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Identifying bipolar knapping in the Mesolithic site of Font del Ros (northeast Iberia)

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Despite recent advances in the identification of bipolar knapping, its role in many sites is not well known. We propose to assess the significance of this technique in the context of changes that occur in the Mesolithic. A lithic assemblage was recovered from unit SG at Font del Ros (Catalunya, Spain) in which pitted stones, cores and products arising from bipolar reduction (flakes, fragments and splintered pieces) were identified. This study indicates that the bipolar technique is fundamental in the settlement. These results are key to defining the organization of Holocene hunter-gatherer subsistence in northeast Iberia.

1. Introduction

Bipolar knapping, originally defined by Breuil & Lantier [1], is a method which involves the interaction of anvils, hammerstones and the raw material exploited. However, bipolar artefacts and the functional contexts in which they are used are not well known. In recent years, there has been increased interest in investigating the technological, cognitive and evolutionary implications of a technique closely linked with the origin of percussive technology [2–4], and which is ubiquitous in its far-reaching geographical and chronological dispersion [5–18].

This method is structured on effortless technical principles and knapping actions [14], but which enable the production and/or shaping of artefacts. The expedient nature of bipolar knapping has caused it to be considered a 'solution of last resort' [14] which, as such, has not motivated much interest in undertaking a more in depth technical diagnosis of the method.

Bipolar knapping is identified through knapping sequences with minimum core management limited to maintenance of the edge from which the volume of stone is exploited recurrently. The method generates a wide variety of blanks, often difficult to distinguish due to low morphological standardization [7,12]. In the past decade, some variability in actions has been identified which allows several methods of bipolar flaking to be described. Depending on the placement of the blank on the anvil and orientation of percussion, it is possible to differentiate between axial and non-axial percussion, internal oblique percussion and vertical splintering percussion. These methods are recognized by the way the knapping surface is split in two, and whether the exploitation area of the core is affected on one or several edges of its periphery. Based on these characteristics, it has been suggested that bipolar knapping generates diagnostic marks which differ from those of freehand percussion [14].

However, these criteria are not easy to identify, and methodological and terminological problems, indicated by Hayden [19] when referring to 'confusion in the bipolar world', persist. In particular, this 'confusion' affects artefacts with similar formal attributes which are described ambiguously as scaled piece, splintered core piece or *pièce esquillé* [20,21]. Likewise, the functional inferences of splintered pieces are an issue of discussion [22–29]. Finally, it should be noted that the bipolar method is commonly used with quartz, which hinders recognition of knapping indicators [10,30].

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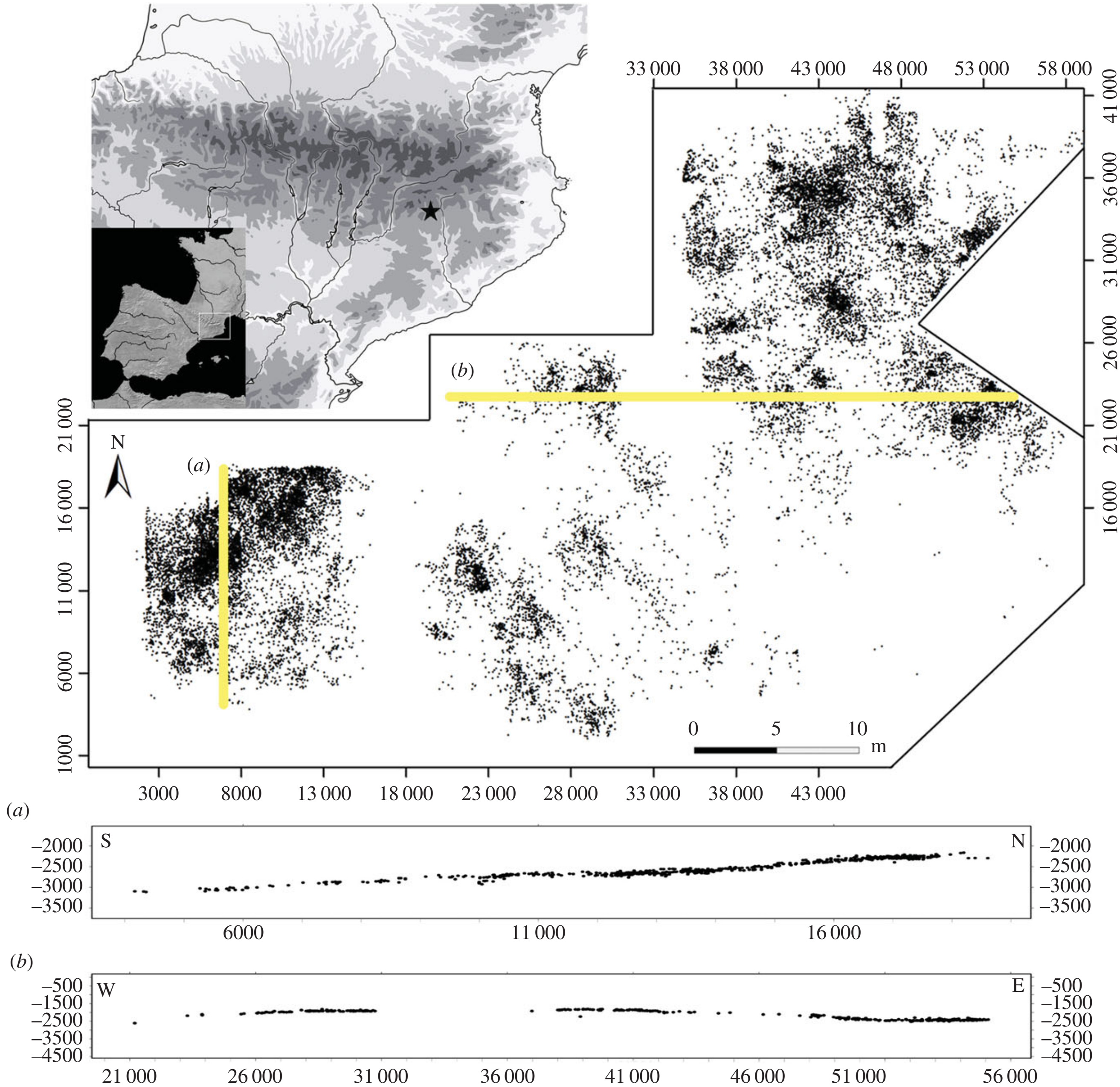

Figure 1. Site location and distribution of materials in unit SG. Top left: location of the Font del Ros site in the southeast Pyrenees ($X = 404\,572$ $Y = 4\,661\,194$ UTM H31N ED509, 670 a.s.l.). Top right: plan of materials recovered from unit SG showing several clusters across a 1200 m^2 area. Vertical plot showing the sparse dispersion of materials in the level. (*a*) Vertical plot (N-S) on the *x*-axis, $x = 7000–7500$ and (*b*) vertical plot (E-W) on the *y*-axis, $y = 22\,500–23\,000$. (Online version in colour.)

