Journal of Archaeological Science: Reports 29 (2020) 102188

Contents lists available at ScienceDirect

Journal of Archaeological Science: Reports

journal homepage: www.elsevier.com/locate/jasrep

Refitting bones: Spatial relationships between activity areas at the Abric Romaní Level M (Barcelona, Spain)

María Cristina Fernández-Laso[a,*], Jordi Rosell[b,c], Ruth Blasco[d], Manuel Vaquero[b,c]

[a] Dpto. Prehistoria, Historia Antigua y Arqueología. Facultad de Geografía e Historia, C/Profesor Aranguren s/n, Ed. B. Ciudad Universitaria, Universidad Complutense de Madrid, 28040 Madrid, Spain
[b] IPHES, Institut Català de Paleoecologia Humana i Evolució Social, Zona Educacional 4, Campus Sescelades, Universitat Rovira i Virgili (URV), Edifici W3, 43007, Tarragona, Spain
[c] Área de Prehistoria, Universitat Rovira i Virgili (URV), Avinguda de Catalunya 35, 43002 Tarragona, Spain
[d] CENIEH, Centro Nacional de Investigación sobre la Evolución Humana, Paseo Sierra de Atapuerca 3, 09002 Burgos, Spain

ARTICLE INFO

Keywords:
Middle Palaeolithic
Spain
Abric Romaní
Occupational patterns
Activity areas
Bone refits

ABSTRACT

Studies on spatial settlement patterns have shed important light on Neanderthal intra-site behavior. Spatial analysis of the human occupations through bone and lithic refitting has contributed to the reconstruction of their settlements, offering temporal interpretations and reconstructions of their activities. Often archaeological units are a consequence of an undetermined number of events, overlapped activities and/or accumulations produced by different taphonomical agents, involving in turn various post-depositional processes. Strict behavioral conclusions may only be valid at sites with a simple taphonomic history; however, biological and non-biological processes seem to alter the most of faunal sets after hominin activity involving even the destruction of some items. The result is a *palimpsest* that can lead to confusing and mixed events of different nature and independent activities. The deposit of the Abric Romaní site (Capellades, Spain), dated to MIS 3-5, was generated by a sequence of sterile travertine platforms of quick formation, among which silty and sandy units containing evidence of human occupations are located. These exceptional geological conditions allow us to isolate anthropogenic units along the sedimentary sequence. Spatial analysis and bone refits from Level M have shown a highly complex occupational organization. The aim of this paper is to contribute to the knowledge of Neanderthal occupations, suggesting that the inclusion of bone refits in the studies developed in the archaeological sites is a fundamental tool to reconstruct the social and spatial organization patterns.

1. Introduction

The study of occupational patterns is fundamental to understand the Middle Palaeolithic human groups' ways of life. The identification of activity areas and the number and type of activities, which have been developed by human groups, is a key element to identify several aspects regarding their social and economic behavior. Some Upper Paleolithic sites are very well preserved in terms of spatial distribution, allowing us to know their intra-site structure and providing us with a context to make behavioral interpretations (e.g., Pincevent, Verberie) (Enloe et al., 1994; Audouze and Enloe, 1997). Traditionally it has been established that only human groups of this period and later developed complex social and economic organizations. On the contrary, the Neanderthals' home base settlements seemed to be the result of simple, un-structured and static activities (Stringer and Gamble, 1996; Pettitt, 1997). However, evidence of different degrees of occupational patterns are found in earlier times and in other hominin populations (Henry et al., 1996, 2004; Vaquero and Pastó, 2001; Vaquero et al., 2001; Alperson-Afil et al., 2009; Vallverdú et al., 2010; Hovers et al., 2011; Enloe, 2012). For example, the use of specific areas of the site for each activity (stone knapping, tool use, floral and faunal processing and consumption) has been suggested at Gesher Benot Ya'aqov (Israel) over 750 kya (Alperson-Afil et al., 2009). According to these authors, this phenomenon demonstrates the advanced organizational skills amongst the early Middle Pleistocene human groups. In subsequent periods, such as in Neanderthal contexts, hearths were seen as focal points around which the space was organized by detecting activities around these structures, as in Abric Romaní (Vaquero and Pastó, 2001), Wallertheim (Conard et al., 1998), Tor Faraj (Henry et al., 2004), Bolomor Cave (Sañudo, 2007), and Kebara (Speth et al., 2011).

Nevertheless, and beyond chronology, we can find important difficulties related to the sedimentation conditions (sedimentation rate)

* Corresponding author.
E-mail address: mferna60@ucm.es (M.C. Fernández-Laso).

https://doi.org/10.1016/j.jasrep.2019.102188
Received 27 July 2019; Received in revised form 20 December 2019; Accepted 22 December 2019

during the formation of the archaeological assemblages. That is, different and independent events (of different nature) may be overlapped and appear mixed archaeologically (Villa and Soressi, 2000; Rosell and Blasco, 2009). From this perspective, the analysis of the palimpsest with high density of archaeological items might be interpreted incorrectly. In other words, a very low sedimentation rate might lead to infer long-term occupations when they may correspond to a succession of overlapped discrete events. Archaeologically, assessing the time involved in the formation of assemblages is very complicated, and this must be considered when making reconstructions related to the way of life of the Pleistocene human groups (Vaquero, 2008; Fernández-Laso, 2010). If we consider that an archaeological assemblage is a sum of an unknown number of individual and group actions, we should look for elements that allow us to identify and/or isolate events limited in time. Only applying this concept, could we try to reconstruct these individual actions or explore distinctive features between groups (Vaquero, 2008; Vaquero et al., 2015, 2017; Fernández-Laso, 2010). In this way, we have considered that the spatial analysis and specifically, the bone and lithic refits are key elements for reconstructing activity areas, which represent the basic structure of a settlement, and constitute a fundamental element to reconstruct human activities (Gabucio et al., 2017; Rosell et al., 2019; Vaquero et al., 2015, 2017; Fernández-Laso, 2010). Ethnoarchaeological and archaeological studies allow us to identify different behavioral patterns, where domestic areas are a common component since early moments (e.g., Leroi-Gourhan and Brézillon, 1972; Binford, 1978a, 1978b; Yellen, 1977; O'Connell, 1987; Henry et al., 1996, 2004; Vaquero and Pastó, 2001; Vallverdú et al., 2005; Alperson-Afil et al., 2009). In archaeological assemblages in which fire was regularly used, such as Middle Palaeolithic sites, domestic activities were usually carried out around a hearth and in some occasions, using natural or intentional structures (large stone blocks or trees).

Bone refits provide a fundamental analytical tool for the reconstruction of the archaeological levels into a geological time scale, increasing the identification of specific taphonomic processes and activity events in limited times and places, solving particular stratigraphic problems (Van Noten et al., 1978; Bunn et al., 1980; Villa, 1982; Hofman, 1986; Kroll and Isaac, 1984; Villa et al., 1986; Lavachery and Cornelissen, 2000; Morin et al., 2005). Bone refits also provide the reconstruction of behavioral patterns of the human groups, namely spatial and economic organization (e.g., Leroi-Gourhan and Brézillon, 1972; Cahen et al., 1979; Cahen and Kelley, 1980; Kroll and Isaac, 1984; Enloe and David, 1989, 1992; Enloe, 1991, 2003; Larson and Ingbar, 1992; Todd and Frison, 1992; Audouze and Enloe, 1997; Rosell et al., 2012a, 2012c, 2012b, 2019; Waguespack, 2002; Fernández-Laso, 2010; Gabucio et al., 2016, 2017; Modolo and Rosell, 2017).

In this paper we present the results from bone refits at Level M of the Abric Romaní (Barcelona, Spain). In principle, the Abric Romaní presents the ideal conditions to address a study of this nature with an extensive stratigraphic sequence, a high rate of sedimentation and a large surface area under excavation (250–300 m^2). In addition, there are data suggesting that the spatial patterns are particularly well-preserved. The spatial analysis approached from bone refitting has allowed us to identify particular human actions and reconstruct the spatial organization of the Neanderthal groups at level M of Abric Romaní. With this study, we try to provide more accurate data about the spatial organization of these hominins, as well as contribute to the knowledge of occupational dynamics during the European Middle Palaeolithic.

2. The Abric Romaní

Abric Romaní is located in the northeast part of the Iberian Peninsula, in the town of Capellades, 50 km west of Barcelona. It is one of many rock shelters located in the travertine complex known as *Cinglera del Capelló* (Capelló Cliff). It is situated on the right bank of the Anoia river at an elevation of 317 m a.s.l. and 50 m above a narrow gorge of the river (Fig. 1). Three main ecosystems occupy the area around the shelter: riverside, mountain uphill and a plain beyond the gorge.

Current excavations started in 1983 and have allowed a ~50 m thick sedimentary deposit, dated by U-Series and ^{14}C AMS between 40 and 110 Kyr BP (Sharp et al., 2016; Vaquero et al., 2013). The stratigraphic sequence is made of a succession of travertinic bioconstruction platforms, where the archaeological levels appear as sandy layers interstratified and well delimited in between those platforms. This sedimentary context is fast (rate of 0.46 mm/yr), providing high temporal resolution (Vallverdú et al., 2012; Vaquero et al., 2013). As a consequence, palimpsests are less developed than in other sites because the overlapping of activity events is more limited. The high temporal resolution, combined with a field methodology based on extensive excavation (up to 300 m^2) and the use of Cartesian coordinates, made it possible to study spatial behaviors and settlement patterns, and make the lithic and bone refitting, as it has been carried out at several archaeological layers (Vaquero et al., 2007, 2015, 2017; Vaquero, 2008; Rosell et al., 2012, 2019; Fernández-Laso, 2010; Gabucio et al., 2016, 2017; Modolo and Rosell, 2017). Archaeostratigraphy and bone and lithic refits were also used to identify synchronic and diachronic patterns (Vaquero et al., 2007, 2012a, 2012b; Gaudzinski and Roebroeks, 2000; Gabucio et al., 2017; Rosell et al., 2012a, 2012b, 2019; Sañudo et al., 2012; Vaquero et al., 2015; Fernández-Laso, 2010). Hearths are numerous at all archaeological levels so far excavated, and they have been used to identify minimal spatial units, as recognizing of activity areas, along with the spatial distribution of lithic and faunal remains (Vaquero and Pastó, 2001). These hearth-related areas are characterized by a clear dominance of small remains, which indicates that activities were carried out on the spot. This dominance of small items is also an argument supporting the good preservation of these activity areas.

Faunal remains, lithic artefacts, charcoals from hearths and wood pseudomorphs compose the archaeological record (Rosell et al., 2012a, 2012c, 2012b; Vallverdú et al., 2012; Vaquero et al., 2001, 2015, 2017; Rosell et al., 2019; Solé et al., 2013; Chacón et al., 2014; Bargalló et al., 2016; Gabucio et al., 2016; Modolo and Rosell, 2017). In regard to the faunal remains, horse (*Equus ferus*) and red deer (*Cervus elaphus*) are the most important ungulates in all archaeological levels. Occasionally, the presence of wild ass (*Equus hydruntinus*), aurochs (*Bos primigenius*), rhino (*Stephanorhinus hemitoecus*), and chamois (*Rupicapra rupicapra*) is observed. The carnivores are marginally present at the Abric Romaní. Remains of bear (*Ursus arctos*), wolf (*Canis lupus*), fox (*Vulpes vulpes*), hyena (*Crocuta spelaea*), lyon (*Panthera spelaea*), panther (*Panthera pardus*), lynx (*Lynx spelaea*), and wild cat (*Felis sylvestris*) have been identified. The presence of these animals is interpreted as sporadic visits to the shelter to scavenge the remains of hominins' leftovers (Chacón et al., 2014; Fernández-Laso et al., 2010; Rosell et al., 2012a; Rosell et al., 2019 Gabucio et al., 2016; Modolo and Rosell, 2017). Middle Palaeolithic stone tools are made with local raw materials (15 km), mainly chert, quartz and limestone (Gómez de Soler, 2009). Flakes are the most common lithic category; they were occasionally retouched to obtain denticulates and notches. Cores are not frequent at this site and, in general, they are recovered in advanced stages of exploitation. Knapping activities are well attested which suggests that the production of stone tools was a frequent activity. However, an important inter-site mobility of stone artefacts can be observed, since many flakes and retouched artefacts were produced outside and brought into the site as single items (Vaquero et al., 2001, 2007, 2015, 2017; Chacón et al., 2013; Bargalló et al., 2016).

