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Pitted stone cobbles in the Mesolithic site of Font del Ros (Southeastern Pre-Pyrenees, Spain): some experimental remarks around a controversial tool type

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ABSTRACT

The presence of cobbles with activity-related marks in the Mesolithic site of Font del Ros (Berga, Spain), and in particular one group of artefacts – pitted stones – raises problematic issues associated with the characterization of percussion activities. Although these artefacts have generated an extensive bibliography on ethological, ethnographic, ethnoarchaeological and archaeological levels, various questions persist in relation to their possible contextual function. In this paper we present the results of an experimental programme in which three types of activities that could create pitted stones are reproduced: bipolar knapping of vein quartz, hazelnut cracking, and hazelnut grinding. The aim of this experimental programme is to describe marks and use-wear traces related to such activities.

Results indicate that pit formation is associated with bipolar knapping activity. However, the description of pitted stones related to hazelnut processing presents problems when it comes to define diagnostic attributes.

1. Introduction

In recent years descriptions of activities undertaken using pebbles and unworked lithic blanks have been stimulated by in-depth studies on the identification of use marks on these artefacts (de Beaune, 2000; Procopiou and Treuil, 2002; Adams, 2002 and references therein). However, the systematic study of percussion and ground stone tools is still at an initial stage, as sometimes it is difficult to go beyond classifications that are exclusively typological. Likewise, the range of vocabulary used in classifications to describe this tool type causes confusion (Kraybill, 1977), so that at times the same type of artefact is referred to in different ways (de Beaune, 2000; Hamon, 2008).

Experimental study has provided an alternative perspective to typological description, as it aims to describe use-wear marks on different types of raw material in order to identify the functional context of such objects. Recent studies have made significant progress in this direction, enabling identification of activities undertaken using these artefacts (among others Dubreuil, 2004; Hamon, 2008). The development of an experimental programme can contribute elements for discussion on two questions: the type of activities in which they were involved and a description of the resulting wear marks on them.

In this study, we will describe the possible functional contexts in which a particular type of percussion tool was used: pitted stones or *percuteurs à cupule*. These artefacts have been recognized in the Mesolithic site of Font del Ros (Berga, Spain), and we maintain that their analysis may indicate activities undertaken at this site, and provide a key towards understanding the spatial patterning of the settlement (Martínez-Moreno et al., 2006a; Martínez-Moreno and Mora, in press; Roda Gilabert et al., submitted for publication).

2. Pitted stones: a controversial tool type

Usually, *pitted stones* are described as flat spherical pebbles with a central zone on which wear traces of battering are visible (Chavaillon, 1979; Leakey, 1971; Leakey and Roe, 1994; Le Brun-Ricalens, 1989; de Beaune, 1989, 1993, 2000; Adams, 2002). Such artefacts have a wide diachronic and geographic distribution which suggests that they may have served multi-functional purposes throughout time (de Beaune, 1989, 1993, 2000).

Although their functional context has been discussed on various occasions, currently there is no broad consensus as to their significance. As such, we find objects that technologically correspond to

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different activities, grouped under the same nomenclature. Typologically, pitted stones share attributes with *pierres à cupules* described in various sites at Melká Kunturé (Chavaillon, 1979; Chavaillon and Piperno, 2004) and Olduvai Gorge (Leakey, 1971; Leakey and Roe, 1994; Jones, 1994), as well as at Gesher Benot-Yaqov (Goren-Inbar et al., 2002). Because of their morphological similarity, they have often been compared as analogous with pebbles used to smash fleshy fruits by *Pan troglodytes* (McGrew, 1992; Joulian, 1996; Mercader et al., 2002, 2007) or *Cebus libidinosus* (Fragaszy et al., 2004; Visalberghi et al., 2007).

Similarly, cobbles with pits are mentioned in numerous Upper Palaeolithic and Mesolithic sites in Western Europe (among others Simonnet, 1976; Champagne and Spitalié, 1981; Gob and Pirnay, 1980; Becker et al., 1994; de Beaune, 1989, 1997, 2000 and references therein). The presence of such artefacts is very common in Mesolithic sites on the slopes of the Pyrenees in the Iberian Peninsula: Mendandia (Alday Ruiz, 2006), Aizpea (Barandiaran and Cava, 2001), Balma Marguineda (Guilaine and Martzluff, 1995), Sota Palou, Font del Ros and Balma Guilanyà (Martínez-Moreno et al., 2006a, 2006b; Martínez-Moreno and Mora, in press; Roda Gilabert et al., submitted for publication; personal observations).

Several hypotheses have been proposed regarding the contextual function of *pitted stones*. Ethnographically, it has been noted that the processing of nuts and fleshy fruits creates artefacts with small, irregular pits, as seen in those called *kebra cocô* (Moura and Prous, 1989). Nut cracking stones are used by the *!Kung* (Yellen, 1977) and by recent hunter-gatherers of the Transvaal (Boshier, 1965; Maguire, 1965). They also form part of the toolkit of some Australian hunter-gatherers who use *kulki*, artefacts with a central depression caused by battering (McCarthy, 1976).

Alternatively, pebbles with pits have been associated with bipolar knapping (Leakey, 1971; Leakey and Roe, 1994), and experimental battering activities have demonstrated that this type of knapping produces pebbles with marks in the form of small depressions (Le Brun-Ricalens, 1989; Jones, 1994; Donnart et al., 2009; de la Peña, 2011). Similarly, it has been suggested that these artefacts are related to fire setting, used as fire-drill hearths or objects subjected to rotary actions (Gob and Pirnay, 1980; Rowe, 1995), a hypothesis that has been queried (Collina-Girard, 1998; de Beaune, 2000; Adams, 2002).

Such interpretations indicate that at present there is no broad consensus on the significance and function of these artefacts. As an alternative, we suggest that a detailed analysis of the marks visible on these cobbles and their archaeological context allow us to establish the significance of pitted stones. In the present case, our interest is in the analysis of their potential integration within tasks undertaken in the Mesolithic site of Font del Ros.

