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The Middle Pleistocene Argali (*Ovis ammon antiqua*) Assemblages at the Caune de l'Arago (Tautavel, Pyrénées-Orientales, France): Were Prehistoric Hunters or Carnivores Responsible for their Accumulation?

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ABSTRACT The argali (*Ovis ammon antiqua*) assemblages from the Middle Pleistocene site of the Caune de l'Arago (Tautavel, southern France) were studied in terms of zooarchaeology and taphonomy. It is possible to discern palaeobiological information lost during fossilisation, as well as the palaeoethology of the bone collector, by the observation of taphonomic details preserved on the bone assemblages. The observations leave no doubt that both humans and carnivores were involved in the accumulation of argali carcasses in the cave. In some assemblages, the type of bones found in articulation and the gnawing marks observed are characteristic of carnivores. In other levels, the intense fracturing of the major limb bones in relation to their marrow content and mineral density, and butchering marks found on specimens in the earlier levels, are in favour of human accumulation, the modalities of which are discussed. The results suggest that the degree of carnivore activity seems to have been higher in levels M, N and O than in level F. Copyright © 2006 John Wiley & Sons, Ltd.

Key words: Caune de l'Arago; southern France; Middle Pleistocene; taphonomy, zooarchaeology; argali

Introduction

Caves where the geochronological distribution of remains can be efficiently studied have always been excellent shelters both for carnivores and humans. In Europe, there are numerous cave sites with bone assemblages ranging from Lower to Upper Pleistocene occupations. The long chronological sequence at the Caune de l'Arago (Tautavel, France) represents an interesting example of such a cave where human and carnivore remains are found together.

The Caune de l'Arago is a large karstic cave naturally carved into the Urgo-Aptian limestone of the Corbières Massif which dominates the Verdouble River (Figure 1). The gallery is 35 m

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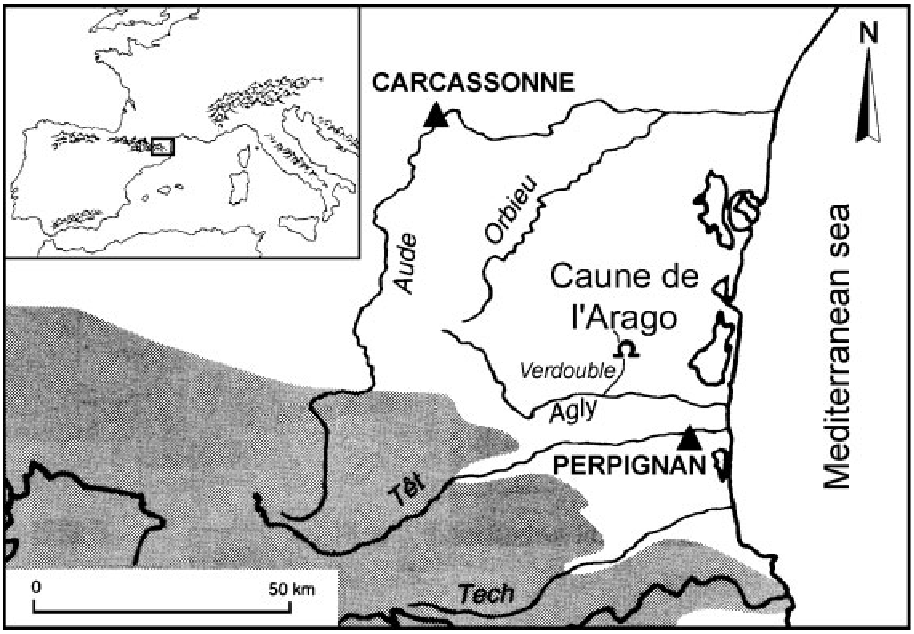


Figure 1. Map showing the location of the Caune de l'Arago (Tautavel, France).

long and 7 to 10 m wide, and the cave has been excavated each year since 1964 by teams directed by Prof. Henry de Lumley. The deposits are almost 15 m thick and cover a period from 690,000 to 100,000 years (de Lumley *et al*., 1984). All units are rich in faunal materials (housed in the Centre Européen de Recherches Préhistoriques of Tautavel), which allow for detailed taphonomical and zooarchaeological studies. Most assemblages are associated with abundant stone tools, and human remains are found in some levels. About 100 human remains and numerous remains of large mammals have been found, such as reindeer (*Rangifer tarandus*), red deer (*Cervus elaphus*), argali (*Ovis ammon antiqua*), tahr (*Hemitragus bonali*), bison (*Bison priscus*), musk-ox (*Praeovibos priscus*), horse (*Equus ferus mosbachensis*) and rhinoceros (*Stephanorhinus hemitoechus*). In addition, the following carnivores are present in some units: Deningeri bear (*Ursus deningeri*), brown bear (*Ursus arctos*), wolf (*Canis lupus mosbachensis*), dhole (*Cuon priscus*), fox (*Vulpes vulpes*), leopard (*Panthera pardus*), cave lion (*Panthera leo spelaea*) and lynx (*Lynx spelaeus*).

Among the mammals, we studied the argali remains (*Ovis ammon antiqua*) because the large attritional assemblage of argali at the Caune de l'Arago is unique. This animal, which was hunted at this site for 300,000 years (Moigne, 1983; Monchot, 1996) represents up to 61% of the total minimum number of individuals (MNI) in some assemblages. Since argali are present in all the excavated levels, which is not the case for the musk-ox or bison (Kacimi, 2003), it is possible to compare several layers. For this study, we selected two archaeological levels in which argali are abundant, in order to couple taphonomic observations with zooarchaeological results to assist us in interpreting the origin of accumulations in the cave. Multiple indicators were used to test the role of humans versus carnivores, and to specify the collector behaviour (i.e. procurement and transport strategies).

The argali assemblages and their context

The argali, *Ovis ammon antiqua* (Mammalia, Bovidae), originated in Asia and lived in southern Europe during the Middle Pleistocene. The argali from the Caune de l'Arago, found in all units, are comparable with extant Asiatic argali. Their weight varied between 100 and 173 kg based on estimates from an allometric relationship using the astragalus (Rivals, 2001). Extant argali are not good mountain-dwellers, unlike mouflon, and prefer slightly sloping areas where they may find grassy vegetation (Shackleton & Shank, 1984; Fedosenko, 2000). These preferences have also been confirmed for the fossil argali from the Caune de l'Arago using both ecomorphological adaptations and microwear dental analysis (Rivals, 2004; Rivals & Deniaux, 2003).

The levels studied in the Caune de l'Arago

There are four main stratigraphic units in the Caune de l'Arago (units I to IV); however, the archaeological levels studied belong to units I and III (Figure 2). Archaeological levels are subdivisions of the stratigraphical units and are based on the archaeological remains found in these units. Also, every layer of archaeological remains corresponds to an archaeological level.

Stratigraphical unit I is composed of coarse layered sands (Amharref, 2003). Archaeological levels S to K are dated to OIS 14 (about 570,000 to 530,000 years, for levels S and K; de Lumley *et al.*, 1984). The landscape was open and the climate cold and dry, based on the presence of reindeer (*R. tarandus*) and argali (*O. ammon antiqua*). In addition, palynological data indicate that trees were rare and that the landscape was a steppe with Poaceae (Graminaceae) and Asteraceae (Renault-Miskovsky, 1980). In this unit, levels M, N and O, excavated over 70 m^2, correspond to a succession of several occupations. Since remains are rather scarce, it was not possible to make the distinction between these three levels during the excavation. Consequently, these three levels are grouped for this study. In levels M, N and O, carnivores are abundant relative to herbivorous taxa (31.5% of the MNI for large mammals; Rivals *et al.*, 2003). In particular, Ursidae and Felidae are abundant in this unit (Quiles, 2002; Rivals *et al.*, 2002). A small-sized fox was also discovered. However, artefacts are rather scarce in this level, while bones are well preserved and frequently in articulated connection and/or complete. No dating is available for these levels. Lithic industry (254 pieces) is characterised by Acheulean technology largely dominated by discoidal flaking and the oldest European