Level M has been dated by U-Series to 51,800 ± 1400 yr. BP, whereas the underlying tufa was dated to 54,900 ± 1700, 54,100 ± 1600 and 55,800 ± 2300 yr. BP (Vaquero et al., 2013). From pollen studies Level M belongs to MIS 3, which is characterized as a cold period, alternating with warmer and more humid phases that may correlate with the interstadial GI 14 (Burjachs et al., 2012). The occupied surface does not show steep slopes and is practically flat in the

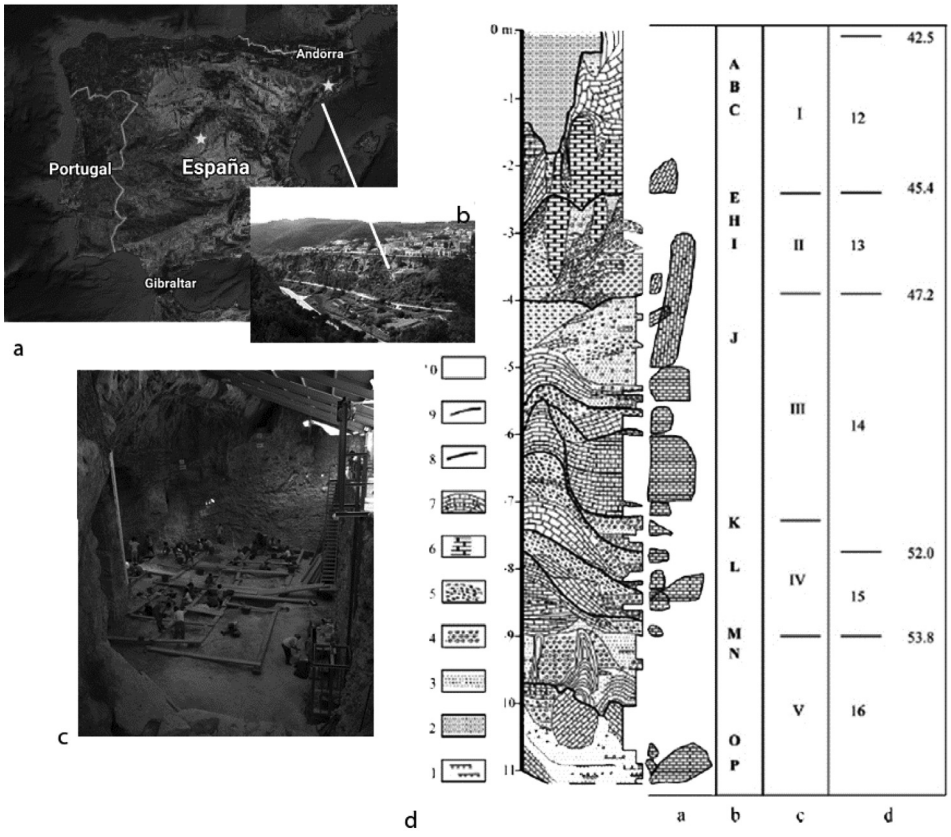

Fig. 1. Abric Romaní geographic location in Northeastern Iberia (a), image of the "Cinglera del Capelló" travertine cliff (b), image general of the excavation at the Level M (courtesy by Gerard Campeny/IPHES) (c), and lithostratigraphy column of the site (Coveta Nord profile; figure elaborated and courtesy by Vallverdú et al. (2012b). Legend for the lithological column: 1 – Organimineral grey horizon, 2 – red siliclastic and calcitic siltry sand, 3 – yellow calcitic sand, 4 – yellow tuffacceous-travertine gravel and calcitic sand, 5 – platy gravels of crystallitic travertine and calcitic sand and silt, 6 – speleothems, 7 – cemented sands ant travertines, 8 – diastem, 9 – paraconformity or erosive unconformity, 10 – archaeological bed. Legend for the comment columns (from left to right): rock-fall of travertine blocks and megablocks, archaeological levels, sedimentary sequences, and the lower chronological boundary (Dansgaard-Oeschger events).

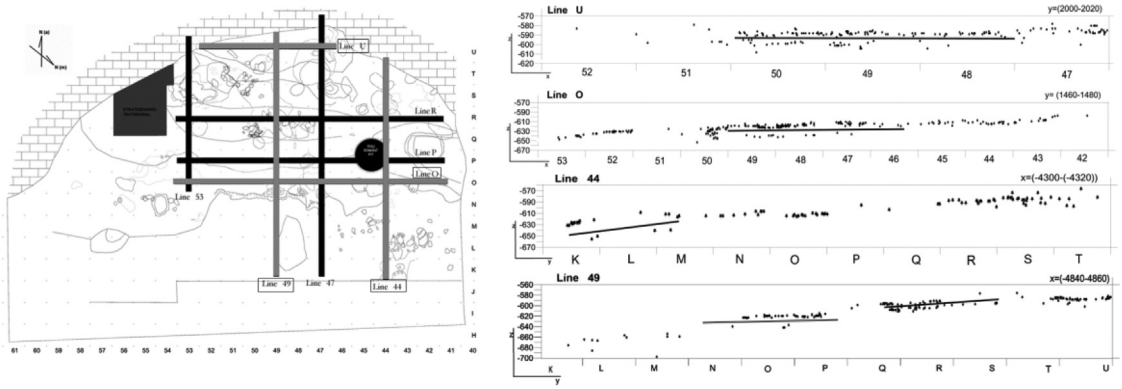

Fig. 2. Archaeoestratigraphic analysis of Level M, showing the vertical projection of the faunal assemblage from M4 and M6 (archaeolevels M and Minf) (Gabucio et al., 2017).

sector closest to the wall. Outwardly, a slight slope to the southwest is observed. Regarding stone tools, the chert remains predominate, although other rocks were also used (chert 81%, quartz 5.3%, limestone 9.5%, and other raw materials 4.2%). Level M exhibits one of the richest lithic assemblages of the Abric Romaní sequence (more than 4800 artefacts greater than 1 cm in size were recovered) but has one of the lowest percentages of retouched artefacts of all the levels (< 1%). The analysis of the lithic artefacts, together with the data from lithic refitting, indicates that flake production was the main technical activity carried out in the rock shelter. In this context, production of small products played a primary role (Chacón et al., 2013; Vaquero et al., 2015). The Level M yielded 37 hearths that represent two different types: simple flat hearths, which predominate, and structures with stones and pits. The study of wood remains shows the intensive use of wood, not only as fuel for the hearths, but also as raw material for implements used in the subsistence activities of the group (Solé et al., 2013).

3. Methodology

3.1. Spatial analysis

Spatial analysis was based on the visual assessment of distribution patterns, which is a common approach used for archaeological data (Binford, 1978; O'Connell, 1987). Spatial pattern analysis is necessary to understand the depositional process and the relationship between bone remains and other archaeological objects and features, especially hearths. In this case, the accumulations generated by biological and no-biological agents at Level M were studied using an archaeostratigraphic methodology, which consists of horizontal and vertical projections of the faunal remains taking into account bone damage (ESRI ArcGIS ® 9.2; Surfer ® 8). These projections, with a thickness between 20 and

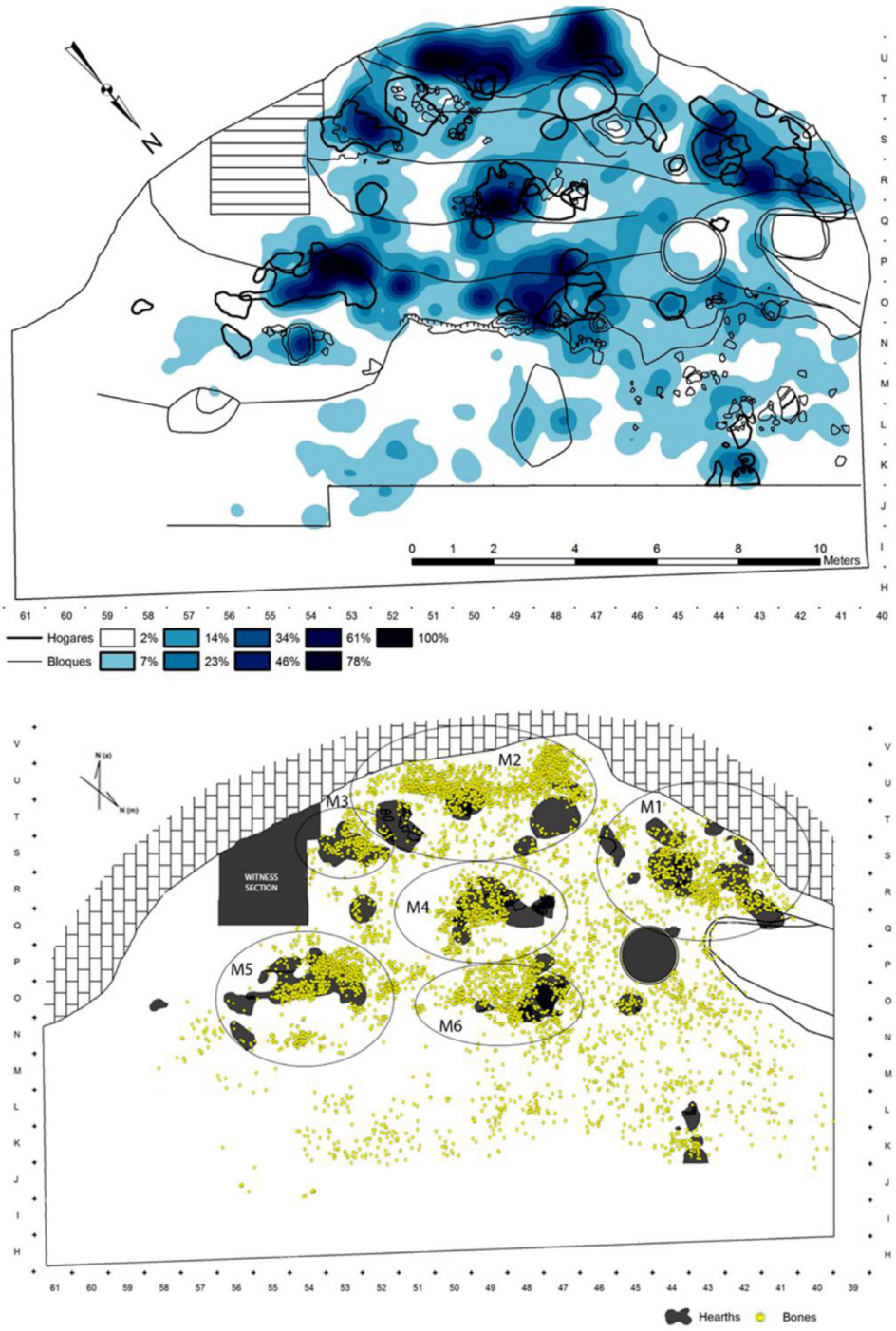

Fig. 3. Faunal distribution and graphical representation of the accumulations at Level M.

10 cm, have allowed us to make temporal readings and identify domestic areas. Two stratigraphic subunits (M and Minf) have been identified in the inner and central sectors of the rock-shelter through archaeostratigraphical analysis (Fernández-Laso, 2010; Vaquero et al., 2015, 2017; Gabucio et al., 2017) (Fig. 2). Taking into account the density of bone remains, six main accumulations (M1 to M6) have been distinguished in archaeolevel M, and two accumulations (M4inf and M6inf) in archaeolevel Minf (Fig. 3). These accumulations are coincident with those suggested by other items such as lithic remains, which have a similar spatial distribution pattern (Vaquero et al., 2015, 2017) (Fig. 4).

3.2. Zooarchaeological and taphonomical method

The analysis of the faunal assemblages from Level M was carried out following the methodological approaches developed in Zooarchaeology and Taphonomy. All the coordinated faunal remains (approximately > 1 cm in size) have been analyzed. To assess the sample, we used NISP (Number of Identified Specimens), MNE (Minimum Number of Elements), MNI (Minimum Number of Individuals), along with MAU (Minimal Anatomic Units) and their frequencies. For these analyses, the identified elements were classified into categories: cranial skeleton (cranium, antler or horn, mandibulae and isolated teeth), axial skeleton (ribs, vertebrae, scapulae and coxal), proximal (stylopodial and

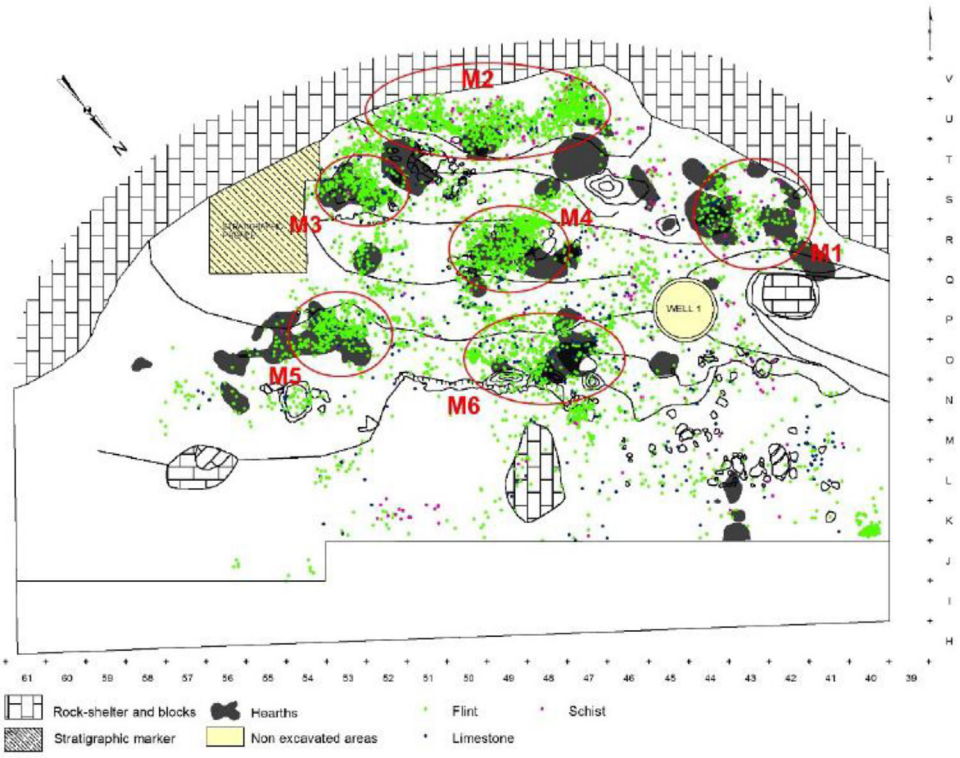

Fig. 4. Spatial distribution of lithic remains, indicating the six main accumulations (Vaquero et al., 2017).

