideas from the previous one. They can find clear differences between cut marks produced in animals of different sizes, also demonstrating that the type of bone and location on bone (e.g. midshaft against metaphysis) can show differences in morphology. In another study, Wallduck and Bello (2018) have introduced the idea that the stage of decomposition of meat can also influence the micro-characteristics of cut marks. In our opinion, these differences could be produced by two reasons: the applied methodology

Table 12
Characteristics of cut marks made by unretouched and retouched flakes, and by experimental trampling as recorded by Domínguez-Rodrigo et al. (2009), and trampling marks recorded at the La Mina site (Pineda et al., 2014).

	Unretouched Flakes		Retouched Flakes		Experimental Trampling		Trampling (Boella site)	
	n	%	n	%	n	%	n	%
Groove trajectory								
Straight	230	93.5	102	97.1	75	29.8	45	84.9
Curvy	16	6.5	0	0	42	16.7	5	9.4
Sinuous	0	0	3	2.9	134	53.4	3	5.7
Barb								
Present	25	10.2	6	5.7	6	2.4	1	1.9
Absent	221	89.8	99	94.3	245	97.6	52	88.1
Mark Orientation								
Parallel	1	0.4	0	0	25	9.9	0	0
Oblique	96	39	3	2.9	20	8	13	20.8
Perpendicular	149	60.6	102	97.1	206	82.1	40	79.2
Groove shape								
V	238	96.7	6	5.7	10	4	32	60.4
_/	8	33	99	94.3	241	96	21	39.6
Symmetry								
Symmetrical	212	86.2	42	40	226	90	49	92.5
Asymmetrical	34	13.8	63	60	25	9.9	4	7.5
Shoulder effect								
Present	81	32.9	78	74.3	15	5.9	2	3.8
Absent	165	67.1	27	25.7	236	94.1	51	96.2
Flaking on shoulder								
Present	36	14.6	54	51.4	7	2.7	3	5.7
Absent	210	85.4	51	48.6	244	97.3	50	94.3
Extent of flaking								
Short	36	14.6	42	40	5	1.9	3	5.7
Long	0	0	12	11.4	2	0.7	0	0
Absent	0	0	51	48.6	244	97.2	50	94.3
Overlapping striations								
Present	12	4.9	0	0	203	80.3	18	34
Absent	234	95.1	105	100	48	19.7	35	66
Internal microstriation								
Present	190	77.2	105	100	188	75	2	3.8
Absent	56	22.8	0	0	63	25	51	96.2
Microstriation trajectory								
Continuous	190	100	105	100	169	67.3	2	100
Discontinuous	0	0	0	0	82	37.2	0	0
Shape microstriation trajectory								
Straight	190	100	105	100	140	82.8	2	100
Irregular	0	0	0	0	29	17.2	0	0
Location of microstriation								
Walls	180	94.7	3	2.9	7	2.9	1	50
Bottom	0	0	93	88.6	219	87.1	0	0
Both	10	5.3	9	8.6	25	10	1	50
Microabrasion								
Present	6	2.4	0	0	250	99.6	53	100
Absent	240	97.6	105	100	1	0.4	0	0

Table 13
Spearman correlation coefficients between the cut marks made by the present experimental quartz flakes and the cut marks on the faunal remains from the Navalmaíllo Rock Shelter, and the marks on the experimental samples of Domínguez-Rodrigo et al. (2009) and those recorded by Pineda et al. (2014).

	Quartz flakes		Navalmaíllo Rock Shelter	
	r	p value	r	p value
Unretouched flakes	0.63	0.0001007	0.65	5.37E-05
Retouched flakes	0.52	0.00122	0.49	0.004755
Experimental trampling	0.04	0.83111	0.23	0.2062
Trampling (La Mina site)	0.24	0.1807	0.50	0.003695

and the type of samples (or both at the same time). Bello and colleagues (2016, 2009) and Wallduck and Bello (2016) used 3D methods for the analysis (i.e. Alicona imaging microscope) and this could produce a difference between their results and ours. On the other hand, the different results also can be explained thorough by the different features of the studied samples in each case. Therefore, future experiments should attempt to explore the application of both methodologies on the same sample.

