

1 **UNRAVELING A NEANDERTHAL PALIMPSEST FROM A ZOOARCHEOLOGICAL**
2 **AND TAPHONOMIC PERSPECTIVE**

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14 **Abstract**

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

27 *Key words:* spatial analysis, faunal refits, tooth microwear analysis, site structure, time spans,
28 Abric Romaní.

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39 **1. Introduction**

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

48 On the one hand, individualizing accumulations derived from different events, by establishing
49 diachronic and synchronic relationships between them, is a difficult task, especially when the
50 palimpsest occurs not only vertically (overlapping at the same point) but also horizontally
51 (different accumulations spread out spatially, some of them potentially contemporaneous).
52 Consequently, dissecting palimpsests requires the use of different methods and techniques, such
53 as archeostratigraphy, micromorphology, taphonomy, refits, mathematically based methods, etc.
54 These studies have more frequently been conducted from technological and geoarcheological

55 approaches, and rarely the faunal remains have been considered. (Audouze and Enloe 1997;
56 Enloe 2012; Vaquero et al. 2007, 2012a, b; Hovers et al. 2011; Carbonell 2012; Rosell et al.
57 2012; Machado et al. 2013; Machado and Pérez in press; Bargalló et al. in press).

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

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

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

77 **2. The Abric Romaní site**

78 The Abric Romaní site is a travertine rock shelter placed at 265 m a.s.l. in the town of
79 Capellades (Barcelona, Spain), on the west bank of the Anoia River. In this location the valley
80 forms a narrow gorge (“Congost de Capellades”) connecting the coastal plains (Vallés-Penedés
81 basin) to the inland plains (Ebro basin) through the Prelitoral chain. Its strategic geographical

82 and geological position, at the crossroads of several ecosystems, offered prehistoric groups a
83 wide variety of resources.

84 The stratigraphic sequence was dated by radiocarbon analysis and U-series to between 40 and
85 70 ka BP (Bischoff et al. 1988) (Fig. 1), being recently expanded to reach 110 ky (Sharp et al.
86 2016). It is composed of several thin archeological levels (16 excavated thus far) separated by
87 thick sterile travertine platforms. This travertine platforms were formed rapidly (rate of
88 sedimentation of 0.46 mm/yr), providing high temporal resolution (Vallverdú et al. 2012b). All
89 the archeological layers belong to the Middle Paleolithic period except for level A, which is
90 associated with the Proto-aurignacian.

91 This high temporal resolution, combined with a field methodology based on extensive
92 excavation (up to 300 m²) and the use of Cartesian coordinates, made it possible to study spatial
93 behaviors and settlement patterns. The sedimentary context also resulted in excellent
94 preservation of wood imprints and hearths (Vallverdú et al. 2012a; Solé et al. 2013). Hearths
95 have been used as a proxy in recognizing activity areas, along with the spatial distribution of
96 lithic and faunal remains (Vaquero and Pastó 2001; Carbonell 2012). Archeostratigraphy and
97 lithic and faunal refits were used to identify synchronic and diachronic patterns (Sañudo et al.
98 2012; Rosell et al. 2012; Vaquero et al. 2007, 2012a, b).

99 The remains analyzed for this study came from Level O and were excavated between 2004 and
100 2011, over an area of about 278 m². The level have been dated by U-series to 54.6 ± 0.4 ka
101 (Vallverdú 2012b; Vaquero et al. 2013). Over 40,000 remains were recovered and coordinated
102 (using Cartesian coordinates) from Level O, including lithic tools (23,399), faunal remains
103 (9299), wood imprints (109), pieces of charcoal, and other materials. Additionally, 63
104 combustion structures were documented.

105 **3. Methods**

106 *3.1. Archeostratigraphy and distribution by sectors*

107 In cultural deposits, there may be a vertical stratification of archeological items as a result of
108 different overlapping occupational events. In this context, archeostratigraphic analysis makes it
109 possible to identify the diachronic relationship between cultural deposits by delimiting

110 continuous sterile layers, which are indicative of times when there was no anthropic presence
111 (Canals 1993; Chenorkian 1988).

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

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

128 *3.2. Anatomical and taxonomic analysis*

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

133 In order to include in the study bones that could not be identified taxonomically, all the remains
134 have been grouped into weight sizes, based on a modification to the criteria proposed by Bunn
135 (1986): 1) very small (< 20 kg); 2) small (20 - 100 kg); 3) medium (100-300 kg); 4) large (300 –
136 1000 kg). Likewise, bones that could not be identified at the anatomical level were classified

137 into three categories: long bones (from limbs), flat bones (axial and cranial skeleton) and
138 articular bones (carpals, tarsals, sesamoides).