zygopodial) and distal (carpal/tarsal and phalanges) appendicular skeleton. Likewise, anatomically non-identifiable bones were classified into the three general categories: long bones (from limbs), flat bones (axial and cranial skeleton), and irregular bones (carparls, tarsals, etc.). The age of death of the animals was established mainly by their teeth (Silver, 1969; Bökönyi, 1972; Mariezkurrena, 1983). The unidentified bones were grouped in weight sizes, following the modified criteria established by Bunn (1986): 1) very small size or size 1 (< 20Kg), 2) small size or size 2 (20–100 kg), 3) medium size or size 3A and 3B (100–300 kg), 4) large size or size 4 (300–1000 kg), and 5). The breakage on faunal remains were analyzed and classified according to Villa and Mahieu (1991). The outline (transverse, curved/V-shaped, longitudinal), fracture angle (oblique, right, mixed) and fracture edge (smooth or jagged) were analyzed. The alterations observed on the bone surfaces were treated at both macroscopic and microscopic level. For the microscopic study an Olympus SZ11 stereoscopic and FEI Quanta 600 FEG Environmental Scanning Electron Microscope was used. Damages observed on the faunal remains mainly included cut-marks, intentional bone breakage and burned bones. Incisions are the most frequent type of cutmarks identified; chopmarks and scrapes were not documented (Binford, 1981; Potts and Shipman, 1981; Shipman, 1983; Shipman and Rose, 1983). The incisions have a V-Shaped section and display internal microstriation (Potts and Shipman, 1981). In some cases, Hertzian cones (Bromage and Boyde, 1984), shoulder effects and barbs (Shipman and Rose, 1983) were observed. The analysis of cut-marks took into account the number of striations, location (size and portion of the bone), distribution on the surface (isolated, clustered, crossed), orientation (oblique, longitudinal, transverse), and delineation (straight or curved). Surface damage caused during the bone breakage was also analyzed and the diagnostic elements of anthropogenic breakage were documented: percussion notches, impact flakes and percussion pits (Blumenschine and Selvaggio, 1988; Capaldo and Blumenschine, 1994; Pickering and Egeland, 2006).

Burning was also identified on the faunal remains from Level M. The main feature of the burned bones is the change of coloration: natural color to black (carbonized) to white (calcined). These changes were related to the intensity of the fire and time exposure. Burned remains were classified following a modification of the criteria described by Stiner et al. (1995). The burned bones from Level M can be classified in 6 color groups: 1) grade 0 for unburned bones; 2) grade 1: the bone surface presents small dots scattered brown; 3) grade 2: brown stain more or less homogeneous across the bone surface; 4) grade 3: the bone was charred (the color is black); 5) grade 4 for grey stain; and 6) grade 5: the bone surface is white (calcined).

Other taphonomic modifications were also observed, such as carnivore toothmarks, trampling, water action (polish and rounding) and roots. The carnivores toothmarks identified on bone remains were very scarce and were mainly pits, punctures and scores (Haynes, 1980, 1983; Binford, 1981; Stiner, 1994; Blumenschine, 1995; *inter alia*). In order to identify the type of carnivore acting at assemblages, toothmarks have been measured and compared by data of Andrews and Fernández-Jalvo (1997), Selvaggio and Wider (2001) and Dominguez-Rodrigo and Piqueras (2003). Trampling was observed on some faunal remains. Polishing and rounding, as a result of water abrasion, were some of the identified bone alterations. These bones were classified following the criteria described by Cáceres (2002) but with some adaptationsFernández-Laso, 2010: grade 0 for unpolished or unrounded bones was not included; but the other three categories were applied: grade 1, the edges' breakages are polished or rounded; grade 2: the bone surface is smooth and shiny or rounded and grade 3: the bone surface is completely polished and shiny or rounded.

The action of roots has also been identified. This natural post-depositional modification was assessed employing methodology developed by Behrensmeyer (1978), Lyman (1994), and Cáceres (2002).

3.3. Faunal refits

According to Lyman (1994, 2008), different types of faunal refits can be made: 1) mechanical, 2) anatomical, 3) bilateral pairs, 4) and intermembral refits. The most used refitting at archaeological sites are

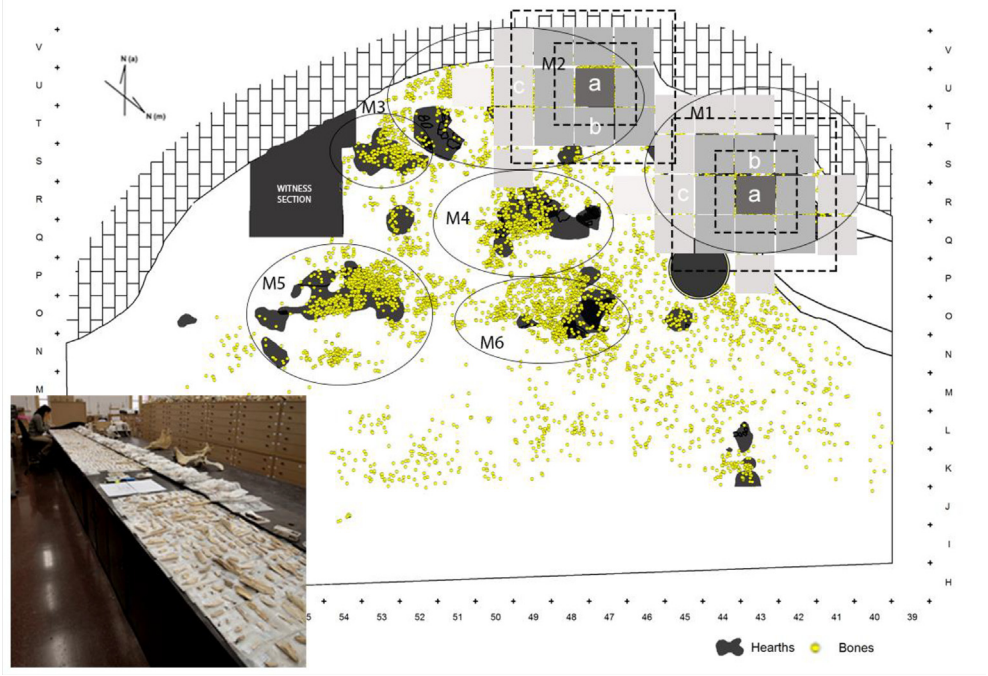

Fig. 5. Method applied for bone refits at Level M.

mechanical and anatomical refits (e.g., Hofman, 1986, 1992; Villa, 1982; Johnson, 1982; Johnson and Holliday, 1989; Todd, 1987; Todd and Frison, 1992; Villa et al., 1986; Enloe and David, 1989, 1992; Enloe, 1991; Rapson and Todd, 1992; Henshaw, 1999; Morin et al., 2005; Rosell et al., 2012; Gabucio et al., 2016; Modolo and Rosell, 2017). In the case of level M, only two types of bone refits were detected (Fernández-Laso, 2010; Gabucio et al., 2017; Vaquero et al., 2017; Rosell et al., 2019): 1) mechanical refits (conjoined fragments from the same broken element) and 2) anatomical refits (i.e. dental series and articulated elements). Refits have been tested with all bones larger than 2 cm long. Furthermore, all percussion flakes have been included in this study due to the important information that they provide on the origin of breakage. Spongy fragments were not included in the refitting program, as these are particularly difficult to conjoin. Bone remains were exposed in a wide area of the lab, in a large space so they could be grouped and visualized according to their spatial location by squares (x/y) (Fig. 5). We began by exposing the elements of the squares in the accumulations identified spatially. Each accumulation was displayed concentrically, starting with the central square (x, y) (Fig. 5a), and subsequently continuing with the nearest one: bottom (S), top (N) and side (E, W) (Fig. 5b, c), until all squares of the eight main accumulations described above were included. Later, they were compared with isolated remains, which were located around the accumulation. After completing the search for connections in these accumulations, it was continued in the nearest spatial accumulations. Once the comparing of two collections was done, the next isolated fragments were studied. Subsequently, the same process was followed for the next accumulation; it was analyzed and compared with the previous accumulations. This way all the accumulations were covered and compared all among them. In each accumulation the elements were grouped by species and skeletal elements. Unidentified bones were grouped by weight and size and by bone type (large, plane and articular). Also, the elements were grouped and separated by percussion notches. This facilitates the comparison between skeletal elements and the connections between the bone fragments, and it also enables the delimitation of the MNI. Both specimens with fresh and dry breakage were taped together with UHU patafix gluepads, in order to allow the study of fracture patterns. Finally, to determinate the spatial associations, the original position of refitting bones according to the other remains and structures, mainly hearths, have been documented.

4. Data presentation

4.1. Spatial distribution data

At Level M, 7614 bone remains greater than 2 cm long have been recovered; they were excavated on a surface of 247 m^2. The average density of bones per m^2 was 30.8. The density map shows that the assemblage was distributed in clear and definite accumulations throughout the rock-shelter (M1, M2, M3, M4, M5 and M6) (Fernández-Laso, 2010; Gabucio et al., 2017; Vaquero et al., 2017; Rosell et al., 2019) (Fig. 3). The vertical projections show two different archaeolevels: M and Minf (Fig. 2). Archaeolevel M with 7163 remains is thicker (up to 40 cm) than Minf. Minf with only 451 remains is the lower archaeolevel (up to 20 cm thick). These archaeolevels only was possible to identify in some areas of the rock-shelter, in area M4 (M4 and M4inf) and M6 (M6 and M6inf) (Fig. 2). Therefore, we distinguished eight main accumulations, six in archaeolevel M, and two in archaeolevel Minf. In addition, other smaller clusters may be identified through of the rock-shelter, and these remains can be included in archaeolevel M. We can observe that three main accumulations (M1, M2 and M3) are close to the wall, while five (M4, M4inf, M5, M6 and M6inf) are located in the middle of the rock-shelter. This spatial pattern is similar for the lithic remains (Vaquero et al., 2015, 2017) (Fig. 4).

In general, all accumulations show an important density of remains, although there are some differences between them (Table 1). All accumulations were located in association with hearths (37 in total, 28 in accumulations), except in M6 where no hearths have been identified. In general, most bone remains are arranged in two ways: either in the interior of the hearth itself or surrounding its proximity. In the rest of areas in the rock-shelter, bone remains tend to be scattered and further away from the hearths. In all accumulations, but especially in other areas of the rock-shelter, bone remains with water abrasion are identified, but mainly those belonging to grade 1. We have not identified concentrations by size or preferential orientations. Bone remains with carnivore damage were located scattered and isolated by the rock-shelter, and in M1, M6 and M4inf accumulations. Trampling are located in M4 and M1, and in a lesser degree scattered along the rock-shelter.

Table 1
General characteristics and human activity identified in the accumulations at the Level M assemblage (Acc.: number of accumulation, or No acc.: not accumulated remains; NR: number of remains; Hearths: number of hearths; Intent. Breakage: bone breakage (diagnostic elements).

Acc.	m^2	NR	Hearths	Cutmarks	Intent. Breakage	Burning	Tooth marks	Trampling	Rounding	Polishing	Plant activity
M1	14	847	7	4.37	4.13	59.27	0.47	0.23	3.66	1.53	3.31
M2	20	1917	6	2.19	2.92	57.43	0.21	–	1.62	0.68	1.62
M3	6	372	3	1.88	1.08	72.31	0.27	–	2.15	1.34	6.72
M4	6	325	1	3.38	1.54	70.77	–	0.30	0.92	0.62	14.46
M5	18	1252	6	3.75	2.40	78.27	0.08	0.15	0.96	0.56	7.19
M6	12	931	3	4.18	3.44	71.54	0.32	–	1.83	0.54	22.13
No acc.	–	1517	9	2.76	4.09	40.41	0.73	0.19	8.04	2.37	22.08
M4inf	7	326	2	1.84	0.92	85.28	0.31	–	–	–	5.21
M6inf	10	125	–	–	0.80	24.80	–	–	0.80	–	7.20

Post-depositional agents like plants activity are located in all accumulations, but specially in M6 and M4, as well as in other areas of the rock-shelter. We have not observed bone concentrations by taxa, size or the same skeletal elements. In archaeolevel M, *C. elaphus* and *E. ferus* are located in all accumulations, although showing some differences. Regarding the distribution of taxa by age, juvenile *E. ferus* were observed in M1 and M2, and adult *E. ferus* were identified in M5 and M6. An adult *B. primigenius* was located in M1 and M5 and juvenile in M2. Adult *C. elaphus* were identified in M1, M2, M5, and M6, and immature *C. elaphus* were recovered from M1 and M6, and senile *C. elaphus* in M1, M2 and M6. Only *C. elaphus* of an unidentified age were identified in M3 and M4. In Minf, *C. elaphus* (unidentified age) was identified in M4inf and M6inf, and only *E. ferus* (unidentified age) was located in M6inf.