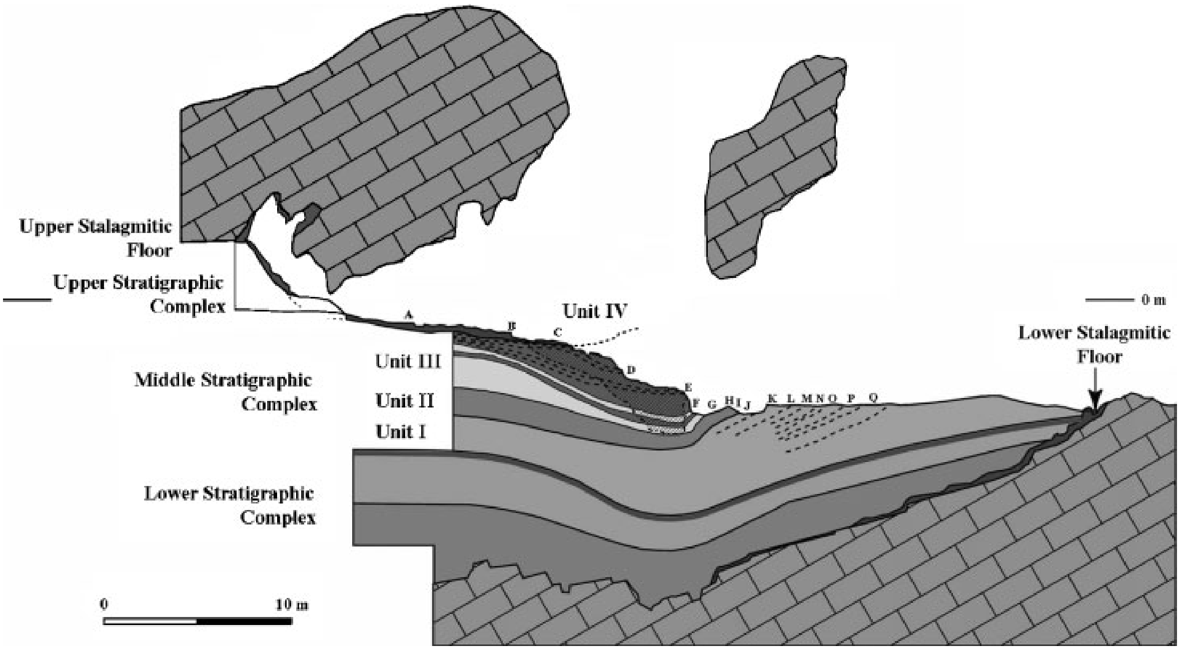


Figure 2. Stratigraphical section showing units I and III (from de Lumley *et al.*, 1984, modified by Falguères *et al.*, 2004).

handaxes yet discovered *in situ* (de Lumley & Barsky, 2004).

Stratigraphical unit II is made of sandy silts transported by water streaming into the cave. This unit includes several human occupation levels (J, I and H) correlated to OIS 13 (about 530,000 to 480,000 years, for levels J and H respectively; de Lumley *et al.*, 1984). Palynological data indicate that trees were abundant, with oak, hornbeam and elm present. Towards the top of this unit, some temperate and thermophile taxa are present, such as plane, walnut and pistachio (Renault-Miskovsky, 1980). Also, the abundance of red deer (*Cervus elaphus*) and fallow deer (*Dama clactoniana*) suggest a forested landscape and a temperate and humid climate.

Stratigraphical unit III is made of coarse layered sand transported by strong winds. It includes several layers of small pebbles which correspond to human occupation levels dated to OIS 12 (about 480,000 to 400,000 years, for the base of level G and level D respectively; de Lumley *et al.*, 1984). The ESR age obtained for level F is 430 ± 85 ka (Yokoyama *et al.*, 1985). The pollen study has revealed several climatic fluctuations, with alternating forest (indicating a temperate and wet climate) and steppe (suggesting a cold and dry climate) (Renault-Miskovsky, 1980). In this unit, level F (located just above level G) was excavated over a 35 m^2 area. Excavations brought to light numerous large mammal remains, associated with abundant stone tools, as well as 19 human remains (*Homo heidelbergensis*). All of the carnivore taxa detailed above were found, plus a wild cat, *Felis silvestris*. The proportion of carnivores is less than 5% of the total mammals found in this level. Stratigraphical unit III includes several layers with a more evolved stone technology than that observed in stratigraphic unit I (6285 coordinated pieces, not including angular fragments), with diverse production techniques including multi-directional and globular cores (de Lumley & Barsky, 2004).

Stratigraphical unit IV, only preserved in the back of the cave, comprises a succession of stalagmitic floors separated from each other by silty sand deposits. This unit includes levels correlated to OIS 11 to 5 (Falguères *et al.*, 2004). Pollens are characteristic of a temperate and humid climate (Renault-Miskovsky, 1980).

Distribution of the argali remains

The spatial distribution of the argali remains in levels M, N and O and F from the Caune de l'Arago is shown in Figures 3 and 4. Each excavation square measures 1 m^2 and is identified by a longitudinal strip (letter) and a transverse one (number). Towards the entrance, levels M, N and O were cut by erosion due to collapse of the roof of the cave and porch regression.

In levels M, N and O we observed objects present along the east wall between 9 and 14, and from east to west in 12, 13 and 14 corresponding to a large dispersion of well-preserved and complete argali bones. Two groups appear in squares F15, F16, G15, G16 and G17: two parts of an argali vertebral column. Most of these elements were found articulated, with cervical vertebrae on one side and on the other side the thoracic, lumbar and sacrum, together with pelvis and proximal ends of the two femurs.

In level F, bone density is significantly higher than in levels M, N and O (NISP, the number of identified specimens = 6577). The area found between 16 to 18, and A to D, represents a geochemically altered area. In both levels, the

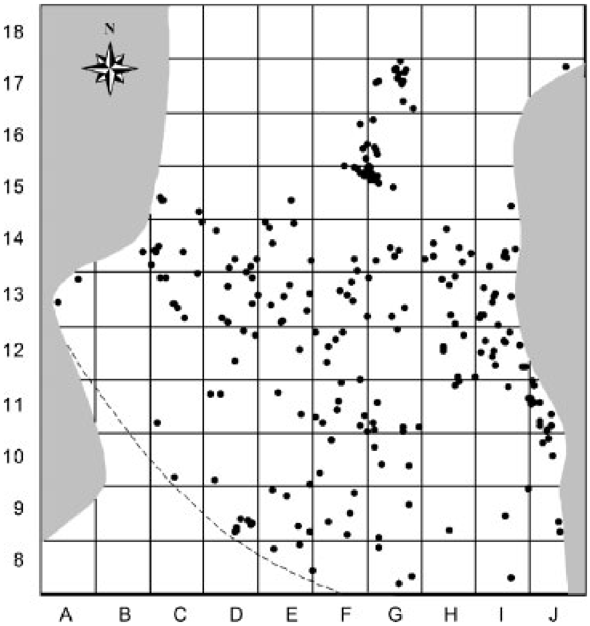


Figure 3. Horizontal distribution of the argali remains in levels M, N and O.

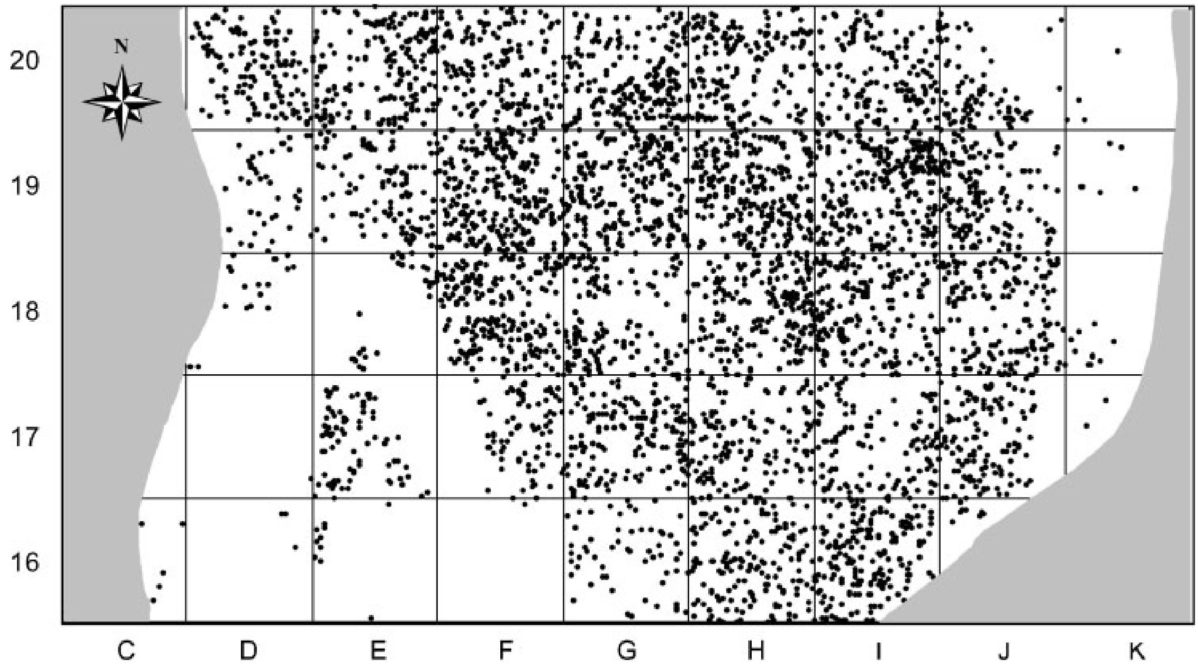


Figure 4. Horizontal distribution of the argali remains in level F.