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

147 *3.3. Analysis of bone modification*

148 With respect to bone breakage, limb bones longer than 3 cm were analyzed based on Villa and
149 Mahieu (1991) in order to establish the state of the bones (green or dry) when they were broken.
150 The completeness of all the bone fragments relative to the complete skeletal element, both in
151 length and in circumference, was also considered, adapting previous works (Bunn 1983). The
152 causes of the fractures were investigated by analyzing the structural and surface damage, such
153 as percussion pits, percussion notches, impact flakes, adhering flakes and peeling (Capaldo and
154 Blumenschine 1994; Pickering and Egeland 2006; White 1992; Pickering et al. 2013).
155 Modifications to bone surfaces were observed using both macroscopic and microscopic
156 techniques (Olympus SZ11 stereomicroscope and ESEM FEI QUANTA 600). Cut marks were
157 analyzed in terms of their morphology (slice, scrape, chop or saw marks), location, distribution,
158 and orientation in the bones (Binford 1981; Bromage and Boyde 1984; Noe-Nygaard 1989;
159 Potts and Shipman 1981; Shipman 1983; Shipman and Rose 1983). Burn patterns were analyzed
160 on the basis of the degrees proposed by Stiner et al. (1995). Non-anthropogenic alterations and
161 processes, such as carnivore damage, water abrasion, plant activity, trampling and manganese
162 oxide pigmentation, were also identified (Binford 1981; Lyman 1994; Shahack-Gross et al.
163 1997; Fernández López 2000; Cáceres 2002; Fernández-Jalvo and Andrews 2003; Blasco et al.
164 2008). The degree and location of all these alterations were recorded, as well as their sequence

165 (by taking into account the overlap between them). Lastly, the distribution of the remains
166 showing different alterations was also explored.

167 3.4. *Tooth wear analysis*

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

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

191 3.5. *Faunal refits*

192 Concerning faunal refits, the terminology proposed by Todd (1987), Todd and Stanford (1992)
193 and Lyman (1994), and the methods developed by Fernández-Laso (2010) were followed. All
194 the remains longer than 1 cm were taken into account. Two types of refits were observed:
195 anatomical refits (i.e. dental series and articulated elements) and mechanical refits (conjoined
196 fragments from the same broken element) (Lyman 1994). In all cases, the location of the
197 remains of the same refit, the distances between them, and their taphonomic features were
198 noted. In addition, the analysis of the mechanical refits included the state of the bone at the time
199 of fracture (dry or green) and the origin of the fractures (anthropogenic percussion, fire,
200 carnivore damage or post-depositional process). Faunal refits can provide very valuable
201 information on taphonomic, behavioral and palaeoeconomic issues related to archeological
202 assemblages (Enloe 1995; Fernández-Laso 2010), and also help us to infer the patterns of
203 synchrony and diachrony in archeological palimpsests (Audouze and Enloe 1997; Rosell et al.
204 2012).

205 **4. Results**

206 *4.1. Archeostratigraphy, elements that determine the space, and sectors*

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

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

215 Ob is thicker (up to 55 cm), slopes more steeply (a SW slope of 12.92°) and contains more
216 remains (8,615) than archeolevel Oa. As the separation into microlevels was only possible in
217 some areas, all the data from archeolevel Ob will be presented together, although the
218 microlevels will be taken into account in the interpretation.

219 The archeolevel Oc is not well preserved, with only five faunal remains clustered at two
220 different points towards the archeological W of the rock shelter (grid squares T61 and P-R/58-
221 59). In addition, there are 189 remains that could not be assigned to any archeolevel, because
222 their coordinates are approximate or because they were located in a place where the Oa and Ob
223 archeolevels were in contact, becoming indistinguishable in archeostratigraphic terms. This
224 occurs in the SW area of the rock shelter, at some points around grid squares M-R/57-60. This
225 work therefore focuses on the remains classified into archeolevels Oa and Ob.

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

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

233 *4.2. Archeolevel Oa*

234 4.2.1. Anatomical and taxonomic analysis

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

241 The remains of *B. primigenius*, clearly dominated by the proximal appendicular skeleton, tended
242 to be clustered towards the archeological E, especially in sector 1 (Fig.6). All the elements
243 located in sectors 1 and 2 are from the proximal appendicular skeleton, including the right tibiae
244 from three different adult individuals. Instead, two metapodial and one maxilla were recovered
245 from the outermost area (sectors 3 and 4).

246 In contrast, the elements identified as from *E. ferus*, *C. elaphus* and *O. cuniculus* do not show
247 any clear pattern. Two tibiae (one right and the other left; sectors 1 and 4), one hemimandible
248 (with M1-M3 teeth, sector 3) and one isolated tooth (PM2 inf., sector 3) were identified as horse
249 (Fig.6). Deer remains were found distributed throughout all the archeolevel and are grouped into
250 cranial (mandible) and limb elements (Fig. 6). The leporid elements are isolated teeth, one coxal
251 and one calcaneus. This taxon is present in all the sectors except in sector 1 (Fig.6). However,
252 some bones from a very small sized animal that was not identified were recovered in this sector.
253 Remains that could not be taxonomically identified, which were classified into large and
254 medium weight groups, were found distributed over the entire surface.

