UNRAVELING A NEANDERTHAL PALIMPSEST FROM A ZOOARCHEOLOGICAL AND TAPHONOMIC PERSPECTIVE

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Abstract

Practically all archeological assemblages are palimpsests. In spite of the high temporal resolution of Abric Romaní site, level O, dated to around 55 ka, is not an exception. This paper focuses on a zooarcheological and taphonomic analysis of this level, paying special attention to spatial and temporal approaches. The main goal is to unravel the palimpsest at the finest possible level by using different methods and techniques, such as archeostratigraphy, anatomical and taxonomical identification, taphonomic analysis, faunal refits and tooth wear analysis. The results obtained are compared to ethnoarcheological data so as to interpret site structure. In addition, activities carried out over different time spans (from individual episodes to long-term behaviors) are detected, and their spatial extent is explored, allowing to do inferences on settlement dynamics. This leads us to discuss the temporal and spatial scales over which Neanderthals carried out different activities within the site, and how they can be studied through the archeological record.
Key words: spatial analysis, faunal refits, tooth microwear analysis, site structure, time spans, 

Abrid Romaní.

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1. Introduction

Cultural deposits are commonly the result of several occupational events that occurred in the same space, forming palimpsests. In addition, the material traces of these occupational events are usually deposited with remains of natural origin, and may be altered, partially destroyed or reworked as a result of a process of superimposition (Bailey 2007; Lucas 2005, 2012). Archeologists have confronted the challenge of interpreting palimpsests roughly in two main ways: 1) By attempting to dissect them into associations that are more finely resolved, focusing on individual episodes or events, or 2) By understanding the palimpsest as a whole and directing their research on long term behaviors.

On the one hand, individualizing accumulations derived from different events, by establishing diachronic and synchronic relationships between them, is a difficult task, especially when the palimpsest occurs not only vertically (overlapping at the same point) but also horizontally (different accumulations spread out spatially, some of them potentially contemporaneous). Consequently, dissecting palimpsests requires the use of different methods and techniques, such as archeostratigraphy, micromorphology, taphonomy, refits, mathematically based methods, etc. These studies have more frequently been conducted from technological and geoarcheological
approaches, and rarely the faunal remains have been considered. (Audouze and Enloe 1997; Enloe 2012; Vaquero et al. 2007, 2012a, b; Hovers et al. 2011; Carbonell 2012; Rosell et al. 2012; Machado et al. 2013; Machado and Pérez in press; Bargalló et al. in press).

On the other hand, interpreting palimpsests from a large-scale perspective requires researchers to work on a coarse temporal resolution, as defended by supporters of time perspectivism. Time perspectivism treats all archeological material records as palimpsests and asserts that there is a relationship between the time scale over which such records can be resolved and the types of research questions they can be used to answer (Bailey 2007; Holdaway and Wandsnider 2008). Some behavioural aspects may be archeological visible only if an activity occurs repeatedly at a specific place, and this cannot be studied from an event perspective.

There is controversy about the strengths and weakness of these approaches (Bailey 2007; Hovers 2011; Vaquero 2012a; Holdaway and Wandsnider 2008). However, both ways of dealing with palimpsests may actually converge, and it is possible to approach work on an assemblage from the perspectives of different time scales (Sewell 1996; Harding 2005; Vaquero et al. 2012a; Machado and Pérez in press).

This work focuses on the faunal assemblage of the Abric Romani level O. Level O, in spite of the high temporal resolution of Abric Romani, is obviously a palimpsest. This paper tries to find criteria for unraveling the palimpsest at the finest possible level through zooarcheological and taphonomic methods, including faunal refits and tooth microwear analyses. The patterns observed have been compared to ethnoarcheological data with the aim of interpreting the site structure. Finally, the temporal and spatial scales over which different Neanderthal activities occurred, and how they can be perceived from the archeological record, are considered.

2. The Abric Romani site

The Abric Romani site is a travertine rock shelter placed at 265 m a.s.l. in the town of Capellades (Barcelona, Spain), on the west bank of the Anoia River. In this location the valley forms a narrow gorge (“Congost de Capellades”) connecting the coastal plains (Vallés-Penedés basin) to the inland plains (Ebro basin) through the Prelitoral chain. Its strategic geographical
and geological position, at the crossroads of several ecosystems, offered prehistoric groups a
wide variety of resources.

The stratigraphic sequence was dated by radiocarbon analysis and U-series to between 40 and
70 ka BP (Bischoff et al. 1988) (Fig. 1), being recently expanded to reach 110 ky (Sharp et al.
2016). It is composed of several thin archeological levels (16 excavated thus far) separated by
thick sterile travertine platforms. This travertine platforms were formed rapidly (rate of
sedimentation of 0.46 mm/yr), providing high temporal resolution (Vallverdú et al. 2012b). All
the archeological layers belong to the Middle Paleolithic period except for level A, which is
associated with the Proto-aurignacian.

This high temporal resolution, combined with a field methodology based on extensive
evacuation (up to 300 m²) and the use of Cartesian coordinates, made it possible to study spatial
behaviors and settlement patterns. The sedimentary context also resulted in excellent
preservation of wood imprints and hearths (Vallverdú et al. 2012a; Solé et al. 2013). Hearths
have been used as a proxy in recognizing activity areas, along with the spatial distribution of
lithic and faunal remains (Vaquero and Pastó 2001; Carbonell 2012). Archeostratigraphy and
lithic and faunal refits were used to identify synchronic and diachronic patterns (Sañudo et al.

The remains analyzed for this study came from Level O and were excavated between 2004 and
2011, over an area of about 278 m². The level have been dated by U-series to 54.6 ± 0.4 ka
(Vallverdú 2012b; Vaquero et al. 2013). Over 40,000 remains were recovered and coordinated
(using Cartesian coordinates) from Level O, including lithic tools (23,399), faunal remains
(9299), wood imprints (109), pieces of charcoal, and other materials. Additionally, 63
combustion structures were documented.

3. Methods
3.1. Archeostratigraphy and distribution by sectors

In cultural deposits, there may be a vertical stratification of archeological items as a result of
different overlapping occupational events. In this context, archeostratigraphic analysis makes it
possible to identify the diachronic relationship between cultural deposits by delimiting
continuous sterile layers, which are indicative of times when there was no anthropic presence (Canals 1993; Chenorkian 1988).

A previous archeostratigraphic study defined the boundary between level O and levels N (top) and P (bottom) and explored the archeostratigraphic nature of level O by using the coordinates of all the archeological material available (Bargalló 2014; Gabucio and Bargalló 2012; Gabucio et al. 2012). Based on this previous study, this work analyzed the distribution of the faunal remains from Level O. Longitudinal, cross-sectional and oblique profiles, with a thickness of between 25 and 10 cm, were used. In the first stage, profiles were plotted across the entire surface, in order to identify the continuous sterile layers separating the different archeolevels. In the second stage, shorter profiles were plotted in those areas where a thinner sterile layer was detected separating different microlevels within an archeolevel.

Once the archeostratigraphic analysis had been made, the faunal remains of each archeolevel were plotted and divided horizontally into different sectors, based on the distribution observed. The objective of this division was to facilitate the identification of local accumulations of items related to specific events or activities. The boundaries of the sectors, although artificial, were determined using criteria such as the clustering of the remains, the slope, the location of the elements that could determine the space (rock shelter walls, hearths, etc.), and refitting connections.

3.2. Anatomical and taxonomic analysis

Faunal remains were analyzed both anatomically and taxonomically. Whenever possible, the laterality (left or right), the portion (relative to the length of the complete skeletal element), the side (cranial, lateral, caudal or medial) and the estimated age at death (based on criteria of tooth eruption, replacement and wear, and epiphysial fusion), were specified.