variance/mean ratio test, used to characterise spatial distributions (Dacey, 1973), does not support the hypothesis that the argali bone assemblages have random patterns in levels M, N and O ($\chi^2 = 372.41$; $P > 0.05$), nor in level F ($\chi^2 = 1029.8$; $P > 0.05$). Moreover, this criterion alone could not be relied upon for discriminating between human and carnivore accumulations (Grayson & Delpech, 1994). Carnivores leaving remains in articulation and humans organising their habitat in areas corresponding to butchering activities may have created the same patterns.

Since the two studied levels differ substantially in sample size (the level F sample is bigger than the sample from levels M, N and O), in order to avoid bias in the non-parametric statistical tests we always used the proportions of bones and MNI and not the actual counts.

Zooarchaeological background

The zooarchaeological study of the argali remains from levels F and M, N and O has been published by Rivals *et al.* (2003). Here we provide a short abstract of the methods and results from the present study which are pertinent to understanding this taphonomical analysis. For example, the determination of individual age is based on the observation of eruption, replacement and wear both of isolated teeth and teeth found in mandibles and maxillae. Such estimates of individual age from tooth eruption and wear are based on dental eruption sequences established from several species of wild sheep (Deming, 1952; Pfeffer, 1967; Hemming, 1969).

The method used to determine sex relies on the morphological differences in the pelvic bone between males and females (Edwards *et al.*, 1982; Prummel & Frisch, 1986). Only fused bones were used to determine sex in order to exclude juveniles. Determination of sex in the argali population was established observing 12 pelvic bones of adult animals. Adults found in these levels are males only. This over-representation of males might be due to the fact that males live alone most of the year except during the mating season at the beginning of winter (Gonzales, 1984). These observations suggest that these animals were killed at any season except early winter.

The season of settlement at the site was estimated using measurements of tooth crown

Table 1. MNI proportions for the argali from levels M, N and O, and from level F

Age groups	Young			Prime adults				Old adults		*n*
	Y1	Y2	Y3	Pa1	Pa2	Pa3	Pa4	Oa1	Oa2	
Level F	7.5	6.5	8.9	13.1	16.4	20.1	14.5	8.9	4.2	214
Levels M, N, O	14.3	7.1	7.1	17.9	7.1	14.3	14.3	10.7	7.1	28

height (Kurtén, 1953) and by studying teeth with reduced use-wear (wear stage corresponding to the eruption of the tooth out of the gum). These criteria were used for detecting seasonality on isolated teeth, mandibles and maxillae using data from modern wild sheep (Deming, 1952; Pfeffer, 1967; Hemming, 1969).

Argali remains represent more than a quarter of the large mammal remains in levels M, N and O (NISP = 253; MNI, the minimum number of individuals = 28). Young and old adults seem to be better represented here than in level F, suggesting a preference towards the weakest animals in level F (Table 1; Figure 5). A comparison of the age proportions between the two levels suggests, however, that the differences are not significant (Kolmogorov-Smirnov test, D = 0.2222, $P = 0.9574$). Young individuals were found to be over-represented compared with a winter free-ranging population (Figure 6), yet they match with a summer population from the Pyrenees Mountains in France (Gonzales, 1984).

In level F, argali is the dominant mammal, representing about 61% of the large mammal MNI (NISP = 6577, MNI = 214). The level F mortality profile (Table 1; Figure 5) shows that the preferences of the collector focused more on mature adults than on young and old ones, which is generally considered characteristic of human selection because the prime adult class is the most abundant (Klein & Cruz-Uribe, 1984). The problem of differential preservation of immature bones and teeth versus those of adults may account for these results. But this profile was not found to be significantly different from the profile from levels M, N and O.

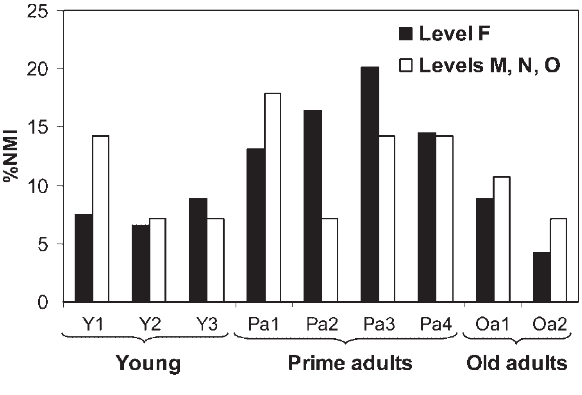


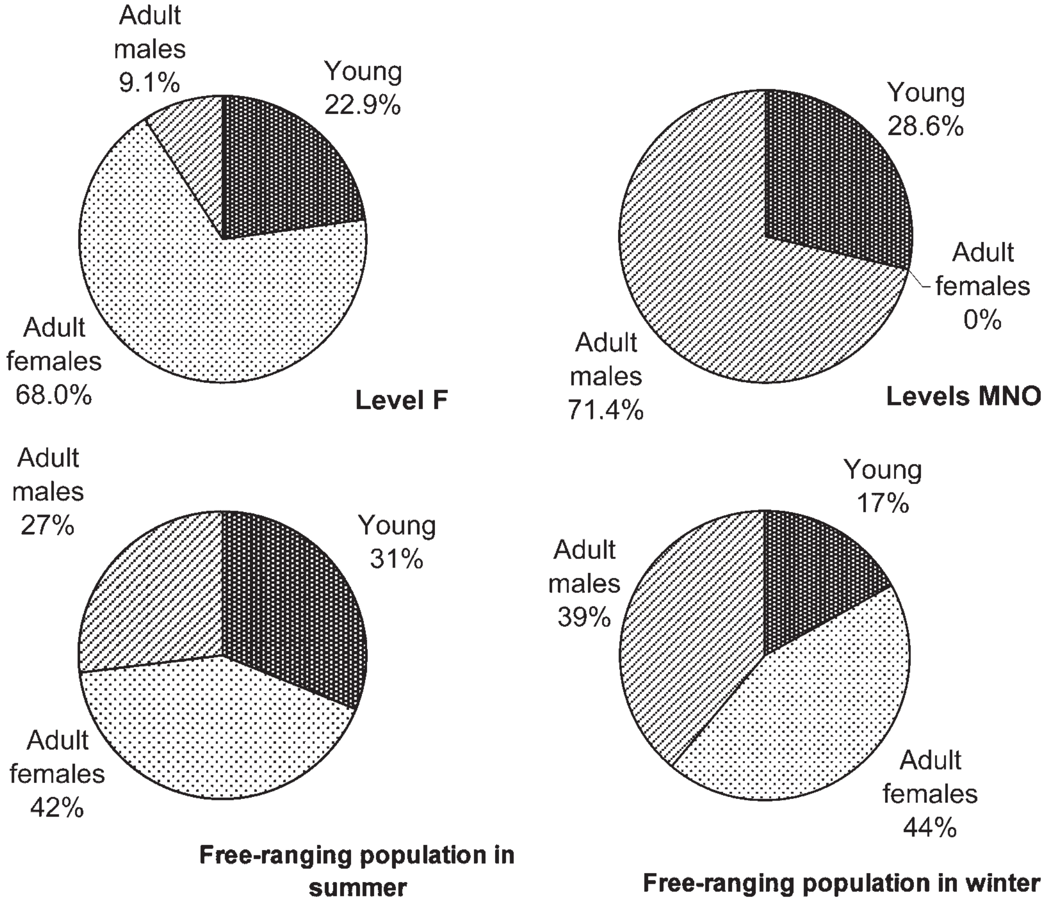
Figure 5. Mortality profiles for the argali sample from levels M, N and O and level F. Labels Y1–3, Pa1–4 and Oa1–2 correspond to the nine age cohorts identified in our sample.