255 4.2.2. Structural and surface modification

256 The results of this section are summarized in table 2 and in figures 7 and 8. All the remains
257 from archeolevel Oa were broken, except for an articular bone of a medium-sized animal. In
258 most cases, each fragment represents less than $\frac{1}{5}$ of the length and $\frac{1}{4}$ of the circumference of the
259 complete skeletal element. Among long bones over 3 cm, most of the fractures seen are curved,
260 oblique and smooth indicating green-bone breakage. Likewise, 33.3% of the material shows
261 structural damage related to intentional bone breakage, highlighting the number of impact
262 flakes. This percentage varies widely across sectors, being higher in sectors 2, 1 and 4, and
263 lower in sector 3. Within sector 1, structural damage seems to be clustered at two points . The
264 elements affected are mainly the long bones of large- and medium-sized animals.

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

272 Modification by burning affects 43% of the assemblage. The percentage is highest in sector 1,
273 followed by sectors 3, 2 and 4. Low and moderate degrees of burning (partially or totally

274 rubefacted or charred) are prevalent, whereas high degrees of burning (partially or totally
275 calcined) are rare, and are absent in sectors 3 and 4. The distribution of burned remains is linked
276 to the locations of hearths: all the fully calcined remains were found inside combustion
277 structures, and the other burned remains tend to be near them, being within or close to hearths
278 (Fig. 3 and 7). Nevertheless, some burned remains were recovered some meters away from the
279 nearest combustion structure in sectors 1 and 4.

280 Tooth marks and rodent gnawing are scarce (0.6% and 3.1%, respectively) and affect remains
281 recovered towards the archeological E. Rounded and polished surfaces caused by water activity
282 are quite common in Oa (42% and 23.3% respectively), although most items show an initial
283 degree. Sectors 4 and 2 show the highest rates, but rounding is more frequent in sector 4 and
284 polishing in sector 2. Modifications caused by plant activity were also frequently found
285 (33.1%). Cementation is present in 46.5% of the assemblage, reaching 67.1% in sector 4,
286 although this alteration generally covers a small part of the remains. Cracking (28%) is also
287 especially abundant in sector 4. Finally, trampling and manganese oxide pigmentation were less
288 scarcer. More information related to non-anthropogenic taphonomic alterations is available as
289 supplementary information (Online Resource).

290 4.2.3. Refits

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

296 Only one group was identified at the taxonomical and anatomical level: a tibia of *B.*
297 *primigenius*. The connecting line, which crosses sector 1 from side to side, is the longest in Oa
298 (5.30 m). The other refits involve long bones from large- or medium-sized animals and
299 unidentified remains.

300 All the refits are mechanical. Two refitting groups, connected by a considerable distance, were
301 broken when green: the refit identified as a tibia of *B. primigenius* and other refit connecting

302 two impact flakes of a long bone from a large-sized animal. Both show evidence of intentional
303 breakage by percussion. In addition, there are cut marks on a fragment of the tibia.

304 The other refitted remains have been fitted together at points where dry fractures occurred. In
305 most cases, these are burned remains that were fractured by the action of fire or by post-
306 depositional agents acting after it, and in general were found very short distances apart.
307 Nevertheless, in the outermost area (sectors 3 and 4) there are two mechanical refits related to
308 dry-bone breakage with connecting lines over 1 m long. In both cases, the refitted remains
309 located furthest from the wall of the rock shelter seem have been moved from locations further
310 north by gravitational or post-depositional movements.

311 There is no evidence of carnivore activity on refitted bones. Other natural taphonomic
312 modifications are, however, present (see the supplementary information in Online Resource).
313 For instance, one fragment of the aurochs tibia (grid square T43) show rodent marks, and the
314 other (grid square T48) has abraded surfaces.

315 *4.3. Sublevel Ob*

316 4.3.1. Anatomical and taxonomic analysis

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

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

328 *S. hemitoechus*, although scarce, is present in all the sectors (Fig. 11). Almost all the remains are
329 teeth (a mandible containing M2 and M3, some isolated teeth and some dental fragments),

330 although a carpal bone was also identified in sector 5. Some of the teeth recovered from sectors
331 7 and 8 belonged to an immature individual, and the other remains to an adult individual.