In order to include in the study bones that could not be identified taxonomically, all the remains have been grouped into weight sizes, based on a modification to the criteria proposed by Bunn (1986): 1) very small (< 20 kg); 2) small (20 - 100 kg); 3) medium (100-300 kg); 4) large (300 – 1000 kg). Likewise, bones that could not be identified at the anatomical level were classified.
into three categories: long bones (from limbs), flat bones (axial and cranial skeleton) and articular bones (carpals, tarsals, sesamoides).

On the basis of this identification, the assemblage was quantified by calculating the following: NSP (Number of Specimens), NISP (Number of Identified Specimens), MNE (Minimum Number of Elements), MNI (Minimum Number of Individuals) and % Skeletal Survival Rate (%SSR) (Brain 1981; Lyman 1994). The MNE was established using the overlap of landmarks and portions and taking into account criteria such as laterality, size, tooth wear pattern and refits (Saladié et al. 2011). The MNI was obtained from the skeletal element having the highest MNE for each taxon identified. Finally, we explored the distribution of the remains according their taxonomic group, anatomical element, region in the element and individual identified.

3.3. Analysis of bone modification

With respect to bone breakage, limb bones longer than 3 cm were analyzed based on Villa and Mahieu (1991) in order to establish the state of the bones (green or dry) when they were broken. The completeness of all the bone fragments relative to the complete skeletal element, both in length and in circumference, was also considered, adapting previous works (Bunn 1983). The causes of the fractures were investigated by analyzing the structural and surface damage, such as percussion pits, percussion notches, impact flakes, adhering flakes and peeling (Capaldo and Blumenschine 1994; Pickering and Egeland 2006; White 1992; Pickering et al. 2013).

Modifications to bone surfaces were observed using both macroscopic and microscopic techniques (Olympus SZ11 stereomicroscope and ESEM FEI QUANTA 600). Cut marks were analyzed in terms of their morphology (slice, scrape, chop or saw marks), location, distribution, and orientation in the bones (Binford 1981; Bromage and Boyde 1984; Noe-Nygaard 1989; Potts and Shipman 1981; Shipman 1983; Shipman and Rose 1983). Burn patterns were analyzed on the basis of the degrees proposed by Stiner et al. (1995). Non-anthropogenic alterations and processes, such as carnivore damage, water abrasion, plant activity, trampling and manganese oxide pigmentation, were also identified (Binford 1981; Lyman 1994; Shahack-Gross et al. 1997; Fernández López 2000; Cáceres 2002; Fernández-Jalvo and Andrews 2003; Blasco et al. 2008). The degree and location of all these alterations were recorded, as well as their sequence.
(by taking into account the overlap between them). Lastly, the distribution of the remains showing different alterations was also explored.

3.4. Tooth wear analysis

Microwear features of dental enamel were examined using a low magnification stereomicroscope on high-resolution epoxy casts of teeth following the cleansing, molding, casting, and examination protocol developed by Solounias and Semprebon (2002) and Semprebon et al. (2004). After cleaning, the occlusal surface of each specimen was molded using high-resolution silicone, and casts were created using clear epoxy resin. The casts were observed under incident light with a Zeiss Stemi 2000C stereomicroscope at 35× magnification, using the refractive properties of the transparent cast to reveal micro-features on the enamel. The number of microwear scars on the enamel (i.e. elongated scratches and rounded pits) within a surface area of 0.16 mm² was counted.

The method used to detect whether the assemblage is the result of multiple death events or a single one was based on assumed changes over time in the food resources available to the animals (Rivals et al. 2009a). Microwear patterns in herbivorous ungulates hunted by humans indicate differences between samples of animals hunted during a single season and those that were hunted over an entire year (or longer periods). The standard deviation (SD) and the coefficient of variation (CV) were used to evaluate the variation of the microwear pattern following the classification tool proposed by Rivals et al. (2015). The variability in the number of scratches permits to classify the sample and estimate the duration as short event, long-continued event, or two separated short events (Rivals et al. 2015). This method was applied to the teeth of *Bos primigenius*, *Equus ferus* and *Cervus elaphus* from archeolevel Ob. However, as only one individual of *C. elaphus* was well preserved enough to permit microwear analysis, the CV could not be calculated for this taxon. Likewise, the microwear data from level Oa cannot be reported or interpreted because the number of individuals that provided suitable teeth for microwear analysis is very low.

3.5. Faunal refits
Concerning faunal refits, the terminology proposed by Todd (1987), Todd and Stanford (1992) and Lyman (1994), and the methods developed by Fernández-Laso (2010) were followed. All the remains longer than 1 cm were taken into account. Two types of refits were observed: anatomical refits (i.e. dental series and articulated elements) and mechanical refits (conjoined fragments from the same broken element) (Lyman 1994). In all cases, the location of the remains of the same refit, the distances between them, and their taphonomic features were noted. In addition, the analysis of the mechanical refits included the state of the bone at the time of fracture (dry or green) and the origin of the fractures (anthropogenic percussion, fire, carnivore damage or post-depositional process). Faunal refits can provide very valuable information on taphonomic, behavioral and palaeoeconomic issues related to archeological assemblages (Enloe 1995; Fernández-Laso 2010), and also help us to infer the patterns of synchrony and diachrony in archeological palimpsests (Audouze and Enloe 1997; Rosell et al. 2012).

4. Results

4.1. Archeostratigraphy, elements that determine the space, and sectors

During the archeostratigraphic analysis, three different archeolevels were detected: Oa, Ob and Oc (Fig. 2). In turn, in the inner area, archeolevel Ob could be divided into two microlevels (Ob1 and Ob2), separated by a thin, discontinuous sterile layer. This classification into archeolevels and microlevels is the same as that observed through spatial analysis of the lithic remains (Bargalló 2014; Bargalló et al. in press).

Oa is the upper archeolevel. In most grid squares its thickness is less than 20 cm, although in some it can be more than 30 cm thick. This archeolevel shows a general slope towards the archeological SW (11.4º), and contains 486 faunal remains.

Ob is thicker (up to 55 cm), slopes more steeply (a SW slope of 12.92º) and contains more remains (8,615) than archeolevel Oa. As the separation into microlevels was only possible in some areas, all the data from archeolevel Ob will be presented together, although the microlevels will be taken into account in the interpretation.
The archeolevel Oc is not well preserved, with only five faunal remains clustered at two different points towards the archeological W of the rock shelter (grid squares T61 and P-R/58-59). In addition, there are 189 remains that could not be assigned to any archeolevel, because their coordinates are approximate or because they were located in a place where the Oa and Ob archeolevels were in contact, becoming indistinguishable in archeostratigraphic terms. This occurs in the SW area of the rock shelter, at some points around grid squares M-R/57-60. This work therefore focuses on the remains classified into archeolevels Oa and Ob.

A significant change in the extent and the distribution of faunal remains is observed between the Oa and Ob archeolevels (Fig. 3). This fact was conditioned by a change in both the depth and morphology of the rock shelter wall. Figure 3 shows the location of combustion structures, blocks, wood imprints and other elements that may have influenced how the Neanderthal groups used the space.

The horizontal surface of the Oa and Ob archeolevels was divided into different sectors: four in Oa (1, 2, 3, 4) and five in Ob (5, 6, 7, 8, 9). Figure 4 shows the distribution of these sectors.

### 4.2. Archeolevel Oa

#### 4.2.1. Anatomical and taxonomic analysis

Archeolevel Oa contains 486 faunal remains. Four taxa were identified: *Bos primigenius* (MNI = 3), *Equus ferus*, *Cervus elaphus* and *Oryctolagus cuniculus* (MNI= 1 for each) (Table 1). Among the remains classified into weight sizes, the medium and large animals are the best represented. Regarding skeletal identification, % SSR shows fairly low values in all the weight groups (Fig.5). In general terms, cranial and limb bones are the most common; axial elements, carpals and tarsals are scarcer; and no phalanges were identified.