3. Archaeological setting

Font del Ros ($X = 404{,}478$, $Y = 4{,}660{,}989$, Zone 31, ETRS89 and 670 masl) is located on a shelf formed of quaternary colluvial deposits in the contact zone between the Central Catalan Depression and lower foothills of the Eastern Pre-Pyrenees of Barcelona

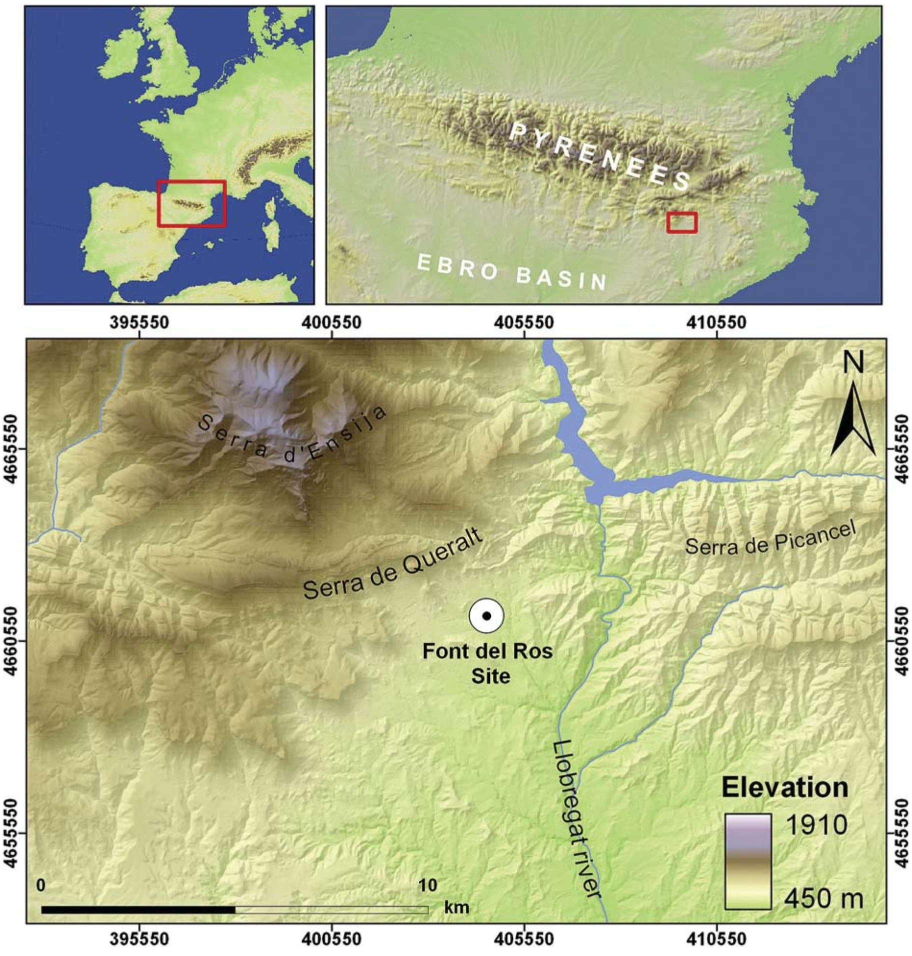

Fig. 1. Location of the Font del Ros site and details of the study area.

(Serra de Queralt) (Pallares, 1999; Pallares and Mora, 1999; Martínez-Moreno and Mora, in press). The Llobregat River that flows in the vicinity connects the Central Catalan Depression and interior of the Pyrenean Massif (Fig. 1).

Building construction in the municipality of Berga (Barcelona, Spain) exposed the existence of the site. Excavation has revealed two Mesolithic occupations (SGA and SG) in stratigraphic context, and a further occupation attributed to the early Neolithic (N).

Excavation of the Mesolithic occupation SG extended over an area of approximately 1200 m^2, from which around 27,800 lithic artefacts, bones and plants (charcoal and seeds) were recovered. Plant bio-indicators provide evidence of temperate taxa (*Quercus, Buxus sempervirens* and *Corylus avellana*, *Ulmus* sp., *Salix* sp., *Sambucus* sp.), all species associated with wet conditions and suggestive of dense deciduous woodland. Nine ^{14}C dates obtained in this level suggest an indefinite number of occupations between 10,400 and 8450 cal BP (calibrated at 2σ), which place the site firmly in the Boreal climatic period, an attribution additionally supported by charcoal analysis (Pallares, 1999; Martínez-Moreno and Mora, in press).

The lithic techno-complex included an abundant toolkit related to percussion activities; percussion tools from the central occupation zone -extending over an area of about 510 m^2- were the