All accumulations show activities related to animal processing. Cutmarks were identified in the diaphysis, and in lesser number on metaphysis, of appendicular bones, related to defleshing and skinning activities in M1, M2, M4, M4inf, M5 and M6, and viscera removal in M5 y M6. On the other hand, intentional bone breakage has been documented in all the accumulations. Burned bones (52.9% in all accumulations) are located with high cremation degree (Grade 4 and 5) in the inner of the hearths, and low and medium degrees (Grade 1–3) surrounding and out of the hearths. Despite the differences in bone remains concentrations identified in M1, M2, M5, M6 and M3, M4 and M4inf, these allow us to infer that groups of hominin have similar behavioral patterns regarding animal processing, except in M6inf. In this last case, the accumulations show a small concentration of burned bones but not associated with hearths (Table 1).

4.2. Zooarchaeological and taphonomical data

At Level M, 7.28% of the bone remains have been anatomically identified (using taxonomical groups). The zooarchaeological and taphonomical analyses of this bone assemblage has been presented in previous preliminary works (Chacón et al., 2014; Fernández-Laso et al., 2010, 2011; Gabucio et al., 2017; Vaquero et al., 2017; Rosell et al., 2019). We identified different species of herbivores and carnivores. Carnivore remains (*Ursus* sp. and *Lynx sp.*) are very scarce. Red deer (*Cervus elaphus*) and horse (*Equus ferus*) are the most abundant species, followed by auroch (*Bos primigenius*). The most common animals are adults, but immature and juvenile individuals are also represented (Table 2). The skeletal profile shows a dominance of cranial skeleton (mainly mandibles and maxilla) and proximal appendicular skeleton (stylopodium and zygopodium). On the contrary, the axial bones and girdles are absent, and acropodials and basipodials are very scarce (Table 3). This skeletal representation coincides with the anatomical elements of high medullar value (Binford, 1981; Emerson, 1993).

Analyses of bone breakage show that curved V-shaped fracture predominate along with oblique angles and smooth edges. The bone breakage features is related mainly to green bone breakage according to the criteria established by Villa and Mahieu (1991). Diagnostic features

Table 2
NR, NISP, NME and NMI according to age (Inf: infantile, Juv: juvenile, Ad: adult, Sen: senile, Undet: undetermined) from Level M.

Taxa	NR	NISP	NME	NMI	MNI by age				
					Inf.	Juv	Ad	Sen	Undet
Equus ferus	58	58	15	6	1	1	4	–	–
Bos primigenius	15	15	10	3	–	1	2	–	–
Cervus elaphus	479	479	110	9	2	–	5	2	–
Ursus spaleaus	1	1	1	1	–	–	–	–	1
Felis sylvestris	1	1	1	1	–	–	–	–	1
Large-sized	123	–	17	–	–	–	–	–	–
Medium-sized	555	–	56	–	–	–	–	–	–
Small-sized	423	–	41	–	–	–	–	–	–
Unidentified	5959	–	–	–	–	–	–	–	–
Total	7614	554	251	20	3	2	11	2	2

Table 3
%Skeletal Survival Rate according to anatomical proportion and categories established by animal weight from Level M. The elements included in each anatomical segment are: skull and mandibles in cranial skeleton, vertebrae and ribs in axial skeleton and stylopodials and zeugoodials in appendicular skeleton.

Skeletal Proportion	Large size	Medium size	Small size
Cranial skeleton	40	60	21.4
Axial skeleton	–	1.9	6.7
Pelvis/Scapular girdles	7.1	13.9	–
Appendicular skeleton	17.8	57	31.2
Metapodials	14.2	77.8	37.5
Acropodials	–	4.2	8.3

of intentional anthropogenic breakage were identified on 3.0% of the bone fragments. These diagnostic features are mainly percussion pits (1.65%), impact flakes (1.23%) on long bones, and adhering flakes and peeling percussion notches (0.12%). Cutmarks were documented on 3% of the bone remains. The incisions were located mainly on the middle-shafts of long bones and they were disposed obliquely and longitudinally. The defleshing and skinning is the most common activity identified, but viscera removal have also been documented (Fig. 7a, b). We identified 61.3% of burned bones, which present different degrees of burning, but were dominated by low grades, mainly Grade 1 (20.4%) and 2 (20.3%) (Fig. 7a, c). We have identified 8% calcined bones (Grade 5).

Carnivore damage is very scarce at Level M (0.3%). Scores and pits are the most common types of tooth-mark identified. The dimension of the tooth-marks indicates that small carnivores, such as a fox, modified the assemblage (Andrews and Fernández-Jalvo, 1997; Selvaggio and Wider, 2001; Domínguez-Rodrigo and Piqueras, 2003) (Fig. 7d). Trampling have been identified on 8 elements (0.1%), and the water action was observed on 4.2% of the remains with polishing (1.1%) and rounding alterations (3.1%), but they were mainly dominated by grade

Table 4
Bone refits (Ref. groups: number of refits; Ref. remains: number of refitted elements; Max. remains: number maximum of remains refitted; Anat.: anatomical refit or Mechan: mechanical refit; Connec. Lines: number of connection lines, and Max. distance: distance maximum in centimetres) identified in the accumulations (Acc.) or not accumulated remains (No acc.) at archaeolevel M and Minf (M4inf).

Acc.	m^2	NR	Hearths	Ref. groups	Ref. remains	Max. remains	Anat.	Mechan.	Connec. Lines	Max. distance (cm.)
M1	14	847	7	28	80	11	3	25	52	869
M2	20	1917	6	27	73	11	1	26	46	253
M3	6	379	3	5	10	2	–	5	5	10
M4	6	325	1	4	8	2	–	4	4	163
M5	18	1252	6	20	40	2	–	20	20	69
M6	12	931	3	18	37	3	–	18	19	113
No acc.	164	1644	9	40	96	5	3	37	56	372
M4inf	7	326	2	2	4	2	–	2	2	72

1 (0.75% and 1.94% respectively). The presence of root-etching was also frequent at Level M (15.5%), mainly mosses and lichens.

4.3. Faunal refits

We have identified 144 bone refits, 142 in archaeolevel M, and 2 in Minf (Table 4). 140 are mechanical and 4 are anatomical refits. They involve 348 bone fragments. The most frequent refits are those made of 2 remains (114 refits) and 3 remains (21 refits); but we have also identified 3 of 4 remains, 2 refits of 5 remains, 1 refit of 6 remains, 1 refit of 7 remains, and 2 refits of 11 remains (Table 5). Bone refits were partial reconstructions of cranial elements, especially mandible, maxilla and dental fragments, along with appendicular elements. At taxonomical level, *C. elaphus* showed the largest number of refits (40 refits), related to a total of 107 remains. *E. ferus* only provided 3 refits, involving 10 elements (Table 6). We also have refits of non-taxonomically identified elements. Among these, the medium-sized animals constitute the largest number of refitted elements, reaching a total of 32 refits affecting 86 remains. Small-sized animals have the second largest number, with a total of 19 refits that affect 42 remains. Large-sized animals represented 5 refits, involving 11 remains. 92 unidentified remains, which could not be classified by weight size, reached a total of 45 refits. Among the identified skeletal elements, metapodials (44 remains) and tibiae (36 remains) were the skeletal elements with the highest number of refits (Table 7). The angles of breakage were mostly oblique and smooth edges. These elements were associated with green breakage. Most of the refitted fragments showed clear evidences of anthropic intervention: cutmarks (13.85%), intentional breakage (9.6%) and thermal impacts of different degrees (5.91%) (Fig. 8).

Spatially, the majority of bone refits (104 refits) were located dispersed in the different accumulations (Fig. 6). Bones refits enabled us to identify 204 connection lines. In general, these connections lines are short (mean length = 51.5 cm) and there are only 2 connections exceeding 5 m in length (Table 8). Longitudinal orientations (ENE-WSW and ESE-NMW) are the most well represented, but the differences between the orientation categories are not statistically significant ($x^2 = 6.7$; df = 5; p = 0.242) (Table 9). These connections are often of small fragments with short connections lines (< 1 m), and it has hampered the analysis of the correlation between connection-line and orientation. Some long-distance connections could be observed. We have identified 5 refits that connect different accumulations: 1) M1 to M2 by 1 refit of 3 isolated teeth of a juvenile *E. ferus*, which formed 3 connection lines of 37, 680 and 712 cm; 2) M1 to M6, a refit of 3 femur fragments from *C. elaphus*. 2 elements were located in M2, with a connection line of 77 cm, and the other element was located in M1 and produced a connecting line of 468 cm. All elements had thermal grade 2 alterations and 2 fragments had cutmarks 3) M1 to M5 and another area of the rock shelter connected by refit of 11 remains of tibiae of *C. elaphus*. This refit provided connection lines, between 7 and 864 cm, some of which were the longest identified connection lines. 7 elements presented grade 3 cremation and 4 elements had cutmarks. 2 fragments were polished and 5 elements were altered by roots (Fig. 9); 4) M2 and M6 were connected (372 cm connection line) by 1 refit of 2 metacarpals fragments of a *C. elaphus*, only 1 element was altered by grade 2 cremation. It is frequent to identify refitted elements and only 1 element presented alterations by cremation (Fig. 8b); 5) finally, M2 to M4 were connected by 1 refit of 2 long bones from a large-sized animal. In this case the distance between them was short (163 cm), but both were located in or around the hearths.

Table 5
Distribution of refitting groups according to the number of elements.

Bone refits	2	3	4	5	6	7	8	9	10	11
N	114	21	3	2	1	1	–	–	–	2
%	79.2	14.6	2.1	1.4	0.7	0.7	–	–	–	1.4

There are very few non-anthropic modifications that affect the refitted elements. Carnivore toothmarks have only been identified on 1 refit (0.8%) in M2. This refit was formed by 3 fragments of metacarpal of *C. elaphus* connected with 2 lines of 74–277 cm. Post-depositional agents have been identified in some refits. 17 elements (4.9%) presented a low degree of water erosion, and only 1 (0.8%) bone refit presents scratch marks by trampling. Root-etching activity had a higher incidence (39%) (Table 6).

5. Discussion and Conclusions

The combination between zooarchaeological and taphonomical studies and spatial analysis applied to Level M faunal assemblage (including faunal refits) represents an excellent tool to assess the identified activity areas and their duration, which is fundamental to reconstruct intra-site spatial behavioural patterns of human groups of the past. In the case of Abric Romaní, this phenomenon is favoured by a rapid sedimentary rate, which provides to the record the necessary high resolution features to carry out successfully this kind of studies. In this work, the study of the bone assemblage from Level M is presented for the first time, although some data were already presented in previous preliminary works together with other archaeological levels (Fernández-Laso et al., 2010, 2011; Gabucio et al., 2017; Rosell et al., 2019), and other items, such as lithic remains (Chacón et al., 2014; Vaquero et al., 2017).

At Level M, most of the faunal remains were clustered in well-defined accumulations always associated to hearths, with the only exception of M6inf. In the archaeolevel M, these accumulations formed two lines parallel to the wall of the rock-shelter: the first one very close to the wall (M1, M2 and M3), and the second one in the center of the site (M4, M5 and M6). Archaeolevel Minf was only identified in the center of site and only composed by two discrete accumulations (M4inf and M6inf), which showed similar patterns of distribution than archaeolevel M.

In these accumulations, some remains suggest the potential role of non-human agents and post depositional processes in the possible

Table 6
Bone refits according to species. Anthrop. modifications (Cut: cutmarks; Bk: Bone breakage (diagnostic elements); Bn: burning bone). Car: carnivore damage. Postdep. Damage (Wt: Water abrasion (polished or rounded); Rt: Root-etching). Distance (*): minimal and maximal distances of connection lines.