The remains of *B. primigenius*, clearly dominated by the proximal appendicular skeleton, tended to be clustered towards the archeological E, especially in sector 1 (Fig.6). All the elements located in sectors 1 and 2 are from the proximal appendicular skeleton, including the right tibiae from three different adult individuals. Instead, two metapodial and one maxilla were recovered from the outermost area (sectors 3 and 4).
In contrast, the elements identified as from *E. ferus, C. elaphus* and *O. cuniculus* do not show any clear pattern. Two tibiae (one right and the other left; sectors 1 and 4), one hemimandible (with M1-M3 teeth, sector 3) and one isolated tooth (PM2 inf., sector 3) were identified as horse (Fig.6). Deer remains were found distributed throughout all the archeolevel and are grouped into cranial (mandible) and limb elements (Fig. 6). The leporid elements are isolated teeth, one coxal and one calcaneus. This taxon is present in all the sectors except in sector 1 (Fig.6). However, some bones from a very small sized animal that was not identified were recovered in this sector. Remains that could not be taxonomically identified, which were classified into large and medium weight groups, were found distributed over the entire surface.

4.2.2. Structural and surface modification

The results of this section are summarized in table 2 and in figures 7 and 8. All the remains from archeolevel Oa were broken, except for an articular bone of a medium-sized animal. In most cases, each fragment represents less than ⅕ of the length and ¼ of the circumference of the complete skeletal element. Among long bones over 3 cm, most of the fractures seen are curved, oblique and smooth indicating green-bone breakage. Likewise, 33.3% of the material shows structural damage related to intentional bone breakage, highlighting the number of impact flakes. This percentage varies widely across sectors, being higher in sectors 2, 1 and 4, and lower in sector 3. Within sector 1, structural damage seems to be clustered at two points. The elements affected are mainly the long bones of large- and medium-sized animals.

Cut marks were identified on 31 bones (6.4%), being more frequent in sectors 1 and 3. Most of them are slices, although saw marks and chop marks were also detected. There are cut marks on aurochs, deer, large- and medium-sized animals and unidentified remains. Cut marks were usually found on diaphyses and metaphyses of proximal appendicular bones from large- and medium-sized animals, and were mainly related to defleshing activities. Some marks, however have been associated with skinning (on metapodials, sectors 1 and 3) or viscera removal (on the internal side of a rib, sector 4).

Modification by burning affects 43% of the assemblage. The percentage is highest in sector 1, followed by sectors 3, 2 and 4. Low and moderate degrees of burning (partially or totally
rubefacted or charred) are prevalent, whereas high degrees of burning (partially or totally calcined) are rare, and are absent in sectors 3 and 4. The distribution of burned remains is linked to the locations of hearths: all the fully calcined remains were found inside combustion structures, and the other burned remains tend to be near them, being within or close to hearths (Fig. 3 and 7). Nevertheless, some burned remains were recovered some meters away from the nearest combustion structure in sectors 1 and 4.

Tooth marks and rodent gnawing are scarce (0.6% and 3.1%, respectively) and affect remains recovered towards the archeological E. Rounded and polished surfaces caused by water activity are quite common in Oa (42% and 23.3% respectively), although most items show and initial degree. Sectors 4 and 2 show the highest rates, but rounding is more frequent in sector 4 and polishing in sector 2. Modifications caused by plant activity were also frequently found (33.1%). Cementation is present in 46.5% of the assemblage, reaching 67.1% in sector 4, although this alteration generally covers a small part of the remains. Cracking (28%) is also especially abundant in sector 4. Finally, trampling and manganese oxide pigmentation were less scarcer. More information related to non-anthropogenic taphonomic alterations is available as supplementary information (Online Resource).

4.2.3. Refits

In archeolevel Oa, 12 refits were identified, grouping 31 remains connected by 17 lines (refitting rate of 6.38%). Data related to these refits are summarized in table 3 and represented in figure 9. Most refitting groups are made up of only two remains, but one refit connects three remains and another four remains. Most refits were separated by less than 50 cm (66.67%). Consequently, refits are generally local.

Only one group was identified at the taxonomical and anatomical level: a tibia of *B. primigenius*. The connecting line, which crosses sector 1 from side to side, is the longest in Oa (5.30 m). The other refits involve long bones from large- or medium-sized animals and unidentified remains.

All the refits are mechanical. Two refitting groups, connected by a considerable distance, were broken when green: the refit identified as a tibia of *B. primigenius* and other refit connecting
two impact flakes of a long bone from a large-sized animal. Both show evidence of intentional
breakage by percussion. In addition, there are cut marks on a fragment of the tibia.

The other refitted remains have been fitted together at points where dry fractures occurred. In
most cases, these are burned remains that were fractured by the action of fire or by post-
depositional agents acting after it, and in general were found very short distances apart.

Nevertheless, in the outermost area (sectors 3 and 4) there are two mechanical refits related to
dry-bone breakage with connecting lines over 1 m long. In both cases, the refitted remains
located furthest from the wall of the rock shelter seem have been moved from locations further
north by gravitational or post-depositional movements.

There is no evidence of carnivore activity on refitted bones. Other natural taphonomic
modifications are, however, present (see the supplementary information in Online Resource).

For instance, one fragment of the aurochs tibia (grid square T43) show rodent marks, and the
other (grid square T48) has abraded surfaces.

4.3. Sublevel Ob

4.3.1. Anatomical and taxonomic analysis

There are 8,615 faunal remains in archeolevel Ob. *C. elaphus*, *B. primigenius* and *E. ferus* are
the taxa with the highest MNI (3 adults and 1 immature of each), followed by *O. cuniculus* and
*S. hemitoechus* (Table 4). The other identified taxa, listed below, are each represented by only
one adult: *Ursus sp.*, *Rupicapra sp.*, *Felis silvestris* and an unidentified bird. Very few remains
were found of *Ursus sp.*, *Rupicapra sp.* or the birds. In contrast, the wildcat is represented by an
almost-complete skeleton (Gabucio et al. 2014a).

Of the remains classified into sizes by weight, medium and large animals are best represented.
The % SSR calculated for these weight categories indicates that cranial and proximal
appendicular skeletons are the best represented, whereas few remains of the axial skeleton,
basipodial bones or phalanges were found (Fig. 10). The remains classified into weight size
groups were found scattered all over the surface.

*S. hemitoechus*, although scarce, is present in all the sectors (Fig. 11). Almost all the remains are
teeth (a mandible containing M2 and M3, some isolated teeth and some dental fragments),
although a carpal bone was also identified in sector 5. Some of the teeth recovered from sectors 7 and 8 belonged to an immature individual, and the other remains to an adult individual.

The remains of *B. primigenius* are scattered throughout all the sectors except sector 5 (Fig. 11). Isolated teeth were quite common, and an accumulation of fragmented teeth in grid squares W52-53 should be especially noted. Limb bones were also abundant. Interestingly, all the remains from sector 6 for which laterality could be indicated are left, including four fragments of tibia that belonged to at least two different adult individuals. In sector 8, however – where a greater variety of skeletal elements was found – right laterality clearly dominate, especially among limb elements. Teeth provided the highest MNI value for *B. primigenius* (Table 4). Teeth that appear to come from the same individual (an adult significantly smaller than the two other adult individuals) were recovered from three different sectors: 6, 7 and 8 (Fig. 11). All the teeth assigned to the other two adult individuals, however, were found in a cluster in sector 8. Lastly, fragments of immature teeth were found throughout the whole of the area. Tooth microwear analysis indicates a high variability in the numbers of scratches (Table 5).

