

Bonn. zool. Beitr.	Bd. 50	H. 3	S. 143–182	Bonn, Dezember 2002
--------------------	--------	------	------------	---------------------

Horse, reindeer and bison hunters at Solutré: an archaeozoological analysis of a Magdalenian bone assemblage

Elaine Turner

Abstract. The site at the base of the Roche de Solutré is the most famous prehistoric locality in Burgundy, France. Excavations at Solutré have revealed five cultural levels (Mousterian, Aurignacian, Gravettian, Solutrean and Magdalenian) in the thick deposits preserved at this site, reflecting repeated use of the locality from the Middle Palaeolithic through to the end of the Upper Palaeolithic. Solutré has been interpreted as a site where mainly horses were hunted, killed and processed. In this paper, data collected during an examination of faunal remains from Magdalenian deposits in sector P16 at Solutré are presented. The paper focuses on skeletal part representation, age-structures, sexual demography, season of death and traces of modification in the form of cut marks, impact notches and carnivore gnawing of the horse, reindeer and bison remains. The results of the analyses support the theory that the Magdalenians hunted mainly horses at Solutré, but also show that they took relatively high numbers of reindeer and bison. Time of death of horses, reindeer and bison suggests that the site was probably used at varying times of the year, and that groups of juvenile reindeer and juvenile bison were possibly hunted on a seasonal basis. One of the characteristics of the faunal assemblage is the low number of humanly modified bones and the comparatively high number of bones gnawed by carnivores.

Key words. Magdalenian, kill-site, archaeozoology, horse, reindeer, bison, France.

Introduction

The site at the base of the Roche de Solutré is, without a doubt, the most famous prehistoric locality in Burgundy, France. Discovered on the 27th September 1866 by Adrien Arcelin, excavations at Solutré have revealed five cultural levels (Mousterian, Aurignacian, Gravettian, Solutrean and Magdalenian) in the thick deposits preserved at this site (Comber 1956, 1976), reflecting repeated use of the locality from the Middle Palaeolithic through to the end of the Upper Palaeolithic. During these periods, the domination of horses in the faunas has earned Solutré a reputation as the “best example of a large game kill-site in western Europe.” (Olsen 1989: 295).

In 1994, a joint project was arranged between the excavator of the site, Jean Comber, the Service Régionale de l'Archéologie in Dijon and the Römisch-Germanisches Zentralmuseum Mainz, Forschungsinstitut für Vor- und Frühgeschichte, Forschungsbereich Altsteinzeit in Neuwied. The aim of the project was to analyse various aspects of the Magdalenian faunal assemblages from the kill-site of Solutré in order to allow a direct comparison with “horse-dominated” faunas from other Magdalenian sites in Europe (Turner in press).

In this paper, data collected during an examination of faunal remains from Magdalenian deposits in sector P16 at Solutré are presented. The paper focuses on skeletal part representation, age-structures, sexual demography, season of death and

traces of modification in the form of cut marks, impact notches and carnivore gnawing of the horse, reindeer and bison remains. The results of the analyses support the theory that the Magdalenians hunted mainly horses at Solutré, but also show that they took relatively high numbers of reindeer and bison. Time of death of horses, reindeer and bison suggests that the site was probably used at varying times of the year, and that groups of juvenile reindeer and juvenile bison were possibly hunted on a seasonal basis. One of the characteristics of the faunal assemblage is the low number of humanly modified bones and the comparatively high number of bones gnawed by carnivores.

The Solutré site

Solutré is located in the “Mâconnais” region of Burgundy, France (fig. 1). The Mâconnais is a small region, some 45 kilometres long by approximately 20 kilometres wide, situated in the southern part of Burgundy in the French department of Saône-et-Loire. The Mâconnais is bordered to the east by the Saône River and to the west by the Mâconnais hills. The “Roche de Solutré” is one of a series of ridges or “cuestas” in the southern part of this region. The cuestas are oriented from east to west and are separated by broad valleys with minor streams. The archaeological site at Solutré is located at the base of the southern face of the “Roche de Solutré” (fig. 1; plate 1).

At the end of the last century, the discoverer and first investigator of the site, Adrien Arcelin, tried to explain the mass of horse bones revealed during his excavations by describing Palaeolithic hunters driving large herds of horses over the edge of the rock (Arcelin 1872/1977). The concept of Solutré as a “jump” site was upheld until the 1950’s, when Jean Combier (1956) re-interpreted Solutré as a site to which hunters periodically returned to kill horses which were passing through the valley between Solutré rock and the neighbouring rock of Mont de Pouilly, during their seasonal wanderings from winter grazing grounds in the Saône Valley to summer grazing pastures on the higher land to the west of the site. Systematic excavations undertaken by Combier between 1968 to 1987, and several independent archaeozoological analyses of the faunas recovered during this period – in particular the researches of Berke (1989), Gordon (1988), Levine (1979, 1983) and Olsen (1989, 1995) – not only supported Combier’s theory, but also provided insights into hunting practices and butchering activities at Solutré.

At the beginning of the 1990’s, the interpretations of these researchers could be summarised as follows: the site was used almost exclusively as a kill-site, at which horses were the most frequently hunted species of large game. Small bands of between 6 to 12 horses were intercepted in the valley below Solutré rock and either driven up against the base of the rock and slaughtered there (Levine 1979) or chased into a corral-like enclosure at the base of the rock and killed (Olsen 1989, 1995). Levine (1979, 1983) reported a low proportion of juvenile horses and a slightly higher proportion of adult horses in her analysis of the age-structure of these animals. Low numbers of juvenile horses were interpreted by Olsen (1989) as possibly resulting from the selective killing of adults and releasing of the young. Olsen also noted the vast numbers of individual horses, many articulated horse bones, scarcity of traces of butchery and lack of evidence of transportation of skeletal elements away from the site, suggesting that large numbers of horses were killed at any one time, and

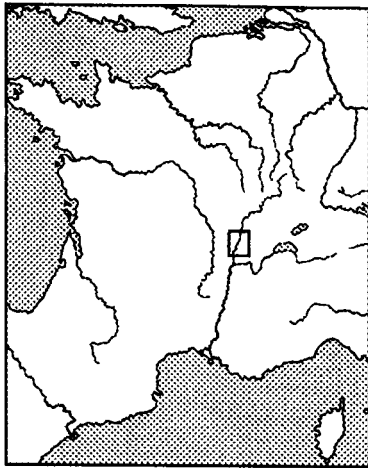
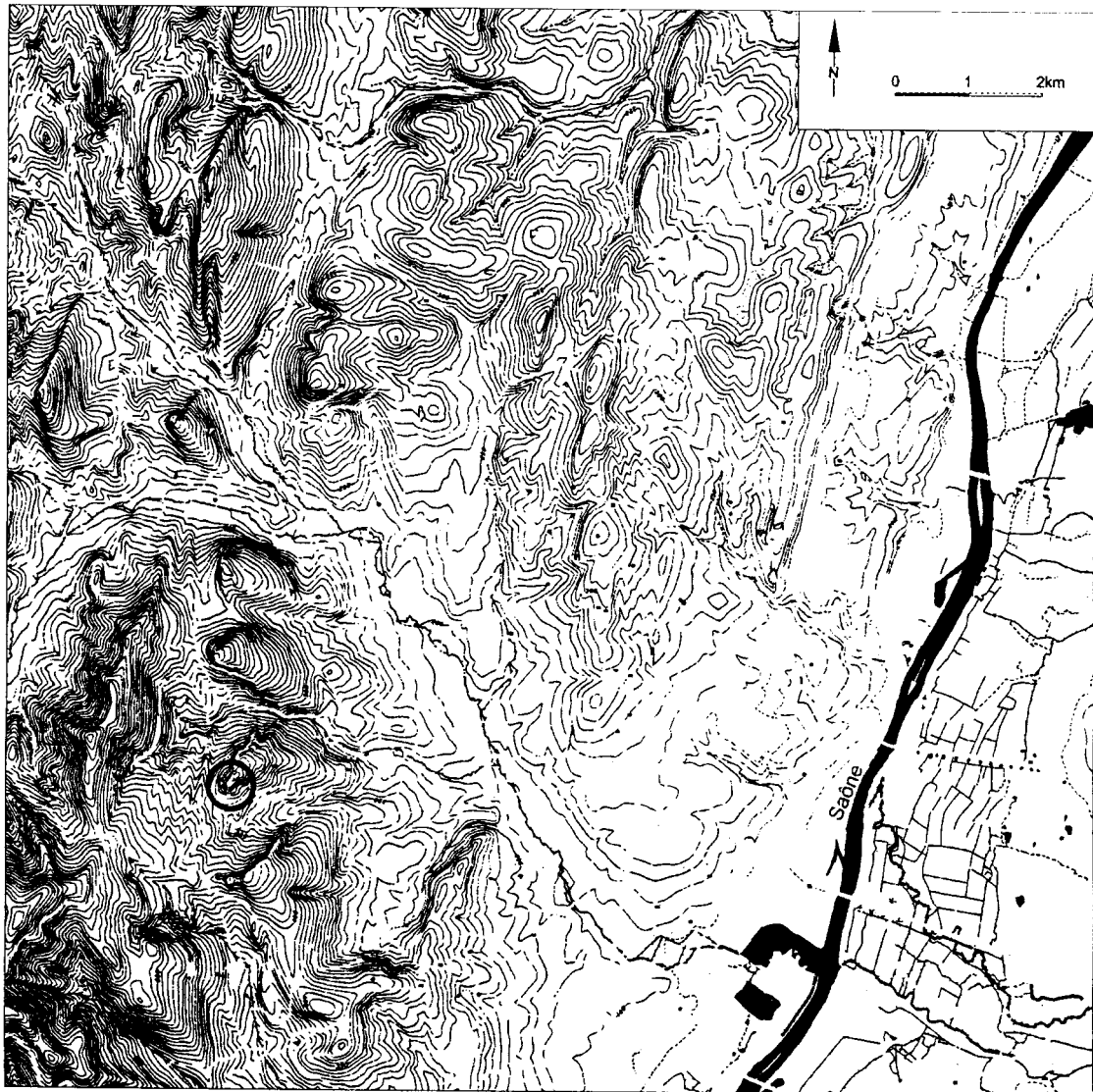


Fig. 1. The location of the the site of Solutré (below) in the Mâconnais region of Burgundy, France (above). The topographical map below shows the valley of the Saône River to the right of the figure and the Mâconnais hills rising to the left. The four cuestas – Mont de Pouilly, Solutré, Vergisson and Montsard – separated by valleys are shown bottom left. The “Roche de Solutré” is marked by a circle.



that their intact carcasses were not fully exploited. Berke (1989) commented on the low numbers of mandibles and portions of the upper rear leg (femurs and patellas) which he interpreted as reflecting the transportation of these flesh-bearing portions of the carcasses of horse to a settlement site elsewhere. He also noted the paucity of evidence for the removal of hides. Seasonal evidence (cementum bands in teeth) showed that horses died at Solutré from spring through to autumn, with the greatest concentration occurring in summer (Olsen 1989). Reindeer were hunted at Solutré in winter and in spring (Gordon 1988). In comparison to horse, the remains of reindeer showed more intensive traces of butchery indicative of full utilisation of reindeer carcasses, possibly because fewer individuals of reindeer were killed: bison remains were only occasionally mentioned, due to their rarity or absence at the site (Olsen 1989).

The sector P16 site

The series of excavations at Solutré organized and led by Jean Combier began in 1968. In that year P16 was opened for the first time for excavation, and investigations continued intermittantly in sector P16 until 1974. Sector P16 is located in the

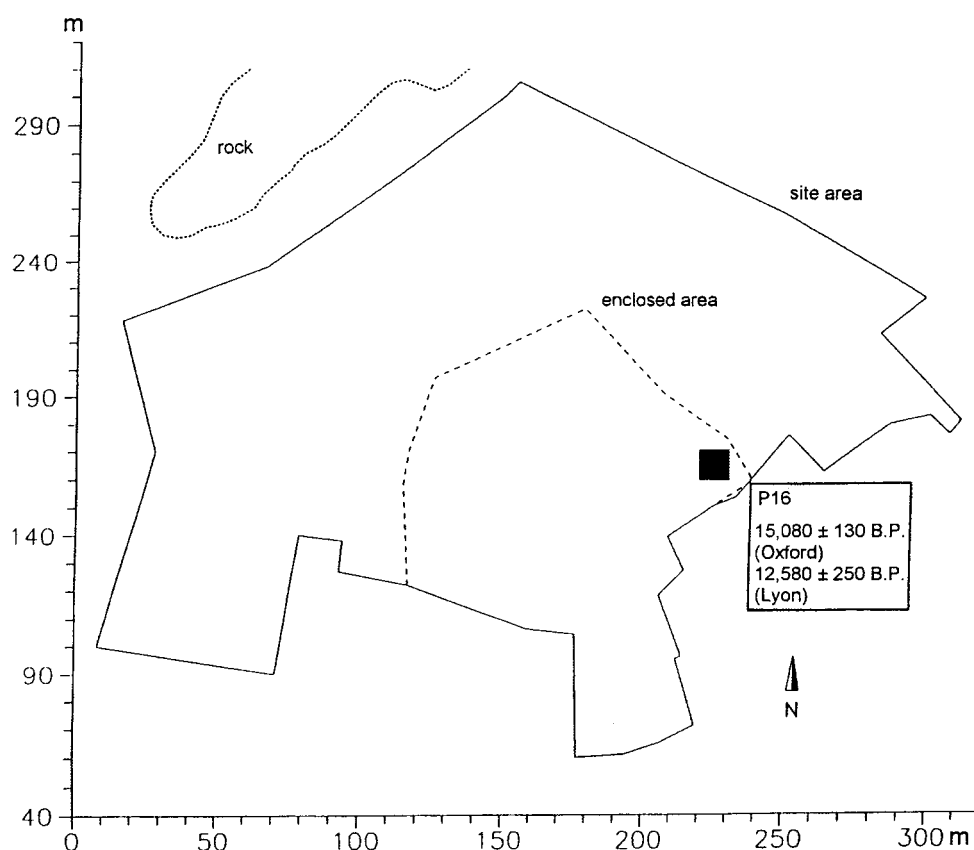


Fig. 2. Location of the sector P16 site at Solutré. The base of the rock (stippled line) and the site area (the total area investigated since the discovery of the site in 1866) are indicated. Combier concentrated his investigations in the area enclosed today by a security fence (broken line). Sector P16 is situated in the eastern part of the area; Radiocarbon dates are shown in the box.

south-eastern corner of the area enclosed today by a security fence (fig. 2) and altogether a total of 95m² of this sector were excavated under Combier's supervision, in which finds dating mainly to the Magdalenian period were revealed.