Taxa	Skeletal element	N° refitted fragments	Distance (cm.)	Cut	Bk	Bn	Car	Wt	Rt
Equus ferus	Maxilla	2	133	–	–	2	–	–	1
	Mandible	3	37–712*	–	–	1	–	–	1
		5	46–252	–	–	–	–	–	–
Cervus elaphus	Maxilla	2	16	–	–	–	–	–	–
		2	11	–	–	2	–	–	–
	Mandible	2	3	–	–	–	–	–	–
		2	45	–	–	–	–	–	2
	Humerus	2	62	–	–	2	–	–	2
	Radio-ulna	6	18–173	–	–	4	–	–	6
	Radio	2	6	1	1	2	–	–	–
		2	9	–	–	2	–	–	–
		2	81	2	1	2	–	–	2
	Metacarpal	2	42	–	1	2	–	–	2
		3	74–277	–	–	–	1	–	2
		2	96	–	–	2	–	–	2
		5	4–22	–	–	–	–	–	5
		2	114	1	1	2	–	–	2
		2	372	–	–	1	–	1	1
	Femur	2	109	–	1	2	–	–	2
		3	77–468	2		3	–	–	1
		2	3	–	–	2	–	–	2
		2	4	–	–	2	–	–	2
		2	249	–	–	–	–	–	2
	Tibiae	2	58	–	–	2	–	–	2
		11	7–864	4	2	7	–	2	5
		2	252	–	1	2	–	–	2
		3	4–42	1	1	2	–	–	2
		3	21–103	–	–	3	–	–	3
		3	10–20	–	–	3	–	–	3
		2	22	–	–	1	–	–	2
		2	37	–	–	1	–	1	1
		2	37	–	–	2	–	–	2
		4	12–48	–	–	4	–	–	3
		2	10	–	1	1	–	–	2
	Metatarsal	3	20–60	1	–	3	–	–	3
		2	39	–	1	2	–	–	2
		2	252	–	1	2	–	–	2
		3	70–119	–	–	2	–	–	1
		3	20–240	–	1	3	–	–	1
		3	5–33	–	–	3	–	–	1
		2	32	–	–	2	–	–	1
		2	10	–	1	2	–	–	–
	Phalange	2	3	–	–	1	–	–	–

perturbation or movements of the remains. One of the most significant is the role played by the carnivores as scavengers. As several researchers have suggested, the introduction of these animals in this kind of anthropogenic contexts seems to be very common (i.e. Binford, 1978; Isaac, 1967; Binford, 1981). Their activities usually produce the disappearance of several remains by destruction and ingestion (i.e. epiphyses) or by the transport outside of the main occupied area. At unit M, carnivore remains are not frequent. Only one fibula of a bear and

Table 7
Bone refits according to size categories. No. of refitted fragments: number of elements refited; no. of refits: number of refits; Anthrop. modifications (Cut: cutmarks; Bk: Bone breakage (diagnostic elements); Bn: burning bone). Car: carnivore damage. Postdep. Damage (Wt: Water abrasion (polished or rounded); Rt: Root-etching). Distance (*): minimal and maximal distances of connection lines.

Sized-animal	Skeletal element	No. of refitted fragments: no. of refits	Distance (cm)	Cut	Bk	Bn	Cv	Wt	Rt
Large	Large	2:4	20–163*	–	–	3	–	2	7
	Plane	3:1	38–212	2	–	3	–	–	–
Medium	Mandible	2:1–3:1	22–56	1	–	1	–	–	5
	Scapula	11:1	4–30	3	–	2	–	–	11
	Metatarsal	2:1	8	–	–	2	–	–	2
	Metapodial	2:1	15	–	1	2	–	–	2
	Large	2:20–3:5–4:1–7:1	1–138	6	1	52	–	8	12
Small	Metapodial	4:1	1–29	–	–	–	–	–	–
	Phalange	2:1	3	–	–	2	–	–	–
	Large	2:13–3:1	1–70	1	3	28	–	–	3
	Plane	2:2–3:1	2–46	–	–	7	–	–	–
Unidentified	Large	2:17	1–69	6	1	32	–	2	7
	Plane	2:1	45	–	–	2	–	–	–
	Unidentified	2:25–3:2	1–177	1	2	59	–	1	11

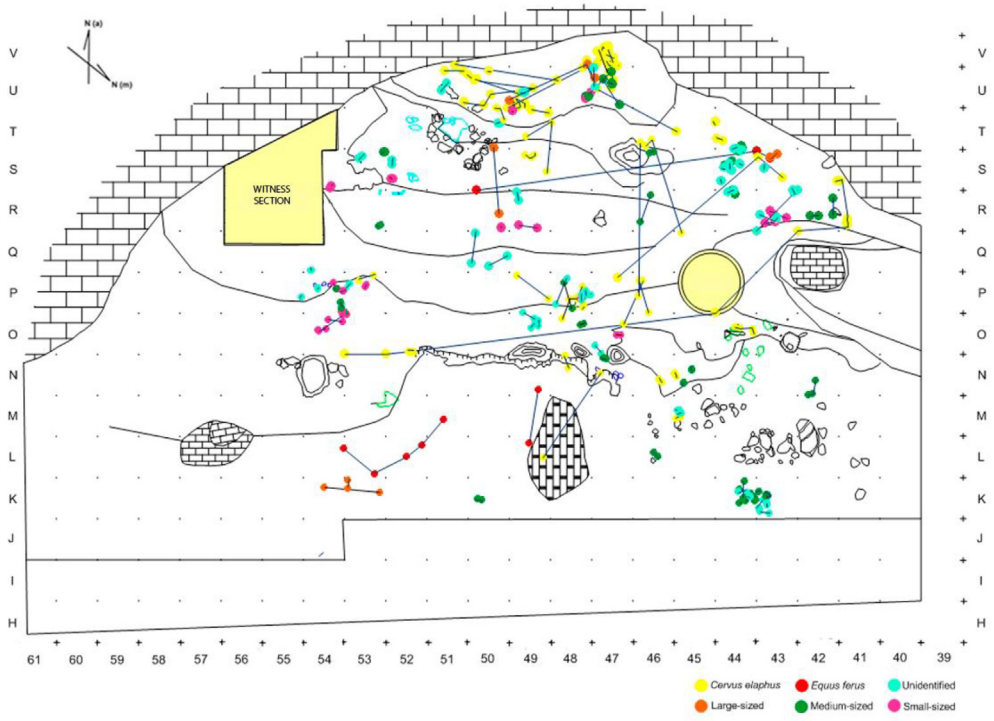

Fig. 6. Faunal refits identified at Level M.

one isolated tooth of a lynx have been identified. However, their activities have been detected at both archaeolevels and in all the accumulations in forms of toothmarks, but with the larger number in the accumulations M1, M6 and outside of these accumulations. The main features and measures of these marks seem to correspond mainly to small carnivores (i.e. foxes) (Arilla et al., 2019; Chacón et al., 2014; Fernández-Laso et al., 2010).

This last aspect could be indicating several movements of bones caused by these animals, with the subsequent disappearance of some elements. Similar phenomena (and with the same proportions) have been observed in other stratigraphic units of the Abric Romaní (Chacón et al., 2014; Fernández-Laso et al., 2011; Gabucio et al., 2017; Rosell

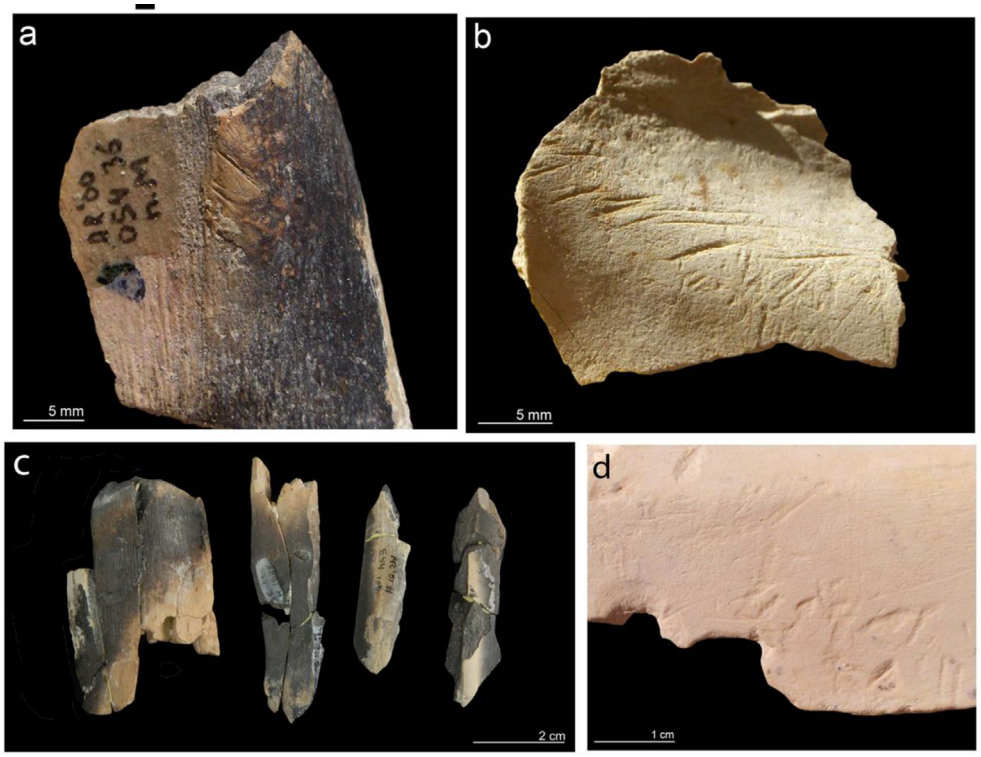

Fig. 7. Examples of elements with identified incisions (a, b) and burned bones with double colouration (a), examples of refitted bones with double colouration identified in M1 (c) and long bones with carnivore damage (d).

Fig. 8. Refitted radio-ulna of *Cervus elaphus* identified in M2 (a), and refitted metatarsal of *Cervus elaphus* with double colouration identified in M6 (b).

Table 8
Distribution of connection lines by length (m.).

Bone refits	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9
N	181	10	8	2	1	–	–	1	1
%	88.7	4.9	3.9	1	0.5	–	–	0.5	0.5

Table 9
Distribution of connection lines according to their orientation.

Bone refits	NNE-SSW	NE-SW	ENE-WSW	ESE-WNW	SE-NW	SSE-NNW
N	30	27	39	42	21	35
%	15.4	13.9	20.1	21.6	10.8	18

et al., 2012a, 2012b), which were used to explain partially the systematic lack of some specific part of the bones by destruction (i.e. epiphyses) or by the transport outside of the main occupied areas (Rosell et al., 2012, 2019).

In this respect, only one refit composed by three fragments of a metacarpal of *C. elaphus* from archaeolevel M show toothmarks. Probably, the movements experimented by these fragments (77 and 277 cm) could be caused by carnivores, but, in general, it represents an isolated case in a context dominated mainly by midshafts unattractive for these animals. As several authors have documented in this kind of contexts (i.e. Binford, 1978; Isaac, 1967; Binford, 1981), carnivores usually transport only the bones that are attractive to them. That allows them to consume the nutrients avoiding the danger of possible return of the humans. Therefore, the intentional intra-site movements caused by the scavengers are not common and, due to this, they should be discarded as the main explanatory agent of bone refits at level M.

The action of water was frequent along all the formation of the stratigraphic sequence of the rock-shelter (Cáceres, 2002; Rosell et al., 2012b, 2019; Fernández-Laso, 2010; Gabucio et al., 2016; Gabucio et al., 2017; Modolo and Rosell, 2017), and it could be responsible for some movements as well. However, this geological agent does not seem to affect the disposition of items at level M in a significant way. There is no evidence of preferential orientations amongst long bones or a

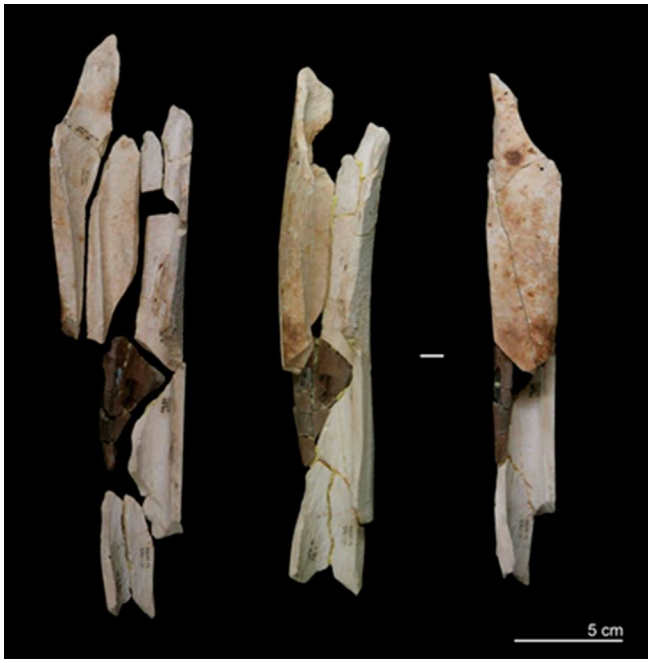

Fig. 9. Refitted tibiae fragment of *Cervus elaphus* identified M1 to M5, and other area of archaeolevel M.

selection and accumulation of items in specific zones regarding their size. On the contrary, only few refits with water abrasion were observed and they usually appear isolated, as a possible result of local water streams. Another post depositional process that could be responsible for the movement of remains is trampling. Nevertheless, trampling is very scarce at archaeolevels M, and was not identified at Minf. Therefore, it seems to have not affected significantly the remains. The marks produced by plants, mainly mosses, are very common in many stratigraphic units of the Abric Romaní rock-shelter (Cáceres, 2002; Fernández-Laso, 2010; Gabucio et al., 2016, 2017). These plants have relatively short roots able to colonize the bones. However, they do not produce displacements of the remains. Therefore, as was suggested by some preliminary works (Fernández-Laso et al., 2010, 2011; Chacón et al., 2014; Gabucio et al., 2017; Vaquero et al., 2017; Rosell et al., 2019), the bone assemblage of unit M (archaeoloevels M and Minf), was mainly consequence of anthropogenic activities, and the position of bone remains could be relatively similar to the original deposition made by the human groups.