*E. ferus* is present in all the sectors (Fig. 11). The items most commonly found were isolated teeth and dental fragments, especially in sector 7. Teeth also provided the highest MNI value for *E. ferus* (Table 4). The remains associated with each adult individual were located in different sectors: 6 (an isolated tooth), 7 (three isolated teeth, two of them refitted) and 9 (an isolated tooth) (Fig. 11). The tooth (dP4 sup) which made it possible to determine the approximate age of the juvenile individual (between 2.5 and 3.5) was recovered from sector 6, although fragments of deciduous teeth and germs of permanent teeth were also found in sector 7. Tooth microwear analysis gave a very low CV and SD for the number of scratches (Table 5).

As for *C. elaphus*, it was identified in all the sectors (Fig. 11). This taxon is represented by a wide range of skeletal elements, although appendicular ones were most commonly found. Many teeth were also recovered, and the accumulation of dental fragments in the inner area of sector 7 should be highlighted. In this taxon, the element with the highest MNE and MNI is the left tibia. It is curious that three tibiae from three different adult individuals were clustered in sector 8, whereas the tibia of an immature individual was recovered from sector 7. Other immature
remains (teeth and metapodials) were distributed throughout sectors 6, 7, 8 and 9. The presence of different elements, such as the right tibia and the left femur, also points to an accumulation of different adult individuals in sector 8.

Remains of *O. cuniclus* were present in all the sectors (Fig. 11), including a wide variety of different elements. The left humerus provided the highest MNI. The humeri of two of these individuals were located in an accumulation in the outermost area of sector 6. Other elements, such as the right tibia, also indicate that there were two adult individuals in the same accumulation.

Unlike previous analyzed taxa, *F. silvestris* was found concentrated within a 5 m² area in sector 9 (Fig. 11). All its remains belonged to a single, nearly complete adult individual (Gabucio et al. 2014a). In general terms, proximal appendicular elements were more widely dispersed than the other skeletal elements.

Bird remains were found clustered in two points: three remains (humerus, radius and ulna) in sector 6, grid squares R-S/42; and two remains (a femur and a long bone) in sector 8 (Fig. 11). The remaining taxa, *Ursus* sp. and *Rupicapra* sp., were recovered from sector 8. Taking into account the size, the laterality (one right and the other left) and the wear use (very similar in both), the two remains of bear (two canines) seem to have come from the same individual.

4.3.2. Structural and surface modification

The observed modifications are shown in table 6 and figures 12 and 13. Only 44 remains from archeolevel Ob are whole elements, 39 of which have been identified as *F. silvestris*. Almost all the remains represent less than \( \frac{1}{5} \) of the length and \( \frac{1}{4} \) of the circumference of the complete skeletal element. As a consequence, 59.4 % of the items are no more than 2 cm long and only 5.5% over 5 cm. However, these percentages fluctuate from one sector to another. An analysis of the fractures indicates that long bones of over 3 cm were mostly broken when green.

Moreover, several remains (15.8%) show structural damage related to intentional bone breakage, especially impact flakes. The damaged elements are mainly the long bones of large- and medium-sized animals. This modification was most frequently found in sectors 6 and 8, although no specific accumulations were observed.
Of the remains, 4.9% present cut marks. The taxonomic groups that show cut marks are *B. primigenius*, *E. fera*, *C. elaphus*, *F. silvestris*, all the weight size categories and the unidentified bones. Slicing marks were most frequently observed, although scrape marks, saw marks and chop marks are also present. Most of them, located on the diaphyses and metaphyses of limb bones found in all the taxonomic groups, were made accidentally during defleshing activities (all the sectors). Other marks may be related to skinning (sectors 7, 8 and 9), disarticulation (8), or removing the viscera (6 and 7), tongue (6, 7 and 8) or periosteum and fat (6, 7 and 8). Bones with cut marks were found distributed across the surface, and no underlying taxa-based pattern has been observed (except for the felid, clustered in sector 9) (Fig. 12).

Burning affected over half of the remains from archeolevel Ob (55.2%). However, the number of burned remains found, as well as the degree of burning, was different for each sector. Thus, sectors 5 and 7 show a very high percentage of burned remains (> 70%), although in sector 5 low and moderate degrees of burning predominate, while in sector 7 calcined remains predominate. The burned remains include elements from all anatomical segments and taxonomic categories, except *Ursus* sp., *Rupicapra* sp. and birds. Burned bones tend to cluster inside hearths. This is especially true of those that were most severely burnt. However some burned remains, including a few calcined items, were recovered at some distance from the nearest hearth. These remains were usually found towards the archeological S-SW of a hearth (following the slope).

In general, non-anthropogenic modifications are rarer in Ob than in Oa and show a low degree of alteration (see supplementary information in Online Resource). Very little evidence of carnivore activity was found in Ob (0.4 %), and modifications by rodents were even scarcer (0.1%). However, it should be noted that, in the archeological SE of sector 6, an accumulation of faunal remains contains two ravaged bones, a digested bone and three other bones with rodent marks. Regarding plant (18.4%) and water (rounding: 19.76%, polishing: 14.76%) activity, cementation (13.5%), cracking (17.06%) and manganese oxide pigmentation (7.6%), the percentage of altered remains fluctuates substantially by sectors, being generally more abundant in the outermost ones and scarcer in sector 7.
4.3.3. Refits

The refits identified in archeolevel Ob are presented in table 7 and in figure 14. A total of 131 refits were detected, grouping 305 remains connected by 204 lines (refitting rate of 3.5%). All the sectors contained remains that have been refitted, although refitted items are proportionally more frequent in sector 5. Most of the refitting groups contain only two remains, but there are groups with three, four, six, seven and even thirteen remains. Although connection lines are generally short, in some cases they are pretty long. The maximum distance is almost 17 m, and connects sectors 6 and 8. This refit is made up of two fragments of a lower M3 from an aurochs, which was fractured when green.

There are refits taxonomically identified as S. hemitoechus (1 refit), B. primigenius (7), E. ferus (4), C. elaphus (13), F. silvestris (3) and O. cuniculus (2). The other refitting groups are classified into weight size groups or remain unidentified. In general terms, the refitted remains of large animals are connected by longer distances than those of smaller animals. On the basis of anatomical identification, elements from all skeletal segments have been refitted, although limb and cranial (especially teeth) ones were the commonest and usually connected over longer distances.

Only 8 refits are anatomical. Of these, three connect consecutive teeth that fit each other (two of the refits were deer and one was horse – sectors 5, 7 and 8). The other five connect articulated appendicular elements from rabbit and wildcat (sectors 6 and 9). Most refits are mechanical. Some of them connect at fractures caused when the remains were green, whereas others are related to bones broken when dry. Unfortunately, in 6 cases, the state of the bone at the time of the breakage could not be determined. Generally, mechanical refits broken when green tend to connect over longer distances than mechanical refits broken when dry and anatomical refits. The mechanical refits will now be explained in more detail.

On the one hand, 40 refits had been broken when green, and these were most commonly found in sector 8. Most of them correspond to long bones from medium-sized or large animals. However, some refitted flat bones, such as mandibles, had also been broken when green.

Thirteen refits broken when green may be directly related to intentional bone breakage by
humans, since evidence of this activity (especially impact flakes and percussion notches) has been identified on these bones. In addition, six refitting groups of this type show cut marks, and signs of burning are commonly seen on them. In contrast, only one refitting group broken when green has puncture marks caused by carnivore ravaging. Although there are groups for which the remains show different taphonomic alterations, natural processes cannot explain the longest connection lines.