In recent years, we have shown the bipolar technique to be very common in the Mesolithic of the southern slopes of the Pyrenees. In this chronocultural context, we have noted the absence of microlithic armatures and the incidence of a significant amount of unspecialized artefacts typologically defined as the 'fond commun' in which indicators of bipolar knapping abound [31–36]. These techno-typological features allow us to assess the role of the bipolar technique in the lithic assemblage of unit SG at Font del Ros.

(a) The Mesolithic level of SG at Font del Ros

Font del Ros is located at the contact zone between the Catalan Depression and the lower foothills of the Pyrenees (figure 1). This open-air site, located in the town of Berga (Barcelona, Spain) and excavated in the early 1990s, revealed a stratigraphic sequence with two Mesolithic units (SGA and SG) and another attributed to the Early Neolithic (N) [31,34,37] (M. Pallares 1999, unpublished data).

Unit SG extends over more than 1200 m^2 in which nine hearths and two pits were recorded, and from which more than 27 800 remains were recovered. A series of ^{14}C dates indicate several occupation events during the early Holocene between 10 250 and 8450 cal BP (electronic supplementary material, figure S1). The interpretation of an indeterminate number of recurring visits over 1800 years corresponds well with the spatial distribution of the archaeological record, consisting of patches with little vertical dispersion (5 cm thick) as indicated in E–W and N–S vertical plots (figure 1*a*,*b*). These horizontal and vertical spatially discrete clusters suggest brief occupation events during which lithic artefacts, bones and plants (seeds and charcoal) were abandoned, providing information on the organization of subsistence activities [34] (M. Pallares 1999, unpublished data).

Table 1. Technical indicators and attributes for identification of bipolar cores and products.

	cores	products
flint	— striking platform and contact zone on anvil with blunt scars — step and hinge terminations of scars produced by percussion — blunting and splintering of the striking platform on recurrent knapping — overlap of removals and possible opposition of extractions	— broken and linear butts — butt fissuration — incidence of parasite chipping — deep ripples on ventral side — hinge bulb — rectilinear profile and sometimes twisting around knapping axis — possible splintering of distal and proximal areas
quartz	— absence of conchoidal negatives — step scars related to low elasticity of the rock — bluntness and fissuration of striking platforms — edge battering on recurrent knapping — presence of overhang extractions	— absence of impact points — linear butts — absence of bulb — rectilinear profile — hammering scars on proximal and distal surfaces — crushing and radial fissures on butt — siret and tranversal fractures

Site formation processes have spatially affected bone conservation, hindering taxonomic identification, although *Cervus elaphus*, *Capra pyrenaica*, *Sus scrofa*, *Bos* sp. and *Oryctolagus cuniculus* have been identified, all of which indicate temperate environmental conditions within a mosaic landscape. Charcoal analysis reveals a community composed of *Quercus* sp., *Buxus sempervirens*, *Corylus avellana*, *Ulmus* sp., *Salix* sp. and *Sambucus* sp., typical of dense deciduous forest requiring high humidity [38]. Shells of *Corylus*, *Quercus* sp. were recovered along with seeds from *Pirus* sp., *Malus* sp., *Prunus avium* and *Prunus spinosa*, implying the regular processing and consumption of plants collected in the vicinity [36]. Such an ecological characterization indicating post-glacial expansion of forests is consistent with the available radiometric framework.

More than 15 different rock types were identified in the SG lithic assemblage, among them flint, quartz, limestone and other rocks. The raw materials most commonly associated with knapping are flint (46%), quartz (36%) and limestone (9%), and to a lesser extent other rocks. Cryptocrystalline and vein quartz are present in the form of irregular cobbles with fissures, flaws and internal planes of weakness, and are found in terraces near the site. Flint appears as small tabular nodules (less than 10 cm) veined with limestone and with internal weaknesses coming from mountains about 10 km away from the site [39]. This management of poor quality raw materials which are abundant in the surrounding area and which are worked using expedient methods is a technical feature defining this assemblage [31,32,34] (M. Pallares 1999, unpublished data), and whose characteristics are presented below.

From a typological perspective, the absence of backed points/bladelets or microliths and bone tools at Font del Ros, along with the poor preservation of fauna, make it difficult to assess the role of hunting in subsistence practices [40,41]. Faced with the absence of lithic armatures, a key element in the cultural identity of the Mesolithic [42], in SG we stress the importance of the 'fond commun' consisting of scrapers, notches, denticulates and splintered pieces, usually associated with domestic activities. Such a composition ascribes this assemblage to a Mesolithic 'without armatures' as identified in the Ebro Basin and the Pyrenean slopes of the Iberian Peninsula [43].

2. Material and methods

In our study of the SG lithic assemblage, we pay particular attention to technical elements and attributes recorded on cores, flakes and knapping debris which define bipolar knapping, as well as other diagnostic artefacts: pitted stones and splintered pieces.

Analysis of volumetric structure and pattern of removals allows us to differentiate blanks originating from freehand knapping [44], while parameters set by Driscoll [10], Prous *et al.* [45] and de la Peña & Wadley [15] are followed for bipolar cores. Products are identified through technical indicators, macroscopic traces and fractures [46–50], and we follow criteria proposed by Donnart *et al.* [12], Prous *et al.* [45] and de la Peña & Vega Toscano [51] to recognize bipolar blanks (table 1). This distinction is not without its problems due to the absence of core preparation and the high fragmentation generated by bipolar knapping [20,21,45]. Typometric and statistical analyses were performed using XLSTAT Statistical Software.

Active areas on percussion tools were identified using a binocular microscope (Olympus SZ-11) (10× – 80×). Functional studies follow criteria and interpretation proposed by Adams *et al.* [52].

Artefacts analysed in this study include cores, flakes, fragments, macrolithic tools and splintered pieces (table 2).

(a) Bipolar knapping in Font del Ros SG

The characterization of bipolar knapping in Font del Ros is complicated due to the great variability in products and the poor quality of the raw material, so that many pieces apparently linked to the bipolar method do not have diagnostic attributes. Given that these problems hinder identification, bipolar must be under-represented in our counts. Nevertheless, attributes and technical traces [13] on cores, cobbles, products and splintered pieces indicate the relevance of this method in the assemblage.