5.3. Stone tool type: another variable that affects cut mark morphology

The type of tool is a variable that should be borne in mind when studying cut mark morphologies (de Juana et al., 2010; Domínguez-Rodrigo et al., 2009; Schick and Toth, 1998). The retouching of natural edges can generate small anomalies that modify cut mark morphology, e.g., in terms of the orientation of the marks with respect to the bone axis, the shape of the groove, or the presence of overlapping microstriations. For example, when bifaces are used as cutting tools they may leave “fork marks”, a result of these tools being intensely retouched (de Juana et al., 2010; Yravedra et al., 2010).

However, the present results show important differences between cut marks resulting not only from the tool type, but from the materials from which the tools were made. Indeed, the marks made by simple and retouched flint and quartzite flakes show more appreciable differences between them than those made by simple quartz flakes. Moreover, it is

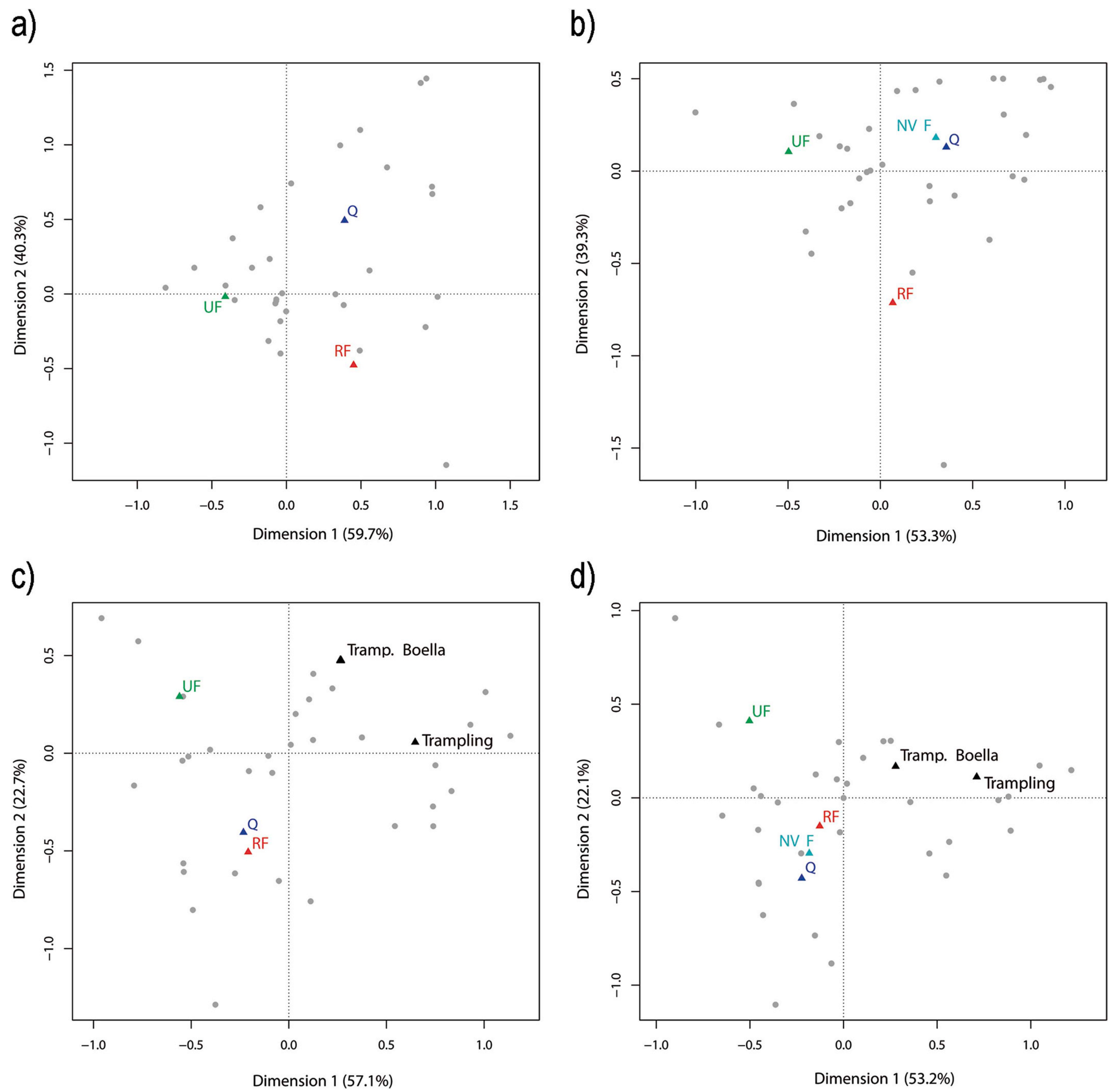

Fig. 7. Multiple correspondence analysis (MCA) examining the experimentally made cut marks/Navalmaíllo Rock Shelter cut marks, and the other samples provided by other authors (Domínguez-Rodrigo et al., 2009; Pineda et al., 2014). Q = cut marks made with simple quartz flakes; NV F = cut marks made on faunal remains from Level F of the Navalmaíllo Rock Shelter; Tramp. Boella = Trampling from the La Mina site, Barranc de la Boella (Pineda et al., 2014); UF = cut marks made with simple flint and quartzite flakes; RF = cut marks made with retouched flint and quartzite flakes; and trampling = experimental trampling (Domínguez-Rodrigo et al., 2009). Grey points represent the different variables used in the analysis. 7a) a comparison between the different samples of experimentally made cut marks is shown; on Fig. 7b) the information related to the cut marks of Navalmaíllo Rock Shelter is added to the previous analysis; 7c) a comparison between the characteristics of experimentally made cut marks and trampling marks is shown; and on picture 7d) the information related to the cut marks of Navalmaíllo Rock Shelter is added to the previous analysis of Fig. 7c.

especially interesting that cut marks made with quartz are more similar to those produced with retouched flint/quartzite flakes than those made with simple flint/quartzite flakes. Thus, both tool type and raw material have a determining influence on the morphology of cut marks. If the reference framework for these marks were widened, this might help researchers interpret butchering processes at sites much more completely, helping us understand, according to time and place, the choices made by hominins regarding tool type and the raw materials from which these were made.