On the other hand, 75 refitting groups connect through fractures made when the bones were already in the dry state. Most of these refits have been burned, with combinations of 3, 4 and 5 degrees of burning visible on opposite sides, as occurred in Oa. It seems that many of these remains were burned after having been deposited, and were broken by fire or by other post-depositional processes which took place after burning. Even though refits broken when dry are normally joined by short connection lines, in five cases the distance exceeds 1 m. Three of these were located in sector 6 and, taking into account the presence of burned remains outside the hearths and the general slope, it appears that one or both of the refitted remains of each group could have been moved locally towards the archeological S or S-W by gravity or post-depositional processes. In the two cases located in sector 7, however, there are no criteria to explain the distance between the refitted remains.

Refits also made it possible to detect local movements in sector 8. In this case, however, displacements were not only horizontal but also vertical, connecting both microlevels. Thus, eleven refits connect remains from Ob1 (ten from sector 8, one bone from sector 7) with others from Ob2 (all from sector 8).

5. Discussion

Evidence of anthropogenic activity is very abundant in both archeolevels Oa and Ob. Taxonomy, age at death, skeletal part representation, location of cut marks, breakage pattern and burn damage all point to Neanderthals having primary and immediate access to the animals and then intensively exploiting their carcasses (Bunn and Ezzo 1993). In addition, hunting appears to have been primarily focused on aurochs, horses and deer.
This study made it possible to identify some of the activities that Neanderthals carried out inside the rock shelter with respect to these animals. In the following sections, the intrasite organization of these activities and their spatiotemporal frameworks are discussed. Before that, however, it is important to consider the post-depositional taphonomic alterations that modified and even moved some faunal remains. Regarding this, detailed data is available as supplementary information (Online Resource). Below we are only providing the main results that allow us to address the interpretation of Neanderthal spatial behavior.

In both archeolevels, Oa and Ob, carnivore activity is anecdotal, discouraging from thinking in these animals as important taphonomic accumulators and modificators. Only the accumulation observed in sector 6 (Ob), and possibly the introduction of mesovertebrates, can be related a priori to carnivores. Post-depositional modifications are clearly more frequent in Oa than in Ob, being especially scarcer in sector 7, the innermost one of Ob (the area more protected by the rock shelter cornice). Water abrasion, plant activity and cementation are the more common alterations, although the reached degree is normally low. The presence of modifications produced by plants (surely mosses), as well as the overlapping of some alterations would more probably be related to a delay in burial (more pronounced and evident in Oa) than to a reelaboration process. The proximity of the rock shelter wall, the limit of the rock shelter cornice, the slope and the vegetation coverage all seem to have contributed to determining the distribution of the remains affected by post-deposition alterations. There are evidences suggesting that some materials were moved in both archeolevels (distance between few refitted fragments broken in dry, some burned remains found away from heath, and few remains very rounded). However, these displacements, probably related to occasional water flows and gravitational movements, were local (generally very short distances, and when longer not exceeding 3m). The water flows were surely related to an upwelling of water, the drip line of the cornice and its associated paleochannel (Gabucio and Bargalló 2012). Vertical movements of material have also been detected, but exclusively in sector 8 (Ob), mainly through the identification of refits between Ob1 and Ob2 (see suppelementary information). In consequence, we think that results allow us to do inferences on Neanderthal spatial behavior from the faunal
remains of level O. Nevertheless, as far as sector 8 is concerned, the exact location of the remains, their classification into microlevels and the distance between the refitted pieces should be approached with great caution.

5.1. Site structure: recognizing different activity areas

Inferring human spatial behavior from site structure is one of the main goals of Paleolithic Archeology. Ethnoarcheology offers the most extensive and useful framework for recognizing and understanding the dynamics of past human behavior. Ethnoarcheological works have defined different occupation sites (Binford 1978, 1980), including camp sites, which are understood to be places where people grouped in domestic units lived and conducted most of their activities (Gamble and Boismier 1991; Kent 1987; Kroll and Price 1991; O’Connell 1987; Yellen 1977). The spatial distribution of remains in camp sites is usually related to different activity areas, such as domestic activity areas (each area where a domestic unit lived and performed most of their daily tasks), communal activity areas (where collective activities take place) and special activity areas (where specific occasional tasks, which cannot be comfortably performed in domestic areas, were carried out) (Vaquero 2013). Other location-related activities, such as waste management, will also have determined the distribution of the remains. Recognizing site structure in a Paleolithic site is, however, problematic. Most, if not all, of the archeological assemblages are palimpsests, i.e. the result of overlapping activities difficult to distinguish. Moreover, the process of superimposition may alter, move and even destroy the material traces of these activities (Bailey 2007; Lucas 2005, 2012). The temporal discrepancy between ethnoarcheologically observed behavior and archeologically recovered accumulations greatly hinders the interpretation of the archeological record, including site structure. Nevertheless, several authors have proposed different methods and techniques to achieve this objective. These include mathematically based methods (such as density and contour plots, K-means, clustering and chi-squared analysis) and several analytic techniques (Archeostratigraphy, Taphonomy, Micromorphology, lithic and faunal refits…) (Binford 1988; Enloe et al. 1994; Audouze and Enloe 1997; Enloe 2012.; Vaquero and Pastó 2001; Vaquero et al. 2007, 2012a; Carbonell 2012; Rosell et al. 2012; Machado et al. 2013).
Some of these methods and techniques have been applied to the faunal assemblage recovered from Abric Romani level O. The results obtained, in conjunction with the location of structural elements and the data available from previous studies, have been used to interpret the site structure of level O. Of course, what follows is an approximation based only on faunal remains and conclusions drawn here should be tested in the future by adding results obtained from other disciplines.

Several pieces of evidence indicate that level O was used primarily as a camp site. The fact that in both archeolevels roasting, marrow removal and eating took place inside the rock shelter, as well as the abundance of the most nutritional elements, is consistent with this assumption. In addition, some of the activity areas that have been described as most characteristic of camp sites may be distinguished in Oa and Ob.

As far as Oa is concerned, the inner area shows the highest rates of anthropogenic modified remains and the greatest variation in human activities related to carcass processing and consuming. For instance, sectors 1 and 2 show more remains less than 2 cm long, and a higher rate of intentional bone breakage products. Moreover, if % SSR is calculated by sectors, sector 1 shows the highest rate for the proximal appendicular and metapodial elements, which are rich in marrow. Cut marked and burned bones are also more abundant in the inner area, especially in sector 1. The degrees of burning identified match with those ethnoarcheologically linked to cooking activities (Hayden 1981; Gifford-Gonzalez 1989a).

Most of these remains which were anthropogenically altered are small bone fragments (such as burned remains and percussion products), which tend to remain in the place where they were originally produced (Binford 1978; Gifford 1980; Schiffer 1983; Enloe et al. 1994).

Consequently, roasting, defleshing and bone breakage appear to have occurred primarily in this inner zone, suggesting its use as a domestic area. The presence of several hammerstones supports this suggestion (Bargalló 2014). In this context, it is possible that the numerous blocks documented in this sector were moved or at least used by Neanderthals. Likewise, the longest wood imprint related to Oa (Fig. 3) may have been used to increase the habitability of the rock shelter.
The domestic activity area documented in sector 1 was organized mainly around the medium-sized combustion structures XI and XII (Fig. 3). It is possible that each hearth was associated with a distinct domestic area whose boundaries are now difficult to delimit. One refit related to green-bone breakage connecting the two hearths (Fig. 8) would suggest that both hearths would have been active at the same time (Rapson and Todd 1992; Rosell et al. 2012). However, at the moment we cannot assure that the bones were deposited when both hearths were active. Besides this, the rounded surfaces of one of the refitted remains (the one close to hearth XII) might indicate that it was moved by water.