The lithic industry with many backed blades, borers and burins and a bone industry which included a "bâton de commandement" were both attributed to the Final Magdalenian (Combier 1976). A cut-marked tooth of a horse from sector P16 recently yielded a radiocarbon age of $15,080 \pm 130$ BP (pers. comm. P. Pettitt, Oxford Radiocarbon Accelerator Unit). A first Radiocarbon date of $12,580 \pm 250$ BP was obtained from a bone from P16 submitted to the Laboratoire de Radiocarbon in Lyon (Delibras et al. 1976).

Documentation and quantification of the bones from sector P16

Faunal remains were classified into two categories during the excavation of sector P16: three-dimensionally recorded finds, which were given an individual catalogue number and drawn on plans, and fragmentary finds which were simply collected and bagged together with only an approximate location within a quadrat. All three-dimensionally recorded finds from sector P16 were examined during the course of this analysis. Bagged finds were sorted through by hand and when bones with cut marks and impact notches or worked bones were found in the bags, these were removed, numbered and stored with the three-dimensionally documented material. Altogether a total of 4,159 numbered bones were recorded during this analysis. These finds include material studied by Berke, Levine and Olsen.

Twenty-six of these bones are fresh in appearance and may represent recent intrusive material. A further 16 bones were reddish in colouration and are possibly a small assemblage of reworked Solutrean faunal remains observed during excavation and mentioned in earlier site reports. The remaining 4,133 faunal remains represent the Magdalenian fauna from this sector.

Altogether some 4,031 bones and bone fragments could be identified to skeletal element and to specific level. These remains were recorded in a data-set in which basic descriptions were given based on the skeletal element, portion and segment system of Gifford & Crader (1977). Additional attributes included, where applicable, side of the body and epiphyseal fusion. Bone modifications, including cut marks, impact notches, traces of carnivore gnawing, and charring were also noted. Basic data recorded on remains identifiable to a species are summarised in table 1.

Horse dominates the fauna and 3,577 bones (88.7%) were identified to this species. Other species such as reindeer (6.6%), bison (3.5%), wolf (3.5%), wolverine (0.09%) and fox (0.17%) are present.

Horse remains comprise a minimum number of 2,672 skeletal elements. The highest minimum number of individuals for this species – 45 – was counted on acetabular portions of pelves from the right side of the body. A much lower quantity of remains was identified as reindeer, comprising a total of 271 finds and a minimum of 216 elements. At least nine individuals of reindeer were counted on the left astragali. Large bovids, identified by morphological criteria as bison, were represented by only 142 finds and a minimum of 119 elements. Five individuals of bison, counted on the left metacarpals, are present. A total of 30 finds from at least two individuals could be attributed to the wolf. Four bones were attributed to the

Table 1. Basic data for faunal remains from sector P16 identifiable to a species. NISP = number of specimens identifiable to species; MNE = minimum number of elements; MNI = minimum number of individuals.

Species	NISP	MNE	MNI	carnivore gnawing	cut marks	impact notches	bone/antler tools	charred bone
horse	3577	2672	45	262	70	44	3	2
reindeer	271	216	9	18	10	2	8	2
bison	142	119	5	20	2	6	0	0
wolf	30	30	2	5	1	0	0	0
wolverine	4	3	1	0	0	0	0	0
fox	7	7	1	0	0	0	0	0

wolverine and seven to fox. In general, wolverine and fox are characterized by very low numbers of remains and low numbers of individuals, reindeer, bison and wolf by low numbers of remains but relatively high numbers of individuals, and horse by high numbers of remains and high numbers of individuals. Another characteristic of the faunal assemblage is the evidence of only minimal utilisation of remains of horse, reindeer and bison by humans in contrast to the relatively higher number of bones with traces of carnivore gnawing.

Skeletal part representation

When examining the skeletal part representation of the species present at Solutré, we are mainly interested in trying to establish how the Magdalenians utilized animal remains as part of their food procurement strategies. It has long been known that the skeletal representations of animals at Palaeolithic sites simply reflects what has been found during excavation and does not necessarily represent the remains that were actually left behind by the human inhabitants of the site, and changes in skeletal representations can equally result from a number of processes such as gnawing by carnivores, bone weathering and sediment compaction (Binford 1971, Brain 1981, Kreutzer 1992, Lyman 1985, Marean 1991, Marean & Spencer 1991, Marean et al. 1992).

Skeletal part representation and bone density

Processes of bone destruction are density-mediated – in other words a solid, “robust” type of bone has a better chance of survival than a fragile one, a phenomenon termed “differential preservation”. Thus a dominance of high-density elements in a faunal assemblage is a good indicator that the assemblage has been strongly affected by processes of bone destruction. A simple method of testing for this is to compare counts of teeth and bones in an assemblage, since teeth are generally the most dense elements in the skeleton and are less affected by processes of bone destruction. A total of 766 horse teeth, including 19 tooth fragments, and 2,811 horse bones have been recorded at sector P16. Expressed as percentages, teeth represent 21.4% and bones 78.5% of the total number of horse remains given in table 1 (NISP = 3,577).

The dominance of bone over teeth shows that the assemblage of horse remains from P16 is, in general, a well-preserved corpus of material which has hardly been affected by differential destruction; Levine (1979) came to a similar conclusion about the preservation of bones from this sector. A comparable state of bone preservation was recorded for the remains of bison, where the proportions of teeth/bones are 19.0%/80.9%. For reindeer remains the proportion is slightly lower – 32.1%/67.8% –, but bones are still the dominant skeletal type.

In the left side of figures 3, 5 and 6, the skeletal elements of horse, reindeer and bison are depicted as percentages of the MNI (appendices 1–3: %MNI, column 3). %MNI's were calculated by taking the highest MNI (column 2) for each species (eg: horse MNI 45=100%) and reckoning the MNI's of each skeletal element as a percentage of this number. For comparative purposes only major skeletal elements were included in figures 3, 5 and 6.

The percentages given in figure 3 show that practically all skeletal elements of horse are present even if some horse bones are better represented than others, and that

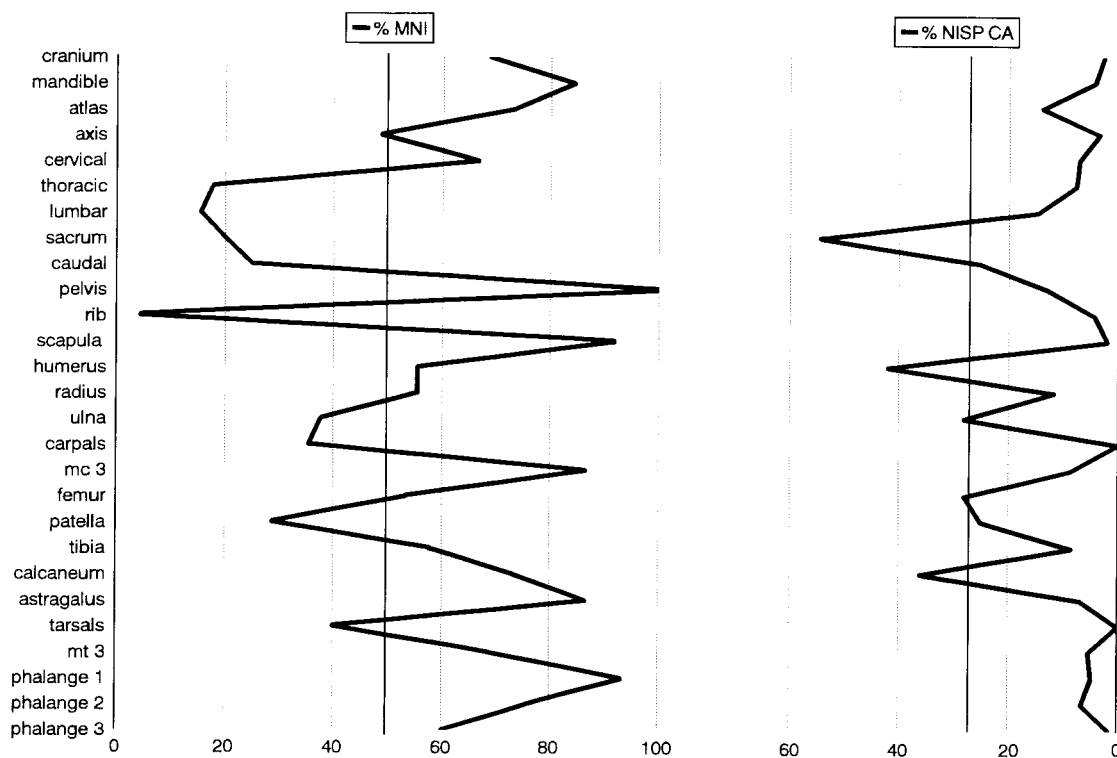


Fig. 3. %MNI (minimum number of individuals) (left) and % NISP CA (carnivore gnawing) (right) of major bones of horse from sector P16. The percentages are taken from columns 3 and 9 in appendix 1 and calculated from counts given in columns 2 and 8.

%MNI's calculated by taking the highest MNI (pelvis MNI 45=100%) and reckoning the percentage MNI's for the remaining skeletal elements from this. % NISP CA expresses the number of bones with carnivore gnawing for each element of the skeleton as a percentage of the total number of bones for each element (NISP). Vertical lines in bold face mark the 50% boundary in both figures; for the % NISP CA the 50% line was calculated from the highest % NISP CA thus: $54.5\% \div 2 = 27.2 = 50\%$.

the bulk of the horse remains have percentages greater than 50.0%. The highest %MNI was recorded on the pelvis (100.0%), followed by the phalange 1 (93.3%), scapula (91.9%) and the third metacarpal and astragalus (both 86.6%). Relatively high %MNI's were calculated for the cranium, mandible, atlas, cervical vertebra, third metatarsal and phalange 2 and 3. Low %MNI's were counted on axial elements such as thoracic (17.7%), lumbar (15.5%) and caudal vertebra (25.0%), and the sacrum (20.0%), and %MNI's lower than 50% were recorded for small-sized elements such as carpals (35.5%) and tarsals (40.0%).

The ribs and the sesamoids have the lowest %MNI's (4.4%). To some extent, the low %MNI for the ribs is certainly due to the fragility of this bone, as testified by the large number of rib fragments collected during excavation, but not three-dimensionally recorded. According to horse bone density data published recently by Lam et al. (1999), cervical vertebrae are more robust than other elements of the back and tail of the horse (thoracic, lumbar and caudal vertebrae, and the sacrum), which probably explains, to some extent, the extreme differential preservation between these elements depicted in figure 3.

Differences in %MNI representation were noted between the bones of the limbs (eg humerus, radius, femur and tibia) and their skeletal neighbours (scapula, pelvis and metapodials). For example, the %MNI of the femur (53.3%) is almost 50% less than that of its skeletal neighbour, the pelvis (100%). A similar pattern of differen-

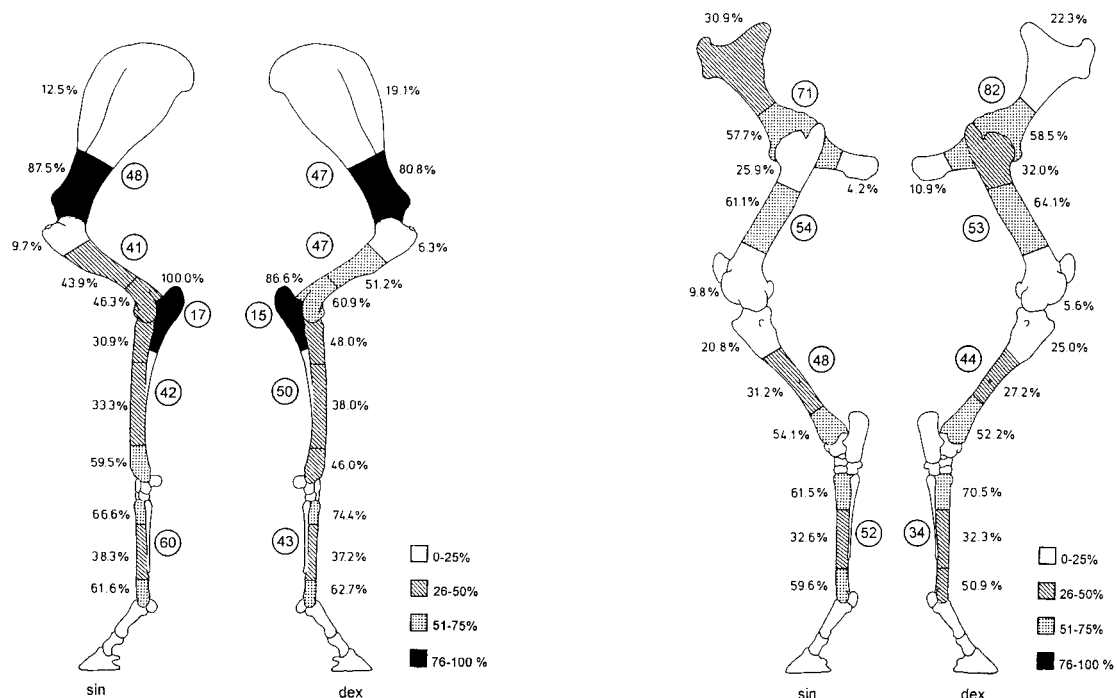


Fig. 4. Representation of portions of fore-leg long bones (left) and portions of the pelvis and rear-leg long bones (right) of horse from sector P16. Percentages of all carpals, tarsals, phalanges, vestigial metapodials (Mc 2 and 4) and sesamoids not indicated. Numbers in circles are total numbers of a particular element (e.g. 48 left scapulae), from which the percentages were reckoned. Thus, 87.5% of the left scapulae are distal ends and only 12.5% are scapula blades. The percentages are also expressed as groups "0-25%" and so on.