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

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

352 As for *C. elaphus*, it was identified in all the sectors (Fig. 11). This taxon is represented by a
353 wide range of skeletal elements, although appendicular ones were most commonly found. Many
354 teeth were also recovered, and the accumulation of dental fragments in the inner area of sector 7
355 should be highlighted. In this taxon, the element with the highest MNE and MNI is the left tibia.
356 It is curious that three tibiae from three different adult individuals were clustered in sector 8,
357 whereas the tibia of an immature individual was recovered from sector 7. Other immature

358 remains (teeth and metapodials) were distributed throughout sectors 6, 7, 8 and 9. The presence
359 of different elements, such as the right tibia and the left femur, also points to an accumulation of
360 different adult individuals in sector 8.

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

366 Unlike previous analyzed taxa, *F. silvestris* was found concentrated within a 5 m² area in sector
367 9 (Fig. 11). All its remains belonged to a single, nearly complete adult individual (Gabucio et al.
368 2014a). In general terms, proximal appendicular elements were more widely dispersed than the
369 other skeletal elements.

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

375 4.3.2. Structural and surface modification

376 The observed modifications are shown in table 6 and figures 12 and 13. Only 44 remains from
377 archeolevel Ob are whole elements, 39 of which have been identified as *F. silvestris*. Almost all
378 the remains represent less than 1/5 of the length and 1/4 of the circumference of the complete
379 skeletal element. As a consequence, 59.4 % of the items are no more than 2 cm long and only
380 5.5% over 5 cm. However, these percentages fluctuate from one sector to another. An analysis
381 of the fractures indicates that long bones of over 3 cm were mostly broken when green.
382 Moreover, several remains (15.8%) show structural damage related to intentional bone
383 breakage, especially impact flakes. The damaged elements are mainly the long bones of large-
384 and medium-sized animals. This modification was most frequently found in sectors 6 and 8,
385 although no specific accumulations were observed.

386 Of the remains, 4.9% present cut marks. The taxonomic groups that show cut marks are *B.*
387 *primigenius*, *E. ferus*, *C. elaphus*, *F. silvestris*, all the weight size categories and the unidentified
388 bones. Slicing marks were most frequently observed, although scrape marks, saw marks and
389 chop marks are also present. Most of them, located on the diaphyses and metaphyses of limb
390 bones found in all the taxonomic groups, were made accidentally during defleshing activities
391 (all the sectors). Other marks may be related to skinning (sectors 7, 8 and 9), disarticulation (8),
392 or removing the viscera (6 and 7), tongue (6, 7 and 8) or periosteum and fat (6, 7 and 8). Bones
393 with cut marks were found distributed across the surface, and no underlying taxa-based pattern
394 has been observed (except for the felid, clustered in sector 9) (Fig. 12).

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

405 In general, non-anthropogenic modifications are rarer in Ob than in Oa and show a low degree
406 of alteration (see supplementary information in Online Resource). Very little evidence of
407 carnivore activity was found in Ob (0.4 %), and modifications by rodents were even scarcer
408 (0.1%). However, it should be noted that, in the archeological SE of sector 6, an accumulation
409 of faunal remains contains two ravaged bones, a digested bone and three other bones with
410 rodent marks. Regarding plant (18.4%) and water (rounding: 19.76%, polishing: 14.76%)
411 activity, cementation (13.5%), cracking (17.06%) and manganese oxide pigmentation (7.6%),
412 the percentage of altered remains fluctuates substantially by sectors, being generally more
413 abundant in the outermost ones and scarcer in sector 7.

414 4.3.3. Refits

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

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

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

438 On the one hand, 40 refits had been broken when green, and these were most commonly found
439 in sector 8. Most of them correspond to long bones from medium-sized or large animals.
440 However, some refitted flat bones, such as mandibles, had also been broken when green.
441 Thirteen refits broken when green may be directly related to intentional bone breakage by

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

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

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

463 **5. Discussion**

464 Evidence of anthropogenic activity is very abundant in both archeolevels Oa and Ob.
465 Taxonomy, age at death, skeletal part representation, location of cut marks, breakage pattern
466 and burn damage all point to Neanderthals having primary and immediate access to the animals
467 and then intensively exploiting their carcasses (Bunn and Ezzo 1993). In addition, hunting
468 appears to have been primarily focused on aurochs, horses and deer.

469 This study made it possible to identify some of the activities that Neanderthals carried out inside
470 the rock shelter with respect to these animals. In the following sections, the intrasite
471 organization of these activities and their spatiotemporal frameworks are discussed. Before that,
472 however, it is important to consider the post-depositional taphonomic alterations that modified
473 and even moved some faunal remains. Regarding this, detailed data is available as
474 supplementary information (Online Resource). Below we are only providing the main results
475 that allow us to address the interpretation of Neanderthal spatial behavior.

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

497 remains of level O. Nevertheless, as far as sector 8 is concerned, the exact location of the
498 remains, their classification into microlevels and the distance between the refitted pieces should
499 be approached with great caution.