In contrast, in sector 2 it is only the abundance of impact flakes that stands out, suggesting that this was a more marginal and/or specialized activity area. Three small combustion structures are linked to this sector: XIII, XIV and XV (Fig. 3). The distance between each hearth (from 1 to 1.5 m) is similar to that observed ethnoarcheologically in resting and sleeping activity areas (Vallverdú et al. 2012a). Hearth IX (sector 3) has been also previously related to this type of activity area, suggesting that its rectangular shape and large surface would be the result of the reuse of several small hearths spaced about one meter apart (Vallverdú et al. 2012a). Moreover, this large hearth contained practically no artifacts, another characteristic of sleeping and resting areas (Vallverdú et al. 2012a). Another possibility is that sector 3 was used as a communal area.

Finally, the low rate of anthropogenic modifications in sector 4 suggests that this area was used more sporadically or for specific uses that have not generated sufficient evidence, such as the initial processing of carcasses.

Regarding archeolevel Ob, the highest number of remains and the widest variation in human activities have also been detected in the innermost sectors: 6, 7 and 8. Sectors 6 and 8 were occupied by domestic areas where roasting and bone breakage took place in situ. This latter activity is also indicated out by the abundance of hammerstones (Bargalló 2014) and mechanical refits broken when green, especially in sector 8. In sector 6, the smallest remains tend to cluster in and near the hearths AR06-1, on the one hand, and between hearths AR07-2, AR07-6 and AR07-7, on the other hand (Fig. 3). In contrast, there are larger remains
approximately one meter to the archeological S of the hearths. This distribution resembles the drop and toss zones proposed by Binford (1978).

This type of distribution has not been observed in sector 8, possibly for two reasons: a) this sector was the area most repeatedly and intensively occupied by Neanderthals, and the overlapping of different occupational events would have masked the original distribution, and b) the remains of this sector have suffered vertical and horizontal post-depositional movements (see supplementary information in Online Resource). However, a high number of large remains were recovered from the zone between sectors 7 and 8. The higher density of remains and the refits with other sectors (6, 7 and 9; Table 9, Fig. 13) suggest that sector 8 dominated the others. Lastly, it should be noted that the wood imprints flanking sector 8 might indicate the presence of anthropogenic structures for delimiting the space (Fig. 3) (Bargalló 2014).

Sector 7 shows evidence of some activities commonly documented in domestic areas, such as roasting or in situ bone breakage. Nevertheless, the singular nature of some of the activities identified in this sector suggests a specialized use of the central innermost area of the rock shelter. The best example is the accumulation of calcined remains in combustion structure AR06-07-10-11/1, around grid squares V/52-53. These calcined bones were recovered from both microlevels but mainly from Ob2. As bones have to be directly exposed to flame to be completely calcined (Mentzer 2009), two complementary hypothesis were proposed to explain this accumulation: a) a complementary use of bones as fuel, and b) the presence of a systematic cleaning area where waste was habitually incinerated (Gabucio et al. 2014b; Chacón et al. 2015). The latter possibility would indicate the existence of a post-hoc zone in this sector (Schiffer 1972).

Also in sector 7, a little closer to the wall, an accumulation of tooth fragments was found. Most of them had been burned to a low degree and seem have been broken when green. This fact, together with the presence of small products of breakage by percussion, such as impact flakes, suggests that Neanderthals had been breaking mandibles and other bones there. The fact that an anvil and two hammerstones were recovered from this area reinforces this assumption.
Furthermore, neither the hammer nor the anvil show percussion marks, suggesting that were not used for lithic production, but for processing fauna (Bargalló 2014).

In contrast, the low density of remains and the results of the analysis indicate that sectors 5 and 9 were the location of occasional or unusual activities. Probably, these marginal zones, in the outermost part of the rock shelter and some distance from activity areas, were used as communal or special areas. It is also possible that they were occupied during short and specific occupations.

In sector 5, a significant amount of the remains were identified as *C. elaphus*. These remains deserve special attention for different reasons (Bargalló et al. in press). Firstly, because elements of all the skeletal segments were identified (the axial skeleton was not identified at the taxonomical level, but there are some remains that were classified as medium-sized group) (Fig. 10). Secondly, because the MNI for this sector indicates that all these remains could have come from a single adult male individual. Several refits and tooth microwear analysis (of two refitted maxilla fragments) confirm the identification of a single deer in this sector. Thirdly, because all the remains for which laterality could be established were right, except in the case of the cranial skeleton (right and left elements). The presence of the cranial skeleton – including antlers – and only the right side of the postcranial skeleton suggest that the carcass might have been quartered there and then the left half transported to somewhere else. Last but not least, because these remains are related to combustion structure I (a *cuvette* hearth), XVIII and XX. *Cuvette* and *à event* hearths, related to significant cultural modifications (erosional truncation, dug tails, slabs, etc.), have only been documented in this sector (Vallverdú et al. 2012a). Sector 5 shows a very high percentage of burned remains, mostly burned to low and moderate degrees. Taking these facts into account, it is possible that this area was used for a special technique of cooking or food preservation related to *cuvette* hearths.

In sector 9 most of the remains belonged to the *F. silvestris* individual. The fact that it was processed and eaten is exceptional, not only in the O level, but also in the European Middle Paleolithic context. Data relating to skeletal part representation, cut marks, breakage pattern, and spatial distribution (vertical and horizontal) indicate that it was acquired, butchered and
consumed by Neanderthals (Gabucio et al. 2014a). Combustion structure XVI, present in this sector, could be related to resting and sleeping areas. Their size may be explained either by: a) pedological weathering or erosion caused by occupational disturbances or natural agents, or b) the use of plants as a construction material for bedding (Vallverdú et al. 2012a).

Finally, the large and empty central area might have been a communal area used, for instance, for the initial processing of carcasses inside the rock shelter and the distributing of food between the different domestic areas. The activities performed in this type of activity area usually generate extremely small amounts of material remains (Vaquero 2013). The few remains recovered from this zone were classified in archeolevel Oa. However, considering the low number of remains and their dispersion, it is possible that some of them actually belonged to Ob.

5.2. Time perspective: recognizing different time spans

In spite of the high resolution of Abric Romani sequence, level O is a palimpsest. As such, it is a superimposition of an unknown number of natural and anthropogenic depositional, erosional and post-depositional events comprising variable periods of time and merging into a single space (Bailey 2007; Lucas 2005, 2012). Consequently, level O contains a time complexity that archeological methods could hardly manage to guess at.

However, the combination of several techniques and methods applied to the faunal record of level O has made it possible to identify activities that Neanderthals performed over different time spans. Simplifying the actual complexity in order to work with the data available, we have classified these activities into three time categories: 1) individual episodes, 2) short-time span activities, and 3) long-time span activities. Of course, these are not closed categories with well-defined boundaries, but rather a methodological approach to better understand both the dynamics that formed the archeological record and the way we perceive them. The use of these categories comprises a scalar view of time that, according to some authors, may be not the most appropriate for archeological interpretation (Ramenofsky and Steffen 1998; Lock and Molyneaux 2006; Lucas 2008). Nowadays, however, we think that it is the best way to
approximate to level O. Even these categories can be applied to other assemblages in order to explore their time complexity.

Individual episodes can be defined as individual activities related to a specific moment and a specific archaeological association. An individual episode may have lasted a few hours or even just a few minutes. Archaeological snapshots of these episodes are difficult to find, but there are some criteria that can help in identifying them. For instance, uncommon categories (in terms of taxa, raw material, etc.), especially when clustered, are a good starting point (Hovers et al. 2011; Eixe et al. 2012).