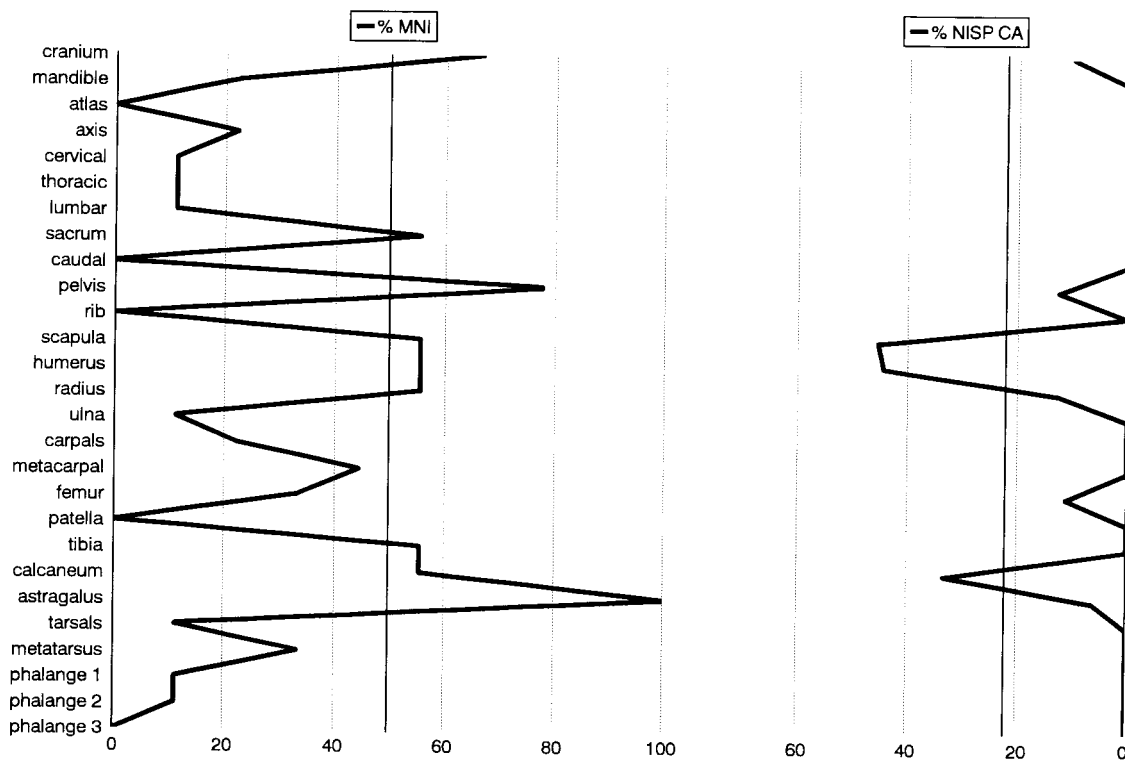


Fig. 5. %MNI (minimum number of individuals) (left) and % NISP CA (carnivore gnawing) (right) of major bones of reindeer from sector P16. The percentages are taken from columns 3 and 9 in appendix 1 and calculated from counts given in columns 2 and 8. See figure 5 for methods of calculating percentages. Vertical lines in bold face mark the 50% boundary in both figures; for the % NISP CA the 50% line was calculated from the highest % NISP CA thus: $45.4\% \div 2 = 22.7 = 50\%$.

tiation can be seen in %MNI's for the humerus and scapula (55.5% and 91.9%), for the radius and third metacarpus (55.5% and 86.8%) and, to a lesser extent, for the tibia and third metatarsal (57.7% and 68.8%). Analyses of bone preservation have shown that scapulae, pelvis, metacarpals and metatarsals do have better chances of survival than major limb bones and, to a certain extent, the lower %MNI's for the leg bones reflect this.

Some portions of horse limb bones are better represented than others (fig. 4). None of the scapulae were complete, but this was not surprising as the scapula consists of a sturdy distal end and a very fragile blade. Thus, the marked differences in preservation – or “intrabone variations” – between the distal ends and the blades of horse scapulae from P16 are clearly related to bone density and preservation (Brain 1981, Kreutzer 1992, Lyman 1994, Lam et al. 1999).

Positive correlations between intrabone variation and bone density could also be observed in the higher percentages of denser portions of some long bones – such as the proximal ulna, the distal humerus, the diaphyses of the femur – and the acetabular portion of the pelvis, and the low percentages of portions of less dense bones such as the proximal humerus and distal femur.

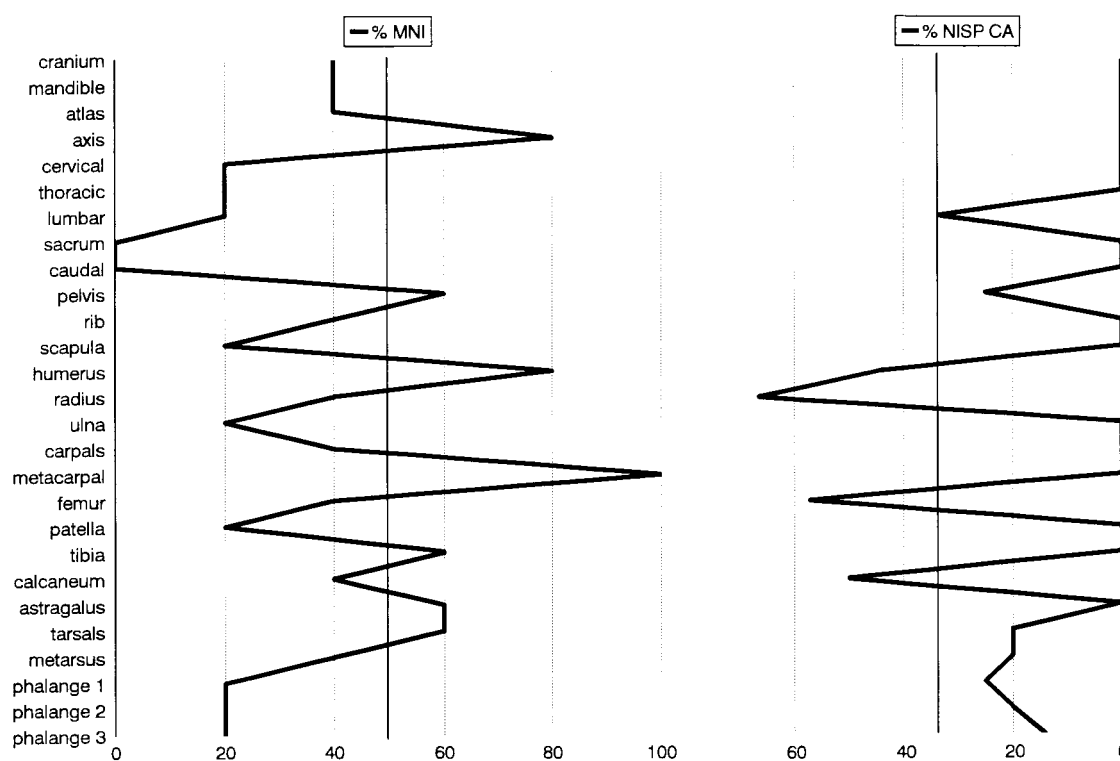


Fig. 6. %MNI (minimum number of individuals) (left) and % NISP CA (carnivore gnawing) (right) of major bones of bison from sector P16. The percentages are taken from columns 3 and 9 in appendix 1 and calculated from counts given in columns 2 and 8. See figure 5 for methods of calculating percentages. Vertical lines in bold face mark the 50 % boundary in both figures; for the % NISP CA the 50 % line was calculated from the highest % NISP CA thus: $66.6\% \div 2 = 33.3 = 50\%$.

Inverse or negative intrabone variations – that is the preservation of portions of bones contrary to the expected preservation according to bone density – were observed in the low percentages for the diaphyses of radii, tibiae, metacarpals and metatarsals, which are usually considered to be the densest portions of these elements.

There are several characteristics common to the skeletal representations of reindeer and bison despite differences in body-size between the two species. In contrast to horse, both are underrepresented in terms of low total NISP (table 1) and low NISP per element (appendices 2 and 3, column 1). With low counts of MNI for many elements, the bulk of the remains of both species have %MNI's lower than 50 % (figs 5 and 6; appendices 2 and 3, columns 2 and 3). Several elements of the skeletons of reindeer and bison are absent.

The presence or absence of the skeletal parts of reindeer appears to be strongly related to the structural densities of the bones, as shown by the high %MNI's recorded on robust elements (astragalus = 100 %) or the sturdier portions of reindeer bones (acetabular part of the pelvis = 77.7 %). Fragile bones, such as ribs, are absent, and extremely low %MNI's were recorded on all types of reindeer vertebrae. Some small bones, such as carpals, tarsals, and sesamoids, are absent. The highest %MNI

for bison was calculated on the metacarpals. Relatively high %MNI's were counted on the axis vertebra, distal humerus, acetabular region of the pelvis, distal tibia, astragalus and tarsals. These are the high density or sturdy portions of bison bones including, for this species, the axis vertebra (Kreutzer 1992). Other axial elements including the ribs, and the scapula, all have low MNI's.

Skeletal representation and carnivore attrition

Traces of carnivore gnawing – also called carnivore attrition or carnivore ravaging – in the form of tooth puncture marks, tooth pitting, tooth scoring and furrowing – were recorded on 262 horse bones, 18 bones of reindeer and 20 bison bones. These counts represent 7.3 %, 6.6 % and 14 % of the total number of bones (table 1, NISP) identified to these species respectively. The remains of three carnivores, wolf, wolverine and fox have been identified in the faunal assemblage from P16. Although some of the smaller tooth puncture marks could have been produced by foxes and wolverines, most of the bones show traces of modification comparable to that recorded on bones chewed by wolves (Haynes 1983).

Counts of bones of horse, reindeer and bison with traces of carnivore attrition are given in appendices 1–3, column 8 and expressed as percentages of the NISP for each element in column 9 (%gnawing). These percentages are illustrated in the right side of figures 3, 5 and 6 and compared with the %MNI's of each species.

Among the horse remains, traces of carnivore gnawing are present on the bases of horse mandibles, on the bodies (corpus, plate 2b) and spines of the vertebrae, around the epiphyses of long bones and on their shafts (plate 4a). Only three types of elements, the sacrum, the humerus and the calcaneum produced percentages of gnawing greater than 50 % (highest count $54.5 \% \div 2 = 27.2 \% = 50.0 \%$) (fig. 3). A positive correlation between carnivore gnawing and skeletal representation – that is a high percentage of traces of carnivore gnawing and a low %MNI – was only observed for the sacrum. Thus the very low numbers of this element in the assemblage of horse bones appears to be strongly related to carnivore destruction of the bone rather than human subsistence practices or other post-depositional processes. There is also a positive correlation between percentages of carnivore gnawing on the caudal vertebrae and a low %MNI for this element.

%MNI's and percentages of carnivore attrition both greater than 50 % were calculated for the humerus and the calcaneum. The proximal end of the humerus is a bone portion rapidly destroyed by carnivore gnawing, and the crenulated proximal ends of 17 horse humeri attest to this type of destruction (see figure 4, for numbers of portions of the long bones). Six of these humeri had been reduced to bone cylinders by carnivores gnawing at both the proximal and the distal ends of the bone.

Loss of bone produced by gnawing was observed on the tuber calcis of the calcanei. Carnivores preferentially chew the end of this element since this bony protruberance is covered by only a thin layer of skin and is accessible even when the bone is articulated. The rest of the calcaneum is usually not affected by gnawing, and this probably accounts for the relatively high %MNI count for the calcanei despite the high percentage of carnivore gnawing observed on this bone.

Negative correlations, that is a low %gnawing and a high %MNI for a particular element, were calculated for the axis and atlas vertebrae, phalanges, carpals and

tarsals, astragalus, tibia, and third metacarpals. Although gnawing traces are visible on these elements, their representation in the assemblage did not appear to have been strongly affected by carnivore destruction. Negative correlations were also observed on crania and mandibles, but in these cases, low percentages of carnivore gnawing are probably associated more with the problems of identifying such traces on these highly-fragmented bones, rather than a lack of carnivore interest in parts of the heads of horses.

The absence of gnawing traces on carpals and tarsals may be due to the ability of carnivores to swallow these small bones whole without chewing. Olsen (1989) suggested that the low numbers of small bones at sector P16 were related to excavation techniques; however, since large numbers of small bones of horse are not present among the bagged finds either, carnivores swallowing these elements and digesting them in their guts or passing them as scat away from the site is a plausible alternative to explain the low numbers of small skeletal elements in the assemblage of horse bones.