A recent study has tried to characterise the cut marks left by stone tools used at the Noisetier Cave in France (Val et al., 2017). The authors, who worked with archaeological materials, concluded that the methodology of Domínguez-Rodrigo et al. (2009) and de Juana et al. (2010) cannot distinguish between the tools/raw material used in the archaeological record. The results of the present work, however, suggest that it indeed can. This discrepancy might be explained in that

Table 14
Data taken from Tables A1, A2 and A3 from the appendix of the study by Val et al. (2017), used in the production of Fig. 6.

Stone tool	Unretouched Flake	Unretouched Flake	Unretouched Flake	Unretouched Flake	Mousterian Flake	Cleaver	Cleaver	Denticulate	Denticulate	Noisetier
Raw material	Quartzite	Fine-grained Quartzite	Schist	Flint	Flint	Quartzite	Ophite	Flint	Quartzite	–
Groove trajectory										
Straight	15	13	9	12	16	38	14	34	15	123
Curvy	6	5	3	2	1	10	1	24	25	43
Sinuous	5	5	3	16	5	14	4	29	32	92
Barb										
"Barb effect" Present	1	3	0	1	2	6	2	12	9	11
"Barb effect" Absent	25	20	15	29	22	56	17	72	63	204
Groove shape										
V	22	19	14	28	19	51	12	72	66	192
_/	4	3	1	2	3	11	7	12	6	20
Symmetry										
Symmetrical	7	6	7	6	4	15	5	32	21	67
Asymmetrical	17	17	7	22	18	47	14	52	44	134
Shoulder effect										
"Shoulder effect" Present	17	16	8	15	20	43	15	61	41	142
"Shoulder effect" Absent	9	7	7	15	2	19	4	23	31	74
Flaking on shoulder										
Flaking Present	0	0	0	2	1	3	0	2	0	11
Flaking Short	0	0	0	2	1	3	0	2	0	8
Extent of flaking										
Flaking Long	0	0	0	0	0	0	0	0	0	3
Flaking Absent	26	23	15	28	21	59	19	82	60	205
Internal microstriations										
Micro-striations Present	3	2	4	4	5	18	1	27	27	50
Micro-striations Absent	22	21	11	26	17	44	18	57	45	166
Microstriations trajectory										
Continuous	2	2	4	3	5	14	0	26	20	38
Discontinuous	1	0	0	1	0	4	1	1	7	12
Shape microstriations trajectory										
Micro. Straight	3	2	4	4	5	18	1	27	27	50
Micro. Irregular	0	0	0	0	0	0	0	0	0	0
Location of microstriation										
Walls	0	2	2	2	10	0	0	13	10	13
Bottom	1	0	0	0	0	0	0	2	0	0
Both	0	0	0	0	1	0	0	8	6	6
Overlapping striations										
Intersecting m. Present	1	1	0	0	2	7	2	4	5	12
Intersecting m. Absent	13	9	15	30	20	55	17	80	28	99