Sex was determined from 26 pelvic bones. Females represent 68% of the population (Figure 6). If adults only are considered and young animals are excluded, 88.2% of the population is female. A statistical method applied to limb bones by Monchot (1999) gave the same results. Also, a study of dental eruption and wear suggests that animals were hunted from the end of spring to the end of summer (Rivals, 2004). This result is in agreement with age and sex observations, since at this season, i.e., after the birthing season, females live in large groups together with the young animals (Gonzales, 1984).

We found that the age profiles were not significantly different between the two levels. Since it has been observed that several predators (such as humans or carnivores) can produce a similar age profile (Stiner, 1990a; Lyman, 1994), these age profiles cannot be used to characterise the actual hunting agent and other indicators must be employed.

Taphonomical characterisation of levels M, N and O and level F

Indicators of differential preservation, skeletal frequency and bone surface modifications were used to test whether carnivores or hominids were


Level F

Levels MNO

Free-ranging population in summer

Free-ranging population in winter

Figure 6. Structure of the argali population in level F and levels M, N and O (from Rivals *et al.*, 2003) and of a free-ranging mouflon population from the Pyrenees Mountains (data from Gonzales, 1984). Percentages correspond to MNI proportions.

the accumulation agents in levels M, N and O and level F.

Skeletal frequency and differential preservation

Skeletal frequency is used to search for differences in the skeletal element abundance in assemblages induced either by the differential preservation of bone remains or by carcass treatment (Binford, 1978). This study of skeletal representation includes epiphyseal and shaft fragments. Shaft fragments were carefully analysed, identified, and included in the MNE estimates for element abundance as proposed by Marean (1998), Marean & Kim (1998) and Pickering *et al.* (2003).

Mandibles and maxillae are less abundant in levels M, N and O with respect to level F (Table 2; Figure 7). This can be attributed to a more intense bone fragmentation and tooth dispersion in level F, whereas in levels M, N and O, cranial elements are more often complete and isolated teeth are less abundant relative to level F. Vertebrae, ribs, pelves, femurs and tarsals are better represented in levels M, N and O. The slight differences between levels observed in the profiles can be explained by different intensities of bone fragmentation.

Table 2. MNE estimates for argali skeletal elements from levels F and levels M, N and O

	Level F	Levels M, N, O
Horncore	4	7
Maxilla	937	23
Mandible	1394	33
Atlas	3	2
Axis	2	3
Cervical	23	6
Thoracic	29	15
Lumbar	23	11
Sacrum	7	1
Caudal	0	0
Rib	124	20
Scapula	6	0
Humerus	24	3
Radius-ulna	60	2
Carpal	242	9
Metacarpal	85	2
Pelvis	26	8
Femur	30	4
Tibia	66	3
Tarsal	307	15
Metatarsal	72	2
First phalanx	168	6
Second phalanx	105	6
Third phalanx	62	4
Total	3799	185

When bones are grouped together by anatomical regions according to the 7 categories of Wilson (1989), that is, head, axial, forequarter (scapula, humerus, ulna and radius), hindquarter (pelvis, sacrum, femur, patella and tibia), forefoot (carpal and metacarpus), hindfoot (tarsal and metatarsus) and foot (metapodium and phalanx), the same results are obtained: skeletal abundance is not very different in the two levels. When all cranial elements are grouped together, the difference between the two levels is not significant (Kolmogorov-Smirnov test, $D = 0.28571$, $P = 0.88275$). This same pattern holds true for the axial skeleton and especially the ribs, which are more fragmented and consequently less identifiable in level F. There is no significant difference for part selection in the levels.

The mode of bone fragmentation can also be tested by comparing the observed number of archaeological specimens with the number expected if the skeleton were complete, as proposed by Reitz & Wing (1999). For each anatomical part, the difference is expressed in natural logarithm (Table 3). In the ratio diagram (Figure 8), the O axis represents the number of bones in a complete skeleton; positive values

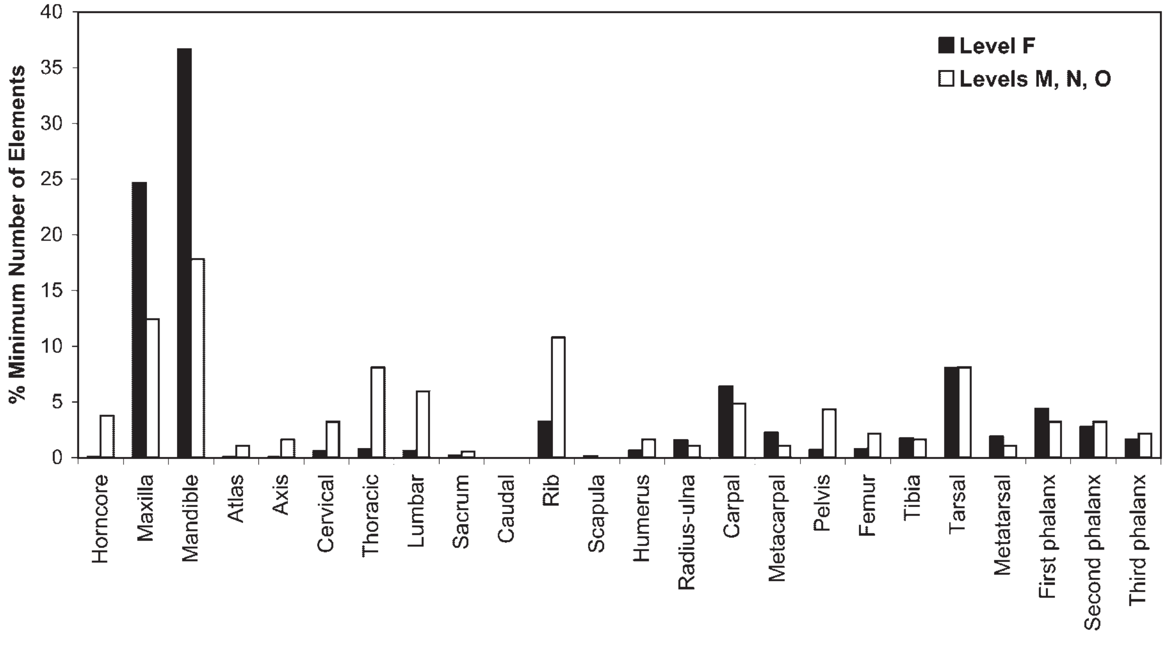


Figure 7. Skeletal abundance of argali from levels M, N and O and level F.

Table 3. Ratios of argali skeletal portions using NISP (number of identified specimens) from levels M, N and O and from level F (d = logarithmic difference)

	Level F (a)		Levels M, N, O (a)		Complete *Ovis* (b)		d = (ln a) − (ln b)	
	NISP	NISP%	NISP	NISP%	NISP	NISP%	d F	d MNO
Head	2377	47.82	90	37.50	63	23.86	0.694	0.45
Axial	398	8.01	58	24.17	73	27.65	−1.241	−0.136
Forequarter	259	5.21	7	2.92	8	3.03	0.552	−0.028
Forefoot	286	5.75	22	9.17	16	6.06	−0.058	0.407
Hindquarter	375	7.55	12	5.00	14	5.3	0.353	−0.058
Hindfoot	473	9.52	18	7.50	14	5.3	0.585	0.347
Foot	802	16.14	33	13.75	76	28.79	−0.579	−0.739
Total	4970		240		264			

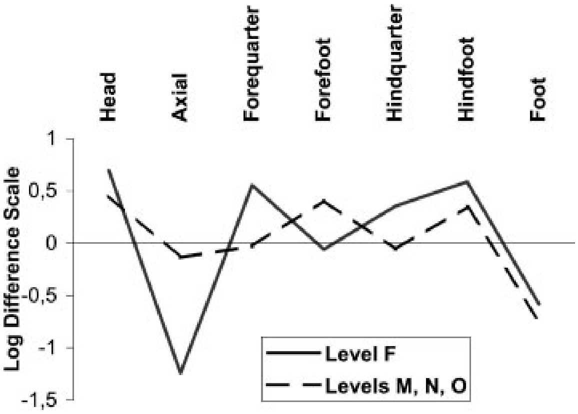


Figure 8. Ratio diagram of argali skeletal portions using NISP from levels M, N and O and from level F. Differences are in logarithmic scale. The reference line ($y = 0$) represents the number of bones in a complete bovid skeleton.

indicate that the skeletal portions are more abundant than the standard, and negative values are those underrepresented. For the levels studied, the skeletal portions are either in normal proportions or overrepresented, with the exception of the foot and the axial skeleton in level F, which are underrepresented. Since for the axial skeleton (vertebrae and ribs) only the proximal end can be identified, these parts are always found in lesser proportions than mandibular remains when subject to breakage. The difference observed for the axial skeleton is related to this mode of bone fragmentation and the similarity of the profiles to a taphonomic bias. This cannot be an indicator of the aggregation agent, since carnivore and human hunters can produce extremely similar bone accumulations, especially when carnivore post-ravaging has been documented in assemblages abandoned by humans (Lyman, 1994; Marean & Cleghorn, 2003).