In level O, individual episodes were only identified in archeolevel Ob. A good example is the *F. silvestris* recovered from sector 9. The scarcity of this taxon in the sequence of the site and the concentration of its remains in a limited area caught our attention. Uncommon taxa are easier to track, but identifying an individual episode associated to a common taxon is also possible. In sector 5, several remains of *C. elaphus* have been interpreted as part of an adult male. In this case, the abundance of remains from this animal in an area with a low density of items was the starting point.

There are other groups of remains that belong to the same individual. This is the case of refits and some teeth from *S. hemitoechus*, *Ursus* sp., *E. ferus* and *B. primigenius*. However, the scarcity of the remains of each group makes it difficult to interpret the specific activities that originated them. In addition, the location of most of these remains in the densest sector also hinders their interpretation and possible identification as individual episodes. As has been observed ethnoarchaeologically, clustered distributions of structures and remains are best preserved in areas of less intense occupation, usually located at the margins of the camp (O’Connell 1987). It is precisely in these marginal areas (sectors 5 and 9) where some individual episodes could be identified in level O.

We define short-time span activities as those that occurred during a short span of time, but cannot be considered individual episodes *sensu stricto*. Whereas individual episodes are related to one specific moment in the past, short-time span activities may have occurred at several different moments within a short period of time (e.g. during a week). In the case *E. ferus* from
archeolevel Ob, tooth microwear analysis indicates that the CV and SD of the number of
scratches are really very low, suggesting that these horses could have died during a short event
(Fig. 15).

Finally, long-time span activities are those that occurred repeatedly during a long period. This
long time span may include different occupational events. In this sense, microwear analysis of
*B. primigenius* tooth indicates a high variation. Compared to other populations from reference
collections or archeological sites (Rivals et al. 2009a, b; Moncel and Rivals 2011; Rivals et al.
2015), the variability is intermediate and indicates that, for these individuals, accumulation
occurred at different times. Thus, the different individuals might correspond to separate events
that occurred during a season, possibly during repeated visits to the rock shelter.

The distribution of *B. primigenius* remains, together with the other items in the domestic
activity areas identified in sectors 6 and 8, suggests that the activities undertaken there by
Neanderthals (bone breakage, roasting, defleshing, etc) also occurred over a long-time span.
Other evidence, such as the reuse of some hearths (Vallverdú et al. 2012a) and the high density
of remains (Gabucio et al. 2014b), supports this assumption. Although there are no results of
tooth microwear for Oa, the concentration of three individuals of *B. primigenius* in sector 1 also
suggests a relatively long period of accumulation (Fig. 15).

Other similar case is the accumulation of calcined remains in sector 7, around grid squares
V/52-53. Field observations, archeostratigraphy and a preliminary analysis of the combustion
structure AR06-07-10-11/1, underscore the superimposition of different combustion events in
this area (Gabucio et al. 2014b). Furthermore, the overlapping of some taphonomic
modifications also suggests diachrony (Chacón et al. 2015).

Before concluding this section, it is important to remember that the boundaries between these
categories are vague. In fact, continuing with the concept of time scale, long-time span activities
(and in most cases also short-time span ones) are made up of multiple individual episodes that
we are not able to fully identify or separate. In the same way, individual episodes are part of
subsistence and social strategies that operate over longer time scales.

5.3. Time in space: comparing time spans with micro-spatial scales
The temporal and spatial properties of archaeological data, closely related, have been widely discussed in the literature (Schiffer 1976, 1987; Behrensmeyer 1982; Stahl 1993; Stern 1994; Lyman and O’Brien 2000; Bailey 2007; Lucas 2008; Vaquero et al. 2012a). We have explored this relationship by classifying the human activities performed in level O into three microspatial scales and later comparing these spatial categories with the temporal ones proposed in the previous section. The three spatial categories are: 1) single-focus activities, 2) multiple-focus activities, 3) connected-multiple-focus activities. As in the case of time span categories, spatial categories are vague, scalar and should be understood as a methodological approach.

Single-focus activities are concentrated in a single point of the site. A clear example in level O is the individual episode of the felid, clustered in a 5 m² area. The spatial concentration of the wildcat remains might suggest that at this time the Neanderthals were not occupying the entire rock shelter (perhaps, there was no camp site then). However, there are other possible explanations. The processing and eating of such small animal probably involved very few people (Gabucio et al. 2014a). Perhaps these people decided to carry out all the activities (skinning, possible roasting, defleshing, marrow removal, eating and abandoning) in a marginal activity area of the site. In fact, some ethnoarchaeological works support the thesis that small animals are shared by fewer people and over shorter distances than large animals (Marshall 1994; Marshall 1998).

Other example is the accumulation of calcined remains identified in sector 7. Although there are calcined remains in all the sectors, a systematic accumulation of them only occurs in grid-squares V/52-53. Unlike the case of the wildcat – also very limited in time – this accumulation was the result of an activity repeated during multiple events. In this case, the spatial redundancy clearly favored the archeological visibility of this association. Surely, if the activity performed here (waste incineration and/or the use of bones as fuel) had not been so insistently repeated in the same space, it would have been very difficult to recognize this special activity area.

Multiple-focus activities are those that take place at different points of the site, but the synchrony or diachrony between them is unknown or not clear. In level O, almost all the activities took place around hearths, and there are several combustion structures in all the
sectors of both archeolevels. Most of these structures were reused suggesting that the hearths
were never all active at once, but accumulated over time. Some combustion structures appear be
connected (by refits or other methods) with others, but in most cases there are no criteria to
distinguish which hearths were synchronic. Likewise, it is very difficult to find out, for
example, if on any occasion the small area in the archeological N of sector 7 was used to break
mandibles and limb bones at the same time as bone fracture occurred in the domestic areas in
sectors 6 or 8.

Finally, connected-multiple-focus activities are those that occur simultaneously at different
points of the site. This type of activity should be recognized only when there are sufficient
criteria to relate these different points. In level O, the clearest case is the processing of *B.
*primigenius* carcasses at the site in archeolevel Ob. Despite the fact that each individual was
acquired at different times, several criteria suggest a synchronic occupation of most of the rock
shelter during these different events. Firstly, teeth that appear to belong to the same individual
were recovered from three different sectors (6, 7 and 8). Secondly, a few refits broken when
green connect different sectors, highlighting the refit between sectors 6 and 8. Some lithic refits
of different raw materials also connect these opposite areas (archeological E and W) of the site.
Thirdly, a laterality-based distribution has been observed: right elements of different individuals
were accumulated in sector 8, while left ones were mainly accumulated in sector 6. All this hints
at both food sharing and a temporal continuity (or repetition) of the same spatial organization.

In the case of *E. ferus*, there are no direct connections between sectors. However, bearing in
mind the tooth microwear results and the presence of remains of this taxon over the entire
surface, it seems probable that the whole of the rock shelter was occupied at the same time. In
any case, horses were not shared and distributed in the same way as aurochs. The case of *S.
hemitoechus* is similar: if all the rhino remains actually belonged to two individuals, an adult
and an immature rhino, the remains of which are scattered throughout the surface, it would be
another sign of synchronic occupation. Likewise, the laterality pattern of the deer elements
recovered from sector 5, suggests that the carcass was shared between more than one sector.
Unfortunately, we could not identify these elements among all the remains.
Thus, it seems that, in general terms, individual episodes tend to cluster in a smaller space, whereas long-time span activities tend to be distributed over a wider area. Actually, there appears to be a natural trend in this direction (Bailey 2007), although there are exceptions. In part, the link between short spans of time and limited distribution is conditioned by methodological problems. Establishing synchrony relationships in horizontal palimpsests is always difficult; that these relationships might connect an identified individual episode with remote remains is still rarer.

The links between time and space inside a site can provide data useful for inferring the approximate duration of the occupations and the number of individuals in the human group. In the case of archeolevel Ob, as there is evidence supporting the simultaneous use of most of the excavated surface, it can be argued that almost in any occasion the rock shelter was occupied by a fairly large group of Neanderthals. However, the occupation length is more difficult to assess.