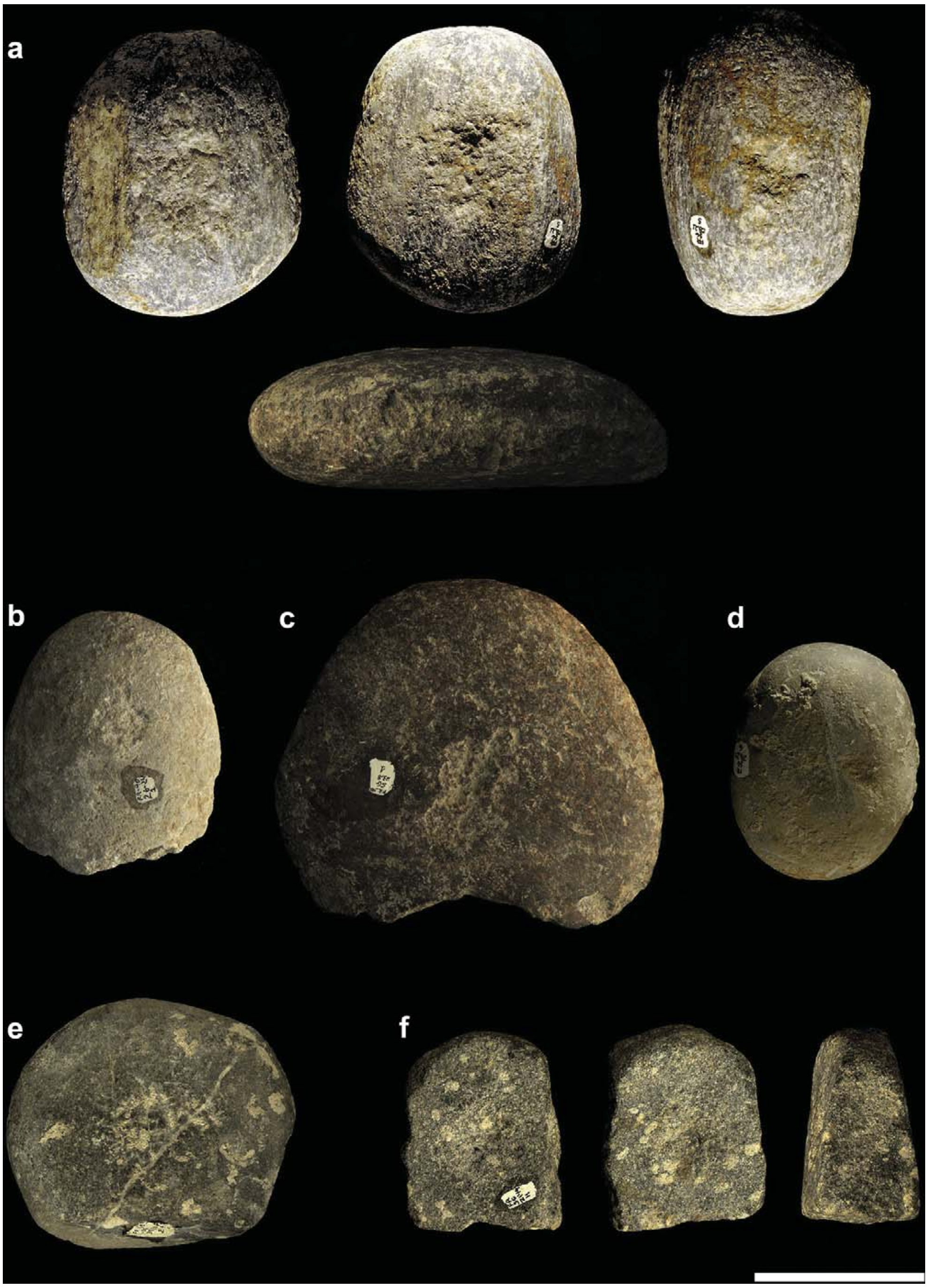

Fig. 2. Pitted stones recovered from the central zone of Font del Ros level SG (graphic scale 5 cm): a) pits with irregular section (quartzite, 77 × 63 × 52 mm); b) cobble with incipient pit (limestone, 78 × 65 × 43 mm); c) pits with irregular section (quartzite, 110 × 97 × 36 mm); d) cobble with incipient pit (limestone, 70 × 55 × 38 mm); f) pits with irregular section (limestone, 83 × 70 × 28 mm); e) pits with regular section (gneiss, 57 × 46 × 30 mm).

subject of systematic study (Roda Gilabert, 2009; Roda Gilabert et al., submitted for publication).

Six pitted stones with superimposed impact points indicating thrusting percussion that causes fractures and depressions were recovered from this sector of the site. This pattern may be associated with several activities implying bipolar battering. Nevertheless, several artefacts also have friction marks on their surfaces that suggest a combination of different activities so that they may be defined as multi-purpose implements (Martínez-Moreno et al., 2006b; Roda Gilabert et al., submitted for publication).

These items can be grouped into three morphological types: pits with a regular section, pits that are irregular in section and incipient pits. Two quartzite cobbles and one limestone cobble have pits with an irregular section (Fig. 2a, c, e). A gneiss fragment has two pits with a regular section (Fig. 2f) having characteristics similar to those resulting from experimental *piquetage* (*sensu* de Beaune, 1993b). Finally, two limestone cobbles have marks on one surface shaping incipient pits (Fig. 2b, d). This description brings to mind a classic methodological problem: we cannot discount the fact that different processes or activities can generate similar wear marks. In other words, these modifications indicate problems of equifinality that affect the identification of wear marks when determining functional correlations.

Based on information from the Font del Ros Mesolithic occupations, several hypotheses have been designed regarding the possible use of pitted stones. In particular, attributes of flint and quartz artefacts and cores indicate bipolar knapping (Le Brun-Ricalens, 1989, 2006; Mourre, 1996; Donnart et al., 2009; de la Peña 2011; Mourre and Jarry, 2011 and references therein). Furthermore, the remains of burnt *C. avellana* shells are regularly found around hearths, where pitted stones have also been recovered, suggesting the use of cobbles to break and pound nuts (Pallares, 1999), something that has been suggested in other Mesolithic sites of a similar chronological age.

As a result of these diverse functional contexts, we have developed an experimental programme to identify possible wear marks that will allow us to establish potential contexts in which these cobbles were used. The determination of diagnostic criteria should provide indicators that are essential for the analysis of activities in which these tools were involved on the site (Roda Gilabert et al., submitted for publication).

4. Materials and methods

We will identify modifications produced by these activities describing the location of marks on the surface of materials, relating them to their kinematics and the work-related modifications (Table 1 and Fig. 3). The experimental programme involves three types of anvil-related behaviour: a) bipolar knapping of poor quality vein quartz nodules, b) hazelnut cracking, c) hazelnut cracking and grinding. Following the conceptual framework proposed by de Beaune (2000, 2004) these activities involve three types of percussive technical gestures: thrusting percussion, diffuse thrusting percussion and diffuse resting percussion. In this sense, it is interesting to determine alterations produced by hazelnut cracking and grinding, due to the fact that these actions combine diffuse thrusting and diffuse resting percussion, which presumable may generate wear through abrasion.

Selection of the cobbles used in the experimental programme was based on the lithology and measurements of the cobbles recovered from Font el Ros; these range between 60 and 80 mm. Cobbles were collected from the Llobregat river ravines which are on the Berga and Vidrà (Middle/Upper Eocene) conglomerate formations. These spots provide access to a great variety of rocks in cobble form, and were used as primary sources of raw materials along with secondary sources located in the immediate vicinity of the site (Terradas, 1995).

Cobble surfaces were studied using a 5×–80× binocular microscope (Olympus SZ-11), and a 50×–100× metallographic microscope (Olympus BH-2). A digital camera was used to photograph some details of marks as the depth of field of the binocular microscope made it impossible to focus on the area to be analyzed.

5. Development and results of the experimental programme

5.1. Bipolar knapping of quartz

The bipolar experiments undertaken do not differ methodologically from those described in other experiences (Barham, 1987; Courtoni, 1996; Vergés and Olle, 2011) (see Table 1 and Fig. 3a). On a technological level, axial and non-axial knapping methods on anvil (*sensu* Mourre, 1996) were used. Application of these systems facilitates a more efficient transmission of energy which physically aids the knapping of poor quality nodules that may be difficult to knap by hand-held percussion (Barham, 1987; Breuil and Lantier, 1951; Prous and Alonso, 1990; Andrefsky, 1994).

Seventeen small to medium- (30–100 mm) sized cobbles of poor quality vein quartz were reduced with hammerstones and anvils of various lithologies (Table 2).

Anvil knapping sequences generated marks that rapidly formed pits as has been indicated by Le Brun-Ricalens (1989);

Table 1
Synthesis of the experimental database.

Experiment	Goal	Development of activity
Bipolar knapping of vein quartz (Fig. 3a)	To determine marks linked with this knapping method	The active blank is grasped in the palm of the hand, preferably using the flat surfaces of the cobble. The other hand then can anchor the quartz blank to be knapped on the anvil. The experimental knappers were in a kneeling position, and aimed blows perpendicular or at an angle to the plane of percussion. Usually several blows were needed to remove blanks.
Hazelnut cracking (Fig. 3b)	To determine possible marks associated with hazelnut cracking	Half of the hazelnut sample (3 kg) was roasted for approximately 5 min in an open-air fire with a temperature that ranged between 170 and 200 °C. Throughout the experiment, the cobble was held in the palm of the hand using flat areas to crack the nuts. The experimenters maintained either a kneeling position or sat with legs crossed. Many blows were often required to break the exocarp, but it was notably much easier to achieve once the nuts had been roasted.
Hazelnut cracking and grinding (Fig. 3c)	To analyze marks associated with hazelnut cracking and grinding	In order to achieve a homogeneous roasting of nuts, a refractive oven was used for 15 min at approximately 200 °C. Gestures used during the nut cracking process were identical to those described above. In the grinding phase, blanks were hand-held and perpendicular blows directed at the passive element, while the crushing phase involved a rocking or rotary movement. Both flat and lateral surfaces of the cobble were used. The combination of movements caused the nuts to reduce in size and the crushed paste to spread towards the edges of the grinding slab.