500 *5.1. Site structure: recognizing different activity areas*

501 Inferring human spatial behavior from site structure is one of the main goals of Paleolithic
502 Archeology. Ethnoarcheology offers the most extensive and useful framework for recognizing
503 and understanding the dynamics of past human behavior. Ethnoarcheological works have
504 defined different occupation sites (Binford 1978, 1980), including camp sites, which are
505 understood to be places where people grouped in domestic units lived and conducted most of
506 their activities (Gamble and Boismier 1991; Kent 1987; Kroll and Price 1991; O'Connell 1987;
507 Yellen 1977). The spatial distribution of remains in camp sites is usually related to different
508 activity areas, such as domestic activity areas (each area where a domestic unit lived and
509 performed most of their daily tasks), communal activity areas (where collective activities take
510 place) and special activity areas (where specific occasional tasks, which cannot be comfortably
511 performed in domestic areas, were carried out) (Vaquero 2013). Other location-related
512 activities, such as waste management, will also have determined the distribution of the remains.
513 Recognizing site structure in a Paleolithic site is, however, problematic. Most, if not all, of the
514 archeological assemblages are palimpsests, i.e. the result of overlapping activities difficult to
515 distinguish. Moreover, the process of superimposition may alter, move and even destroy the
516 material traces of these activities (Bailey 2007; Lucas 2005, 2012). The temporal discrepancy
517 between ethnoarcheologically observed behavior and archeologically recovered accumulations
518 greatly hinders the interpretation of the archeological record, including site structure.
519 Nevertheless, several authors have proposed different methods and techniques to achieve this
520 objective. These include mathematically based methods (such as density and contour plots, K-
521 means, clustering and chi-squared analysis) and several analytic techniques
522 (Archeostratigraphy, Taphonomy, Micromorphology, lithic and faunal refits...) (Binford 1988;
523 Enloe et al. 1994; Audouze and Enloe 1997; Enloe 2012.; Vaquero and Pastó 2001; Vaquero et
524 al. 2007, 2012a; Carbonell 2012; Rosell et al. 2012; Machado et al. 2013).

525 Some of these methods and techniques have been applied to the faunal assemblage recovered
526 from Abric Romani level O. The results obtained, in conjunction with the location of structural
527 elements and the data available from previous studies, have been used to interpret the site
528 structure of level O. Of course, what follows is an approximation based only on faunal remains
529 and conclusions drawn here should be tested in the future by adding results obtained from other
530 disciplines.

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

536 As far as Oa is concerned, the inner area shows the highest rates of anthropogenic modified
537 remains and the greatest variation in human activities related to carcass processing and
538 consuming. For instance, sectors 1 and 2 show more remains less than 2 cm long, and a higher
539 rate of intentional bone breakage products. Moreover, if % SSR is calculated by sectors, sector
540 1 shows the highest rate for the proximal appendicular and metapodial elements, which are rich
541 in marrow. Cut marked and burned bones are also more abundant in the inner area, especially in
542 sector 1. The degrees of burning identified match with those ethnoarcheologically linked to
543 cooking activities (Hayden 1981; Gifford-Gonzalez 1989a).

544 Most of these remains which were anthropogenically altered are small bone fragments (such as
545 burned remains and percussion products), which tend to remain in the place where they were
546 originally produced (Binford 1978; Gifford 1980; Schiffer 1983; Enloe et al. 1994).
547 Consequently, roasting, defleshing and bone breakage appear to have occurred primarily in this
548 inner zone, suggesting its use as a domestic area. The presence of several hammerstones
549 supports this suggestion (Bargalló 2014). In this context, it is possible that the numerous blocks
550 documented in this sector were moved or at least used by Neanderthals. Likewise, the longest
551 wood imprint related to Oa (Fig. 3) may have been used to increase the habitability of the rock
552 shelter.

553 The domestic activity area documented in sector 1 was organized mainly around the medium-
554 sized combustion structures XI and XII (Fig. 3). It is possible that each hearth was associated
555 with a distinct domestic area whose boundaries are now difficult to delimit. One refit related to
556 green-bone breakage connecting the two hearths (Fig. 8) would suggest that both hearths would
557 have been active at the same time (Rapson and Todd 1992; Rosell et al. 2012). However, at the
558 moment we cannot assure that the bones were deposited when both hearths were active.
559 Besides this, the rounded surfaces of one of the refitted remains (the one close to hearth XII)
560 might indicate that it was moved by water.