(i) Macrolithic tools: pitted stones

Level SG at Font del Ros yielded more than 350 cobbles or fragments of limestone, quartzite and sandstone with use-wear on

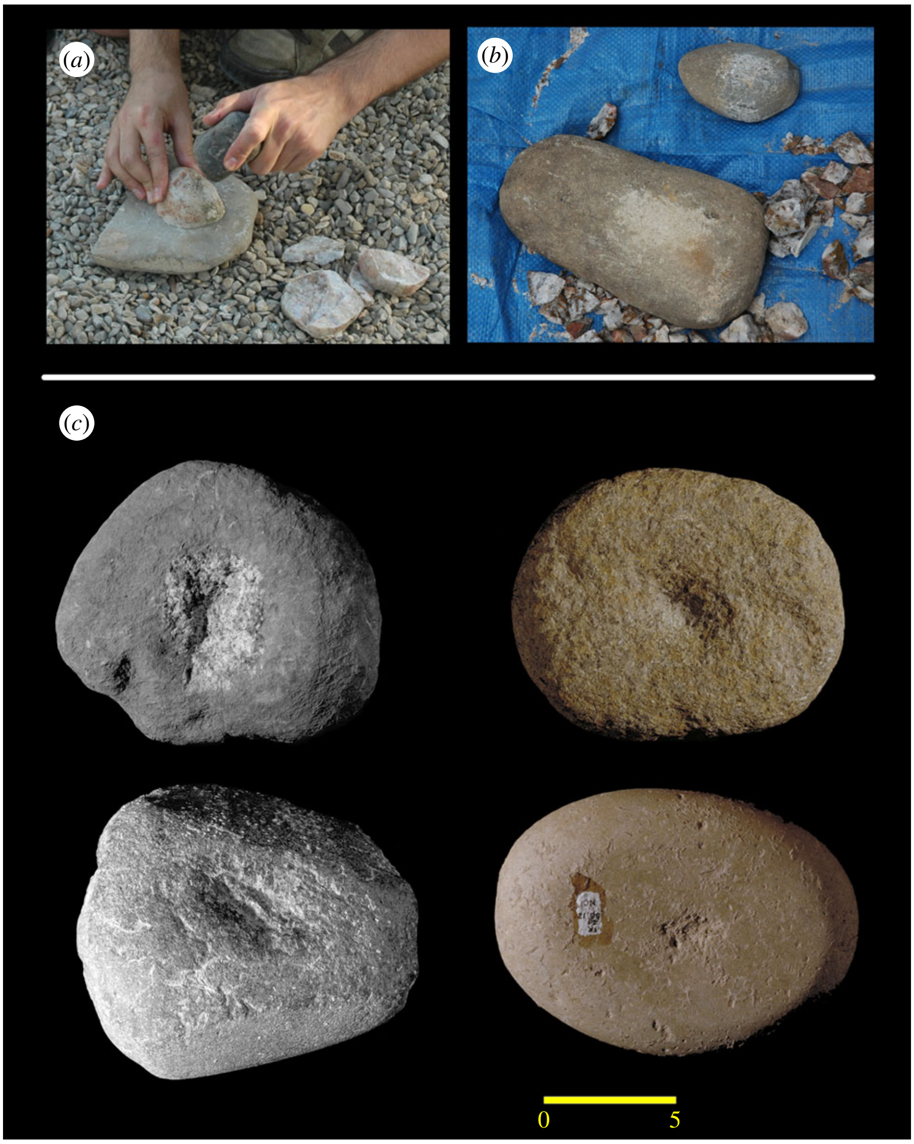

Figure 2. Macrolithic artefacts related to bipolar knapping. (*a*) Elements linked to experimental bipolar knapping (hammerstone, anvil, knapped nodule) and technical actions characteristic of anvil stone working; (*b*) example of a pitted stone obtained during the experimental knapping of quartz [35]; and (*c*) pitted stones from level SG at Font del Ros with central pits caused by use as hammerstones or anvils. (Online version in colour.)

Table 2. Frequency, percentages and weight of the SG lithic assemblage.

categories	pieces	%	weight (kg)
cores	369	1.67	19.99
splintered	192	0.87	0.5
flakes	1599	7.26	8.08
macrolithic	387	1.75	19.99
retouched	385	1.75	4.2
manuports	2873	13.05	203.86
blade/bladelet	239	1.08	0.48
debris	7543	34.28	0.3
fragments	4722	21.46	16.54
chunks	3693	16.78	55.52
Σ	22 002	100	329.46

their surfaces. These oval cobbles, averaging 10 cm and 400 g, provide essential information for the recognition of knapping and the processing of bones, plants, ochre or skin, and are key for the analysis of daily activities at Font del Ros [34–36] (M. Pallares 1999, unpublished data).

We focus here on pitted stones, cobbles showing battering marks in their central area [2,25,35,53–57]. Usually, description of these tools has focused on their morphological traits evident at a macroscopic level. Following an experimental programme and use-wear analysis, we were able to link the SG pitted stones to bipolar knapping [35], similar to that indicated by other studies [12,29,45] (figure 2*a*,*b*).

The most diagnostic tools are 24 pitted stones with use-wear generated by battering (figure 2*c*). Their active surfaces have a frosted appearance, show grain crushing and use-wear linked to compression of the active surface. Step fractures and microflaking are observed when the intensity of the task modifies the topography of the contact surface. From a technical perspective, distinct morphotypes are related to different degrees of intensity of use such as pits of irregular section (16), or incipient pits (four). Pits which are regular in section (four) could correspond to intentionally shaped depressions. In some cases, tools are multi-functional, bearing knapping traces which are associated with or superimposed on wear traces related to the crushing and grinding of plants [36] (table 3).

One question on which there is no consensus is whether artefacts linked with bipolar knapping are active or passive elements.

Table 3. Typology of pitted stones and corresponding rock types.

	quartzite	gneiss	limestone	sandstone	Σ
irregular pit	6	5	4	1	16
incipient pit	2		2		4
regular pit	1	2		1	4
Σ	9	7	6	2	24

Table 4. Relative and absolute frequencies of cores in Unit SG.

	quartz	%	flint	%	other	%	Σ	%
bipolar	26	30.95	154	43.63	2	5.56	182	38.48
blade/bladelet	1	1.19	15	4.25	2	5.56	18	3.81
unifacial	31	36.90	10	2.83	27	75	68	14.38
bifacial	2	2.38	2	0.57	1	2.78	5	1.06
multifacial	3	3.57	4	1.13	1	2.78	8	1.69
splintered	21	25	168	47.59	3	8.33	192	40.59
Σ	84	100	353	100	36	100	473	100

We agree with the idea that hammerstones and anvils can be interchanged during the reduction process, passing from active to passive elements and vice versa [12]. In Font del Ros, only the heavier pieces (more than 2 kg) function as resting anvils [2].