Fig. 3. Development of the experiments presented: a) bipolar knapping of vein quartz; b) hazelnut cracking; c) hazelnut cracking and grinding (see Table 1 for details).

Jones (1994); Donnart et al. (2009) and de la Peña (2011). From the patterns observed, and similarly to those indicated elsewhere (Le Brun-Ricalens, 1989), formation of these depressions can be divided into three phases (Table 3).

Several morphological indicators relating to pit formation are apparent under a binocular microscope (Fig. 4). Initially, a fracture forms in the cortical surface of the cobble and spreads from the perimeter to the centre of the blank. As the fracture advances towards the centre, the pit increases in depth, exhibiting a stepped appearance with impact cracks, ripping and crushing of grains (Fig. 4a). In some cases, microscopic removals are visible, produced by subsidence of the surface due to repeated compression on some zones (Fig. 4b). Finally, the interior of the pit displays intense percussion marks and a frosted appearance (*sensu* Adams, 1989, 2002) affecting most of its surface (Fig. 4c).

These results suggest that variability in marks arise from the combination of different types of material. The most clearly defined marks occurred when using limestone hammerstones and anvils, decreasing when other rock types were used. It is possible that the greater capacity of sandstone anvils to absorb impact resulted in marks of lesser intensity than those evidenced on other blanks. This variability ensures that in some cases we can define marks created as incipient pits (Fig. 5a and b). That is, the development and depth of pits is related to the mechanical quality of the raw material (Donnart et al., 2009). Similarly, the intensity of marks depends on the number and force of blows on the blank rather than length of time used.

Some experimental studies have shown that after a similar period of use, anvils employed in bipolar knapping develop marks that spread forming an extended section (Moura and Prous, 1989).

Table 2
Bipolar knapping experiments with specification of raw material of active and passive elements, quantity and nature of processed materials and modality of percussion.

Active element	Passive element	Quantity & nature	Time	Percussion
Limestone	Sandstone	1 vein quartz nodule	25 min	Indirect thrusting
Limestone	Sandstone	4 vein quartz nodules	25 min	Indirect thrusting
Limestone	Limestone	2 vein quartz nodules	25 min	Indirect thrusting
Limestone	Limestone	3 vein quartz nodules	5 min	Indirect thrusting
Quartzite	Sandstone	4 vein quartz nodules	15 min	Indirect thrusting
Gneiss	Limestone	2 vein quartz nodules	12 min	Indirect thrusting
Granite	Limestone	1 vein quartz nodule	4 min	Indirect thrusting
Sandstone	Limestone	1 vein quartz nodule	6 min	Indirect thrusting

Table 3
The process of pit formation during bipolar knapping.

Stages of formation	Description
Stage 1	The first punctiform marks appeared after 10/15 blows. These were small chips and compression points that could be seen on the cobble surface. The superposition of these modifications on a specific zone formed a pattern that we term 'incipient pit' (Fig. 5).
Stage 2	As work continued (c.10–15 min), the original form of the blank was altered. The superposition of marks on the same zone led to identification of active zones as pit-shaped (Fig. 4).
Stage 3	Finally, due to the compression and fatigue of the active surface the cobble is fractured. In some cases it is possible to detect the impact point from which the fracture originated. Association between fracture and pit development is involved more with the internal structure of the rock than time or intensity of cobble use.

This morphology originates, often imperceptibly, from the sliding movement of the blanks knapped on the anvil that abrades earlier marks (Donnart et al., 2009). Nevertheless, distinction between active and passive blanks on the basis of wear marks is not conclusive, and attempts to associate depth of marks with blank function remain inconsistent. The anvils used in our experimental programme display an extensive active zone, elongated in section and with marks similar to those evident on active cobbles, combining compression marks with grain crushing and fatigue wear.

As Donnart and his colleagues suggested (Donnart et al., 2009) we accept that there is certain versatility in the part played by active elements (hammerstones) and passive elements (anvils) whose roles may interchange during their use-life. This hypothesis applies to most of the Font del Ros percussion blanks provided that the only determining factor is object size, since weight is the attribute that differentiates between hammerstones and anvils (de Beaune, 1993a).

5.2. Hazelnut cracking

The aim of the second experimental programme was to distinguish the possible modifications generated in hazelnut cracking (Table 1 and Fig. 3b). The experiment began by cooking half the hazelnuts that were to be used. Roasting dry fruits eliminates tannins and lessens toxicity which contributes to a better processing of digestive enzymes and greater absorption of the nutritive value of the fruit (Stahl, 1989; Wandsnider, 1997). Equally, this process has been widely documented on an ethnographic level (Stahl, 1989) and is a practice suggested in various Mesolithic sites in Western Europe (Mithen et al., 2001; Holst, 2010). Indeed, all the *Corylus* remains recovered at Font del Ros were charred which might indicate roasting as a process associated with the consumption and/or storage of dry fruits (Martínez-Moreno and Mora, in press).

Roasting probably affects the type of marks visible on cobbles used to break dried fruits, as it generates use-wear traces that are not very clear, at least from the intensity of the work undertaken