Fragmentation causes differential preservation of bones in the assemblages which can be studied through several indices. These indices, proposed by Brugal & Patou-Mathis (1993), are calculated in order to evaluate the relative preservation of cranial and post-cranial elements:

- The general skeletal preservation index, or IGCS (*indice général de conservation squelettique*), is the ratio between the cranial NISP and the post-cranial NISP. For a complete skeleton of bovid, the assumed ratio is 0.27. For levels M, N and O the IGCS is 0.51, and 0.90 for level F (Table 4).
- The bone breakage intensity index, or IFO (*indice de l'intensité de fragmentation des ossements*), is the ratio between the number of complete bones and the number of broken bones for each taxa. It gives information on the magnitude of the destruction. For levels M, N and O the IFO is 0.26, and 0 for level F (Table 4)– argali remains are highly broken in level F.

Table 4. Comparison of preservation indices for argali from the Caune de l'Arago

	NISP	MNI	IGSC	IFO	ICD
Level F	6577	214	0.90	0	0.85
Levels M, N, O	253	28	0.51	0.26	0.43

IGSC, general skeletal preservation index; IFO, bone breakage intensity index; ICD, dental preservation index.

- The dental preservation index, or ICD (*indice de conservation dentaire*), evaluates dental preservation for a species relative to the total skeleton (isolated teeth NISP / post-cranial NISP). For bovids, the hypothetical ICD is 0.20. For levels M, N and O the ICD is 0.43, and 0.85 for level F (Table 4). The ICD values indicate a higher representation of isolated teeth in level F than in levels M, N and O. This has already been observed and is due to a high degree of fragmentation of the mandibles and dispersion of the isolated teeth in level F.

All these indicators show that breakage, especially for vertebrae and ribs, was more intense in level F where bone identification is more difficult due to stronger alteration. The abundance of isolated teeth in level F is related to strong fragmentation processes, but may also be related to higher MNIs in this level. The post-cranial skeleton is less fragmented in levels M, N and O than in level F. At Scladina cave, Patou-Mathis (1998) showed that the post-cranial skeleton is more fragmented in a human occupation with secondary carnivore activity (IGSC = 0.56) than in exclusively carnivore occupation levels (IGSC = 0.39).

Bone surface modifications

In order to pinpoint more precisely the assemblage collector, we observed the bone surface modifications as either carnivore tooth marks by gnawing, or butchering marks made by lithic tools used for skinning, evisceration, disarticulation, and marrow extraction from animal carcasses. The bones were systematically observed, firstly using a magnifying lens. Binocular microscope observations confirmed the identification and detected inconspicuous marks. Many carnivore marks were doubtful and problematic, mostly likely due to trampling. Such marks were excluded from our counting regime. Because bone surface analysis should distinguish between bones with good cortical preservation and those with poor cortical preservation (Domínguez-Rodrigo, 2003), only bones with good cortical preservation were observed (alteration of the sample is minimal, however). A total of 6485 bones with good cortical preservation were sampled for level F, and 244 for levels M, N and O (i.e. 98.6% and 96.5% of the total argali NISP respectively).

Carnivore marks

In their attempts to remove meat from bone, and even to transport bones themselves, carnivore teeth leave characteristic markings on bone surfaces. Two patterns of carnivore marks are identifiable: mechanical and chemical attacks (Fosse *et al*., 1998). Mechanical marks are provoked by carnivore jaw action, resulting in more or less pronounced gnawing marks. Chemical marks are due to the action of gastric juices. The proportion of bones showing carnivore marks (gnawing and biting marks, digestive corrosion) was 1% of the argali NISP in level F, and 17.6% in levels M, N and O. The alteration by carnivores was found to be caused by partial corrosion by digestive acids in some areas of the bones. This suggests that bones were actively accumulated by carnivores by regurgitation and/or by digestion and excretion. Some carnivore marks were found on the broken diaphysis of long bones from level F, suggesting that carnivores could have scavenged on this human-made assemblage (Moigne, 1983).

The bone accumulation from levels M, N and O shows a low frequency of tooth marks. However, if prey is abundant in an area, competition between carnivores is low, resulting in lesser amounts of damage on carcasses (Domínguez-Rodrigo, 1999). In such cases, it is possible to find bones with few conspicuous traces of carnivore activity (Domínguez-Rodrigo, 1994). Prey abundance could explain the low frequency of carnivore marks in levels M, N and O. Moreover the proportion of carnivores (versus herbivorous taxa) in both levels corroborate this observation, since they appear to be more abundant in levels M, N and O than in level F (31.5% and 4.5%, respectively).

Carnivore gnawing marks were observed, for example, on a pelvis from level N (Figure 9). Firstly, the bone shows the marks left when a carnivore bites down hard on bone: the teeth leave impressions such as pits and punctures on the bone surface. Secondly, the impression forms

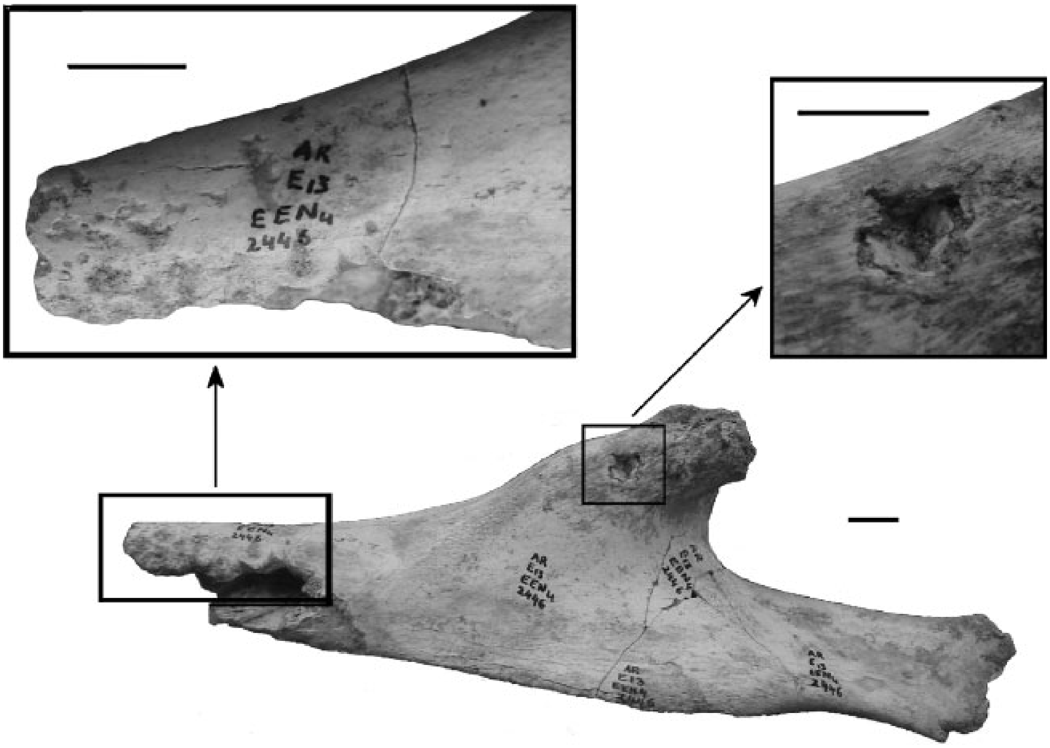


Figure 9. Punctures and pitting on a left argali pelvis from level N (specimen AR E13 EEN4 2446) (scale bars = 1 cm).

scores and furrows as the carnivore moves its teeth along the bone (Haynes, 1980; Binford, 1981).