There are criteria suggesting that some occupational events might have lasted quite time. Generally, the longer the time occupation is, the higher the number of occupants and the larger the space they need to inhabit. In addition, long occupations usually result in different overlapping accumulations that gradually become indistinguishable, as occurred in archeolevel Ob. Lastly, the hypothesis of a long occupation would be reinforced if the accumulation of calcined remains were finally interpreted as a post-hoc area, since these areas of secondary accumulation specifically used as dumps become more frequent the longer the occupation lasts (O’Connell 1987). Nevertheless, demonstrating conclusively the nature of the occupation of the site – that it was occupied for long periods or, rather, was frequently visited - is a very difficult task and will require an interdisciplinary study.

When compared to Ob, archeolevel Oa, seems have been the result of shorter occupations and/or smaller groups. Nevertheless, as already mentioned, interdisciplinary studies are needed to confirm or reject these assumptions and explore in depth this line of interpretation. Likewise, a study integrating as many disciplines as possible will be required if an approximation to the number of occupational events and their individualized interpretation is to be reached.
This work shows that archeological faunal material is also suitable for spatiotemporal analysis of palimpsests, encouraging their study and application in the future. At level O, as at other levels of Abric Romani (Vaquero et al. 2007) and other sites (Sewell 1996; Harding 2005; Machado and Pérez in press), it is possible to discern activities performed over different time spans. On its own, trying to dissect a palimpsest into short-term events does not prevent a study of long-term behaviors. In fact, there is a lot of information that can be lost if only one temporal approach is used. The really difficult task is to find ways to relate individual episodes and short-time span activities to long-time span ones and to fit them into a picture (Haldaways and Wandsnider 2008; Vaquero et al. 2012a). On the one hand, it could be argued that long-term patterns determine what happens at the short-term event scale. Thus, according to Giddens (1979), short-term events are founded on the underlying structures, i.e., the long-term behavioral patterns and natural conditions. On the other hand, it might be considered that the short-term individual engagements determine the larger-scale entities and processes (Harding 2005).

Perhaps attempting to locate in space activities that occurred over different time scales inside a site could help us understand the relationship between long-term and short-term activities at that site. For instance, the links between time and space can provide data useful for interpreting site structure, the duration of the occupations and the number of individuals in the human group. In turn, these parameters may be used to contextualize individual episodes and attempt to relate them to long-term dynamics.

**Conclusions**

Several analytical methods and techniques were applied to the zooarcheological assemblage of Abric Romani level O: archeostratigraphy, anatomical and taxonomical identification, taphonomic analysis, refits and tooth wear analysis. From the data obtained we recognized different Neanderthal activities performed inside the rock shelter, while paying special attention to their spatiotemporal framework. With the aim of interpreting the site structure, the patterns observed have been compared to ethnoarcheological data. In this regard, different activity areas have been identified, indicating that level O was used mainly as a camp site.
In addition, it was possible to classify Neanderthal activities into different time scales. Firstly, two individual episodes were identified, related to the processing of a wildcat and a deer. Secondly, tooth microwear patterns indicated that horses from archeolevel Ob were acquired during a short-time span, surely during the same occupational event. Thirdly, different criteria suggested that other activities, such as the acquisition and processing of *B. primigenius* carcasses or the accumulation of calcined remains in the innermost area of the rock shelter, occurred repeatedly in different events over a long-time span.

Likewise, data related to taxonomical and anatomical identification (MNI and laterality) and refits, made it possible to classify Neanderthal activities into three spatial categories. In the first place, single-focused activities are those occurring in a limited space, such as the butchering of the wildcat and the accumulation of calcined remains. Other activities are multiple-focused, i.e., they occur in more than one place, but there are no evident links between them (for instance, the bone breakage). Finally, there are connected-multiple-focus activities, occurring in more than one place simultaneously, such as the processing of *B. primigenius* carcasses.

All this work allowed us to reflect on the relationship between the temporal and spatial scales over which different Neanderthal activities occurred, and how they can be perceived from the archeological record. Although it seems that individual episodes tend to cluster in a reduced space, and long-time span activities tend to be distributed over a wider area, there are some exceptions, such as the accumulation of calcined bones (long-time span and single-focused activity). In any case, a time-space approach suggests that occupational events in Ob could have been longer and/or the Neanderthal groups more numerous than in Oa. However, these assumptions, as well as the proposed site structure, will need to be reviewed in future studies that employ transdisciplinary analysis.

In conclusion, this work demonstrates that the study of a zooarcheological assemblage is suitable for a time-space approach. In level O, it is possible, from faunal analysis, to discern activities performed over different time spans (from individual episodes to long-term behaviors), explore their spatial extent and then hypothesize about settlement dynamics. Undoubtedly, the Abric Romani presents optimal conditions for spatiotemporal studies: high
resolution sequence, large excavated surface and preservation of combustion structures.

However, most methods and techniques developed in this work, as refits, archeostratigraphy and
distribution of the remains in different categories (taxonomic, anatomical and taphonomic ones),
can be applied to many other sites. Also, the temporal and spatial categories identified in our
work can be adapted and applied to other assemblages, both faunal or based on other materials.

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**Figure captions**

**Fig. 1** Location of the Abric Romaní site (Capellades, Barcelona) in relation to the Iberian Peninsula (top left) and the region near the town of Capellades (middle left). General stratigraphy and level dating of the Abric Romaní (top right). Level O in the excavation of 2005 (bottom left) and 2010 (bottom right).
Fig. 2 Profile projections showing the different archeolevels and microlevels identified at Level O.

Fig. 3 Location of different elements (combustion structures, wood imprints, blocks) that may have influence how the Neanderthal groups used the space.

Fig. 4 Distribution of the different sectors established in archeolevels Oa and Ob.

Fig. 5 % Skeletal Survival Rate of archeolevel Oa calculated by weight size groups.

Fig. 6 Distribution of identified specimens from Oa by skeletal segment and taxon. The numbers indicate the different individuals identified.

Fig. 7 A: Distribution of the remains from Oa by burning degree. B: Distribution of the remains from Oa showing cutmarks, breakage damage, punctures or rodent marks.

Fig. 8 Distribution of the remains from Oa showing post-depositional alterations. Classification by alteration degree.

Fig. 9 Connecting lines between refitted remains from archeolevel Oa. A: Classification according to taxonomic group. B: Clasification according to skeletal segment or type of bone. C: Classification according to refit type.

Fig. 10 % Skeletal Survival Rate of archeolevel Ob calculated by weight size groups.

Fig. 11 Distribution of identified specimens from Ob by skeletal segment and taxon. The numbers indicate the different individuals identified, and the “i” the immature individuals.

Fig. 12 A: Distribution of the remains from Ob by burning degree. B: Distribution of the remains from Ob showing cutmarks, breakage damage, punctures or rodent marks.

Fig. 13 Distribution of the remains from Ob showing post-depositional alterations. Classification by alteration degree.

Fig. 14 Connecting lines between refitted remains from archeolevel Ob. A: Classification according to taxonomic group. B: Clasification according to skeletal segment or type of bone. C: Classification according to refit type.

Fig. 15 Boundary lines with the error probability (heat map) based on SD and CV values of microwear data used for the classification of the samples from level Ob. The classification
distinguishes short events (region A) where plots Equus ferus, long-continued events (region B) where plots Bos primigenius, and two separated short events (region C).

**Online Resource caption**

**ESM.** Supplementary information related to non-anthropogenic taphonomic alterations and processes. The first section provides the results, while the second one focuses on its interpretation. Both sections are subdivided by archeolevels (Oa and Ob).