561 In contrast, in sector 2 it is only the abundance of impact flakes that stands out, suggesting that
562 this was a more marginal and/or specialized activity area. Three small combustion structures are
563 linked to this sector: XIII, XIV and XV (Fig. 3). The distance between each hearth (from 1 to
564 1.5 m) is similar to that observed ethnoarcheologically in resting and sleeping activity areas
565 (Vallverdú et al. 2012a). Hearth IX (sector 3) has been also previously related to this type of
566 activity area, suggesting that its rectangular shape and large surface would be the result of the
567 reuse of several small hearths spaced about one meter apart (Vallverdú et al. 2012a). Moreover,
568 this large hearth contained practically no artifacts, another characteristic of sleeping and resting
569 areas (Vallverdú et al. 2012a). Another possibility is that sector 3 was used as a communal area.
570 Finally, the low rate of anthropogenic modifications in sector 4 suggests that this area was used
571 more sporadically or for specific uses that have not generated sufficient evidence, such as the
572 initial processing of carcasses.

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

580 approximately one meter to the archeological S of the hearths. This distribution resembles the
581 drop and toss zones proposed by Binford (1978).

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

591 Sector 7 shows evidence of some activities commonly documented in domestic areas, such as
592 roasting or *in situ* bone breakage. Nevertheless, the singular nature of some of the activities
593 identified in this sector suggests a specialized use of the central innermost area of the rock
594 shelter. The best example is the accumulation of calcined remains in combustion structure
595 AR06-07-10-11/1, around grid squares V/52-53. These calcined bones were recovered from
596 both microlevels but mainly from Ob2. As bones have to be directly exposed to flame to be
597 completely calcined (Mentzer 2009), two complementary hypothesis were proposed to explain
598 this accumulation: a) a complementary use of bones as fuel, and b) the presence of a systematic
599 cleaning area where waste was habitually incinerated (Gabucio et al. 2014b; Chacón et al.
600 2015). The latter possibility would indicate the existence of a *post-hoc* zone in this sector
601 (Schiffer 1972).

602 Also in sector 7, a little closer to the wall, an accumulation of tooth fragments was found. Most
603 of them had been burned to a low degree and seem have been broken when green. This fact,
604 together with the presence of small products of breakage by percussion, such as impact flakes,
605 suggests that Neanderthals had been breaking mandibles and other bones there. The fact that an
606 anvil and two hammerstones were recovered from this area reinforces this assumption.

607 Furthermore, neither the hammer nor the anvil show percussion marks, suggesting that were not
608 used for lithic production, but for processing fauna (Bargalló 2014).

609 In contrast, the low density of remains and the results of the analysis indicate that sectors 5 and
610 9 were the location of occasional or unusual activities. Probably, these marginal zones, in the
611 outermost part of the rock shelter and some distance from activity areas, were used as
612 communal or special areas. It is also possible that they were occupied during short and specific
613 occupations.

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

631 In sector 9 most of the remains belonged to the *F. silvestris* individual. The fact that it was
632 processed and eaten is exceptional, not only in the O level, but also in the European Middle
633 Paleolithic context. Data relating to skeletal part representation, cut marks, breakage pattern,
634 and spatial distribution (vertical and horizontal) indicate that it was acquired, butchered and

635 consumed by Neanderthals (Gabucio et al. 2014a). Combustion structure XVI, present in this
636 sector, could be related to resting and sleeping areas. Their size may be explained either by: a)
637 pedological weathering or erosion caused by occupational disturbances or natural agents, or b)
638 the use of plants as a construction material for bedding (Vallverdú et al. 2012a).

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

646 *5.2. Time perspective: recognizing different time spans*

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

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

662 approximate to level O. Even these categories can be applied to other assemblages in order to
663 explore their time complexity.

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

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

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

686 We define short-time span activities as those that occurred during a short span of time, but
687 cannot be considered individual episodes *sensu stricto*. Whereas individual episodes are related
688 to one specific moment in the past, short-time span activities may have occurred at several
689 different moments within a short period of time (e.g. during a week). In the case *E. ferus* from

690 archeolevel Ob, tooth microwear analysis indicates that the CV and SD of the number of
691 scratches are really very low, suggesting that these horses could have died during a short event
692 (Fig. 15).

693 Finally, long-time span activities are those that occurred repeatedly during a long period. This
694 long time span may include different occupational events. In this sense, microwear analysis of
695 *B. primigenius* tooth indicates a high variation. Compared to other populations from reference
696 collections or archeological sites (Rivals et al. 2009a, b; Moncel and Rivals 2011; Rivals et al.
697 2015), the variability is intermediate and indicates that, for these individuals, accumulation
698 occurred at different times. Thus, the different individuals might correspond to separate events
699 that occurred during a season, possibly during repeated visits to the rock shelter.