Mandibles of argali from levels M, N and O show different fracture damage compared with those from level F (Figures 10 and 11), where no carnivore marks were found. Moreover, levels M, N and O mandibles were systematically broken and their marrow cavities have been opened by splitting the base of the horizontal ramus away from the tooth row. Intentional breakage is evident by impact points present in two areas. The first, located above premolars, causes a smooth and distinct fracture surface. The other point is located on the internal side, between the second and third molars, and causes the breakage of the horizontal and vertical rami, as well as of the crown tip of the last molars. Cut marks are rather scarce and located on the mandibular condyle. In levels M, N and O, mandibles were gnawed along the margins of the coronoid process and in the anterior region of the mandible between the symphysis and the mental foramen. We also found irregular marks on the jagged edges of the bones. When observed using ESEM, these marks are different from cut marks since their edges are irregular and not sharp, and there are no micro-striations visible inside the mark (Figure 12). This is typical of mandibles from assemblages deposited by carnivores (Stiner, 1990a).

In levels M, N and O, chemical marks of digestion were observed on various bones (mainly short bones such as carpals, tarsals and phalanges). These marks result from the outer surface flaking off. The bone reliefs are softened and the foramina are often enlarged (Fosse *et al.*, 1998). The fact that the majority of bones affected by such damage are small-sized bones would seem to indicate that they had been swallowed and then excreted in faeces rather than regurgitated.

Since gnawing damage on specimens of some fossils has been attributed to specific carnivores (Haynes, 1983; Selvaggio & Wilder, 2001), we tried to identify the actual carnivores responsible for the bone accumulation from levels M, N and O. The dimensions of tooth marks on bones were

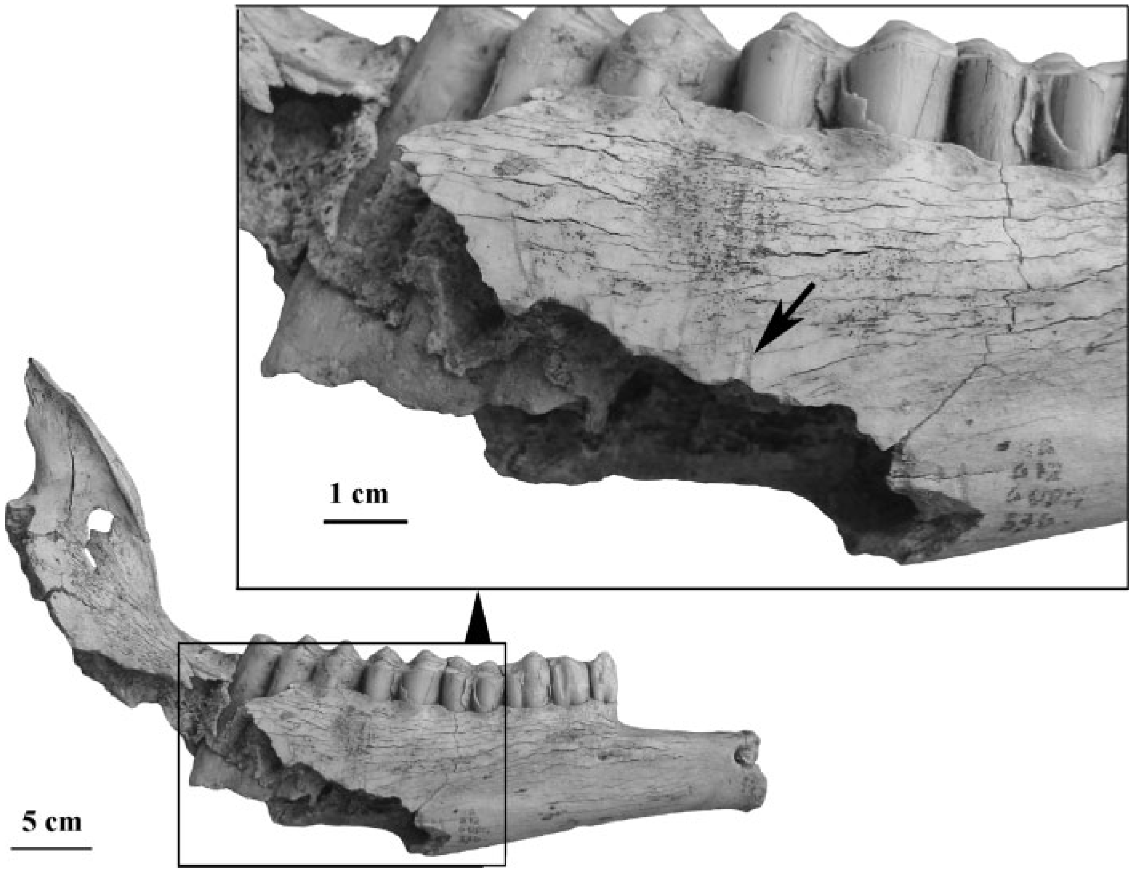


Figure 10. Scores on an argali right mandible from level O (Specimen AR G12 GDP17 536). The arrow in the insert shows the location of the ESEM observation in Figure 12.

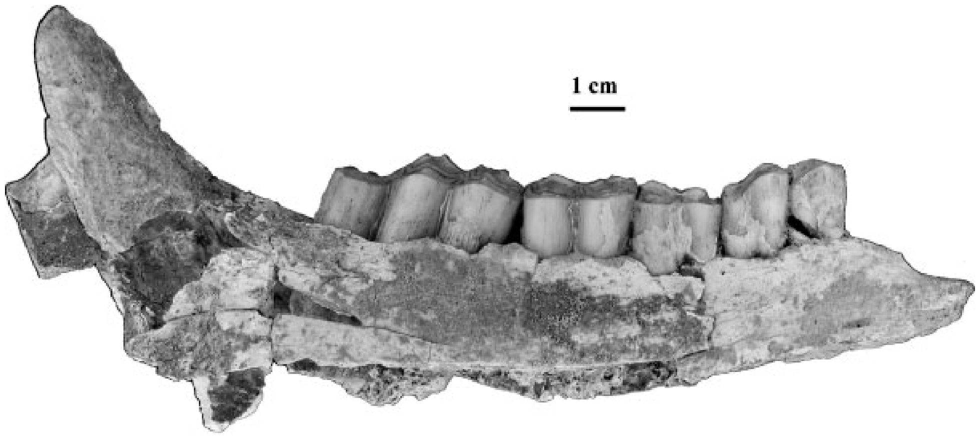


Figure 11. Argali right mandible from level F (Specimen AR D20 DLF8 1349).

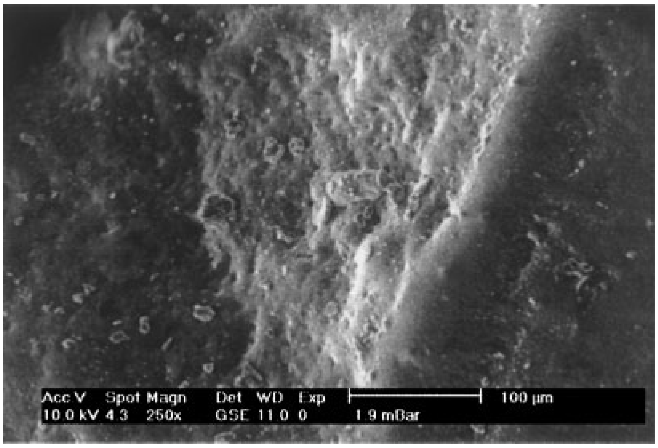


Figure 12. Scores on an argali right mandible from level O (Specimen AR G12 GDP17 536; Fig. 11), observation at × 250 magnification (ESEM photography by Brigitte Deniaux, CNRS UMR 5590 Tautavel). The location of this observation is indicated by an arrow on Figure 10.

not used in this study, since they cannot characterise the carnivore involved (Domínguez-Rodrigo & Piqueras, 2003). However, other criteria have been proposed by Haynes (1983) and Domínguez-Rodrigo (1999) to discriminate between ursids, canids, felids and hyenids. Hyena gnawing typically results in severe crenellation and salivary rounding of broken edges, large punctures and tooth drag marks (Stiner, 1990b). Long bone epiphyses may be literally eaten away during feeding at dens. In situations where hyenas gnaw bone intensively, this behaviour may lead to the selective deletion (via ingestion) of smaller bone elements and/or less dense bone tissues (Sutcliffe, 1970; Stiner, 1990b; Lam, 1992). Hyenas and canids leave far more scratches or tooth marks on compact bone surfaces than large cats (Haynes, 1985). Wolves or hyenas frequently wear away epiphyses with their teeth in a gradual process that leaves numerous tooth marks; when large felids are concerned, entire epiphyseal ends of limb bones may appear to have been simply bitten off (Haynes, 1985). Since no hyena remains were found in the excavated levels and because the marks on the compact tissues were weak, these criteria tend to exclude hyenids.