The bone assemblage of Level M was mainly composed of *C. elaphus*, *E. ferus*, and in a lower proportion of *B. primigenius*. These animals are represented mainly by cranial (mainly mandibles and maxillae) and appendicular elements (mid-shafts fragments of proximal limb bones and, in lesser proportions, metapodials) from adult individuals. By contrast, axial and distal appendicular elements are scarce, mainly in the large-sized animals. The abundance of skeletal elements with high nutritional values (especially in bone marrow), the age of death (mainly prime-adults) and the significant number of cutmarks on the midshafts, suggest repeated primary and immediate accesses of the human groups to the carcasses (i.e. Binford, 1981; Blumenschine, 1988; Bunn and Ezzo, 1993; Capaldo, 1997; Domínguez-Rodrigo, 1999; Gaudzinski and Roebroeks, 2000; Domínguez-Rodrigo and Piqueras, 2003) and a transport of selected anatomical units (mainly heads and legs) from the kill/butchery place to the Abric Romaní in a similar way that observed in other Middle Palaeolithic sites (i.e. Farizy, 1994; Stiner, 1994, 2005; Gaudzinski, 1996; Gaudzinski and Roebroeks, 2000; Speth and Tchernov, 2001; Yeshurum et al., 2007; Speth, 2012; Salazar et al., 2013). After the consumption, the resulting assemblages are characterized mainly by fragments of midshafts, mandibles and maxilla (including isolated teeth) and the lack of fragments of axial elements (ribs and vertebrae). On the other hand, there is a regular disappearance of the limb-ends, which could be produced during the consumption sequences (smashing and exposition to fire), or by carnivores in later scavenger activities or, by a combination of both possibilities (Rosell et al., 2012a, 2012b, 2012c, 2019).

The anthropogenic activities related to meat and marrow consumption were carried out around the hearths (Vaquero and Pastó, 2001). This phenomenon contributes, in a significant way, to develop a spatial pattern characterized by the dominance of small elements (percussion notches, impact flakes and, numerous small fragments) around the fireplaces. In this regard, faunal assemblages from unit M do not differ excessively of those recovered in other stratigraphic units from this site, which could be suggesting a persistence in the region of groups with similar behavioral patterns regarding prey processing and its consumption, and spatial organization (Vallverdú et al., 2005; Fernández-Laso et al., 2010, 2011; Rosell et al., 2012a, 2012b, 2012c, 2019; Gabucio et al., 2016, 2017; Chacón et al., 2014; Modolo and Rosell, 2017; Vaquero et al., 2017).

At unit M, many of the identified faunal refits are a consequence of this high degree of bone breakage. In many cases, green fractures, impact notches and impact flakes were conjoined at short distances in the same hearth-related accumulation.

The amount of materials in these activity areas associated with different hearths (M1, M2, M5 y M6) suggest a recurrent organizational pattern, in which the different human events were developed repeatedly in the same spaces, and, therefore, forming significant palimpsests in all the areas.

The similarities and differences observed between accumulations could be used to infer some social and economic aspects of the human groups. These significant accumulations of faunal remains are associated with large – or medium – sized combustion structures in the inner and medial zones of both levels, especially in areas M1, M2, and M5. A high percentage of anthropogenic modifications related to carcass processing and consumption, may be observed in these assemblages. Short-distance refits, the most frequent in all the accumulations, are consequence of these activities: meat processing, bone breakage for marrow consumption, burning for cleaning or for fuel, etc. In this respect, all the accumulations can be considered as multifunctional hearth-related activity areas from a faunistic point of view. This idea is reinforced by the presence of multiple activities related to knapping in each area as well (Vaquero et al., 2017). Therefore, these activity areas could be considered independent of one another and, probably, without temporal relations between them. Both mean connection length and the percentage of long-distance refits suggest that lithics were more likely to be moved than bones (Vaquero et al., 2017). This was interpreted as the consequence of the recycling potential of lithic artefacts. In this context, the lithic refitting pattern would be clearly different from that of bone remains, which generally do not have such recycling potential. Nevertheless, some long-distance bone refits show connections from different activity areas. At this point it is important to recall that no taphonomic process able to displace fragments of bones between areas, has been recognized in the Abric Romaní beyond those produced anthropogenically with an intentional purpose. Therefore, it is possible to suggest a certain simultaneity in the use of different areas and zones of the rock-shelter, at least in the moment in which the movements of the refitted elements were produced.

M1 is one of the most significant accumulation in this aspect. In this area, 7 hearths have been identified (4 at the central part and 3 overlapped between them next to the wall). These last 3 hearths contain a short number of remains, which could be indicating a function related to non-productive activities, such as lighting or resting. In the other hearths, faunal remains show evidence of skinning, defleshing and bone breakage of large and medium-sized animals. Therefore, M1 can be considered a multifunctional area (Vaquero et al., 2017). On the other hand, M1 shows several connections with other areas by faunal refits: 3

faunal refits connecting this area with M2, M5 and M6: 1) M1 to M2, an anatomical refit of three consecutive juvenile horse teeth, where 2 of the 3 teeth included in this refitting are in M1; 2) M1 to M6, a refit of 2 fragments of femur of red deer showing green fractures; 3) and M1 to M5 and area without clustered remains, a refit is composed of 11 shaft fragments of a red deer tibia, with the longest connection identified in level M (869 cm). This refit contains different anthropogenic evidences: all fragments showing green breakage, 4 showing cutmarks, 7 burned, 2 with anthropic breakage, and 2 with abrasion water in a low degree. These refits show movements after intentional bone breakage related to marrow extraction. Thus, the most parsimonious hypothesis to explain this phenomenon is some contemporaneity of the respective activity areas, at least in the moment in which the movements were produced. These connections could thus be considered evidence of food sharing and suggesting that these activity areas were contemporaneous. Normally the sharing of food is established between anatomical units (Enloe, 2003; Todd and Frison, 1992). However, the practically generalized absence of epiphysis at Abric Romaní prevents to recognize this activity in the same way.

On the other hand, it is also difficult to infer the direction of the movements (from one area until the other one) without specific elements in the same way that it can be seen among lithic refits (cores *vs.* flakes) (Vaquero et al., 2015, 2017). The greater number of remains in M1 is not enough to suggest that these elements come out from M1 to M2 and M5. But if M1 is considered as the starting point of these movements, the mobility pattern showed by faunal refits is significantly different to this proposed from the lithic remains. Lithic refitting shows several long-distance connections between M1 and other accumulations. In all the cases in which the direction of the movement has been identified, accumulation M1 was the place of arrival. That is, artefacts were moved from these other accumulations to accumulation M1 (Vaquero et al., 2015, 2017).

In M2, 6 partially overlapped hearths have been identified. This accumulation is similar to M1. Anthropogenic activities are related with skinning, defleshing and bone breakage in large and medium-sized animals. Two bone refits show a connection of this area with M4 and M6: 1) one connects M2 to M6 (3 fragments of red deer metacarpal) and shows a distribution in which 2 remains are very close while the third is located at 277 cm and exhibits carnivore damage. This displacement could be a consequence of the actions of these animals; 2) the other refit (connecting M2 and M4) is formed by 2 diaphysis fragments of a large-sized animal. The connection distance is not long (163 cm) and could be interpreted as a consequence of anthropogenic breakage. In M2, we have observed that some refits are moving N-S (archaeological N-S) towards the area closest to the wall, where the largest remains are located. In this respect, these specific refits could be explained from cleaning activities. The orientation of these refits is opposite to level O, where the refits tend to connect archaeological E-W (Gabucio et al., 2017).

M5 is similar to M1 and M2. 6 hearths have been identified, 4 clustered hearths, and 2 overlapped. In this area skinning, viscera removal, defleshing and bone breakage activities on large and medium-sized ungulates can be identified. All the refits identified in this area are local, with the exception of a red deer tibia, described above, which are connected to M1. At M6, 3 hearths have been identified. Regarding developed activities, this area shows similar evidence than in M5: skinning, viscera removal, defleshing and breakage in all weight sized.

On the other hand, M3, M4 and M4inf show a scarce number of remains. As a result, these areas show a fragmented *chaine opératoire* related to faunal processes. With these evidences, this phenomenon could be interpreted in two ways: 1) they are independent areas that do not record all the activities because of the scarce number of items and, 2) they are complementary areas related to other accumulations, in this case, M1, M2 and M5. In any case, faunal refits suggest that, in certain periods of the formation of unit M, some areas could work simultaneously.

The accumulation M6inf can be considered an exception. This accumulation contains several burned remains. However, no hearths or traces of water streams capable of accumulating this significant amount of materials in this area have been identified. In this respect, it is possible that this area was used as a dump area of the waste and the resulting elements of cleaning. Similar areas were identified in other stratigraphic units of the Abric Romaní, such as Ja, L, and O (Gabucio et al., 2017; Rosell et al., 2012b, 2019; Fernández-Laso, 2010), and in other sites of the same period, such as Kebara Cave unit X, where faunal residues appeared on one hand in three accumulations in a dump areas close to de wall, and on the other hand in three accumulations further away from the wall (Speth et al., 2011).

From this perspective, four types of faunal refits at level M can be stablished: 1) refits with short distance with cremation, as a result of accidental or intentional deposition (fuel, cleaning), and/or sharing food; 2) refits with medium distance (120–200 cm) as a consequence of processing activities, mainly anthropogenic bone breakage and/or sharing food; 3) refits with long distance as a result of sharing food or eliminating waste like drop zone (Binford, 1978a, 1978b, 1983) and, 4) refits with variable distance as a consequence of other agents, such as movements generated by carnivores.

At Level M, most of the faunal refits can be used to reconstruct temporal relationship between activity areas. All accumulations are multifunctional areas with similar patterns as drop zones described by Binford (Binford, 1978a, 1978b, 1983), except M6inf, which might look more like a dumping area. In these areas the human groups developed activities related to subsistence strategies (production of lithic tools, processing, exploitation and consumption of animal carcasses, and vegetal resources). Each of these areas seems to have been used by small groups regarding the spatial requirements, and they operated in isolation or simultaneously with other areas, as some intentional displacements of materials seems to suggest. These features identified in multifunctional areas are common among hunters-gatherers in etnoarchaeological contexts (Yellen, 1977; Binford, 1983), and they are observed at archaeological sites, such as Pincevent and Verberie (France) (Enloe and David, 1989, 1992; Enloe et al., 1994) or in Paleoindian contexts (e.g., Todd and Frison, 1992; Rapson and Todd, 1992). Nonetheless, we stated that Level M was occupied in short-term interruptions, which may be due to the repeated seasonality during winter (Fernández-Laso et al., 2010), by small or large groups with complex spatial and social organization. Patterns of structured space and activity organization was documented at other Middle Palaeolithic sites such as Tor Faraj (Henry et al., 2004), Wallthertheim (Adler and Conard, 2005), Les Canalettes (Meignen, 1993) and Grotte Vaufrey (Rigaud and Geneste, 1988), Kebara (Speth et al., 2011) together to other archaeological levels at Abric Romaní (Gabucio et al., 2014, 2017; Modolo and Rosell, 2017; Rosell et al., 2012a, 2012c, 2012b, 2019). At Level M, human groups structured their activities around hearths, rearranged the space and showed clear evidence of fitting out the space distributing activities and resources.

In summary, these areas have been used by small groups regarding the spatial requirements, and they operated either isolated or simultaneously with other areas. Faunal refits can contribute to palaeoeconomic knowledge, with reconstruction of the different steps of faunal processing, consumption, food sharing and waste management. They can help in the identification of individual episodes and the interpretation of the different activities areas (temporal evidence of the different events in an archaeological assemblage), and provide approximate data on the occupational dynamics, such as the number of occupants and the intra-site mobility of the human groups on the occupation surface.