(ii) Cores: freehand knapping versus bipolar technique

One hundred and eighty-two of the analysed cores were positively identified as resulting from bipolar reduction, indicating a high incidence of the technique as opposed to other modes such as freehand, unifacial knapping and other methods (table 4).

Bipolar knapping is systematically used with flint (44%) and to a lesser degree quartz (31%). This dynamic is accentuated when splintered pieces, which should be considered as exhausted bipolar cores, are included in the bipolar assemblage as we show in §2*a*(iv). In this case, almost all the flint (91%) and 56% of the quartz assemblages are connected to anvil work.

These cores show little preparation of platforms and knapping surfaces but take advantage of flat cortical areas and natural fractures (figure 3*a*). Surfaces are generally cortical and can be parallel or have diverging morphologies forming quadrangular or rectangular volumes. Superimposed removals around striking platforms and blows from orthogonal axes are common (figure 3*b*). On occasion, striking and counterstrike surfaces are blunt and fissured from prolonged contact between the anvil surface and hammerstone before detachment of the flake [13] (figure 3*c*). There are dihedral scars on the knapping platform and contact surface of cores which are symmetrical in profile; however, scars are unifacial on asymmetric cores (particularly quartz cobbles) (figure 3*d*). Likewise, cores with polygonal section present secant planes on the knapping platform and are the result of core fracture or several sequences of extractions [45].

The most striking feature of both flint and quartz bipolar cores is their small size (electronic supplementary material, tables S1–S4). A metrical comparison of bipolar cores and those produced by freehand knapping shows a bimodal distribution. Attributes such as length, width, thickness and mass, indicate a similar pattern, grouping bipolar cores in lower ranges, while those resulting from freehand percussion show greater dispersion, especially in the quartz group. This difference is due to exploitation of cobbles in the case of quartz and small tabular fragments for flint. The dual distribution is conclusive when mass is considered, with 75% of bipolar cores falling within the less than 10 g range, as opposed to 17% of freehand cores (figure 4). Differences are statistically significant; a normality test shows that only length, width and thickness of bipolar quartz cores have a normal distribution (table 5). Likewise, comparison using the Mann–Whitney *U*-test reveals significant differences in these metrical attributes (table 6).

Interesting technical inferences stem from these results. On the one hand, they suggest that freehand knapping is undertaken on blanks of all sizes associated with core reduction; by contrast, bipolar knapping is used systematically on small-sized blanks, possibly to extend exploitation of the core and get pieces of smaller dimensions. On an organizational level, these techniques of core management are not mutually exclusive, but rather the contrary; metrical data define two segregated but complementary populations found at each end of blank size distribution (figure 4). This suggests rotation or succession of reduction techniques, a pattern similar to the recycling window [16], whereby bipolar reduction allows exploitation of cores for which freehand percussion is not viable.

(iii) Bipolar flakes, fragments and knapping waste

From a mechanical perspective, products resulting from bipolar knapping are the consequence of interaction between anvil and hammerstone. It is not easy to recognize this technique on flakes and fragments due to the great quantity of non-diagnostic pieces generated throughout the knapping process. A classic attribute such as the presence of bulbs at both extremes of the product—counterstrike—[1,7,58–60] is rare in the Font del Ros assemblage. The absence of platforms and distinct bulbs on quartz flakes makes it difficult to identify bipolar knapping on quartz [10,61].

There are 393 bipolar products in flint (80%) and quartz (20%), 226 flakes and 167 fragments with technical indicators similar to those described in other assemblages [10,15,27,62].