while Val and colleagues analysed the marks of flint and quartzite tools separately, their final analysis only took into account the type of tool used. The present work, however, examines the importance of the raw material as a variable affecting cut mark morphology. To compare the results of the latter authors with those of the present work, the information in their Tables A1, A2 and A3 (Val et al., 2017, pp. 26–27) in which the characteristics of cuts marks with respect to tool type and raw material appear - plus the corresponding present results for both the experimental and faunal remains (i.e., the trajectory of the marks, presence of barbs, cross sectional shape [narrow or wide V cross section], symmetry, shoulder effect, flaking, length of flaking, presence, direction, position and continuity of microstriations, and the presence of overlapping striations) (Table 14), plus those of Domínguez-Rodrigo et al. (2009), were subjected to multiple correspondence analysis (Fig. 8).

The results revealed important differences between the cut marks of Val et al. (2017) and all the other marks analysed. Those of Val and colleagues all cluster on the positive side of the X axis, while all the others cluster on the negative side. The differences between the cut marks on the Navalmaíllo faunal remains/those of the samples of Domínguez-Rodrigo et al. (2009), and those of Val et al. (2017), do not appear to be explained simply by cut mark morphology. Of course, the results of Val et al. (2017) refer to simple and retouched flint and quartzite flakes rather than simple quartz flakes, but neither is there any agreement between these results and those involving such materials in the work of Domínguez-Rodrigo et al. (2009).

The large differences seen between the results obtained by these authors are probably explained by the under-representation of certain variables in the latters' experimental and archaeological samples, e.g., the number of remains with microstriations and flakings. These authors in fact made mention of this reduced representation, which they believed perhaps due to taphonomic processes (Val et al., 2017). Their experimental material may have been taphonomically altered since it was buried in order to clean it, a methodology chosen since, as other authors have indicated, microstriations and flaking etc. might disappear if biochemical cleaning processes are used (Behrensmeyer et al., 1986; Pineda et al., 2014). If Val et al.'s sample of experimental tools/raw materials would have been larger, different analytical results may have

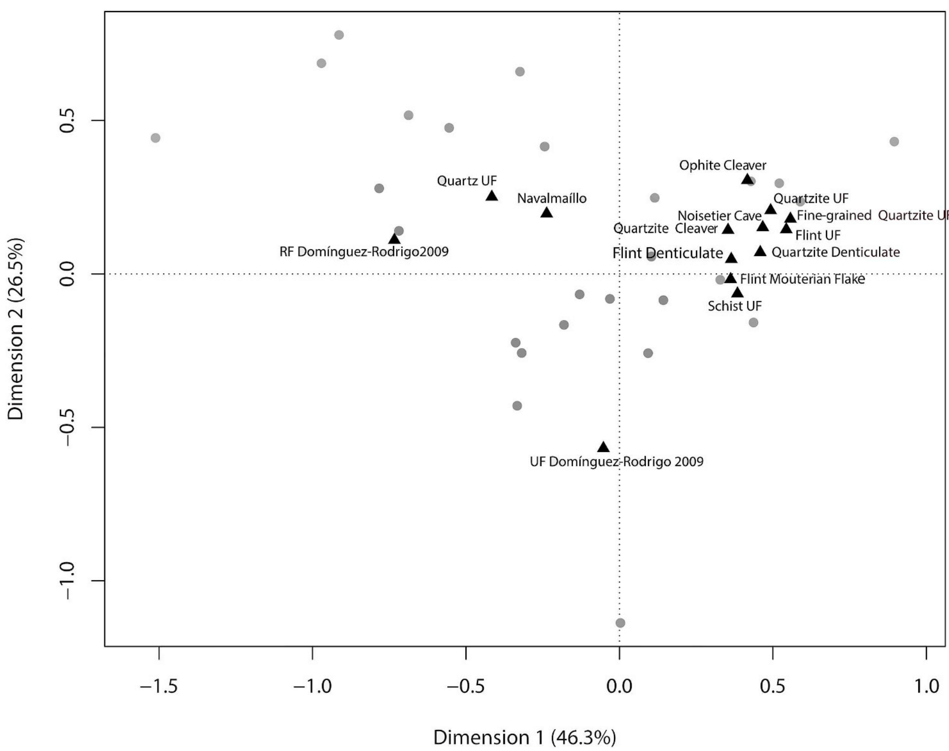

Fig. 8. Multiple correspondence analysis (MCA) involving the data from Tables A1, A2 and A3 from the study by Val et al. (2017, pp. 26–27), data from the study by Domínguez-Rodrigo et al. (2009), the experimentally made cut marks, and the cut marks on the faunal remains from the Navalmaíllo Rock Shelter. UF = Unretouched flakes; RF = Retouched flakes.