Interesting is the discrepancy between the high percentages of carnivore modification observed on the proximal joint of the humeri and the low percentages recorded for the distal ends of the scapulae. The strong differences in percentages suggest that these bones were already disarticulated before carnivores began to gnaw them. However, high numbers of cut marks indicative of the intensive dismemberment of these joints initially by humans are also missing (see below: human modification of the bones) and other factors (natural disintegration of the carcass?) have to be considered to explain the discrepancy between the percentages of carnivore modification on these two elements. In general, the percentages of gnawing show that carnivores were attracted to the “meaty” parts of the carcasses of horse, such as the humerus and the femur; less meaty parts, such as the radius, tibia and metapodials were less attractive.

Three bones of reindeer – scapula, humerus (plate 4b) and calcaneum (plate 4e) – have percentages of carnivore gnawing greater than 50 % ($45.5\% \div 2 = 22.7\%$) (fig. 5), but a strong positive correlation between %carnivore gnawing and %MNI is not apparent for these elements. A negative correlation was observed for the astragalus (plate 4c). A high %MNI and a relatively low %gnawing was recorded for the pelvis, despite traces of gnawing on this bone comparable to those observed on North American prey carcasses which had been heavily utilised by carnivores (Haynes 1982). The discrepancy between evidence of heavy carcass utilisation on the one side but high %MNI on the other, probably relates to numbers of individuals being counted on the acetabulum, a robust portion of the pelvic girdle which usually survives carnivore attrition. Tooth notches on the fractured edges of long bone shafts show that carnivores also cracked open the shafts of reindeer bones.

The, relatively speaking, higher total percentage of modification observed on bison bones suggests that these remains were more intensively utilised by carnivores than the remains of horse or reindeer.

Percentages of carnivore gnawing equal to or greater than 50 % ($66.6\% \div 2 = 33.3\%$) were calculated on three bones – radius, femur and calcaneum – but there is no strong positive correlation between %gnawing and %MNI for these elements (fig. 6). A positive correlation was, however, observed for the lumbar vertebrae of bison, and destruction by carnivores may be responsible for the low numbers of this element. Carnivore preference for bison humerus and femur is probably related to the

amount of meat left on the bones or a preference for greasy bone ends. Interesting is the presence of relatively large numbers of open-ended cylinders of bison bone. Three femurs (plate 4d) and two, or possibly three, humeri had been modified in this manner. Bone cylinders result from the lengthy chewing of long bones by carnivores and are often found at wolf homesites. Haynes writes (1982, p. 268) "If carcasses or body parts are too bulky for adult wolves to transport to pups or to rendezvous sites, the wolf group may relocate itself close to certain carcasses, which become temporary rendezvous sites". The same may have happened at Solutré.

Although all stages of carcass utilisation, from light through to heavy, were recorded on the bones of horse, bison and reindeer, strong positive correlations between %gnawing and %MNI's were only recorded on the sacrum and caudal vertebrae of horse and the lumbar vertebrae of bison. None of the reindeer bones show strong positive correlations between these attributes.

The evidence of heavy carcass utilisation does, however, suggest that carnivores were able to spend relatively long periods of time gnawing bones undisturbed at the site, during the periods when humans were not present. Although the interpretation of carnivores as opportunistic scavengers of remains of animals killed by the Magdalenian hunters is probably correct, the evidence of intensive carnivore attrition means that we cannot exclude the possibility that the bones of some animals at sector P16 were from carnivore kills.

To summarise, although it could be shown that bone density and differential preservation and carnivore attrition were responsible for the low numbers and/or absence of some elements or portions of elements of horse, reindeer and bison at sector P16, the general patterns of skeletal representation observed in the bone assemblages recovered during excavation are probably very similar to those present originally at the site. This is important, as it shows that the strong difference between the skeletal representation of horse and the skeletal representation of reindeer and bison is valid, and that this difference is probably attributable to different methods of utilisation of these animal resources by humans.

The skeletal representation of horse is characterised by the presence of practically all parts of the skeleton, large numbers of finds per element (NISP), high minimum numbers of individuals per element (MNI), %MNI's for the bulk of the bones greater than 50% and almost equal numbers of bones from the right and left sides of the body (latter shown in figure 4). Taken altogether the evidence produced during this analysis supports the idea (Olsen 1989) that intact carcasses of horse were originally deposited below Solutré rock, and that the bulk of the bones were left behind at the site. Descriptions in site reports (Combiér 1973) and the results of a study of conjoining bones (Turner in press) show that some of these bones were in anatomical connection. Although death of perhaps one or two of the horses at the site due to natural causes (e.g. old age, disease) cannot be excluded, the location of the site precludes mass deaths of herds of animals as observed at river-crossings (Behrensmeyer 1975) or during episodes of seasonal flooding (Voorhies 1969), deaths at waterholes (Haynes 1991), or death due to bogging down in quagmires (Berger 1983). In this analysis, the bulk of the horse remains at the sector P16 site is interpreted as resulting primarily from the hunting activities of the Magdalenian population.

Olsen (1989) found no indication of a deliberate selection of high or of low-utility parts of the horse at Solutré, and the current analysis has produced the same result with high %MNI's being recorded for portions of the limbs which are referred to as "high-utility parts" (parts considered in terms of human subsistence to carry high meat yields), such as the upper parts of the fore and rear haunches (scapula and pelvis), but also for parts of the limbs which are usually considered low in utility (carrying little or no meat) such as the metacarpals and first phalanges. The only possible exceptions to this are differences in %MNI's between vertebrae of the neck and of the back and tail of horse, as well as variations between the %MNI's of some limb bones (humerus, radius, femur and tibia) and their skeletal neighbours (scapula, pelvis and metapodials). Although these %MNI differences are probably mainly related to bone density, the possibility that some portions of the backs and legs of horse were transported away from the site by humans cannot be excluded, since transportation by humans of low density bones or poor preservation of low density bones produces the same result – a low %MNI for the element concerned.

On the other hand, negative correlations with density data observed for the diaphyses of radius, tibia, metacarpal and metatarsal do suggest that the low counts of portions of the shafts of these bones may be related to human activities at the site. Fracturing bone in order to extract marrow would have already reduced bone shafts to smaller fragments at an early stage in the taphonomic histories of these finds, possibly making these fragments more susceptible to post-depositional bone destruction. Another alternative is that these fragmented finds were simply collected during excavation and not recorded during this analysis.

Even though factors such as differential bone preservation and their effects on the remains of reindeer and bison appear to have played a greater role in the skeletal part representations of reindeer and bison, it is still very difficult to interpret the small assemblages of bone of these two species. On their own, the skeletal representations of reindeer and bison give little indication as to whether these elements represent the remains of intensively processed carcasses of game hunted and killed close to the sector P16 site, or portions of carcasses of animals hunted elsewhere which were transported to Solutré by the hunters. Whatever the interpretation, the Magdalenian hunters appear to have shown no interest in selecting particular parts of these carcasses, as can be seen from the relatively high %MNI's recorded on both the high and low-utility body parts of the two species.

Human modification of the bones

Butchering activities

One of the characteristics of the faunal assemblage from the Magdalenian deposits in sector P16 is the very low number of the "archaeologically visible results" (Lyman 1994: 295) of butchering activities on the bones of horse, reindeer and bison. In this study the term "archaeologically visible results" refers to cut marks made by sharp-edged stone tools during carcass processing and impact notches induced by hammerstones during marrow extraction. Olsen (1989) also found low numbers of bones with butchery traces from all levels at Solutré, and numbers of horse bones with butchery traces published by Berke (1989) are comparable to those given in this paper (see Olsen's and Berke's papers for their descriptions of butchery marks from sector P16).

Numbers of cut marks and impact notches are given in table 1 for all of the species present in the faunal assemblage from this sector. For the three main species, cut marks were observed on 70 bones of horse, 10 bones of reindeer and only two bones of bison. They represent 19.6 %, 3.6 % and 1.4 % respectively of the total NISP's given for these species. In general, counts of bones with impact notches were even lower than counts of cut marks and represent 12.3 % of the horse bones (n=44), 0.73 % of the reindeer bones (n=2) and 4.2 % of the bones of bison (n=6).

Despite the low counts, the different locations of the cut marks and the presence of the impact notches show that several stages of butchery had been carried out, including evisceration (extraction of the contents of the thoracic and abdominal cavities), possibly skinning, disarticulation, muscle stripping or peeling off the periosteal tissues (filleting), removal of tendons, and marrow extraction. Main stages of butchery identified on the remains of horse, reindeer and bison are summarized in table 2 and this evidence suggests that more carcass products were obtained from horse than from reindeer and that bison bones were only filleted or used as a source of bone marrow.

Table 2. Butchery activities identified on the remains of horse, reindeer and bison from sector P16 at Solutré.

	skinning	evisceration	disarticulation	filleting	tendon removal	marrow extraction
horse	x	x	x	x	x	x
reindeer	x		x	x		x
bison				x		x

In appendices 1–3, counts (columns 4 and 6) and percentages (columns 5 and 7) of cut marks and impact notches are listed for the bones of horse, reindeer and bison. The percentages are illustrated and compared in figure 7. The highest percentage of cut marks on horse remains was observed on the atlas vertebrae (9.3 %) (plate 2b), and relatively high percentages were recorded for the ribs (8.7 %), mandibles (5.0 %) (plate 2f), scapulae (5.0 %), ulnae (6.2 %) and fourth metacarpals (6.6 %). Reindeer mandibles have the highest percentage of cut marks (50.0 %); cut marks on reindeer scapulae are relatively high (27.2 %).

Impact notches are most common on third metacarpals of horse (10.6 %) and are relatively common on horse radii (6.3 %) and tibiae (8.5 %). Only two bones of reindeer – a tibia and a metacarpal – have impact notches. Notches were also recorded on bison tibiae (20.0 %), but the highest percentage of notches was recorded on bison humeri (22.2 %). Only two bison bones, a humerus and a femur, bore traces of cut marks. The evidence presented in figure 7 shows that of the bison bones preserved at sector P16, only limb bones were butchered. A similar butchery pattern could be postulated for reindeer, but in this species parts of the head were also processed.

Several skeletal elements of horse (except vertebrae other than the atlas) bore archaeologically visible traces of butchery. The lack of cut marks on thoracic, lum-

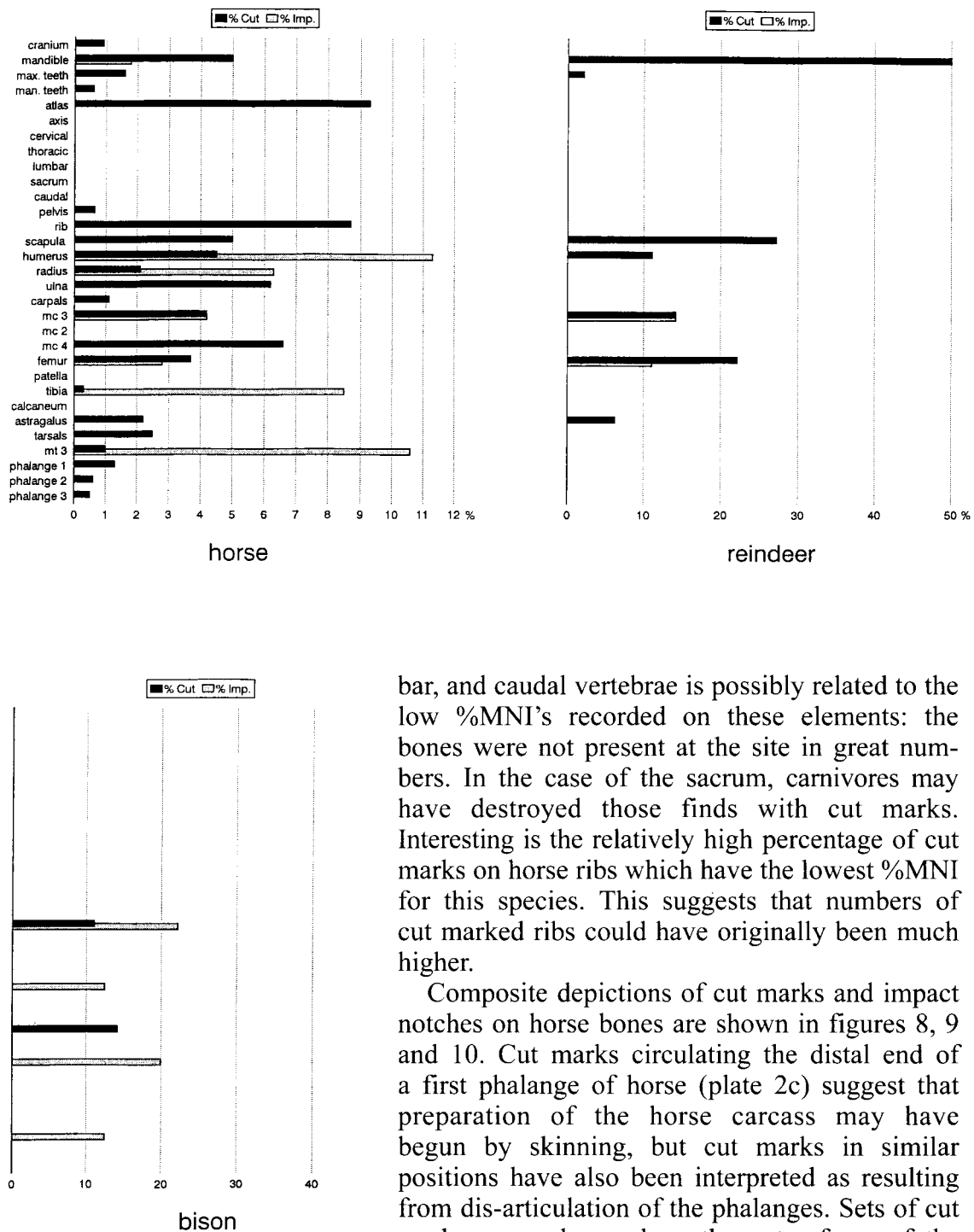


Fig. 7. Comparison of percentages of cut marks and impact notches on the remains of horse, reindeer and bison from sector P16. Max = maxillary; man = mandibular; mc = metacarpus 3; mt = metatarsus 3.

bar, and caudal vertebrae is possibly related to the low %MNI's recorded on these elements: the bones were not present at the site in great numbers. In the case of the sacrum, carnivores may have destroyed those finds with cut marks. Interesting is the relatively high percentage of cut marks on horse ribs which have the lowest %MNI for this species. This suggests that numbers of cut marked ribs could have originally been much higher.