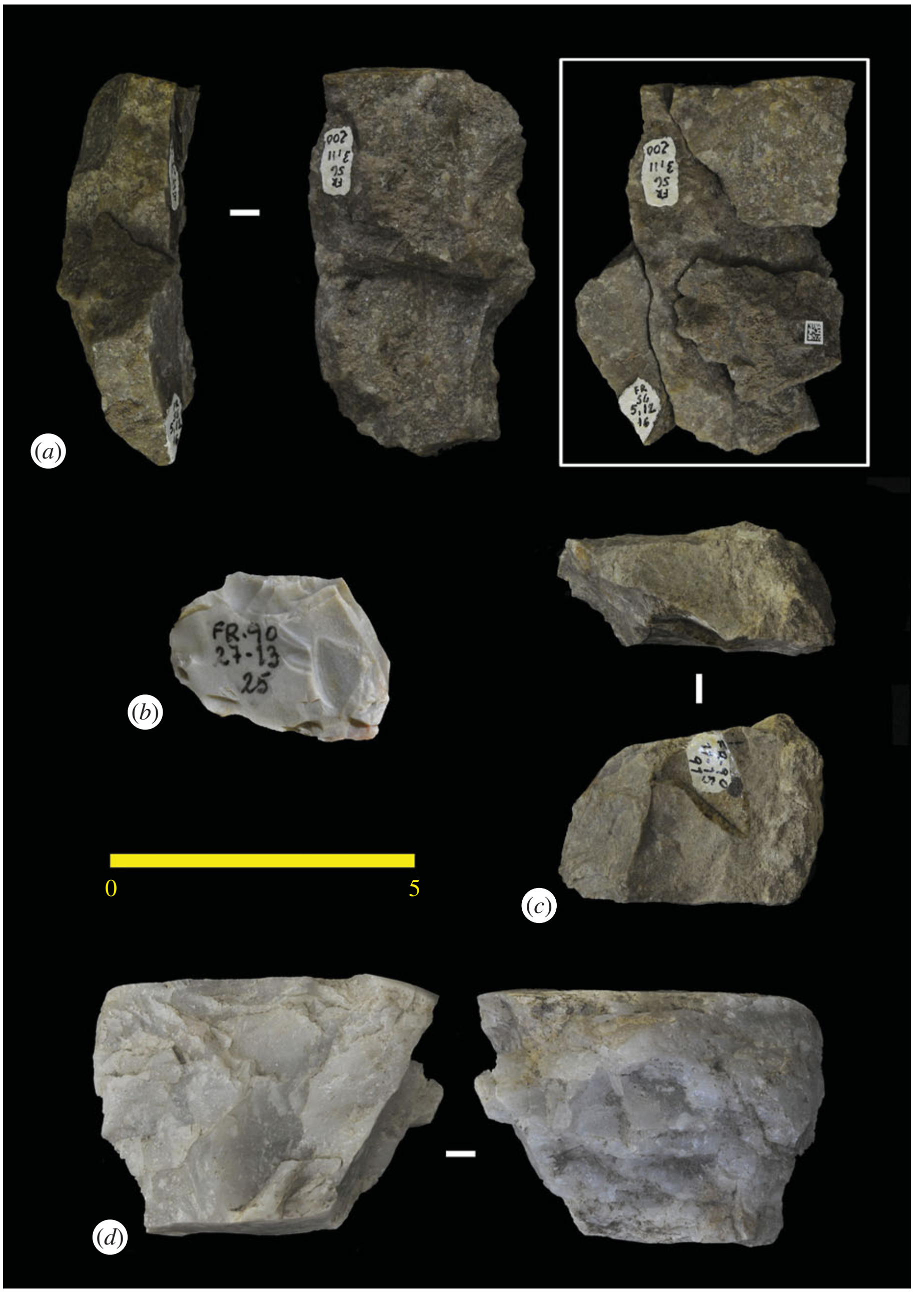

Figure 3. Bipolar cores from unit SG. (*a*) Bipolar quartz core with cortical platforms, and refit series with an example of opposed extractions; (*b*) bipolar flint core with superimposed removals around striking platforms; (*c*) flint core with cortical platform and splintering; and (*d*) bipolar quartz core on cobble with step extractions and striking platform fissures. Scale bars, 5 cm. (Online version in colour.)

Although previously we have indicated the limited preparation of cores, products share some features in common. The repeated impact on poorly prepared cores produces pieces which are rectilinear in profile and with parallel or subparallel edges.

Relevant attributes indicating bipolar origin are recorded when documenting striking platforms. Platforms are often cortical and the intensity of percussion produces crushing of the edges. Evident on the dorsal face in particular are removals opposed to the direction of the knapping axis. Striking platforms on flint flakes tend to be lineal, and usually have micro fissures. Ventral faces show marked percussion ripples, bulbar fractures and cracked bulbs (figure 5). On quartz pieces, the absence of bulbs and ripples hinders recognition of the bipolar method.

Bipolar percussion causes much fragmentation in the form of chunks (fragments and knapping waste), which are very common in SG (table 2) and associated with a high frequency of pieces with longitudinal fractures (Siret burins) and transversal breaks. Indications of bipolar knapping among knapping debris include features such as crushing of the bulb due to impact damage, platform surface morphologies which are punctiform or trihedral, twisting around the knapping axis (figure 5*a*) or flakes with very highly defined ripples known as 'eclats vibres' [62]. Other very characteristic by-products include 'batonets' (spalls), non-cortical flakes with a longitudinal fracture and triangular or quadrangular section [63,64] (figure 5*a*), or 'aiguilles', long segments obtained from fissures in the blank [45].

(iv) Splintered pieces: cores or tools?

Splintered pieces form another category usually associated with the anvil technique [34,35]. Generally, they are rectangular pieces which show splintering on the sides and ends of both faces and have well-defined impact points [63,65]. These are common tools in Upper Palaeolithic and Mesolithic assemblages of Western Europe [66–68]. However, recently there has been debate on whether they could be cores [20,21,27] or, alternatively, wedges or chisels for the working of wood or bone [69–71]. Due to this dispute, an in depth identification of attributes to assess such distinct functional implications should be undertaken. Given the lack of use-wear analysis on archaeological pieces,