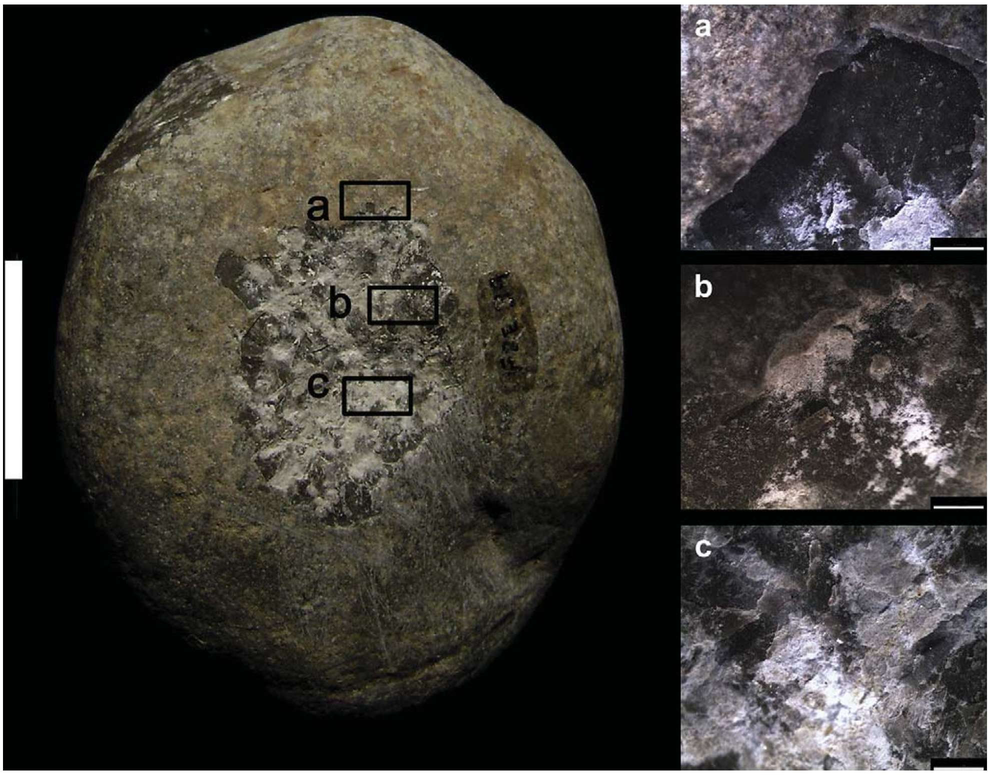

Fig. 4. Experimental pitted stone associated with bipolar knapping (limestone, 84 × 65 × 45 mm) (graphic scale 3 cm): a) detail of the external zone showing rupture of the cortical surface by impact cracks; b) micro removals associated with surface deterioration through compression; c) frosted appearance and compression points located in the centre of the pit. (a, b, c, graphic scale 1 mm).

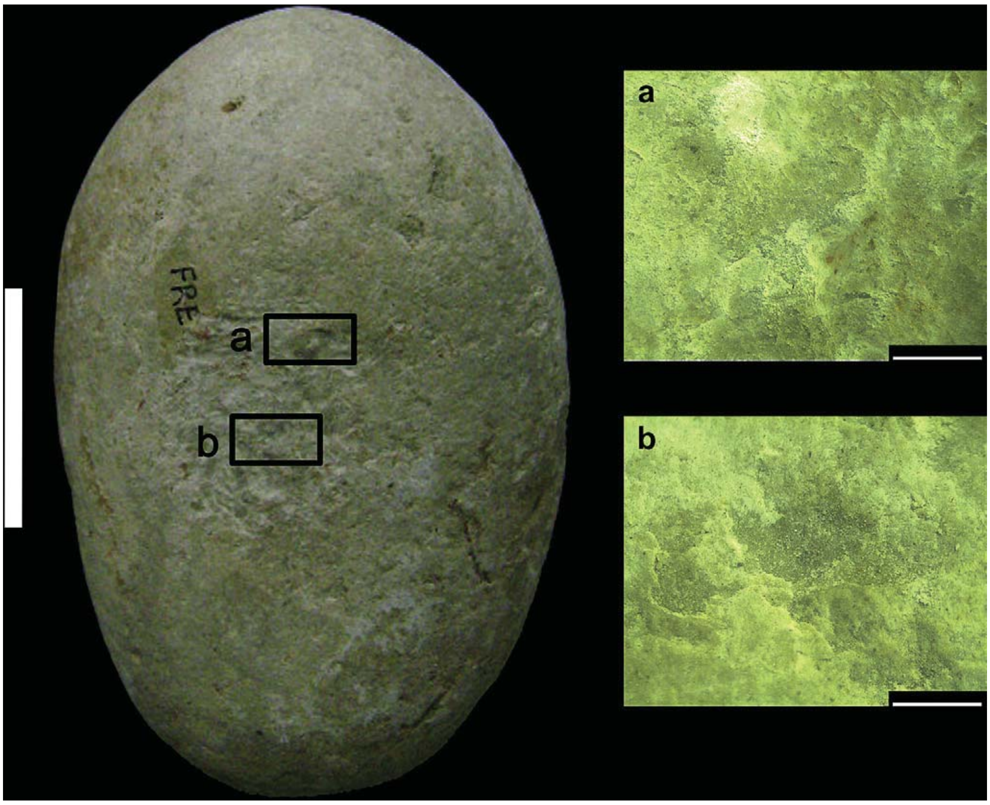

Fig. 5. Experimental incipient pit associated with bipolar knapping (limestone, 79 × 50 × 42 mm) (graphic scale 3 cm): a) external zone where impact points initiate pit depression; b) detail of the central zone with cracks, ripping and crushing of the surface (a and b graphic scale 1 mm).

in our experimental programme (Table 4). The binocular and metallographic microscopes revealed no specific marks; modifications observed could be intrinsic to the cobble, or confused with taphonomic modifications (Fig. 6). On a macroscopic level it is not easy to recognize use marks if they are not associated with residues adhering to the cobble surface (Fig. 6b and Fig. 7). Likewise, these residues are more abundant when fruits have been roasted (Fig. 7a and b). In sum, it is difficult to detect roasting without microscopic analysis or physicochemical description of residues preserved on these cobbles (Roda Gilabert, 2009).

In recent years, many analytical studies undertaken to identify plant residues on ground stone tools have yielded positive results (Fullagar et al., 2008; Piperno et al., 2009; Revedin et al., 2010). Likewise, some experimental studies have demonstrated that it is possible to identify the nature of the material of the hammerstone or anvil used in knapping activities (Byrne et al., 2006; Vergés and Ollé, 2011). Similar studies of the Font del Ros percussion tools are scheduled for the future.

5.3. *Hazelnut cracking and grinding*

We have noted that a pattern of modifications identified on some of the Font del Ros pitted stones indicates a repeated combination of diffuse thrusting percussion and diffuse resting percussion. Such modifications affect the horizontal plane and perimeter of the cobble creating morphologies that have been classified as *edge-ground cobbles* (Rodríguez Ramos, 2005). Our third experiment focused on replicating sequences of actions related to hazelnut cracking and grinding (see Table 1 and Fig. 3c), to assess whether these marks were associated with these percussion modalities. Six kilograms of roasted hazelnuts were processed during this experiment (Table 5).

The initial cracking open of nuts confirmed an absence of conspicuous marks that enabled precise identification of this activity. However, crushing and grinding generated diagnostic wear traces such as the formation of use facets, striations and slight glossy sheen (Fig. 8). Repeated use of the cobble surface in crushing and grinding created longitudinal striations (Fig. 8a) as well as tribochemical dissolution that particularly affected the central area of the artefact (Adams, 1989) (Fig. 8b). These striations are linked to friction action on the surface resulting from longitudinal movements used when cleaning off the product resulting from grinding. On the other hand, degradation of the cobble surface could be due to the lubricating action of *Corylus* dough which in the zone of greatest friction causes wear that is identified by glossy sheen, and which is associated with many oily residues

Table 4
Hazelnut cracking experiments with specification of raw material of active and passive elements, quantity and nature of processed materials and modality of percussion.