Composite depictions of cut marks and impact notches on horse bones are shown in figures 8, 9 and 10. Cut marks circulating the distal end of a first phalange of horse (plate 2c) suggest that preparation of the horse carcass may have begun by skinning, but cut marks in similar positions have also been interpreted as resulting from dis-articulation of the phalanges. Sets of cut marks were observed on the outer faces of the upper (plate 2a) and lower cheek teeth of horse. These marks were probably produced when the gingival tissues were stripped from around the mouth as part of skinning activities or during removal of tissues from the head. Cut marks on the inner faces of cheek teeth, inner side of a

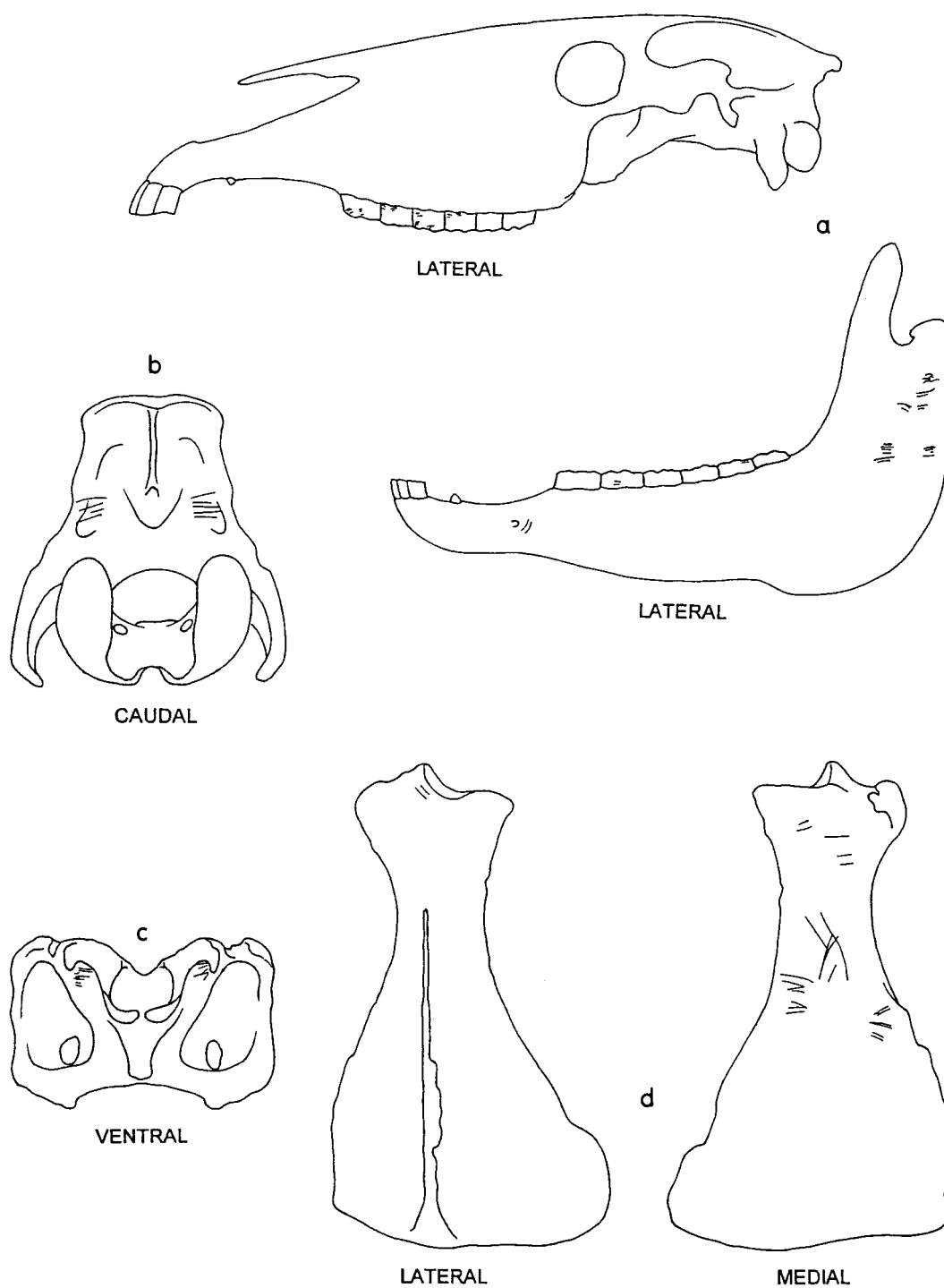


Fig. 8. Composite depictions of cut marks on bones of horse from sector P16. a: upper and lower cheek teeth and mandible. b: caudal face of the cranium. c: ventral face of an atlas. d: scapula.

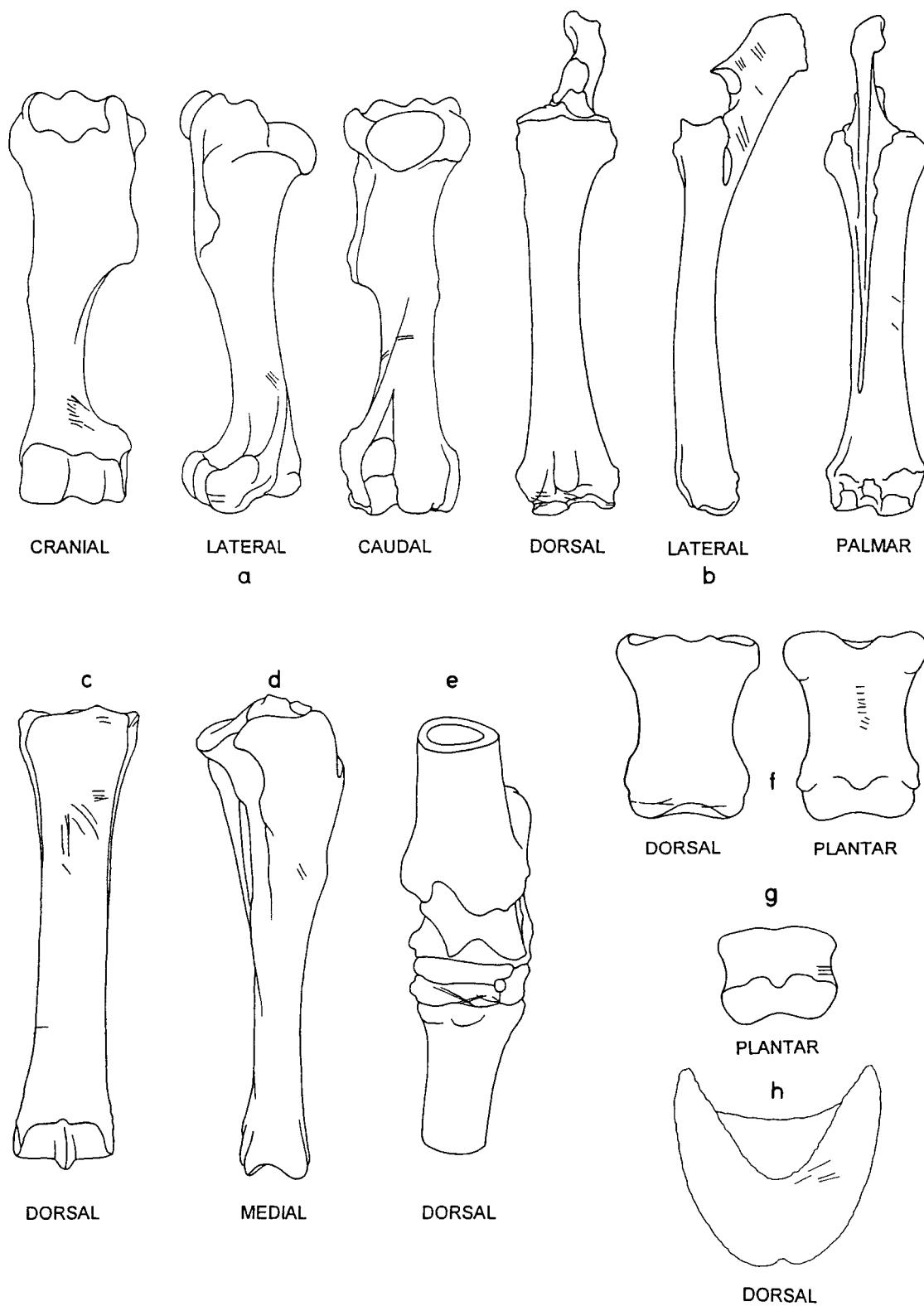


Fig. 9. Composite depictions of cut marks on bones of horse from sector P16. a: humerus. b: radius. c: metacarpus. d: tibia. e: tarsal. f: phalange 1. g: phalange 2. h: phalange 3.

mandible and inner side of a mandibular symphysis all suggest removal of the tongue. Cut marks on the inner sides of ribs and a pelvis were probably produced during evisceration.

The bulk of the cut marks on horse remains was produced during carcass disarticulation. Disarticulation appeared to be confined to separation of the head and neck (three cases) (plate 2b), separation of the vertebral column (one case), separation of parts of the fore-leg including the scapula from the proximal humerus (3 cases), disjuncting the elbow (at least 2 cases), separation of the radius from the fore-foot (at least 2 cases), and disjuncting the rear hock (2 cases). Sets of cut marks indicating removal of the masseter muscle – a process termed filleting *in situ* (Binford 1981) – were recorded on five mandibles of horse (plate 2f). Oblique cut marks on bone shafts indicate muscle stripping or removal of the periosteum (as observed on the scapula, humerus, femur and tibia), and removal of periosteal tissues or tendons (in the case of the metapodials). There was evidence of tendon cutting on the phalanges (plate 2d).

The location of cut marks on reindeer bones suggests that butchery techniques similar to the ones used on the carcasses of horse were also employed on the carcasses of reindeer, and marks on reindeer remains are consistent with removal of flesh and skin around the mouth, dismemberment of limb bones, and muscle stripping or the removal of periosteal tissue. Cut marks located around the glenoid cavity of three scapulae were produced during disarticulation of the distal scapula from the proximal humerus (plate 2e). Binford (1981) considers that in medium-sized animals, dismemberment of this joint is a secondary butchery operation and that considerable numbers of cut marks around the glenoid cavity are most likely to be seen on bones from sites where meat has been consumed.

Cut marks on bison bones are located mid-shaft and were produced when cutting through muscle attachments or during stripping of periosteal tissue.

Relatively high percentages of impact notches on horse bones (appendices 1–3, column 7, figure 7) show that mandibles (1.8%), femurs (2.8%), metacarpals (4.2%), radii (6.3%), tibiae (8.5%) and metatarsals (10.6%) had been chosen for marrow extraction. Humeri have the highest percentage of specimens with impact notches (11.3%) and appear to have been the element most preferred for this stage of butchery. A similar pattern, with high percentages of impact notches on humeri (22.2%) and tibia (20.0%) is shown in figure 7 for bison bones. Reindeer metacarpals and femurs were also chosen for marrow extraction (fig. 7).

Composite illustrations of impact notch locations show distinct patterning in the placement of impacts on some elements of horse (figure 10). For the humeri, impact notches occur mainly mid-shaft on the cranial, lateral and caudal surfaces. On the radius, the most common locations for impact notches are towards the proximal end of the bone on the dorsal surface (plate 3e). On the femur, the caudal surface and lateral edge were the preferred areas for impacts and, on the tibia impact notches are mainly located on the flat plantar surface of this bone. With the exception of impact notches on the plantar surface of the tibia, blows to the humerus, radius and femur were mainly placed on parts of the bones that would have been difficult to strike effectively. Mandibles (plate 3a) were fractured by one or two blows placed on the outer and/or inner surfaces of the jaw, at the same height as the tips of the roots of the cheek teeth.