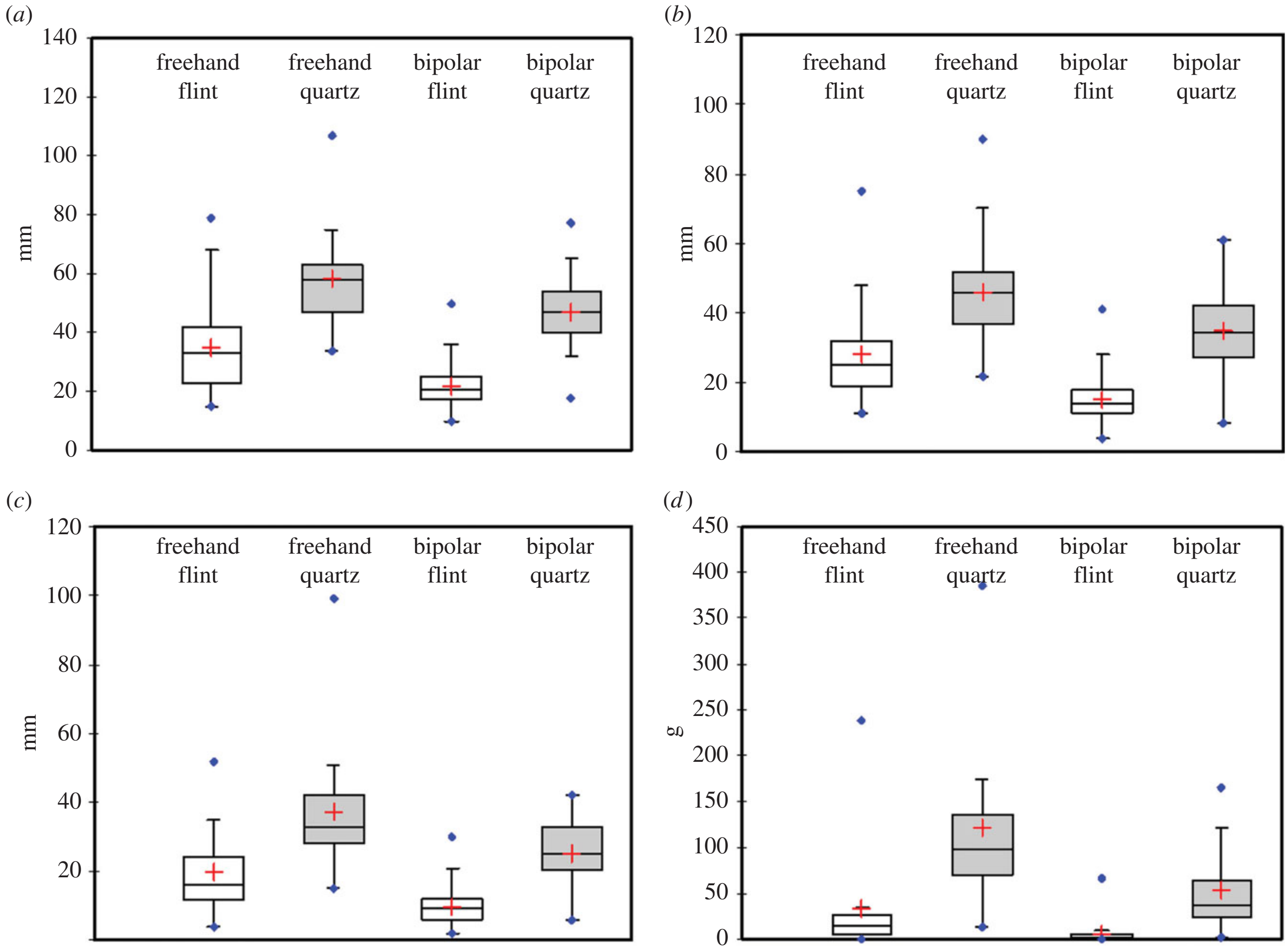

Figure 4. Box plots of (*a*) length, (*b*) width, (*c*) thickness and (*d*) mass comparing freehand and bipolar cores. (Online version in colour.)

Table 5 Shapiro–Wilk test for normal distribution.

	freehand		bipolar	
	flint	quartz	flint	quartz
W (length)	0.9071	0.8868	0.9157	0.9794
P (normal)	0.0109	0.0013	<0.0001	0.8608
W (width)	0.8543	0.9334	0.9181	0.9523
P (normal)	0.0006	0.0285	<0.0001	0.9187
W (thickness)	0.874	0.7828	0.9217	0.9725
P (normal)	0.0017	<0.0001	<0.0001	0.6894
W (mass)	0.6123	0.8394	0.5501	0.8566
P (normal)	<0.0001	<0.0001	<0.0001	0.0019

several experimental studies show that bipolar knapping produces marks similar to those on scaled pieces [26,29,72].

According to typological classification, splintered pieces ($n = 192$) are the most abundant type in level SG, forming 30% of the retouched assemblage. Laplace [68] differentiated between scraper splintered pieces (E1) which account for 78% of retouched pieces, and 'burin' splintered pieces (E2). Nonetheless, we think that classification of these pieces as a specific tool type derives from a problem of morphological convergence in which pieces classified as splintered pieces are exhausted bipolar cores. Likewise, it has been shown that use of splintered pieces as wedges does not produce scalariform traces [29], which is a principle attribute of the Font del Ros pieces.

Table 6. Mann–Whitney *U*-test comparing freehand and bipolar cores.

	flint		quartz	
	U	*p*(same)	*U*	*p*(same)
length	3733.5	<0.0001	670.5	<0.0001
width	3951	<0.0001	718	<0.0001
thickness	3831.5	<0.0001	721.5	<0.0001
mass	3930	<0.0001	740	<0.0001

The average dimensions of splintered pieces are lower than bipolar cores (figure 6) (electronic supplementary material, tables S4–S8), which suggest that these products originated from bipolar knapping, and could correspond to a final phase of exploitation, which is confirmed at a statistical level where significant differences are seen between bipolar core and splintered piece dimensions (table 7).

It seems to be more appropriate to consider most splintered pieces in SG as nucleiform [45] (figure 5*b*), on which superposition of removals indicates that they are exhausted or heavily exploited bipolar cores which produced small, elongated blanks similar to bladelets, but morphologically irregular (figure 5*c*).

3. Discussion

The points presented in §2 show the use of bipolar knapping to be common in the SG lithic assemblage. This technical system coexists with freehand flaking and is used with flint