Active element	Passive element	Quantity & nature	State	Time	Percussion
Limestone	Limestone	2 kg (c. 800 nuts)	Roasted	135 min	Diffuse thrusting
Limestone	Limestone	1 kg (c. 400 nuts)	Roasted	60 min	Diffuse thrusting
Granite	Sandstone	1 kg (c. 400 nuts)	Roasted	70 min	Diffuse thrusting
Limestone	Sandstone	2 kg (c. 800 nuts)	Fresh	125 min	Diffuse thrusting
Limestone	Sandstone	1 kg (c. 400 nuts)	Fresh	40 min	Diffuse thrusting
Granite	Sandstone	1 kg (c. 400 nuts)	Fresh	65 min	Diffuse thrusting

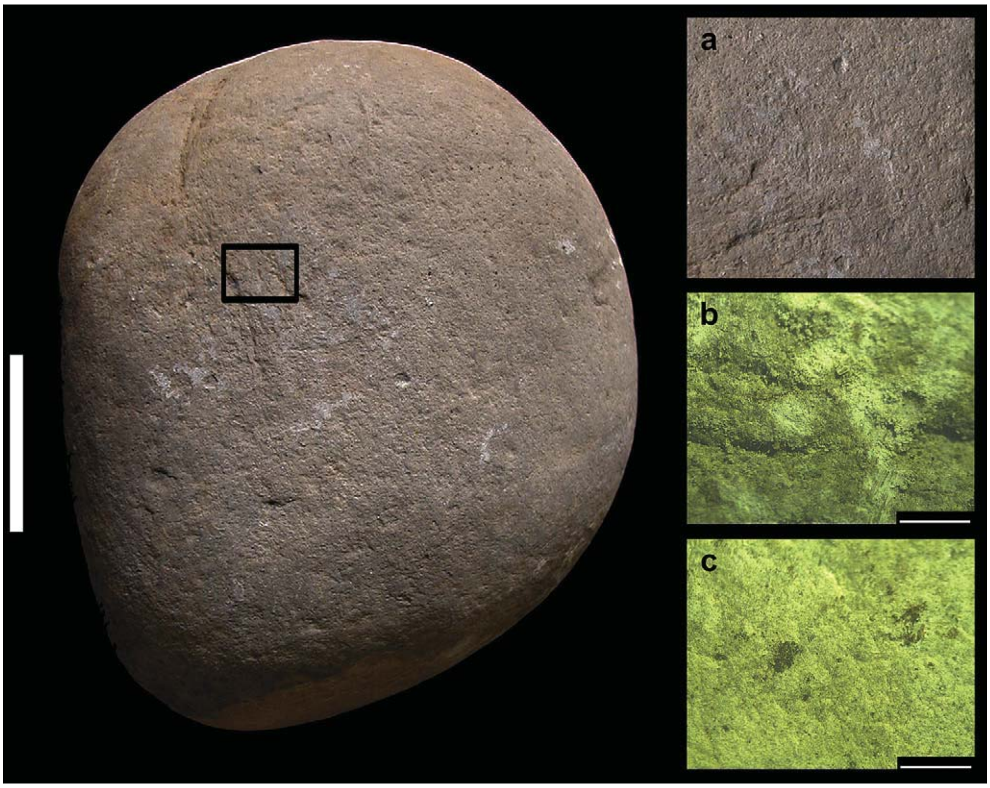

Fig. 6. Experimental cobble used to crack fresh hazelnuts (limestone, 80 × 67 × 51 mm) (graphic scale 3 cm): a) macro view of an unused zone sowing surface alterations previous to the experimentation; b) residues and traces of use-wear polish associated with hazelnut cracking; c) use-zone after cleaning in ultrasonic bath showing slightly evident of use (b and c graphic scale 1 mm).

produced during crushing and grinding activities (Adams, 1989; Dubreuil, 2004).

6. Discussion

Despite the limited number of blanks included in this study, some observations can still be made. The results presented here indicate a strong association between bipolar reduction and the formation of depressions and pits in percussion tools. Similar marks, documented since the earliest experiments on anvil percussion (Breuil and Lantier, 1951), have also been identified in experimental programs (Moura and Prous, 1989; Jones, 1994; Donnart et al., 2009).

In this sense, similar pounding activities using intermediate tools such as stone chisels or wedges can also be associated with

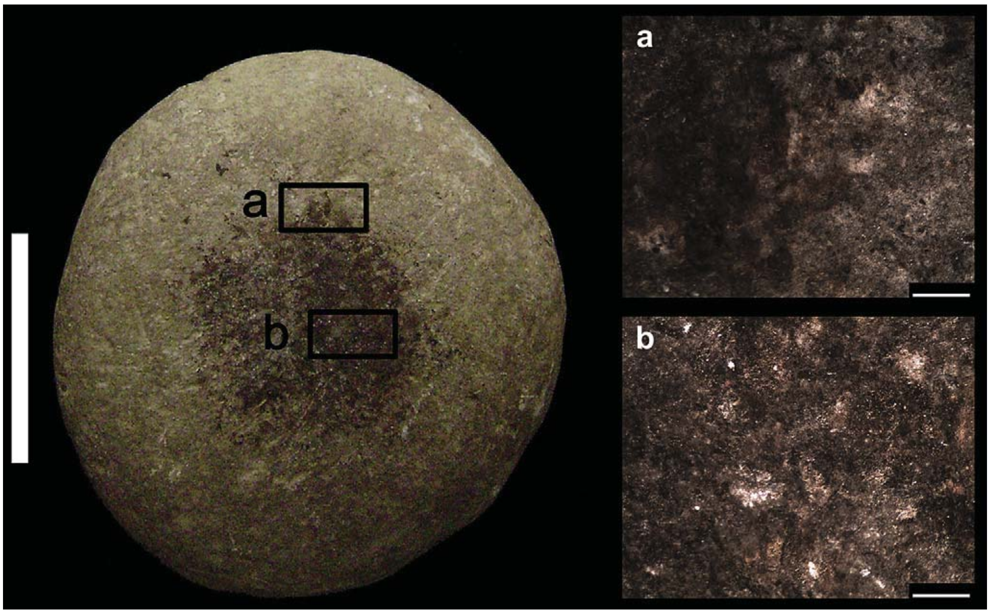

Fig. 7. Experimental cobble used to crack roasted hazelnuts (limestone, 63 × 60 × 33 m) (graphic scale 3 cm): a) contact zone between the cobble surface and location of residues; c) detail of *Corylus* associated residues (b and c graphic scale 1 mm).