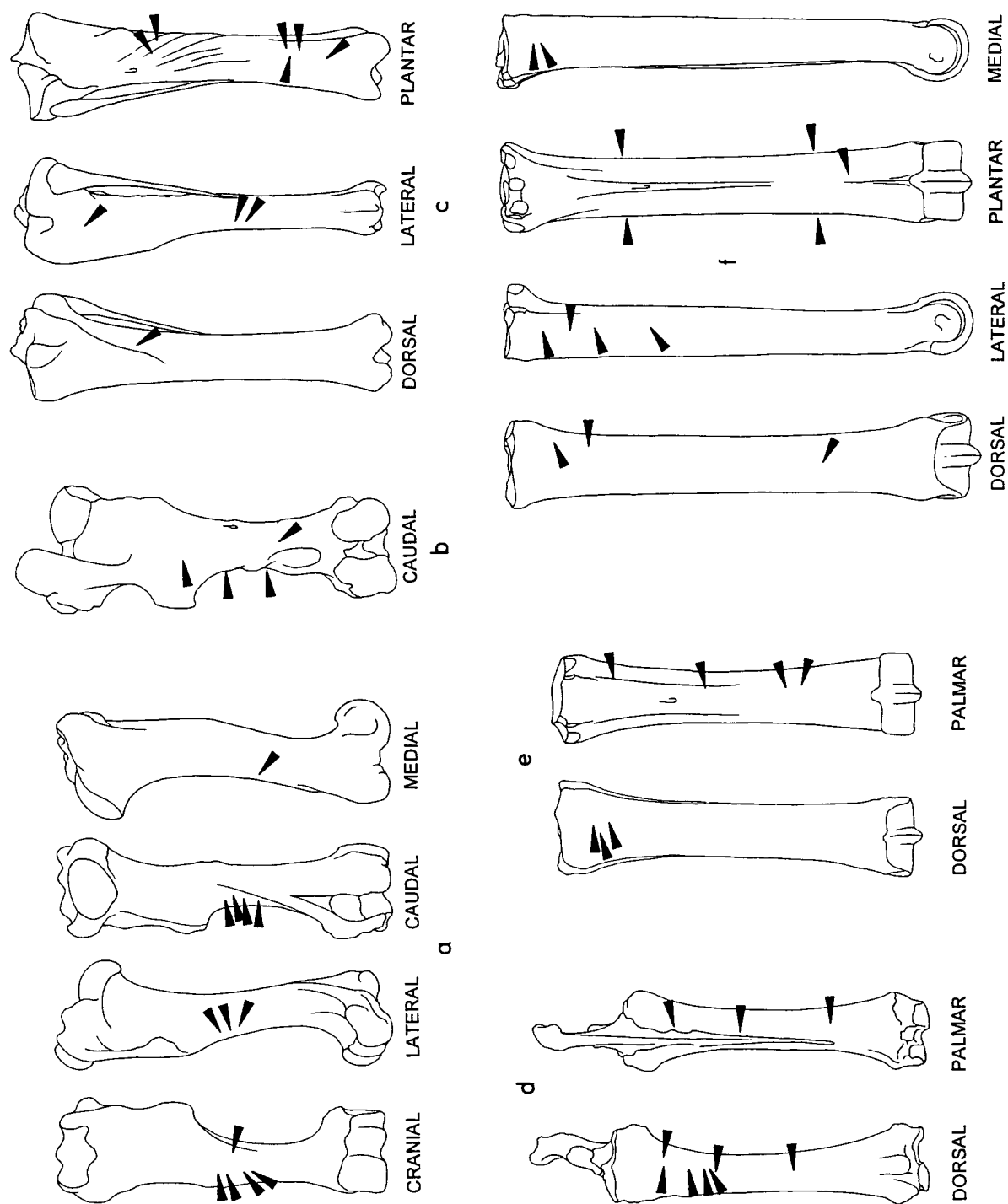


Fig. 10. Composite depictions of impact notches on bones of horse from sector P16. a: humerus. b: femur. c: tibia. d: radius. e: metacarpus. f: metatarsus.

Metacarpals were struck on the dorsal and palmar faces, and metatarsals were struck on all faces of the bone. Impact notches on these specimens are often placed towards the proximal end of the bone, and conjoining fragments of metapodials show that this technique had occasionally split the proximal end of the bone through the joint (plate 3d). On other specimens, the shaft of the bone has been opened, but the proximal end is intact. On some finds, impact notches truncated by secondary fracture planes suggest that distal portions of metapodials had been removed after the shaft had been struck.

Some bones had been split open longitudinally by a series of controlled blows to the shaft. This technique is restricted to metacarpals, metatarsals and radii (plate 3b) – in other words those bones whose relatively straight form lends itself well to this method of fracture. Opposing sets of notches on metatarsal shafts (plate 3c) show that the undersides of these bones had been laid on an anvil during fracturation (=reflective percussion and see Berke [1989] for his descriptions of impact notches on finds from this sector).

Although only a small sample of bison bones have impact notches, similar techniques to those used on horse bones were recorded. These include impacts located mid-shaft and towards the proximal ends of bones, use of an anvil as a support, and the use of controlled blows to split bones open longitudinally. Articulatory ends of bison bones had been removed prior to fracture of the shaft. A phalange of bison had been split open, but the bulk of the phalanges of horse have no impacts and are preserved intact.

The cut marks on mandibles of five different individuals give an approximate indication of the number of horse carcasses butchered by humans. Cut marks and impact notches are present on the remains of both adult and juvenile horses. At least three reindeer carcasses had been butchered and bones from juvenile or sub-adult individuals had been processed as well as those of adult reindeer. Only bones of adult bison bore traces of butchery.

In the case of large animals, such as horse and bison, primary butchery activities such as skinning, evisceration, removal of the masseter muscle, removal of the tongue and disarticulation would have taken place at, or very close to, the kill-site. This compares well with the evidence from the skeletal part representation of horse in which large amounts of remains from many individuals were recovered at sector P16, showing that intact carcasses of these animals were deposited more or less at the place where they had died. The absence of cut marks produced during primary butchery activities on bison bones combined with the low total number of bison bones, suggest that these remains may have been transported as carcass portions to the site.

The remains of reindeer are more difficult to interpret, since medium-sized animals do not necessarily have to be butchered at the kill site, and their intact carcasses can be transported just as easily as portions of carcasses from the kill site to a processing site elsewhere. Thus, cut marks indicating some primary butchery activities (?skinning, disarticulation) on the bones of reindeer, a relatively higher percentage of butchery marks on reindeer bones than on the bones of horse and bison, and low numbers of reindeer bones can be interpreted either as the more intensive processing of the remains of animals which were killed at the site, or the remains of parts of processed carcasses of reindeer which were transported to the site.

Worked bone and antler

Three horse bones – two metapodials and a fragment of a long bone which could not be more closely identified – had been modified further by humans. These finds had been used as needle-cores (see also Berke [1989]). Reindeer antler had been used as a material for tool production. The antler industry from sector P16 comprises a bâton-percé and a fragmentary double bevel-based point. Fragments of reindeer antler with the remains of grooves on their outer surfaces represent the waste products of antler worked by the groove and splinter technique. Cut marks on the root of an incisor tooth from a reindeer suggest this tooth was intended for wear as a pendant.

Charred bones

Altogether four bones – two of horse and two of reindeer – had been charred in a fire.

Age structure, sexual demographics and season of death

Age structures using teeth wear and crown heights

Comparative eruption-wear and crown-height wear data published by Levine (1979, 1982, 1983) were used to age 232 upper and lower deciduous and permanent cheek teeth of horse from sector P16. The sample consisted only of teeth which could be precisely identified to tooth type and position in the jaw, and the results of the analysis are shown in figure 11. Each age-class represents 10% of the natural longevity of

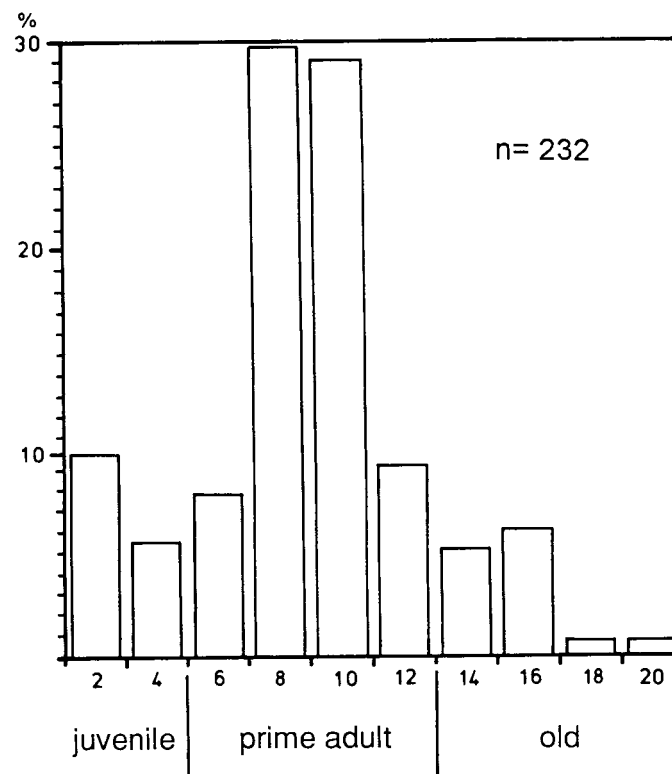


Fig. 11. Age-structure of the horses from sector P16 taken from a sample of 232 teeth. See text for explanation of age-classes (1–10) and juvenile, prime adult and old categories.

the horse, which was set at 20 years. The numbers of teeth in each age-class are expressed as a percentage of the total number of teeth in the sample ($n=232$).

The bulk of the teeth, 30%, are in age-class 4 (6–8 years old); a similar number (29%) in age-class 5 (8–10 years old). The remaining age-classes are represented by 10% or less of the teeth sampled. Very low percentages were recorded in classes 9 and 10 (together 16–20 years).

Stiner (1990) defined three different age-classes, juvenile (approximately the first 20% of the natural longevity [Lyman 1994]), prime-adult (breeding-age [ibid]) and old (approximately the last 30% of the natural longevity [ibid]), for her assessments of mammalian mortality patterns, and these criteria were applied to the age-classes from the P16 sample. Using this method, teeth from juveniles can be seen to form about 15% of the sample and old horses only about 13%. A total of about 76% of the horses are in the prime-adult group. Similar results were obtained from the analysis of wear stages of a small sample ($n=47$) of incisors. The bulk of these teeth, 80.8%, belong to older juveniles and prime adults. Very young (4.2%) and very old horses (14.8%) are represented by low percentages.

Levine (1979, 1983) also noted a rather low proportion of teeth of juveniles (0–3 years) and slightly higher proportions of teeth of adult horses aged 8–10 years in the sample of 364 teeth she analysed from the sector P16 site.

Six individuals of reindeer were established on mandibular teeth and eight individuals on maxillary teeth. These individuals were grouped into broad age-classes or age-cohorts according to their crown-heights and by comparing their tooth wear patterns with those observed in recent reindeer of known age at death (Miller 1974, Spiess 1979). The six individuals established on mandibular teeth could be placed into three age-cohorts, comprising one animal younger than 15–29 months and certainly younger than two years at death (juvenile), four animals which probably died at between 3–5 years of age (sub-adults and adults), and one animal aged between 6–9 years at time of death (adult). Similar groupings were observed among the individuals established on maxillary cheek teeth. Of the eight animals represented by the maxillary dentition, two could be approximately aged to younger than two years (juveniles), two belonged to the 3–5 year cohort (sub-adults and adults), two or three to the 6–9 year cohort (adults) and one was ten years of age or older at time of death (old adult). Thus, according to tooth eruption and wear patterns, young, adult and old individuals of reindeer were present at the site. However, the dominance of teeth from sub-adult and adult reindeer (3–5 years of age) suggests that these animals were the preferred prey of the Magdalenian hunters.

The teeth of four individuals of bison were approximately aged by comparison with dental development in age-groups described by Todd & Hofman (1987) and Wilson (1980) for fossil bison. Three young bison – a calf about 6 months old and two juveniles aged between 2–2½ years old – were identified. The fourth individual was somewhat older and died between 4½ – 5½ years of age.

Age structures using bone epiphyseal fusion

The times of fusion of epiphyses on mammalian skeletal elements can serve as indicators of age at death. However, as almost all the epiphyses in a horse skeleton are fused by 4 or 5 years of age, information pertaining to age using epiphyseal fusion is restricted to juveniles and to young members of the prime-adult group in this species.

Several bones of horse had unfused or partially fused epiphyses which could be approximately aged using data published by Levine (1979) and Schmid (1972). Six horses were represented by six axis vertebrae which were unfused caudally. These individuals were younger than 3½ years of age at death, this being the time when fusion of the caudal plate to the corpus begins in the axis vertebrae. A distally unfused second phalange and humeri with both proximal and distal ends unfused, and the known times of epiphyseal fusion in these elements, show that some horses could have been as young as 9 months of age at the time of their death.

The fifteen unfused skeletal elements of reindeer provided no further demographic data for the population of this species from sector P16 not only because of the small number and fragmentary state of these bones, but also due to inconsistencies between comparative epiphyseal fusion data published by Hufthammer (1995) and by Spiess (1979) for recent reindeer which make assessments of age very difficult to apply.

Epiphyseal fusion stages observed on 12 bison bones also indicate the presence of at least two individuals younger than five years of age at time of death (Habermehl 1961, Schmid 1972, Grigson 1982).

Sexual demographics

Although canine teeth have been observed in female horses, they are more commonly found in the jaws of stallions (Sisson & Grossman 1953). A total of only three horse canines, one upper, one lower and a third canine unerupted in a mandible symphysis, were recorded from sector P16. The low number of canines is interpreted as reflecting a dominance of mares among the horses which died at the site.