References

Adler, D.S., Conard, N.J., 2005. Tracking hominins during the last interglaciar complex in the Rhineland. In: Gamble, C., Porr, M. (Eds.), The hominid individual in context. Archaeological investigations of Lower and Middle Palaeolithic landscapes, locales

and artefacts. Routledge, London and New York, pp. 133–153.
Alperson-Afil, N., Sharon, G., Kislev, M., Melamed, Y., Zohar, I., Ashkenazi, S., Rabinovich, R., et al., 2009. Spatial organization of hominin activities at Gesher Benot Ya'aqov, Israel. Science 326, 1677–1680.
Andrews, Peter, Fernández Jalvo, Yolanda, 1997. Surface modifications of the Sima de los Huesos fossil humans. J. Hum. Evol. 33 (2/3), 191–216.
Arilla, M., Rosell, J., Blasco, R., 2019. Contributing to characterise wild predator behaviour: consumption pattern, spatial distribution and bone damage on ungulate carcasses consumed by red fox (*Vulpes vulpes*). Archaeol. Anthropol. Sci. 11 (5), 2271–2291.
Audouze, Francoise, Enloe, James G., 1997. High resolution archaeology at Verberie: limits and interpretations. World Archaeol. 29 (2), 195–207.
Bargalló, A., Gabucio, J., Rivals, F., 2016. Puzzling out palimpsest: testing an interdisciplinary study in level O of Abric Romaní. Quat. Int. 417, 51–65.
Behrensmeyer, A.K., 1978. Taphonomic and ecologic information from bone weathering. Paleobiology 4 (2), 150–162.
Binford, L.R., 1978a. Numamiut ethnoarchaeology. Academic Press, New York.
Binford, L.R., 1978b. Dimensional analysis of behavior and site structure: learning from an Eskimo hunting stand. Am. Antiq. 43, 330–361.
Binford, L.R., 1981. Bones. Ancient men and modern myths. Academic Press, New York.
Binford, L.R., 1983. In pursuit of the past. Decoding Archaeological Record. Thames and Hudson, London.
Blumenschine, R.J., 1988. An experimental model of the timing of hominid and carnivore influence on archaeological bone assemblages. J. Archaeol. Sci. 15, 483–502.
Blumenschine, Robert J., 1995. Percussion marks, tooth marks, and experimental determinations of the timing of hominid and carnivore access to long bones at FLK Zinjanthropus, Olduvai Gorge, Tanzania. J. Hum. Evol. 29, 21–51.
Blumenschine, R.J., Selvaggio, M., 1988. Percussion marks on bone surfaces as a new diagnostic of hominid behavior. Nature 333, 763–765.
Bökönyi, S., 1972. Zoological evidence for seasonal or permanent occupation of prehistoric settlements. In: Ucko, P.J., Tringham, R., Dimbleby, G.W. (Eds.), Man, settlement and urbanism. Duckworth, London, pp. 121–126.
Bromage, Timothy G., Boyde, Alan, 1984. Microscopic criteria for the determination of directionality cutmarks on bone. Am. J. Phys. Anthropol. 65, 359–366.
Bunn, Henry T., 1986. Patterns of skeletal representation and hominids subsistence activities at Olduvai Gorge, Tanzania, and Koobi Fora, Kenya. J. Hum. Evol. 15, 673–690.
Bunn, H.T., Ezzo, J.A., 1993. Hunting and scavenging by Plio-Pleistocene hominids: nutritional constraints, archaeological patterns, and behavioural implications. J. Archaeol. Sci. 20, 365–398.
Bunn, Henry, Harris, John W.K., Glynn, Isaac, Kaufulu, Zefe, Kroll, Ellen, Schick, Kathy, Toth, Nicolas, et al., 1980. FxJj50: An Early Pleistocene site in northern Kenya. World Archaeol. 12 (2), 109–136.
Burjachs, F., López-García, J.M., Allué, E., Blain, H.-A., Rivals, F., Bennàsar, M., Expósito, I., 2012. Palaeoecology of Neanderthals during Dansgaard-Oeschger cycles in northeastern Iberia (Abric Romaní): from regional to global scale. Quatern. Int. 247, 26–37.
Cáceres, I., 2002. Tafonomía de yacimientos antrópicos en karst. Complejo Galería (Sierra de Atapuerca, Burgos), Vanguard Cave (Gibraltar) y Abric Romaní (Capellades, Barcelona): Ph.D. Thesis, Universitat Rovira i Virgili, Tarragona.
Cahen, Daniel, Keeley, Lawrence H., Van Noten, F.L., Behm, Jeffery A., Busby, Colin I., Robert, C., Dunnell, Brian Hayden, et al., 1979. Stone tools, toolkits, and human behavior in prehistory. Curr. Anthropol. 20 (4), 661–682.
Capaldo, S.D., 1997. Experimental determinations of carcass processing by Plio-Pleistocene hominids and carnivores at FLK 22 (Zinjanthropus), Olduvai Gorge, Tanzania. J. Hum. Evol. 33 (5), 555–597.
Cahen, Daniel, Keeley, Lawrence H., 1980. Not less than two, not more than three. World Archaeol. 12 (2), 166–180.
Capaldo, D. Salvatore, Blumenschine, Robert J., 1994. A quantitative diagnosis of notches made by hammerstones percussion and carnivore gnawing on bovid long bones. Am. Antiq. 59 (4), 724–748.
Chacón, M.G., Bargalló, A., Gómez de Soler, B., Picin, A., Vaquero, M., Carbonell, E., 2013. Continuity or discontinuity of Neanderthal technological behaviours during MIS 3: Level M and O of the Abric Romaní site (Capellades, Spain). In: Pastoors, A., Auffermann, B. (Eds.), Pleistocene Foragers on the Iberian Peninsula: Their Culture and Environment. Festschrift in Honour of Gerd-Christian Weniger for his Sixtieth Birthday. Wissenschaftliche Schriften des Neanderthal Museums 7, Mettmann, pp. 101–129.
Chacón, M.G., Fernández-Laso, M.C., Florent, R., 2014. Comportements des populations néandertaliennes pendant le MIS 3 à l'Abric Romaní: les niveaux K, L et M. Variabiliré ou continuité? In: Jaubert, N., Fourment, N., Depaepe, P. (Eds.), Transitions, ruptures et continuité en Préhistoire. Actes du XXVIIe, Congrès préhistorique de France. Paléolithique et Mésolithique. vol. 2. Bull. Soc. Prehist. Fr, Paris, pp. 207–228.
Conard, N.J., Prindiville, T.J., Adler, D.S., 1998. Refitting bones and stones as a means of reconstruction middle Paleolithic subsistence in the Rhineland. In: Brugal, J.-P., Meignen, L., Patou-Mathis, M. (Eds.), Économie préhistorique: les comportaments de subsistance au Paléolithique. XVIIIe Rencontres Internationales d'Archéologie et d'Histoire d'Antibes. Sophia Antipolis. APDCA, pp. 273–590.
Domínguez-Rodrigo, M., 1999. Flesh availability and bone modification in carcasses consumed by lions. Paleogeogr. Paleoclimatol. Palaeoecol. 149, 373–388.
Domínguez-Rodrigo, Manuel, Piqueras, Ana, 2003. The use of tooth pits to identify carnivore taxa in tooth-marked archeofaunas and their relevance to reconstruct hominid carcass processing behaviours. J. Archaeol. Sci. 30, 1385–1391.
Emerson, A.M., 1993. The role of body part utility in small-scale hunting Ander two strategies of carcass recovery. University at Carbondal, Center for Archaeological Investigation, Southern Illinois, pp. 138–155.
Enloe, J.G., 1991. Subsistence organization in the Upper Paleolithic: Carcass refitting and food sharing at Pincevent. Ph.D. Thesis. University of New Mexico, México.
Enloe, J.G., 2003. Acquisition and processing of reindeer. The Paris Basin. BAR International Series 1144, Archaeopress, Oxford, pp. 23–31.
Enloe, J.G., 2012. Middle Paleolithic Spatial Analysis in Caves: discerning humans from hyenas at Arcy-sur-Cure, France. Int. J. Osteoarchael. 22, 591–602.
Enloe, J.G., David, F., 1989. Le remontage des os par individus: le partage du renne chez les Magdaléniens de Pincevent (La Grande Paroisse, Seine-et-Marine). Bull. Soc. Prehist. Fr. 86 (9), 275–281.
Enloe, J.G., David, F., 1992. Food sharing in the palaeolithic: carcass refitting at Pincevent. BAR International Series 578, Archaeopress, Oxford, pp. 296–299.
Enloe, James G., David, Francine, Hare, Timothy, 1994. Patterns of faunal processing at section 27 of Pincevent: the use of spatial analysis ant ethnoarchaeological data in the interpretation of archaeological site structure. J. Anthropol. Archaeol. 13, 105–124.
Fernández-Laso, M.C., 2010. Remontajes de restos faunísticos y relaciones entre áreas domésticas en los niveles K, L y M del Abric Romaní (Capellades, Barcelona, España). Ph.D. Thesis. Universitat Rovira i Virgili, Tarragona.
Fernández-Laso, M.C., Rivals, F., Rosell, J., 2010. Intra-site changes in seasonality and their consequences on the faunal assemblages from Abric Romaní (Middle Palaeolithic, Spain). Quaternaire 21, 155–163.
Farizy, C., 1994. Spatial patterning of middle palaeolithic sites. J. Anthropol. Archaeol. 13, 153–160.
Fernández-Laso, M. Cristina, Chacón, M.G., García-Antón, M.D., Rivals, F., 2011. Territorial mobility of Abric Romaní Level M Neanderthals groups (Capellades, Barcelona, Spain). In: Conard, Nicolas J., Ritcher, Jürgen (Eds.), Neanderthal lifeways, subsistence and technology: one hundred fifty years of Neanderthal study. Springer, New York, pp. 187–202.
Gabucio, J., Cáceres, I., Rivals, F., Bargalló, A., Rosell, J., Saladié, P., Vallverdú, J., Vaquero, M., Carbonell, E., 2016. Unraveling a Neanderthal palimpsest from a zooarchaeological and taphonomic perspective. Archaeol. Anthropol. Sci. 10 (1), 197–222.
Gabucio, Joana, Cáceres, Isabel, Rosell, Jordi, Saladié, Palmira, Vallverdu, Josep, 2014. From small bone fragments to Neanderthal activity areas: the case of Level O of the Abric Romaní (Capellades, Barcelona, Spain). Quat. Int. 330, 36–51.
Gabucio, J., Fernández-Laso, M.C., Rosell, J., 2017. Turning a rock shelter into a home. Neanderthal, use of space in Abric Romaní Levels M and O. Hist. Biol. 30 (6), 743–766.
Gaudzinski, S., 1996. On bovid assemblages and their consequences for the knowledge of subsistence in the Middle Palaeolithic. Proc. Prehist. Soc. 62, 19–39.
Gaudzinski, Sabine, Roebroeks, Wil, 2000. Adults only. Reindeer hunting at the Middle Palaeolithic site Salzgitter-Lebenstedt, Northern Germany. J. Hum. Evol. 38, 497–521.
Gómez de Soler, B., 2009. Àrees de captació, tecnologia lítica i estratègies d'aprovisionament de roques silícies en el nivell L de l'Abric Romaní (Capellades, Barcelona). Quad. Prehis. Catalana 17, 11–56.
Haynes, G., 1980. Evidence of carnivore gnawing on Pleistocene and recent mammalian bones. Paleobiology 6, 341–351.
Henry, Donald O, Hietala, Harold J., Rosen, Arlene M., Demidenko, Yuri E., Usik, Vitaly I., Armagan, Teresa L., 2004. Human behavioral organization in the Middle Paleolithic: Were Neanderthals different? Am. Anthropol. 106, 17–31.
Haynes, G., 1983. Frequencies of spiral and green-bone fractures on ungulate limb bones in modern surface assemblages. Am. Antiq. 48 (1), 102–114.
Henry, D.O., Hall, S.A., Hietala, H.J., Demidenko, Y.E., Usik, V.I., Rosen, A.M., Thomas, P.A., 1996. Middle Paleolithic behavioral organization: 1993 excavation of Tor Faraj, Southern Jordan. J. F. Archaeol. 23 (1), 31–53.
Henshaw, Anne S., 1999. Location and appropriation in the Arctic: an integrative zooarchaeological approach to historical Inuit household economies. J. Anthropol. Archaeol. 18, 79–118.
Hofman, Jack L., 1986. Vertical movement of artefacts in alluvial and stratified deposits. Curr. Anthropol. 27 (2), 163–171.
Hofman, J.L., 1992. Enloe putting the pieces together: introduction to refitting. BAR International Series 578. Archaeopress, Oxford, pp. 1–15.
Hovers, E., Malinsky-Buller, A., Goder-Goldberger, M., Ekshtain, R., 2011. Capturing a moment: identifying short-lived activity locations in Amud Cave, Israel. In: Le Tensorer, J.-M., Jagher, R., Otte, M. (Eds.), The Lower and Middle Palaeolithic in the Middle East and neighbouring regions. vol. 126. Basel Symposium (May 8–10, 2008), Liége, ERAUL, pp. 101–114.
Isaac, Glynn L., 1967. Toward the interpretation of occupation debris: some experiments and observations. Kroeber Anthropol. Soc. Paper 37, 31–57.
Johnson, Eileen, 1982. Paleoindian bone expediency tools: Lubbock Lake and Bonefire Shelter. Can. J. Anthropol. 2, 145–157.
Johnson, Eileen, Holliday, Vance T., 1989. Lubbock Lake: Late Quaternary studies on the southern High Plains, USA. J. Quat. Sci. https://doi.org/10.1002/jqs,3390040206.
Kroll, Ellen M., Isaac, Glynn, 1984. Configurations of artefacts and bones at early Pleistocene sites in East Africa. In: Hietala, Harold J. (Ed.), Intrasite spatial analysis in archaeology. Cambridge University Press, Cambridge, pp. 4–31.
Larson, Mary L., Ingbar, Eric E., 1992. Perspectives on refitting: critique and complementary approach. BAR International Series 578. Archaeopress, Oxford, pp. 151–162.
Lavachery, P., Cornelissen, E., 2000. Natural and cultural spatial patterning in the Late Holocene deposits of Shum Laka Rock shelter, Cameroon. J. F. Archaeol. 27 (2), 153–168.
Leroi-Gourhan, A., Brézillon, M., 1972. Fouilles de Pincevent. Essai d'analyse ethnographique d'un habitat magdalénien (la section 36). Gall. Préhist., 2 vols (VIIe Supplément).
Lyman, R. Lee, 1994. Vertebrate taphonomy. Cambridge University Press, Cambridge.