Table 5
Hazelnut cracking and grinding experiments with specification of raw material of active and passive elements, quantity and nature of processed materials and modality of percussion and gestures involved.

Active element	Passive element	Quantity & nature	State	Time	Percussion type and main gestures
Limestone	Sandstone	2 kg (c. 800 nuts)	Roasted	145 min	• Indirect thrusting and diffuse resting percussion • Longitudinal friction movements
Limestone	Sandstone	2 kg (c. 800 nuts)	Roasted	180 min	• Indirect thrusting and diffuse resting percussion • Longitudinal friction and rotary movements
Limestone	Granite	2 kg (c. 800 nuts)	Roasted	175 min	• Indirect thrusting and diffuse resting percussion • Longitudinal friction and rotary movements

pitted stones (Hayden, 1980; Mazière, 1984; Chauchat et al., 1985; Le Brun-Ricalens, 1989; Jones, 1994; Gibaja et al., 2007; de la Peña, 2011). Among the different functional hypothesis proposed for this pair of artefacts is remarkable their use for cracking organic materials such as wood or bones. This later assumption seems to be confirmed regarding recent archaeological evidences (Bicho and Stiner, 2005; Gibaja and Bicho, 2006; Gibaja et al., 2007). Although these behaviours have not been included in our experimental program these functional inferences cannot be ruled out in the interpretation of the Font del Ros pitted cobbles.

The presence of pitted stones with irregular pits -disorganized impact points- have been identified on several of the cobbles from level SG, allowing us to associate pitted stones and splintered pieces/*outils écailles* (Roda Gilabert et al., submitted for publication). On the other hand, at Font del Ros this observation exists side by side with other bipolar by-products associated with axial percussion on an anvil (Pallares, 1999). Indeed, a bipolar knapping system is commonly used to remove blanks from tough, poor quality rocks, as has been noted in Mesolithic levels of several sites on the southern slopes of the Pyrenees (Martínez-Moreno et al., 2006b). Future research will contribute new data to the ongoing discussion on whether splintered pieces identification as tools or cores (Hayden, 1980; Chauchat et al., 1985; Shott, 1989, 1999; Le Brun-Ricalens, 1989, 2006; Lucas and Hays, 2004).

In parallel, we note that scanty hardness of the *Corylus* exocarp does not cause a pattern of marks on cobble surfaces that can be positively identified macroscopically and/or mesoscopically. We think that association of these tools with fleshy fruit processing stems from the transfer by analogy of archaeological and ethnographic models onto different contexts. Processing of different types of nuts by *P. troglodytes* (Joulian, 1996; Mercader et al., 2002, 2007; Carvalho et al., 2008) and *C. libidinosus* (Fragaszy et al., 2004) produces cobbles and fragments with centralized pits and depressions. It should be noted that such of these nuts requires a very powerful force to get at the kernel (Joulian, 1996; Mercader et al., 2002). These small depressions, then, result from the compression of materials of poor elasticity which deform under repeated powerful blows (Visalberghi et al., 2007). The cited examples remark the possibility that processing hard-shelled nuts could explain the evident modifications indicated in descriptions of artefacts at Olduvai or Gesher Benot-Yaqov (Leakey, 1971; Leakey and Roe, 1994; Goren-Inbar et al., 2002; Mora and de la Torre Sainz, 2005).

It has been suggested that during the European Mesolithic cobbles with pits and friction facets are associated with hazelnut processing (Holst, 2010). However, if we consider the results presented in this paper this interpretation cannot be supported. The physical characteristics of dried fruits consumed in temperate zones do not match those described in the above cases (Mason and Hather, 2002), implying that pitted stones documented in these contexts are associated with other bipolar activities on hard materials. At present, we do not rule out the fact that hazelnut processing causes the formation of clear deep pits. Alternatively, we propose that the combination of use-wear patterns associated with grinding causes friction wear that regularises the cobble

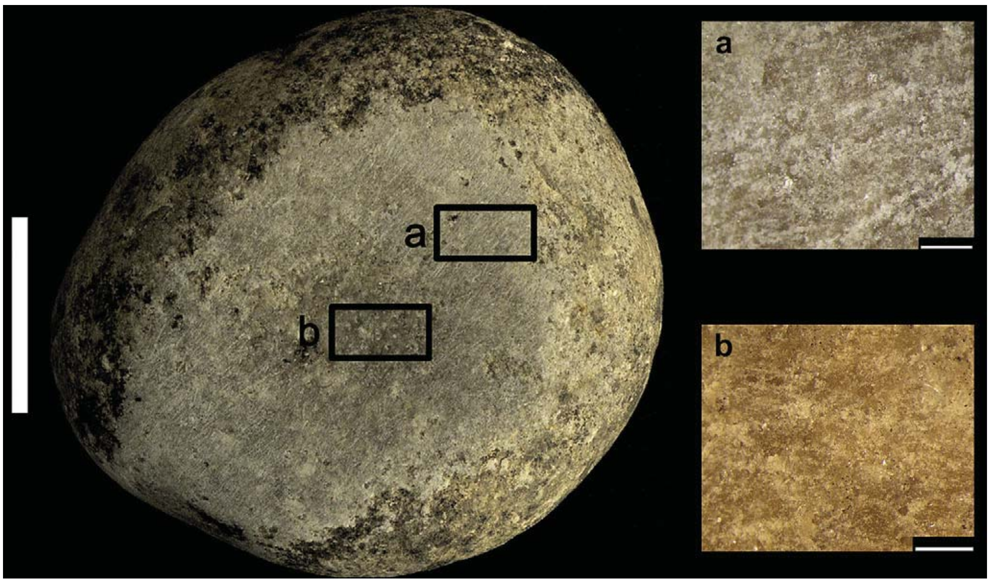

Fig. 8. Experimental cobble used to crack and grind hazelnuts (limestone, 84 × 73 × 46 mm) (graphic scale 3 cm): a) longitudinal striations and glossy sheen; c) detail of the tribochemical dissolution (a and b graphic scale 1 mm).