Sexual dimorphism is particularly marked in both the genera *Bos* and *Bison*, and the males of the genera are much larger than the females. This overall difference in

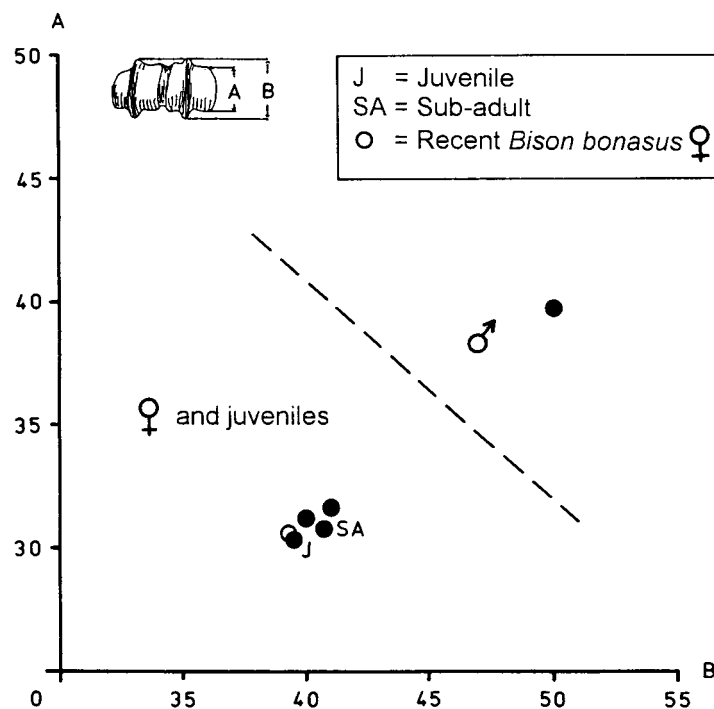


Fig. 12. Sexual dimorphism in the bison population from the sector P16 site.

body-size is also reflected in the size of the bones from adult individuals and a similar sexual dimorphism has been assumed and quantified for bison bones from archaeological contexts. The presence of both males and females amongst the bison remains at P16 had already been tentatively established during the analysis of five metacarpals of bison. Four of these specimens are more or less equal in size; the distal end of a fifth metacarpus is much larger, surpassing the other finds in both distal breadth and depth.

In order to illustrate this difference in size more clearly, the depth of the distal end of the bone was measured and plotted against the depth of the medial part of the trochlea (David 1994). The metacarpals clearly divide into two groups in the graph (fig. 12), with the single large specimen belonging to a male and the four other metacarpals belonging to two adult females and to two younger animals. It could be postulated that the two younger individuals are also females, since both finds fall within the female size range.

Attempts to determine the sexual demography of the reindeers using, for example, mandibular measurements (Spiess 1979, Morrison & Whitridge 1997) or measurements on certain post-cranial bones (Spiess 1979) could not be undertaken due to the lack of intact mandibles in the sample and the small size of the total sample of measurable bones of this species.

Season of death and physical condition

Skeletal elements from the fetuses of two horses were identified among the finds from sector P16. The stages of development of the foetal bones (Prummel 1987) show that one foetus was about 36 weeks old when the mare died. The second foetus was about two weeks younger. Horse gestation lasts for almost one year (345 or 348 days [Berger 1986]). Thus, the two mares at Solutré died about 2½ months before they were due to give birth. As the majority of foals are born in the period April to June, the two females appear to have died sometime between February and March (fig. 13a). At this time of the year female condition is poor and the mares are just about to start moulting their winter coats (West 1997, fig. 4.2).

A more reliable method of determining season of death is the analysis of incremental bands of tooth cementum and 5 horse teeth from Magdalenian deposits in sector J10 at Solutré were submitted for tooth increment analysis during a previous study of the fauna from Solutré (Olsen 1989), and an approximate season of death as spring/early summer was given for two teeth, two further specimens were from horses that had died in summer and one tooth was from an animal that had died in winter (fig. 13b). These results indicate that horses were killed during periods when both males and females are in poor condition (spring/early summer), in periods when horses are in good condition (late summer/autumn) and in periods when their condition is deteriorating (winter) (West 1997, fig. 4.2).

Two antler frontlets with weakly-developed antlers typical of young reindeer of both sexes and seven thin, short pedicles – also from young reindeer – provide important seasonal evidence for this species. A resorption line – the line along which the antler separates from the pedicle during shedding – below the burr of one of the antler frontlets indicate that this individual had died just before shedding its antler. The pedicles belong to animals which had just shed their antler, but regrowth had not begun. As the period between the shedding of antler and antler re-growth in young

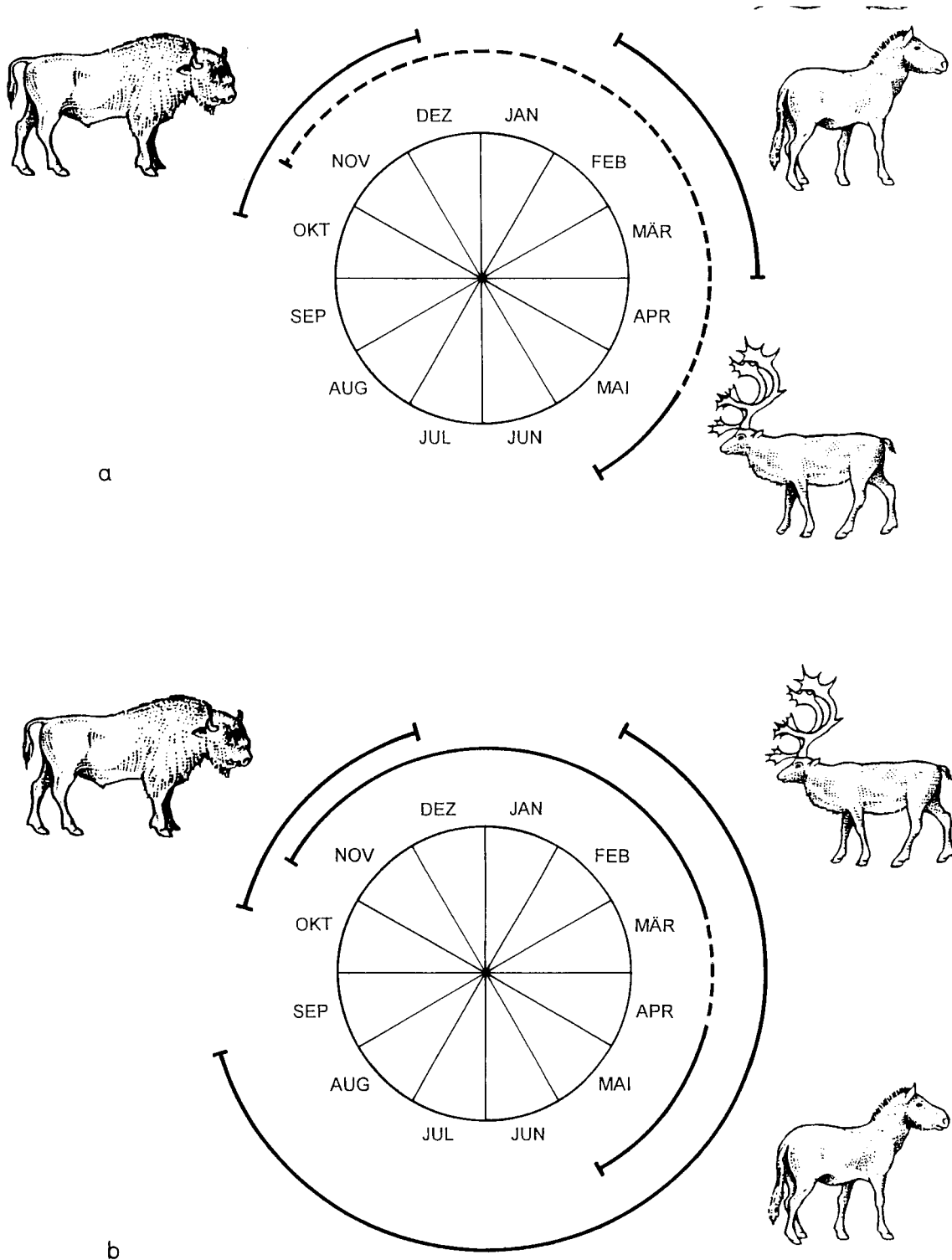


Fig. 13. a) The season of death of horse, reindeer and bison established during the current analysis. b) compilation of a) and the results of incremental analyses of horse and reindeer teeth produced during previous studies of the faunas. Incremental analysis of horse teeth from Magdalenian deposits in sector J10 undertaken by M. Beasley (published in Olsen 1989) and incremental analysis of reindeer teeth undertaken by B. Gordon (1988).

reindeer comprises only a few days within the month of May (Schmid 1972), the state of antler regeneration indicates that eight reindeer from sector P16 died during this period (fig. 13a).

A second frontlet was more difficult to place seasonally. Antler growth in young reindeer begins in the second half of May and antlers are carried until the following May (Schmid 1972). As there was no trace of a resorption line below the burr indicating incipient shedding, this animal died any time between November (after the velvet on the antler has worn away) and May.

Gordon (1988) examined incremental bands of cementum on a small sample of reindeer teeth ($n=14$) from an Early Magdalenian horizon at Solutré, and established that 52.3 % had been killed in winter (December-March) and 47.6 % in spring (April-May) (fig. 13b). This seasonal information indicates that reindeer were being hunted during periods when female condition is relatively good to poor and male condition is poorest (November to March), and during periods when male condition is beginning to improve and female condition is poorest (April/May) (West 1997, fig. 4.1).

Bison are usually born in the spring, and the time of death established for the calf and for the two juveniles suggests that some bison were hunted during autumn/winter (fig. 13a). At this time of the year, adult females are probably in a relatively good condition, as this is the period after parturition when they are building up or have built up their fat resources. In contrast, adult bulls are in a relatively poor physical condition (Lott 1979, Brooks 1978).

To summarise, the dominance of prime adult – probably female – horses, the presence of foals and pregnant mares, suggests that mainly family groups of horses were hunted at Solutré (Wild horses usually live in two types of groups: the “family group” which consists of mares of different ages, their foals and a stallion. Young males leave the family group at around two years of age and together with other males form “bachelor groups”). The seasonal evidence suggests horses were taken during the period February through to autumn. The stage of antler regeneration in a group of eight young reindeer indicates that these animals died during a short period of time in the month of May. They were possibly killed together during a single hunting episode which probably took place at the site, assuming that the hunters did not selectively transport parts of the heads of eight reindeer to Solutré from a kill-site elsewhere. Otherwise, sub-adult and adult reindeer appear to have been preferentially hunted. The age and sex structure of the bison population, which comprises adult female and male bison, along with a calf and juveniles, compares closely with that described for “cow-calf” groups. If the group died together during a single hunting episode, then the killing of bison at the site could be postulated. The stage of tooth eruption and wear on the teeth of the calf and the juveniles show that these individuals of bison died in autumn/winter.

The condition of the hunted animals did not appear to play an important role in the subsistence strategies of the Magdalenian hunters at Solutré, and horse, reindeer and bison appear to have been killed during periods when their condition varied from poor to excellent.

Conclusion

The main results of a recent examination of horse, reindeer and bison remains recovered during excavation of the sector P16 site at Solutré are summarised in the following table.

Table 3. Summary of the main characteristics of the assemblages of horse, reindeer and bison remains from sector P16 including seasonal data for horse taken from Olsen (1989) and for reindeer taken from Gordon (1988).

horse	reindeer	bison
high MNI	relatively high MNI	relatively high MNI
high NISP, bulk of horse bones at site	low NISP, few bones at site	low NISP, few bones at site
low numbers of cut marks and impact notches, but several stages of carcass processing from ?skinning and disarticulation to marrow extraction shown	very low numbers of cut marks and impact notches, but several stages of carcass processing from ?skinning and disarticulation to marrow extraction shown	very low numbers of cut marks and impact notches evidence of filleting and marrow extraction only
very low numbers of worked bone	very low numbers of worked bone and antler	no worked bone
very low numbers of charred bones	very low numbers of charred bones	no charred bones
members of mainly family groups of horses killed, adults and juveniles killed and processed	dominance of sub-adult and adults, adults and juveniles killed and processed	possibly cow-calf groups killed, bones of adults processed
February – September evidence (butchery marks, skeletal part representation) that horses were killed and butchered at site, some bones (vertebrae; leg bones) may have been transported away from the site by the hunters	November – May evidence that reindeer were killed at site and intensively processed (butchery marks; skeletal part representation, social groupings), or killed elsewhere and transported to site as carcass portions (butchery marks; skeletal part representation)	October – December (juveniles) evidence that bison were either killed elsewhere and transported to site as carcass portions (butchery traces; skeletal part representation) or killed at site (social groupings) and intensively processed
high numbers of carnivore gnawed bones in comparison to those with traces of human modification	high numbers of carnivore gnawed bones in comparison to those with traces of human modification	high numbers of carnivore gnawed bones in comparison to those with traces of human modification

At sector P16, traces of human modification were found on the remains of horse, reindeer and bison indicating that these species were the ones hunted by the Magdalenian occupants of the site. The fauna from sector P16 is, however, dominated by horse, represented by at least 45 individuals. In general, reindeer and bison are characterized by low numbers of identifiable remains and relatively high numbers of individuals. Horse is characterized by high numbers of remains and high numbers of individuals.

The evidence suggests that horses were hunted, killed and processed at the site. In contrast to this, the interpretation of the remains of reindeer and bison is dichotomous. The low number of reindeer remains and evidence of traces of primary

butchery (e.g. disarticulation) on reindeer bones suggests that reindeer were also killed and fully processed at the site. The presence of pedicles and antler from eight young reindeer which might have been killed during a single hunting episode support this theory, assuming that the hunters did not selectively transport parts of the heads of eight reindeer to Solutré from a kill-site elsewhere. An alternative theory is that portions of carcasses of reindeer killed elsewhere were transported to the site; in other words, were intended as “snacks” for the hunters during their stay at Solutré. The numbers of cut marks around the distal scapulae of reindeer, indicative of the consumption of meat (Binford 1981), might support this theory.