Lyman, R. Lee, 2008. (Zoo)Archaeological refitting a consideration of methods and analytical search radius. J. Anthropol. Res. 64, 229–248.
Mariezkurrena, Koro, 1983. Contribución al conocimiento del desarrollo de la dentición y el esqueleto postcraneal de *Cervus elaphus*. Munibe 35, 149–202.
Meignen, Liliane, 1993. L'abri des Canalettes. Un habitat moustérien sur les grands Causse (Nant, Aveyron). Fouilles 1980–1986. Monographie du CRA. Editions du CNRS, Paris.
Morin, Eugene, Tsanova, Tsenka, Sirakov, Nicolay, Rendu, William, Mallye, Jean-Baptiste, Lévêque, François, 2005. Bone refits in stratified deposits: testing the chronological grain at Saint-Césaire. J. Archaeol. Sci. 32, 1083–1098.
Modolo, M., Rosell, J., 2017. Reconstructing occupational models: bone refits in level I of Abric Romaní. Quat. Int. 435 (Part A), 180–194.
O'Connell, James F., 1987. Alyawara site structure and its archaeological implications. Am. Antiq. 52 (1), 74–108.
Pettitt, P.B., 1997. High resolution Neanderthals? Interpreting Middle Paleolithic intrasite spatial data. World Archaeol. 29 (2), 208–224.
Pickering, Travis R., Egeland, Charles P., 2006. Experimental patterns of hammerstone percussion damage on bones: implications for inferences of carcass processing by humans. J. Archaeol. Sci. 33, 459–469.
Potts, R., Shipman, P., 1981. Cutmarks made by stone tools on bones from Olduvai Gorge, Tanzania. Nature 291, 577–580.
Rapson, D.J., Todd, L.C., 1992. Conjoins, contemporaneity, and site structure: distributional analyses of the Bugas-Holding Site. BAR International Series 578. Archaeopress, Oxford, pp. 238–263.
Rigaud, J.-P., Geneste, J.-M., 1988. L'utilisation de l'espace dans la Grotte Vaufrey. In: Rigaud, J.-P., Geneste, J.-M. (Eds.), La Grotte Vaufrey: paléoenvironnement, chronologie, activités humaines. Mémoire de la Soc. Préhist. Fr, pp. 593–611.
Rosell, Jordi, Blasco, Ruth, 2009. Home sharing: carnivores in anthropogenic assemblages of the middle Pleistocene. J. Taphonomy 7 (4), 305–324.
Rosell, J., Blasco, R., Fernández-Laso, M.C., Vaquero, M., Carbonell, E., 2012a. Connecting areas: faunal refits as a diagnostic element to identify syncronicity in the Abric Romaní archaeological assemblages. Quat. Int. 225, 56–67.
Rosell, J., Cáceres, I., Blasco, R., Bennàsar, M., Bravo, P., Campeny, G., Esteban-Nadal, M., et al., 2012b. A zooarchaeological contribution to establish occupational patterns at level J of Abric Romaní (Barcelona, Spain). Quat. Int. 247, 69–84.
Rosell, J., Blasco, R., Huguet, R., Cáceres, I., Saladié, P., Rivals, F., Bennàsar, M., et al., 2012c. Occupational patterns and subsistence strategies in level J of Abric Romaní. In: Carbonell, E. (Ed.), High Resolution Archaeology and Neanderthal Behavior. Time and Space in Level J of Abric Romaní (Capellades, Spain). Springer, Dordrecht, pp. 313–372.
Rosell, J., Modesto-Mata, M., Fernández-Laso, M.C., Modolo, M., Blasco, R., 2019. Reffiting bones to reconstruct the diversity in middle paleolithic human occupations: the case of the Abric Romaní site (Capellades, Barcelona, Spain). Archaeol. Anthropol. Sci. 11, 4601–4619.
Salazar, Domingo C, Power, Robert C., Serra, Alffred Sanchís, Villaverde, Valentín, Walker, Michael J., Henry, Amanda G., 2013. Neanderthal diets in central and southeastern Mediterranean Iberia. Quart. Int. 319, 3–18.
Sañudo, P., 2007. Análisis espacial del nivel IV de la Cova del Bolomor (La Valldigna, Valencia). Hogares y áreas domésticas a inicios del Pleistoceno superior. Dissertation, Universidad Rovira i Virgili, Tarragona.
Sañudo, P., Vallverdú, J., Canals, A., 2012. Spatial patterns in Level J. In: Carbonell, E. (Ed.), High Resolution Archaeology and Neanderthal Behavior. Time and Space in Level J of Abric Romaní (Capellades, Spain). Springer, Dordrecht, pp. 47–76.
Selvaggio, Marie M., Wilder, Joseph, 2001. Identifying the involvement of multiple carnivore taxa with archaeological bone assemblages. J. Archaeol. Sci. 28, 465–470.
Sharp, Warren D., Mertz-Kraus, Regina, Vallverdú, Josep, Vaquero, Manuel, Burjachs, Francecs, Carbonell, Eudald, Bischoff, James L., 2016. Archeological deposits at Abric Romaní extend to 110ka: U-series dating of a newly cored, 30 meter-thick section. J. Archaeol. Sci. 5, 400–406.
Shipman, Pat, 1983. Early hominid lifestyle: hunting and gathering or foraging and scavenging? BAR International Series 163. Archaeopress, Oxford, pp. 31–49.
Shipman, Pat, Rose, Jennie, 1983. Early hominid hunting, butchering and carcass-processing behaviors: approaches to the fossil record. J. Anthropol. Archaeol. 2, 57–98.
Silver, I.A., 1969. La determinación de la edad en los animales domésticos. Ciencia en Arqueología, México.
Solé, A., Allué, E., Carbonell, E., 2013. Hearth-related wood remains from Abric Romaní layer M (Capellades, Spain). J. Anthropol. Res. 69, 535–559.
Speth, J.D., 2012. The paleoanthropology and archaeology of big-game hunting. Protein, fat, or politics? Interdisciplinary contributions to archaeology 58, Springer, New York and London.
Speth, John D., Meignen, Liliane, Bar-Yosef, Ofer, Goldberg, Paul, 2011. Spatial organization of Middle Paleolithic occupation X in Kebara Cave (Israel): Concentrations of animal bones. Quart. Int. 245, 85–102.
Speth, J.D., Tchernov, E., 2001. Neandertal hunting and meat-processing in the near East: Evidence from Kebara Cave (Israel). In: Stanford, C.B., Bunn, H.T. (Eds.), Meat-eating and human evolution. Oxford University Press, New York, pp. 52–72.
Stiner, Mary C., 1994. Honor among thieves: a zooarchaeological study of Neandertal ecology. Princeton University Press, Princeton.
Stiner, M.C., 2005. The Faunas of Hayonim Cave, Israel. A 200.000-year record of Paleolithic diet, demography and society. American School of Prehistoric Research Bulletin 48. Harvard University, Cambridge, MA.
Stiner, Mary C., Kuhn, Steven L., Weiner, Stephen, Bar-Yosef, Ofer, 1995. Differential burning, recrystallization, and fragmentation of archaeological bones. J. Archaeol. Sci. 22, 223–237.
Stringer, Christopher, Gamble, Clive, 1996. En Busca de los Neandertales. Crítica, Barcelona.
Todd, L.C., 1987. Taphonomy of The Horner II bone bed. In: Frison, G.C., Todd, L.C. (Eds.), The Horner Site: The type site of the cody cultural complex. Academy Press, Orlando, pp. 107–198.
Todd, L.C., Frison, G.C., 1992. Reassembly of bison skeletons from The Horner Site: A study in anatomical refitting. BAR International Series 578. Archaeopress, Oxford, pp. 63–82.
Vallverdú, J., Allué, E., Bischoff, J.L., Cáceres, I., Carbonell, E., Cebrià, A., García-Antón, M.D., 2005. Short occupations in the Middle Palaeolithic Level I of the Abric Romaní rock-shelter (Capellades, Barcelona, Spain). J. Hum. Evol. 48, 157–174.
Vallverdú, J., Vaquero, M., Cáceres, I., Allué, E., Rosell, J., Saladié, P., Chacón, M.G., et al., 2010. Sleeping activity area within the site structure of archaic human groups. Evidence from Abric Romaní Level N combustion activity areas. Curr. Anthropol. 51, 137–145.
Vallverdú, J., Gómez de Soler, B., Vaquero, M., Bischoff, J.L., 2012. The Abric Romaní Site and the Capellades Region. In: Carbonell, E. (Ed.), High Resolution Archaeology and Neanderthal Behavior. Time and Space in Level J of Abric Romaní (Capellades, Spain). Springer, Dordrecht, pp. 19–46.
Vaquero, Manuel, 2008. The history of stones: behavioural inferences and temporal resolution of an archaeological assemblage from the Middle Palaeolithic. J. Archaeol. Sci. 35, 3178–3185.
Vaquero, Manuel, Pastó, Ignasi, 2001. The definition of spatial units in Middle Palaeolithic sites: the hearth-related assemblages. J. Archaeol. Sci. 28, 1209–1220.
Vaquero, M., Vallverdú, J., Rosell, J., Pastó, I., Allué, E., 2001. Neandertal behaviour at the Middle Palaeolithic site of Abric Romaní, Capellades, Spain. J. F. Archaeol. 28, 93–114.
Vaquero, M., Chacón, M.G., Cuartero, F., García-Antón, M.D., Gómez de Soler, B., Martínez, K., 2012a. The lithic assemblage of Level J. In: Carbonell, E. (Ed.), High resolution archaeology and neanderthal behaviour. Time and space in Level J of Abric Romaní (Capellades, Spain). Springer, Dordrecht, pp. 189–311.
Vaquero, M., Chacón, M.G., García-Antón, M.D., Gómez de Soler, B., Martínez, K., Cuartero, F., 2012b. Time and space in the formation of lithic assemblages: the example of Abric Romaní Level J. Quatern. Int. 247, 162–181.
Vaquero, M., Chacón, M.G., Rando, J.M., 2007. The interpretative potential of lithic refits in a Middle Paleolithic site: the Abric Romaní (Capellades, Spain). BAR International Series 1596. Archaeopress, Oxford, pp. 75–89.
Vaquero, M., Allué, E., Bischoff, J.L., Burjachs, F., Vallverdú, J., 2013. Environmental, depositional and cultural changes in the Upper Pleistocene and Early Holocene: the *Cinglera del Capelló* sequence (Capellades, Spain). Quaternaire 24 (1), 49–64.
Vaquero, M., Bargalló, A., Chacón, M.G., Romagnoli, F., Sañudo, P., 2015. Lithic recycling in a Middle Paleolithic expedient context: evidence from the Abric Romaní (Capellades, Spain). Quat. Int. 361, 212–228.
Vaquero, M., Fernández-Laso, M.C., Chacón, M.G., Romagnoli, F., Rosell, J., Sañudo, P., 2017. Moving things: comparing lithic and bone refits from a Middle Paleolithic site. J. Anthropol. Archaeol. 48, 262–280.
Van Noten, F.L., Cahen, D., Keeley, L.H., Moeyersons, J., 1978. Les chasseurs de Meer, de Temple. Brugge.
Villa, Paola, 1982. Conjoinable pieces and site formation processes. Am. Antiq. 47, 276–290.
Villa, P., Bouville, C., Courtin, J., Helmer, D., Mahieu, E., Shipman, P., Belluomini, G., et al., 1986. Cannibalism in the Neolithic. Science 233, 431–437.
Villa, Paola, Mahieu, Eric, 1991. Breakage patterns of human long bones. J. Hum. Evol. 21, 27–48.
Villa, P., Soressi, M., 2000. Stone tools in carnivore sites: the case of Bois Roche. J. Anthropol. Res. 56, 187–215.
Waguespack, Nicole M., 2002. Caribou sharing and storage: refitting the Palangana site. J. Anthropol. Archaeol. 21, 396–417.
Yellen, John E., 1977. Archaeological approaches to the present: models for reconstructing the past. Academic Press, New York.
Yeshurum, R., Bar-Oz, G., Weinstein-Evron, M., 2007. Modern hunting behavior in the Early Middle Paleolithic: Faunal remains from Misliya Cave, Mount Carmel, Israel. J. Hum. Evol. 53, 656–677.