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

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

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

717 *5.3. Time in space: comparing time spans with micro-spatial scales*

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

726 Single-focus activities are concentrated in a single point of the site. A clear example in level O
727 is the individual episode of the felid, clustered in a 5 m² area. The spatial concentration of the
728 wildcat remains might suggest that at this time the Neanderthals were not occupying the entire
729 rock shelter (perhaps, there was no camp site then). However, there are other possible
730 explanations. The processing and eating of such small animal probably involved very few
731 people (Gabucio et al. 2014a). Perhaps these people decided to carry out all the activities
732 (skinning, possible roasting, defleshing, marrow removal, eating and abandoning) in a marginal
733 activity area of the site. In fact, some ethnoarcheological works support the thesis that small
734 animals are shared by fewer people and over shorter distances than large animals (Marshall
735 1994; Marshall 1998).

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

743 Multiple-focus activities are those that take place at different points of the site, but the
744 synchrony or diachrony between them is unknown or not clear. In level O, almost all the
745 activities took place around hearths, and there are several combustion structures in all the

746 sectors of both archeolevels. Most of these structures were reused suggesting that the hearths
747 were never all active at once, but accumulated over time. Some combustion structures appear to be
748 connected (by refits or other methods) with others, but in most cases there are no criteria to
749 distinguish which hearths were synchronic. Likewise, it is very difficult to find out, for
750 example, if on any occasion the small area in the archeological N of sector 7 was used to break
751 mandibles and limb bones at the same time as bone fracture occurred in the domestic areas in
752 sectors 6 or 8.

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

765 In the case of *E. ferus*, there are no direct connections between sectors. However, bearing in
766 mind the tooth microwear results and the presence of remains of this taxon over the entire
767 surface, it seems probable that the whole of the rock shelter was occupied at the same time. In
768 any case, horses were not shared and distributed in the same way as aurochs. The case of *S.*
769 *hemitoechus* is similar: if all the rhino remains actually belonged to two individuals, an adult
770 and an immature rhino, the remains of which are scattered throughout the surface, it would be
771 another sign of synchronic occupation. Likewise, the laterality pattern of the deer elements
772 recovered from sector 5, suggests that the carcass was shared between more than one sector.
773 Unfortunately, we could not identify these elements among all the remains.

774 Thus, it seems that, in general terms, individual episodes tend to cluster in a smaller space,
775 whereas long-time span activities tend to be distributed over a wider area. Actually, there
776 appears to be a natural trend in this direction (Bailey 2007), although there are exceptions. In
777 part, the link between short spans of time and limited distribution is conditioned by
778 methodological problems. Establishing synchrony relationships in horizontal palimpsests is
779 always difficult; that these relationships might connect an identified individual episode with
780 remote remains is still rarer.

781 The links between time and space inside a site can provide data useful for inferring the
782 approximate duration of the occupations and the number of individuals in the human group. In
783 the case of archeolevel Ob, as there is evidence supporting the simultaneous use of most of the
784 excavated surface, it can be argued that almost in any occasion the rock shelter was occupied by
785 a fairly large group of Neanderthals. However, the occupation length is more difficult to assess.
786 There are criteria suggesting that some occupational events might have lasted quite time.
787 Generally, the longer the time occupation is, the higher the number of occupants and the larger
788 the space they need to inhabit. In addition, long occupations usually result in different
789 overlapping accumulations that gradually become indistinguishable, as occurred in archeolevel
790 Ob. Lastly, the hypothesis of a long occupation would be reinforced if the accumulation of
791 calcined remains were finally interpreted as a *post-hoc* area, since these areas of secondary
792 accumulation specifically used as dumps become more frequent the longer the occupation lasts
793 (O'Connell 1987). Nevertheless, demonstrating conclusively the nature of the occupation of the
794 site – that it was occupied for long periods or, rather, was frequently visited - is a very difficult
795 task and will require an interdisciplinary study.

796 When compared to Ob, archeolevel Oa, seems have been the result of shorter occupations
797 and/or smaller groups. Nevertheless, as already mentioned, interdisciplinary studies are needed
798 to confirm or reject these assumptions and explore in depth this line of interpretation. Likewise,
799 a study integrating as many disciplines as possible will be required if an approximation to the
800 number of occupational events and their individualized interpretation is to be reached.

801 This work shows that archeological faunal material is also suitable for spatiotemporal analysis
802 of palimpsests, encouraging their study and application in the future. At level O, as at other
803 levels of Abri Romaní (Vaquero et al. 2007) and other sites (Sewell 1996; Harding 2005:
804 Machado and Pérez *in press*), it is possible to discern activities performed over different time
805 spans. On its own, trying to dissect a palimpsest into short-term events does not prevent a study
806 of long-term behaviors. In fact, there is a lot of information that can be lost if only one temporal
807 approach is used. The really difficult task is to find ways to relate individual episodes and short-
808 time span activities to long-time span ones and to fit them into a picture (Haldaway and
809 Wandsnider 2008; Vaquero et al. 2012a). On the one hand, it could be argued that long-term
810 patterns determine what happens at the short-term event scale. Thus, according to Giddens
811 (1979), short-term events are founded on the underlying structures, i.e., the long-term
812 behavioral patterns and natural conditions. On the other hand, it might be considered that the
813 short-term individual engagements determine the larger-scale entities and processes (Harding
814 2005).