The pattern observed for levels M, N and O is quite similar to that described by Domínguez-Rodrigo (1999) for extant lions. We observed the following similarities: the skulls were abandoned almost unaltered except the front facial bones which were chewed; the mandibles show scattered scores or pits on their surfaces on the angle and on the coronoid process; on the vertebrae, some damage has affected the neural spine and transverse processes; the ribs are broken and their distal sections consumed during the evisceration; the pelvis shows furrowing on the iliac crest together with punctures and scores; and the sacrum is unaltered, as well as the rest of the pelvis. Consequently, felids and some canids should be considered as the most probable carnivore agents of the M, N and O accumulations.

Breakage and cut marks

In levels M, N and O, no butchering marks were found on argali remains. In level F, however, some bones show cut marks. In level F, the proportion of bones with cut marks is 5.4% of the argali NISP (181 bones with cut marks). These cut marks were found on all argali bones: mandibles, axial, and limbs.

Humans typically open the marrow cavity of the mandible by breaking it transversally into several segments and by splitting the base of the horizontal ramus away from the tooth row (Stiner, 1994). This breakage pattern is frequently observed in level F, resulting in a series of pieces with angular contours. We also observed a large number of cut marks on an argali rib (Figure 13a). These cut marks are distinct, short and asymmetrical, with a

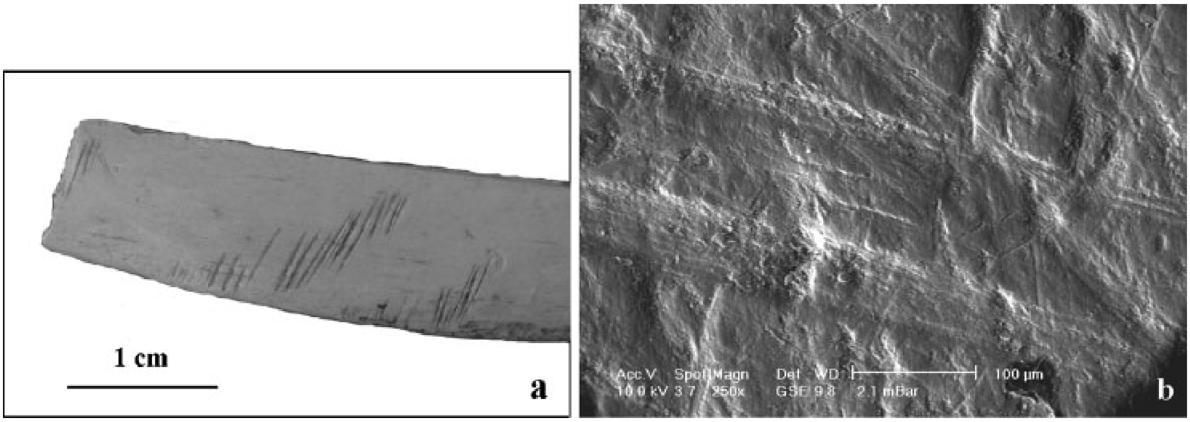


Figure 13. Cut marks on an argali rib from level F (Specimen D16 K0 2056). View of the rib fragment showing several short cut marks (a) and ESEM magnification ×250 (b). (ESEM photography by Brigitte Deniaux, CNRS UMR 5590 Tautavel).

microstriation (Figure 13b). These are characteristic signs of human butchery.

The observations of bone surface modifications offer more conclusive results than skeletal frequency. The M, N and O argali assemblages were most probably the result of felid and/or canid predators. Also, it is unlikely that carnivores had secondary access to human-made assemblages, since no cut marks were found on the well-preserved bone surfaces. The observation of the bone fragmentation patterns, coupled with well-identified cut marks, agrees with the high value of the bone breakage index (IFO) in identifying a greater influence of human activity in level F than in levels M, N and O. In level F, humans were occasionally followed by carnivore scavengers.

The variability observed in carnivore behaviour is well documented (Brain, 1981; Haynes, 1983; Palmqvist *et al.*, 1996; Kruuk, 2002), but there are some arguments in favour of a human-dominated occupation in level F and a carnivore-dominated occupation in levels M, N and O. However, given the small sample sizes in levels M, N and O, we cannot exclude the possibility that these levels represent a mixed set of carnivore and human activities.

Procurement and transport of carcasses

In order to clarify the human versus carnivore question, we attempted to elucidate the mode of procurement of the carcasses (i.e. hunting or scavenging) as well as the mode of carcass transport to the cave (i.e. total or partial).

Procurement of carcasses: hunting or scavenging

In the case of carnivore accumulations, primary bone assemblages collected by predators (such as leopards) can be differentiated from secondary assemblages accumulated by scavengers (such as hyenas) (Palmqvist & Arribas, 2001). Table 5 presents the criteria of this differentiation (zooarchaeological as well as taphonomical) for levels M, N and O at the Caune de l'Arago. Five of the six criteria indicate that the bone accumulation of levels M, N and O correspond to a primary assemblage. The only criterion that differs is the abundance of limb bone epiphyses in relation to diaphyses. With the exception of the latter, the criteria are highly in favour of the primary assemblage hypothesis, in that vertebrae and limbs are well represented with respect to limb bones, articulated bones are frequent, and carnivore remains are abundant. Many bones were found complete, well-preserved, and often in articulation. This pattern follows the dislocation process characteristic of carnivores proposed by Haynes (1980). Since no butchering marks were found on the argali bone sample, humans do not seem to have taken part in the constitution of the M, N and O assemblage, or to have scavenged the carcasses after they were left behind.

Table 5. Synthesis of the differences between extant primary and secondary bone assemblages (data from Palmqvist & Arribas, 2001). Comparative study of level M, N and O assemblages from the Caune de l'Arago

Characteristics of the bone assemblage	Primary assemblage, collected by predators	Secondary assemblage, collected by scavengers	Caune de l'Arago levels M, N, O assemblage
Proportion of vertebrae and ribs in relation to pelvis and limb bones	High, >25%	Low, <25%	63.0%
Abundance of articulated bones, in anatomical connection	Articulated elements are quite abundant	Articulated bones are scarce	21.7%
Abundance of major long bones preserved complete	High and not related to their marrow content	Low, inversely related to marrow yield	26.0%
Abundance of limb bone epiphyses in relation to diaphyses	High (2:1)	Comparatively low (1.5–1:1)	1:1
Carnivore/ungulate index, calculated from MNI counts	High (25–50%) or very high (>50%, in death traps)	Low, 5–15%	46.0%
Relative abundance of juvenile ungulates	High proportion, >25%	Low proportion, <25%	28.6%
Conclusion			Primary assemblage

In the case of human accumulations during the Lower Palaeolithic, food procurement strategies varied. Humans practised scavenging, as in the units II and III of Galería, in the Atapuerca sierra (Huguet *et al.*, 1999; Díez *et al.*, 1999). Hunting is attested to in some localities, such as the 'Ubeidiya Formation in Israel (Gaudzinski, 2004) or at Schöningen in Germany (Thieme, 1997) and in several levels at the Caune de l'Arago (Moigne, 1983; Monchot, 1996). In levels M, N and O, the evidence is in favour of primary collectors—prey was hunted and carried into the cave by predators. As mentioned above, animal predators were most probably felids and canids whose remains were found in these levels associated with coprolites (Jouy-Avantin *et al.*, 1999), rather than scavenging hyenas whose remains were not found in these levels. In level F, where the assemblage is closely associated with human artefacts, we did not find evidence of human scavenging. Argali, representing more than 60% of the large mammals, were hunted by human primary collectors. Hunting was opportunistic, that is, without selection of individuals, and specialised on this single species (Rivals *et al.*, 2002).