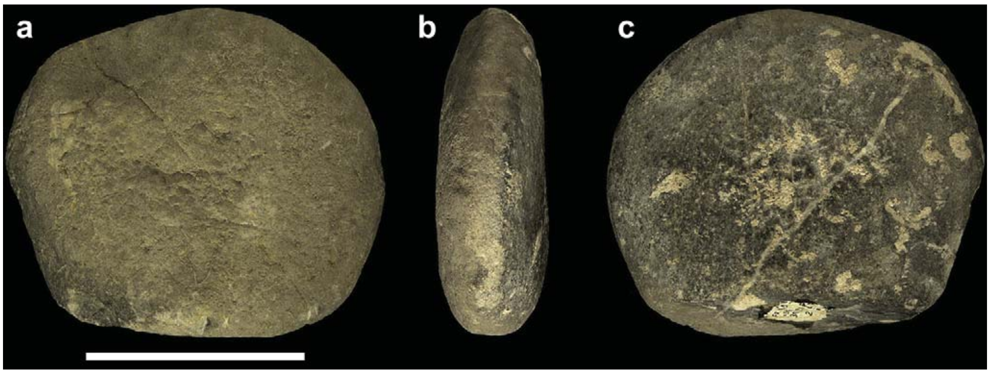

Fig. 9. Archaeological pitted stone from Font del Ros level SG (limestone, 83 × 70 × 28 mm): a) central pitting associated with bipolar knapping; b) edge use-wear facet caused by friction movements; c) central pitting associated with bipolar activity surrounded by tribochemical dissolution (graphic scale 5 cm).

surface causing striations and tribochemical dissolution of the surfaces noted in some artefacts (Fig. 2e). In fact, kinematically such alterations are opposed with the mechanical alterations related with the pit formation (Roda Gilabert, 2009).

Similarly, such use-wear patterns showing the superposition of several activities indicate the multifunctionality of these tools, understood as their use for different, overlapping activities. The overlapping of diffuse resting percussion and friction on the cobble edge creates use-wear pattern facets that are similar to those described for *edge-ground cobbles* (Rodríguez-Ramos, 2005) (Fig. 9b). Added to these features is the presence of light modification in the central zone produced by thrusting percussion (Fig. 9a), and tribochemical changes evident in the presence of polish on the tool surface (Fig. 9c). The combination of the above attributes may be macroscopic indicators of the use of this artefact, among other tasks, as tools for crushing and grinding of dried fruits. Interestingly, preliminary studies of some of the Font del Ros cobbles revealed starch from *Corylus* and *Quercus* on a pitted stone which displayed wear traces resulting from friction activities along the perimeter (Juan, 1997).

Finally, a gneiss cobble showed intentional shaping of two central pits, regular in section, displaying in this case well delimited pecking patterns on opposite surfaces of the artefact (Fig. 10b and c). On the other hand, friction traces associated with pounding and grinding activities, were present on all surfaces of the same cobble as well as on the lateral and transversal edges. Some

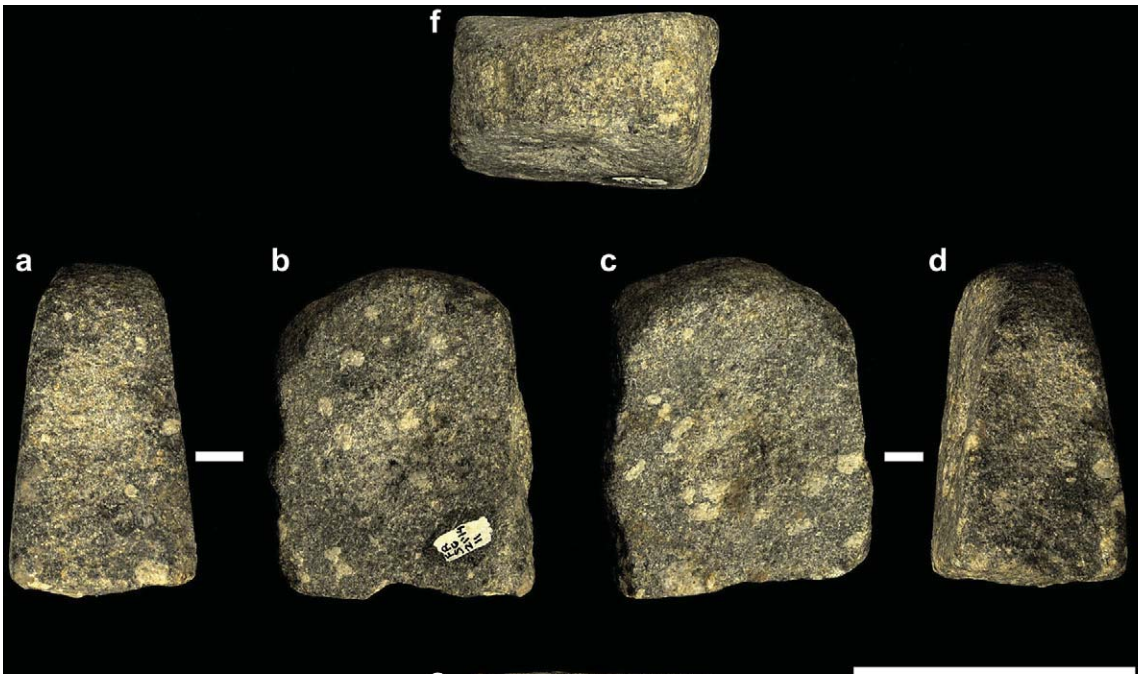

Fig. 10. Archaeological pitted stone fragment showing multi-functional use-wear marks from Font del Ros level SG (gneiss, 57 × 46 × 30 mm): a, d, f) thrusting percussion marks; b, c) pits with regular section suggesting intentional pecking; e) convex use-wear facet produced by friction (graphic scale 5 cm).

ethnographic observations stress the utility of central, regular depressions as *finger grips* (de Beaune, 2000; Adams, 2002) to hold worked materials. In this sense, we agree that it is not always easy to differentiate between manufacture and use-wear scars (de Beaune, 1993b). It is not the remit of this paper to analyze potential context of this type of artefact.

7. Conclusions

The results of the experimental programme presented here contribute towards a greater understanding of percussion activities. We have shown that most of the Font del Ros pitted cobbles included in this study, have modifications associating them with bipolar knapping, an observation that complements results indicated by other studies (Le Brun-Ricalens, 1989; Donnart et al., 2009; de la Peña, 2011).

Nevertheless, we emphasize the fact that in other cases these modifications may signify different activities. We have indicated that the association of marks on the same active surface, in which the combination of thrusting and resting percussion linked with tribochemical changes, may be related to nut cracking (Fig. 9). This activity is difficult to verify without concomitant analysis to identify the presence of residues (Piperno et al., 2009), as it is necessary to establish protocols regarding the recuperation of residues from these artefacts. It would be interesting if this hypothesis were analyzed in other sites where similar artefacts have been identified, in order to determine whether or not they are related with food processing.

In summary, the marks identified on pitted stones show a certain degree of variability, and in principle pose a problem of equifinality in the exact determination of the function of these tools. However, we should not forget that such variability is an important attribute given the multi-functional nature of these artefacts that are relatively simple and easy to make, but at the same time are used effectively for a wide range of activities (de Beaune, 2000). Likewise, because of their use in essential domestic activities, we emphasize their diagnostic potential for the analysis of spatial activity patterns.

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Appendix. Supplementary material

Supplementary data related to this article can be found online at doi:10.1016/j.jas.2011.12.017.

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