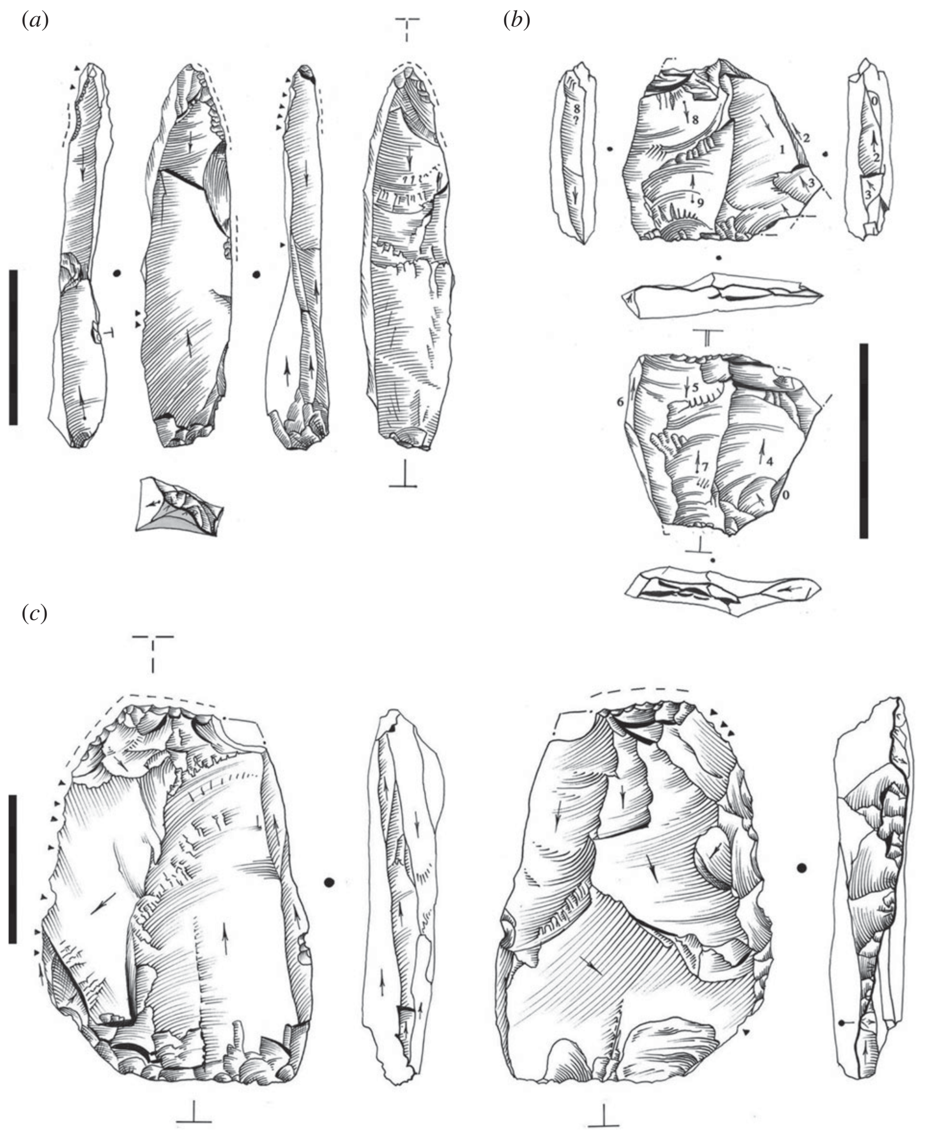

Figure 5. Flint pieces from level SG with diagnostic marks from bipolar knapping. Note the direction of removals on the faces and edges of the pieces indicating previous removals produced by rotating the knapping axis. (*a*) Bipolar by-product «bâtonnet» (spall) which shows curving around the axis and micro retouch on the point suggesting rotational movement of this active area. Due to its size, this piece must have been hafted or formed part of a composite tool. (*b*) Blank shaped by multiple opposing removals indicating rotation of bipolar knapping which generated a miniscule core-like blank (nucleiform). (*c*) Splintered piece showing crushing of the edges, and in particular microdenticulation on one side. Scale bar, 1 cm. (Drawings by Michel M. Martzluff).

and quartz. It is a knapping method which overcomes constraints derived from poor quality raw materials and produces small, short, but relatively standardized products [15,32] (M. Pallares 1999, unpublished data).

The use of bipolar knapping in the Mesolithic has generated a great diversity of interpretations, from techno-economic aspects to socio-organizational factors of Holocene hunter-gatherers [73]. Usually it is considered as an immediate response to contexts where raw material is limited or of poor quality. This reflects 'expediency' in design, manufacture and raw material procurement, and has been linked to an immediate use in special-purpose sites [74], or it may be related to a task undertaken by a determinate age/sex group. On this assumption, were women and children more actively involved than men in on-site activities, then bipolar debitage increases because generally they were less skilled knappers than men [75].

We believe that environmental, functional and cultural arguments only partially explain use of the bipolar technique at Font del Ros. The technique enabled the production of non-specialized tools from raw materials which were locally abundant. Such simple artefacts made it possible for groups to acquire, process and consume animal and plant nutrients essential for their livelihood and their socio-organizational continuity. We consider that the process of technical simplification affecting knapping strategies and tool shape is a characteristic attribute of the technical organization of Mesolithic hunter-gatherers and is not an isolated occurrence. Similar behaviour has been described at the end of the Pleistocene in Mesolithic contexts in Scandinavia [76–78], Ireland [10], Scotland [79,80], and has been identified in numerous sites in Italy, Spain and Greece [43].

Due to the similarity of technical parameters of Font del Ros, it is relevant to recall discussion on the significance of the regional group of sites located in the eastern Pyrenees and western Languedoc. Here, many assemblages are made on locally available poor quality materials and thus appear atypical in classic typological terms; many sites, mainly rock shelters, seem to show expedient use of raw materials collected during fairly specialized activities [81]. However,

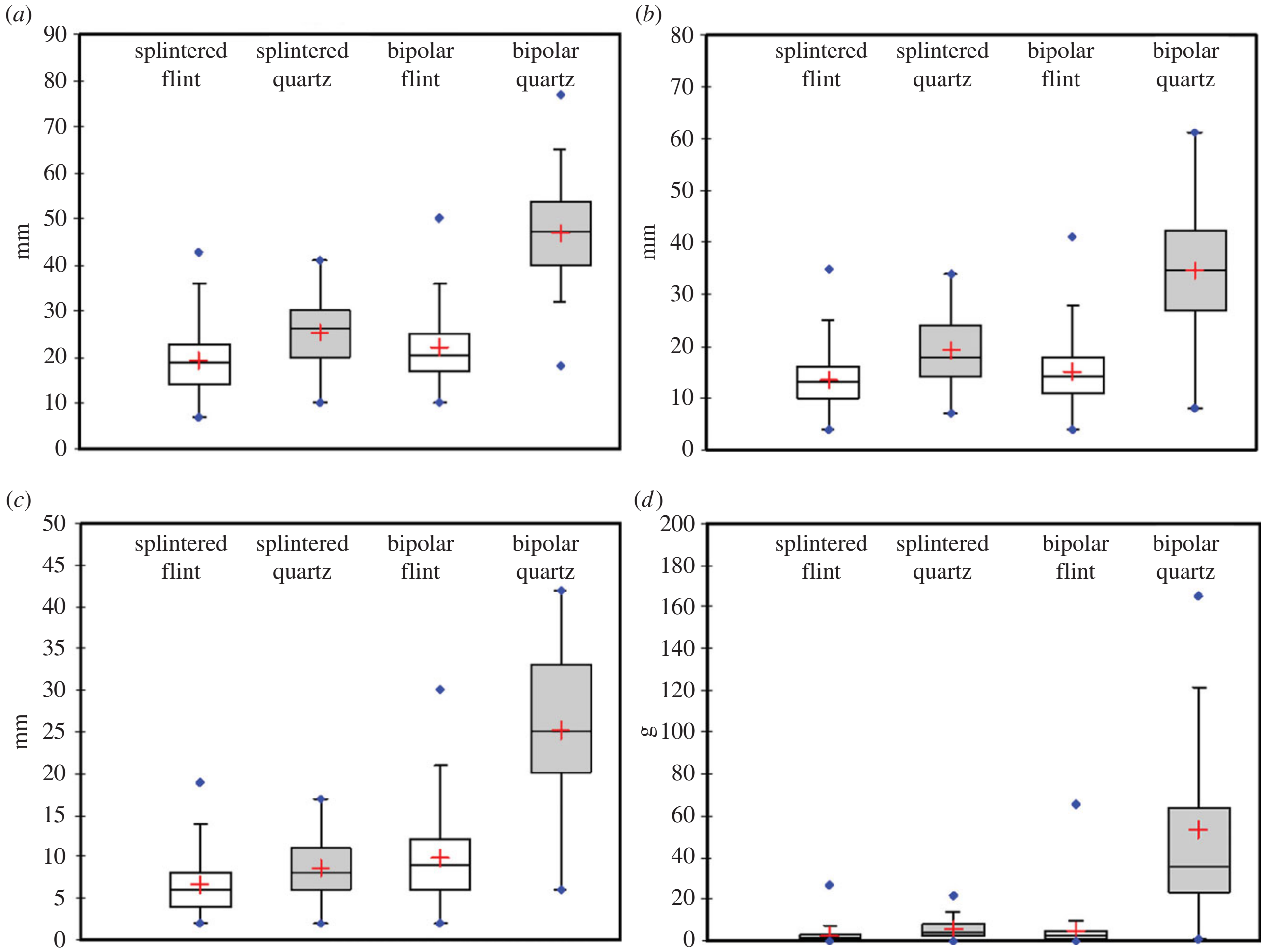

Figure 6. Box plots of (*a*) length, (*b*) width, (*c*) thickness and (*d*) mass comparing splintered pieces and bipolar cores. (Online version in colour.)