Mode of transport

The procurement mode of carcasses is reflected by the assemblages. In the case of scavenging, collectors generally have secondary access to the carcass, and consequently, only the less nutritive parts remain. In the case of hunting, the whole carcass is available and the predator chooses either to transport it totally or partly towards the butchering site (Binford, 1978). This varies with the size of the hunted animals, the distance of the hunting site from the cave, and/or the difficulty of access. The less nutritive parts of the carcass may be abandoned at the killing site. We applied two indices to interpret the variations observed.

- The Food Utility Index (FUI) as defined by Metcalfe & Jones (1988) corresponds to the nutritive value estimated for each skeletal part. FUI measures the same property as MGUI, but it is interpreted more easily. In the two levels we observed a negative trend between MAU and FUI (Figure 14). The correlation coefficients ($R^2 = 0.0665$ and 0.0325 for level F and levels M, N and O, respectively) are not significant at the 95% confidence level

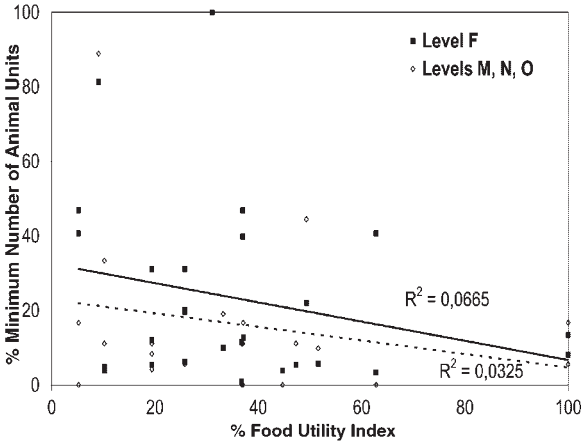


Figure 14. Standardised food utility index (%FUI from Metcalfe & Jones, 1988) plotted against the %MAU (Minimum number of Animal Units) of surviving domestic sheep (*Ovis aries*) bones. Full and dotted lines correspond to level F and levels M, N and O, respectively.

(degrees of freedom = 25). This result may be biased by the intensive breakage by humans in level F and by differential preservation of low-density elements in levels M, N and O. However there is no relationship between MAU and FUI. In other words, the low nutritive elements whose FUI is low, cannot be considered as less represented than those of high nutritive value. Also, differential preservation may explain the observed pattern.

- The structural density of bones first proposed by Brain (1969) and Behrensmeyer (1975), and then refined using CT scans by Lam *et al.* (1999), is based upon the comparison between density and MAU. Since we recorded the detailed fragmentation of the bones, we used all the scan points provided by Lam *et al.* (1999) for reindeer. The structural density is used to be sure that the frequencies of skeletal parts observed are actually a reflection of the hunters' strategies and not of some other factor such as differential preservation. In level F we found a positive correlation, with a coefficient ($R^2 = 0.0672$; $t = 2.26$) significant at the 95% confidence level. In level F, dense elements are more abundant, in that there was no differential transport and the variations observed in skeletal frequency have to be attributed to differential preservation (Figure 15). This indicates that the carcasses of argali could have

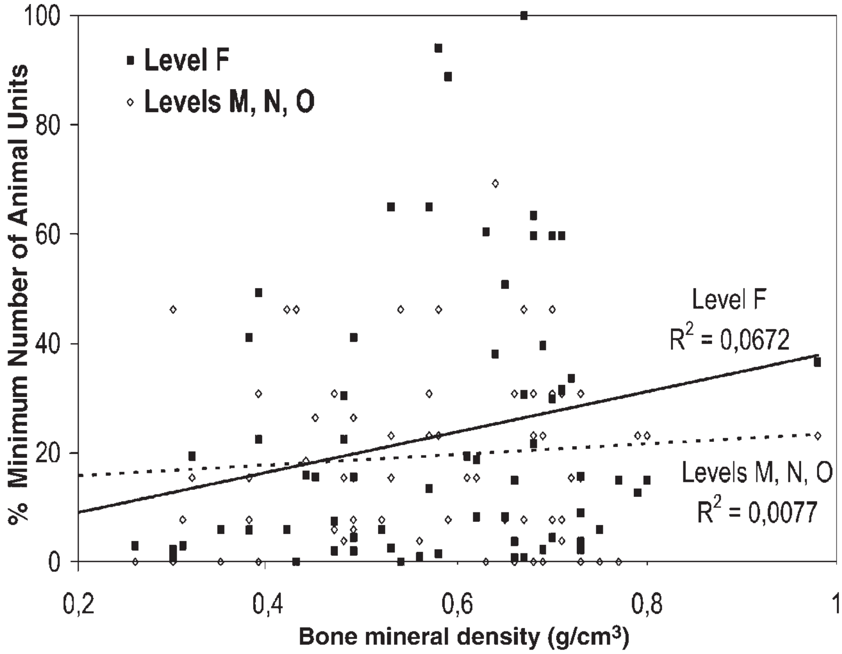


Figure 15. Scatterplot of argali %MAU (Minimum number of Animal Units) values from the Caune de l'Arago against bone mineral density values (in g/cm^3) for reindeer, *Rangifer tarandus* (Lam *et al.*, 1999). Full and dotted lines correspond to level F and levels M, N and O, respectively.

been transported whole from the hunting place to the cave. In levels M, N and O, the null hypothesis of no relationship cannot be rejected ($R^2 = 0.0077$; $t = 0.74$).

In short, the indices lead us to conclude that differential preservation altered the assemblages, particularly in level F, even more than the original strategies used by their accumulators. Considering the results of plotting the FUI and the structural density versus the MAU, the carcasses of argali may have been brought back whole to the cave.

Conclusions

This study of assemblages of argali remains from the Caune de l'Arago (Tautavel, France) shows how taphonomical observations coupled with zooarchaeological studies contribute to recreating a significant part of the information lost during the taphonomic history of accumulations. It is possible here to infer information about the behaviour of humans and carnivores (felids and/or canids). In both levels, the main preservation process affecting the bone assemblages was bone breakage. The problems of differential preservation are well known and were encountered at several prehistoric sites around the Mediterranean Basin, such as Eglises cave (Delpech & Villa, 1993), Lazaret cave (Valensi, 1996), and at several Italian sites (Stiner, 2002).

Zooarchaeological and taphonomical criteria, especially bone surface modifications, allow us to consider both carnivores and humans to be the principals responsible for the accumulation of argali carcasses in levels M, N and O. Although human occupation is evident in levels M, N and O by the presence of stone tools discovered between the levels with argali remains, artefacts were not directly associated with the argali bone assemblages. In level F, criteria indicate that humans exploited argali, and because some carnivore remains were found in this level, we cannot totally exclude carnivore intervention for the formation of this accumulation, as a succession of short interventions by carnivores at this archaeological level.

In both of these levels, there is no definitive evidence to support only one explanation for the origin of the accumulations. Since humans and carnivores are present in both levels, we can suggest that the degree of carnivore activity seems to be a determinant in levels M, N and O. In level F, the degree of anthropogenic activity seems to be higher. There are several arguments in favour of a human-dominated occupation in level F and a carnivore-dominated occupation in levels M, N and O.

Another point shown by this study is the systematic exploitation of argali in the two levels analysed. In other levels of the Caune de l'Arago, different species have been selected. For example, the exploitation focused on reindeer in level L, on fallow deer and red deer in level J, and on musk-ox at the top of level G (Rivals *et al.*, 2004). While selective exploitation is a common phenomenon at prehistoric sites, argali are quite scarce in Western European localities. By adopting a regional approach, Gamble (1995) noticed that there is a correlation between the type of faunal community and the presence of hominids and large and small carnivores. Taking the ibex as an example, he showed that when ibex occurs in faunal assemblages, the number of large carnivores is also greater than in assemblages where it is absent. Moreover, the presence of ibex in communities where evidence of both large and small carnivores as well as hominids is present correlates with rich resources in the area (Gamble, 1995). Although argali have a different ecological niche and dietary preferences than ibex, it is possible that its presence favoured the presence of both carnivores and humans in the area. The frequent presence of several species of carnivores (especially wolf and lion) points to precisely those environments where hominids were best adapted. In this case, inter-predator competition was high due to resource richness (Gamble, 1995). This could explain the presence of both human and carnivore accumulations sat the Caune de l'Arago.

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