been yielded. In fact, in different experimental samples, Val et al. (2017) did not use a significant number of cases: Unretouched quartzite flakes (n = 26), Unretouched fine-grained quartzite flakes (n = 23), unretouched schist flakes (n = 15), Mousterian flint flakes (n = 22) and ophite cleavers (n = 19).

In summary, the present results suggest that the method of Domínguez-Rodrigo et al. (2009) can be used to determine the type of raw material used to fashion cutting flakes, if the fossilised material examined is well preserved and the sample size sufficiently large.

6. Conclusions

The construction of new experimental frameworks should be a priority in taphonomy, certainly highlighting the importance of overcoming problems in equifinality as presented from a neotaphanomical point of view. Multivariate statistical analyses could lead the way towards much more meaningful results (Domínguez-Rodrigo, 2008; Domínguez-Rodrigo and Yravedra, 2009). Recently papers have started to appear in which the use of new technologies have shown how problems in equifinality can be overcome through more detailed analysis of cut marks (Bello et al., 2009, 2016; Bello and Soligo, 2008; Courtenay et al., 2017, 2018; Maté González et al., 2015; Maté-González et al., 2017; Palomeque-González et al., 2017; Wallduck and Bello, 2016; Yravedra et al., 2017), also expanding this research of bone surface modifications to include tooth marks (Aramendi et al., 2017; Arriaza et al., 2017b) and percussion marks (Yravedra et al., 2018).

In the present work, the methodology of Domínguez-Rodrigo et al. (2009) allowed us to distinguish the raw material responsible for making cut marks. This methodology originally sought to differentiate between cut marks and marks made by trampling, but the present results show it can be used to determine the raw materials from which butchering tools were made.

The present results highlight the need to widen the reference framework for cut marks. Conclusive data are required on the characteristics of cut marks made with flint and quartzite tools to overcome the confusion in this respect in the work of Domínguez-Rodrigo et al. (2009). Val et al. (2017) tried to move in this direction but the results obtained were unsatisfactory; more, well preserved samples need to be examined. It would also be interesting to see whether differences exist in the morphologies of the cut marks made by different butchers. However, since no differences were seen between the cut marks on the remains of animals of different sizes or their anatomical elements, they might not be expected, therefore, between different butchers (other than the frequency of marks they made) (Domínguez-Rodrigo, 1997).

The following conclusions can be drawn from the present work.

a. The morphology of the cut marks made with simple quartz flakes is clearly different to those made by other tools/raw materials.
b. The morphology of these cut marks is always the same; it is unaffected by the type of bone on which they are made, or the size of the animal from which those bones come. The following interpretation has been made with the fossil remains of the Navalmaíllo Rock Shelter. This idea should be tackled in the future with new experimental approaches, considering the contrasting interpretations of other authors using different methodologies (Bello et al., 2016, 2009; Wallduck and Bello, 2016).
c. Cut mark morphology is seems to be influenced by the type of tool (i.e. unretouched or retouched tools) used and the material from which it was crafted.
d. The marks on the Navalmaíllo Rock Shelter faunal remains could be made by simple quartz flakes, as suggested by studies on use-wear analysis. It his highly recommended that future studies into the morphology of cut marks produced by retouched quartz tools be investigated.
e. The cut marks made by the simple quartz flakes are clearly different to trampling marks.

These results suggest a very pragmatic use of the raw materials available to the Neanderthals who visited the Navalmaíllo Rock Shelter, as suggested by studies on the site's lithic industry (Márquez, 2016; Márquez et al., 2016a, 2013). The use of quartz (a material largely overlooked by archaeological researchers) would appear to have been very important in butchering at this site. The use of local materials by the Neanderthal groups that settled the rock shelter would appear to reveal their adaptive capacity.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.quaint.2018.09.033.

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