Table 7. Mann–Whitney *U*-test comparing physical data of splintered pieces and bipolar cores.

	flint		quartz	
	U	*p*(same)	*U*	*p*(same)
length	10 024	<0.0001	48.5	<0.0001
width	11 450	0.0746	72.5	<0.0001
thickness	7766	<0.0001	37	<0.0001
mass	9086.5	<0.0001	35	<0.0001

such a link between an expedient technical option and special-purpose sites or specialized activities has been questioned by some researchers who suggest that use of low quality, local material is an attribute of technical regression signalling a widespread crisis affecting post-glacial hunter-gatherer subsistence and social organization [82–84].

Faced with these processual and cultural-historical scenarios, we propose that bipolar technique is a key attribute in the simplification of technical systems attested in the early Holocene. This knapping method enables management of ecosystems with raw material constraints but in which predictable and highly nutritional resources are accessible [36,85].

Possibly, an opportunistic approach to the use of bipolar knapping would help overcome constrictions related to limited/poor quality raw material [33], and so could not strictly be considered as adaptive behaviour to environmental conditions [86]. These options are integrated within a technical knowledge which was used repeatedly from the Late Upper Palaeolithic onwards, but such approaches have been identified in earlier periods as will be discussed below.

The aim of knapping at Font del Ros was to get products smaller than 2 cm. This pattern of miniaturization aimed at obtaining standardized products is a technical option clearly rooted in the early Upper Palaeolithic in Western Europe, present since the emergence of backed points/bladelets, basic components throughout the Upper Palaeolithic [51,87]. It should be emphasized that in the earlier Howiesons Poort of the South African MSA, microlithic artefacts were made using the bipolar technique [15]. Similarly, in the Iberian Peninsula, it has been shown that this process of tool reduction intensified during the late Upper Palaeolithic (Magdalenian), and particularly in the Mesolithic [88–90]. Furthermore, the bipolar technical tradition has been recognized throughout late prehistory in some areas of Western Europe [62,86,91].

We do not rule out that current understanding of the use of bipolar is under-represented because systematic studies of lithic assemblages in which it was used are limited. Nevertheless, the bipolar method has interesting properties such as its versatility. The reduction system can be used directly on cores to get functional blanks, but also allows continued knapping of cores produced by freehand percussion which are too small for further freehand knapping. The bimodal distribution of blank size in level SG suggests a continuity of reduction of freehand cores which were subsequently exploited on an anvil for the production of some small, albeit poorly standardized, products equivalent to bladelets. Such a system is not novel; bladelets were regularly obtained from burins and/or end scrapers throughout the Upper Palaeolithic [92,93]. In some late Glacial and early Holocene lithic assemblages from sites in the Pyrenees and Alps, it has been proposed that micro-backed points and geometrics were made from scaled pieces and/or bipolar cores [33,84,94]. Based on metrical criteria, it is relevant to name pieces resulting from bipolar knapping as 'microliths', although they are not retouched [95].

Although many spalls and fragments can be considered as residuals derived from bipolar knapping, some of them have been used for the manufacture of specialized tools such as Gravettian and Azilian backed points [51]. Other small artefacts may be equally functional; in fact, recognition of evident macroscopic wear on some pieces indicates they formed part of composite or hafted tools [33] (figure 5*c*), and it is possible that some pieces may be identified through microwear analysis [94,96,97].

Finally, we emphasize the importance of the study of macrolithic tools. Pitted stones are diagnostic artefacts of the bipolar knapping system and are accurate markers of activity on a functional and spatial level [35]. As these tools were very common in the northern Iberian Peninsula from the beginning of the Holocene [43], we cannot dismiss the possibility that the importance of bipolar knapping at Font del Ros had its roots in this regional context.

Many questions remain to be explored, among them examination of the spatial and temporal dimension of the bipolar knapping system in Font del Ros, a site of more than 1500 m^2 and which, according to ^{14}C dating, was intermittently occupied over 1800 years (10 250–8 450 cal BP). Within this wide spatial/temporal scale, future studies will try to identify possible variations in reasons for using this knapping system.

4. Conclusion

At present, there is much literature on the recognition of bipolar percussion, with experimental studies and macroscopic analyses forming the basis for its identification [5,9–18,29]. Previously, we have emphasized the temporal and spatial ubiquity of the method, present from the earliest evidence of stone tools [98] and lasting until late prehistory [8–18]. Although there is no doubt that a large part of its success is due to its simplicity, nevertheless there is a need to define patterns in which the same knapping system is apparently applied. Its persistence indicates it to be an effective technique for various technical and functional contexts, and as such, studies should be undertaken to determine whether there are differences in the employ of this practice.

Bipolar knapping is an important technique used in the production of the Font del Ros lithic assemblage. Cores, pitted stone and products with diagnostic attributes unequivocally identify this reduction system, and form a benchmark for the technical diagnosis of the method. In a context in which the corpus of experimental data is increasing, the results presented here constitute an archaeological example in which signs and attributes of the bipolar method have been identified systematically in a precise temporal context related to changes developed by post-glacial hunter-gatherers [99].

The explanation of bipolar knapping as an adaptive response to restrictions imposed by poor quality raw material is a reductionist interpretation. It is worth bearing in mind that Mesolithic artefacts and subsistence patterns are not incompetent attempts of Neolithic behaviour or degenerated Upper Paleolithic products. Mesolithic toolkits were well designed and well adapted to achieve an adequate food supply from the environment [100,101]. This alternative scenario suggests that the versatility of the bipolar method enabled expansion into new environments based on the management of local, poor quality raw materials. Use of the bipolar technique enabled hunter-gatherers to deal resolutely with daily subsistence activities and is essential in the characterization of Holocene hunter-gatherer lifestyles. In this sense, we think that Font del Ros provides important perspectives which characterize organizational changes occurring in the Mesolithic of the northern Iberian Peninsula.

Data accessibility. The datasets supporting this article have been uploaded as part of the electronic supplementary material.

Authors' contributions. X.R.G., R.M. and J.M.-M. designed the research programme. X.R.G. and R.M. performed the analysis of datasets. X.R.G., R.M. and J.M.-M. interpreted the resulting data and wrote the manuscript.

Competing interests. We declare we have no competing interests.

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