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

821 **Conclusions**

822 Several analytical methods and techniques were applied to the zooarcheological assemblage of
823 Abri Romaní level O: archeostratigraphy, anatomical and taxonomical identification,
824 taphonomic analysis, refits and tooth wear analysis. From the data obtained we recognized
825 different Neanderthal activities performed inside the rock shelter, while paying special attention
826 to their spatiotemporal framework. With the aim of interpreting the site structure, the patterns
827 observed have been compared to ethnoarcheological data. In this regard, different activity areas
828 have been identified, indicating that level O was used mainly as a camp site.

829 In addition, it was possible to classify Neanderthal activities into different time scales. Firstly,
830 two individual episodes were identified, related to the processing of a wildcat and a deer.
831 Secondly, tooth microwear patterns indicated that horses from archeolevel Ob were acquired
832 during a short-time span, surely during the same occupational event. Thirdly, different criteria
833 suggested that other activities, such as the acquisition and processing of *B. primigenius*
834 carcasses or the accumulation of calcined remains in the innermost area of the rock shelter,
835 occurred repeatedly in different events over a long-time span.

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

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

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

857 resolution sequence, large excavated surface and preservation of combustion structures.
858 However, most methods and techniques developed in this work, as refits, archeostratigraphy and
859 distribution of the remains in different categories (taxonomic, anatomical and taphonomic ones),
860 can be applied to many other sites. Also, the temporal and spatial categories identified in our
861 work can be adapted and applied to other assemblages, both faunal or based on other materials.

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1120 **Figure captions**

1121 **Fig. 1** Location of the Abric Romaní site (Capellades, Barcelona) in relation to the Iberian
1122 Peninsula (top left) and the region near the town of Capellades (middle left). General
1123 stratigraphy and level dating of the Abric Romaní (top right). Level O in the excavation of 2005
1124 (bottom left) and 2010 (bottom right).

1125 **Fig. 2** Profile projections showing the different archeolevels and microlevels identified at Level
1126 O.

1127 **Fig. 3** Location of different elements (combustion structures, wood imprints, blocks) that may
1128 have influence how the Neanderthal groups used the space.

1129 **Fig. 4** Distribution of the different sectors established in archeolevels Oa and Ob.

1130 **Fig. 5** % Skeletal Survival Rate of archeolevel Oa calculated by weight size groups.

1131 **Fig. 6** Distribution of identified specimens from Oa by skeletal segment and taxon. The
1132 numbers indicate the different individuals identified.

1133 **Fig. 7** A: Distribution of the remains from Oa by burning degree. B: Distribution of the remains
1134 from Oa showing cutmarks, breakage damage, punctures or rodent marks.

1135 **Fig. 8** Distribution of the remains from Oa showing post-depositional alterations. Classification
1136 by alteration degree.

1137 **Fig. 9** Connecting lines between refitted remains from archeolevel Oa. A: Classification
1138 according to taxonomic group. B: Clasification according to skeletal segment or type of bone.
1139 C: Classification according to refit type.

1140 **Fig. 10** % Skeletal Survival Rate of archeolevel Ob calculated by weight size groups.

1141 **Fig. 11** Distribution of identified specimens from Ob by skeletal segment and taxon. The
1142 numbers indicate the different individuals identified, and the “i” the immature individuals.

1143 **Fig. 12** A: Distribution of the remains from Ob by burning degree. B: Distribution of the
1144 remains from Ob showing cutmarks, breakage damage, punctures or rodent marks.

1145 **Fig. 13** Distribution of the remains from Ob showing post-depositional alterations.
1146 Classification by alteration degree.

1147 **Fig. 14** Connecting lines between refitted remains from archeolevel Ob. A: Classification
1148 according to taxonomic group. B: Clasification according to skeletal segment or type of bone.
1149 C: Classification according to refit type.

1150 **Fig. 15** Boundary lines with the error probability (heat map) based on SD and CV values of
1151 microwear data used for the classification of the samples from level Ob. The classification

1152 distinguishes short events (region A) where plots *Equus ferus*, long-continued events (region B)
1153 where plots *Bos primigenius*, and two separated short events (region C).

1154 **Online Resource caption**

1155 **ESM.** Supplementary information related to non-anthropogenic taphonomic alterations and
1156 processes. The first section provides the results, while the second one focuses on its
1157 interpretation. Both sections are subdivided by archeolevels (Oa and Ob).