Similar arguments can be applied to bison. The low number of remains of this species and the lack of traces produced during primary butchery suggest that only portions of bison carcasses were transported to the site. However, the age-structure and sexual demography of bison at sector P16 suggests that the individuals belonged to a cow-calf group. If this is the case, and these animals did die together, then killing bison and fully processing their remains at the site would be a more plausible explanation of the characteristics of the assemblage of bison bone at the sector P16 site.

On the whole, the results of this examination of faunal remains from Magdalenian deposits at the sector P16 site at Solutré support many of the results produced during previous analyses of some of these remains (Berke 1989, Levine 1979, 1983, Olsen 1989, 1995). Both Berke (*ibid.*) and Olsen (*ibid.*) have already commented on the minimal utilisation of the remains of horse at Solutré, and the discrepancy between the large number of horses that apparently died here and the low number of horse remains with traces of butchery is the most unusual aspect of the assemblage of bones from sector P16. In my opinion, the low numbers of cut and other butchery marks is certainly not wholly due to bone preservation. Artistic depictions show that the Magdalenians were not only fully conversant with the appearance of living horses but also with horse anatomy, as can be seen in the sculpture of a de-fleshed horses head from the Magdalenien site of Mas d’Azil in France (Piette 1907). The low numbers of butchery marks, especially cut marks, could thus be due to the expertise of the Magdalenian butchers whose carcass processing left few traces behind on the bones, an argument also considered, but rejected by Olsen (1989).

The minimal processing of horse carcasses could be linked to the way in which horses were hunted, a theory that was also discussed by Olsen (1989). Researchers have long been preoccupied with the methods used to hunt horses at Solutré, and at the beginning of the 1990’s the general opinion was that herds of horses were intercepted by the hunters in the valley below Solutré and driven up the slope towards the base of the face of the rock, possibly into a corral, where they were killed. Another alternative, and this is the one preferred in this paper, is Combier’s theory (taken from an unpublished manuscript) that horses were simply ambushed as they skirted around the base of the rock following a migratory trail which had been used for generations (small-scale models currently exhibited in the museum at the site of Solutré depict this method of hunting horses at Solutré). Hunters waiting in ambush close to the trail would probably have killed as many horses as possible, before the rest of the herd panicked and took flight. This method of hunting would have produced many carcasses, from which perhaps only a few were selected for further processing.

Thanks

I would like to thank Jean Combier, the Service Régionale de l'Archéologie in Dijon and Genévieve Lagardère and her team in the museum at Solutré for their help during my stay in Burgundy. Paul Pettitt (Oxford) kindly allowed me to use the unpublished Radiocarbon date. The figures and the plates were prepared by Regina Hecht (Monrepos).

Zusammenfassung

Bei dem Platz am Fuße des Felsens von Solutré handelt es sich ohne Zweifel um die berühmteste prähistorische Fundstelle Burgunds. In den mächtigen Ablagerungen der Fundstelle wurden bei Ausgrabungen fünf Kulturschichten freigelegt (Mousterian, Aurignacian, Gravettian, Solutrean and Magdalenian), die eine wiederholte Belegung des Platzes vom Mittelpaläolithikum bis zum Ende des Jungpaläolithikums reflektieren. Solutré ist als Platz interpretiert worden, an dem hauptsächlich Pferde gejagt, getötet und verarbeitet wurden. In diesem Beitrag werden Daten präsentiert, die während einer Untersuchung der Faunenreste der magdalenienzeitlichen Ablagerung des Abschnittes P16 ermittelt wurden. Im Zentrum des Beitrages steht die Skelettteilpräsenz, Altersstrukturen, Geschlechtsdemographie, die Jahreszeit des Todes und Modifikationsspuren in Form von Schnittpuren, Schlagspuren und Raubtierverschleiß an Resten von Pferden, Rentieren und Wisenten. Die Untersuchungsergebnisse unterstützen die Annahme, daß die magdalenienzeitlichen Menschen hauptsächlich Pferde in Solutré jagten, jedoch ebenso Rentiere und Wisente in großer Zahl erbeuteten. Der Todeszeitpunkt der Pferde, Rentiere und Wisente legt nahe, dass der Platz wahrscheinlich zu unterschiedlichen Jahreszeiten genutzt wurde und Gruppen juveniler Rentiere und juvenile Wisente offenbar auf jahreszeitlicher Basis erbeutet wurden. Eines der Merkmale des faunistischen Inventars ist die geringe Anzahl der menschlich modifizierten Knochen und die vergleichsweise hohe Zahl der durch Raubtiere verletzten Faunenreste.

References

- Arcelin, A. (1977): Chasseurs de Rennes à Solutré. 2nd Edition. – Editions Bourgogne Rhône-Alpes. 1st Edition, Hachette, 1872.
- Behrensmeyer, K. (1975): The taphonomy and paleoecology of Plio-Pleistocene vertebrate assemblages east of Lake Rudolf, Kenya. – *Bulletin of the Museum of Comparative Zoology* 164: 473–573.
- Berger, J. (1983): Ecology and Catastrophic Mortality in Wild Horses: Implications for Interpreting Fossil assemblages. – *Science* 220: 1403–1404.
- Berger, J. (1986): Wild Horses of the Great Basin. – In: G.B. Schaller (ed.) *Wildlife Behaviour and Ecology*. University of Chicago Press, Chicago and London.
- Berke, H. (1989): Solutré-Peterfels-Pekarna-Kniegrotte. Schlachtspuren an Pferdeknochen. – *Archäologische Informationen* 12 (2): 180–194.
- Binford, L. R. (1971): Bone frequencies – and attritional processes. – In: L. R. Binford (ed.) *For Theory Building in Archaeology*. Academic Press, Chicago.
- Binford, L. R. (1981): *Bones. Ancient Men and Modern Myths*. – Academic Press, New York.
- Brain, C. K. (1981): *The Hunters or the Hunted? An Introduction to African Cave Taphonomy*. – University of Chicago Press, Chicago.
- Brooks, P. M. (1978): Relation between body condition and age, growth, reproduction and social status in impala, and its application to management. – *South African Journal of Wildlife Research* 8(4): 151–157.
- Combier, J. (1956): Les Fouilles de 1907 à 1925. – Extrait des Travaux du Laboratoire de Géologie de la Faculté des Sciences de Lyon. Nouvelle Série No. 2.
- Combier, J. (1973): Unpublished site report.
- Combier, J. (1976): Solutré. – In: Combier, J. & Thevenot, J.-P. (eds.) *Bassin du Rhone. Paléolithique et Néolithique. Livret-Guide de l'Excursion A8*. UISPP, Nice.
- Combier, J. (unpublished manuscript): Solutré, Haut-lieu de la Préhistoire.

- David, F. (1994): La Faune II. Le Bison: description autres espèces. – In: C. Farizy, F. David and J. Jaubert (eds.) *Hommes et Bison de Paléolithique Moyen à Mauran* (Haute-Garonne), CNRS Editions, Paris: 46–56.
- Delibras, G., G. Guillier, M.-Th. Évin & Y. Thommeret (1976): Datations absolutes des dépôts quaternaires et des sites préhistoriques par la méthode Carbone 14. – In: H. de Lumley (ed.) *La Préhistoire Française I*, 2: 1499–1514.
- Gifford, D. P. & D. C. Crader (1977): A computer coding system for archaeological faunal remains. – *American Antiquity* 42 (2): 225–238.
- Gordon, B. (1988): *Of Men and Reindeer Herds in French Magdalenian Prehistory*. – British Archaeological Reports 390. Oxford.
- Grigson, C. (1982): Sex and age determination of some bones and teeth of domestic cattle: a review of the literature. – In: B. Wilson, C. Grigson and S. Payne (eds.) *Ageing and sexing animal bones from archaeological sites*. British Archaeological Reports, British Series 109: 7–23.
- Habermehl, K.-H. (1961): *Die Altersbestimmung bei Haustieren, Pelztieren und beim jagdbaren Wild*. – Paul Parey, Berlin & Hamburg.
- Haynes, G. (1982): Utility and skeletal disturbance of North American Prey Carcasses. – *Arctic* 35 (2): 266–281.
- Haynes, G. (1983): A guide for differentiating mammalian carnivore taxa responsible for gnaw damage to herbivore limb bones. – *Paleobiology* 9 (2): 164–172.
- Haynes, G. (1991): *Mammoths, mastodons and elephants. Behaviour, and the fossil record*. – University Press, Cambridge.
- Hufthammer, A. K. (1995): Age determination of Reindeer (*Rangifer tarandus* L.). – *Archaeozoologia* VII/2: 33–41.
- Kreutzer, L. A. (1992): Bison and deer bone mineral densities: comparisons and implications for the interpretation of archaeological faunas. – *Journal of Archaeological Science* 19: 271–294.
- Lam, Y. M., X. Chen & O. M. Pearson (1999): Intertaxonomic variability in patterns of bone density and the differential representation of bovid, cervid, and equid elements in the archaeological record. – *American Antiquity* 64 (2): 343–362.
- Levine, M. A. (1979): *Archaeo-zoological analysis of some Upper Pleistocene horse bone assemblages in western Europe*. – Ph. D Dissertation, University of Cambridge.
- Levine, M. A. (1982): The use of crown height measurements and eruption-wear sequences to age horse teeth. – In: B. Wilson, C. Grigson and S. Payne (eds.) *Ageing and sexing animal bones from archaeological sites*. British Archaeological Reports 109: 223–250.
- Levine, M. A. (1983): Mortality models and the interpretation of horse population structure. – In: G. Bailey (ed.) *Hunter-gatherer Economy in Prehistory*. Cambridge University Press, Cambridge: 23–46.
- Lott, D. F. (1979): Dominance relations and breeding rate in mature male bison. – *Zeitschrift für Tierpsychologie* 49: 418–432.
- Lyman, R. L. (1985): Bone frequency: differential transport, in situ destruction and the MGUI. – *Journal of Archaeological Method and Theory* 12: 221–236.
- Lyman, R. L. (1994): *Vertebrate Taphonomy*. – Cambridge University Press, Cambridge.
- Marean, C. W. (1991): Measuring the postdepositional destruction of bone in archaeological assemblages. – *Journal of Archaeological Method and Theory* 18: 677–694.
- Marean, C. W. & L. M. Spencer (1991): Impact of carnivore ravaging on zooarchaeological measures of element abundance. – *American Antiquity* 56(4): 645–658.
- Marean, C. W., L. H. Spencer, R. Blumenshine & S. B. Capaldo (1992): Captive hyaena bone choice and destruction, the Schlegel effect and Olduvai archaeofaunas. – *Journal of Archaeological Science* 19: 101–121.
- Miller, F. L. (1974): *Biology of the Kaministiquia Population of barren-ground caribou*. Part 2: Dentition as an indicator of age and sex, composition and socialization of the population. – Canadian Wildlife Service Report series 31. Ottawa.
- Morrison, D. & P. Whitridge (1997): Estimating the Age and Sex of Caribou from Mandibular Measurements. – *Journal of Archaeological Science* 24: 1093–1106.

- Olsen, S. L. (1989): Solutré: A theoretical approach to the reconstruction of Upper Palaeolithic hunting strategies. – *Journal of Human Evolution* 18: 295–327.
- Olsen, S. L. (1995): Pleistocene Horse-Hunting at Solutré: Why Bison Jump Analogies Fail. – In: E. Johnson (ed.) *Ancient Peoples and Landscapes*. Museum of Texas Tech University, Lubbock, Texas: 65–75.
- Piette, É. (1907): *L'Art pendant l'Âge du Renne*. – Leroux, Paris.
- Prummel, W. (1987): Atlas for the identification of foetal elements of Cattle, Horse, Sheep and Pig. Part 2. – *Archaeozoologia* 12: 11–42.
- Schmid, E. (1972): *Atlas of Animal Bones*. – Elsevier. Amsterdam, London, New York.
- Sisson, S. & J. D. Grossman (1953): *The Anatomy of the Domestic Animal*. – W. B. Saunders, Philadelphia.
- Spiess, A. E. (1979): *Reindeer and Caribou-Hunters*. – Academic Press, New York, San Francisco, London.
- Stiner, M. C. (1990): The use of mortality patterns in archaeological studies of hominid predatory adaptations. – *Journal of Anthropological Archaeology* 9: 305–351.
- Todd, L. C. & J. L. Hoffman (1987): Bison mandibles from the Horner and Finley sites. – In: G. C. Frison and L. C. Todd (eds.) *The Horner site. The type site of the Cody Cultural Complex*. Academic Press, Orlando, Florida.
- Turner, E. (in press): An archaeozoological analysis of faunal remains from the Magdalenian horizon (sectors P16 and I11) at Roche de Solutré, France. – *Jahrbuch Römisch-Germanisches Zentralmuseum, Mainz*.
- Voorhies, M. (1969): Taphonomy and population dynamics of an early Pliocene vertebrate fauna, Knox County, Nebraska. – *Contributions in Geology, Special Paper No. 1*. University of Wyoming Press, Laramie.
- West, D. (1997): *Hunting Strategies in Central Europe During the Last Glacial Maximum*. – *British Archaeological Reports International Series 672*. Archaeopress, Oxford.
- Wilson, M. (1980): Population dynamics of the Garnsey site bison. – In: J. D. Speth and W. J. Parry (eds.) *Late Prehistoric bison procurement in southeastern New Mexico: the 1978 season at the Garnsey site (LA-18399)*. Museum of Anthropology, University of Michigan, Technical Reports, 12. Ann Arbor.

Dr. Elaine Turner, Römisch-Germanisches Zentralmuseum, Forschungsinstitut für Vor- und Frühgeschichte, Forschungsbereich Altsteinzeit, Schloss Monrepos, D-56567 Neuwied

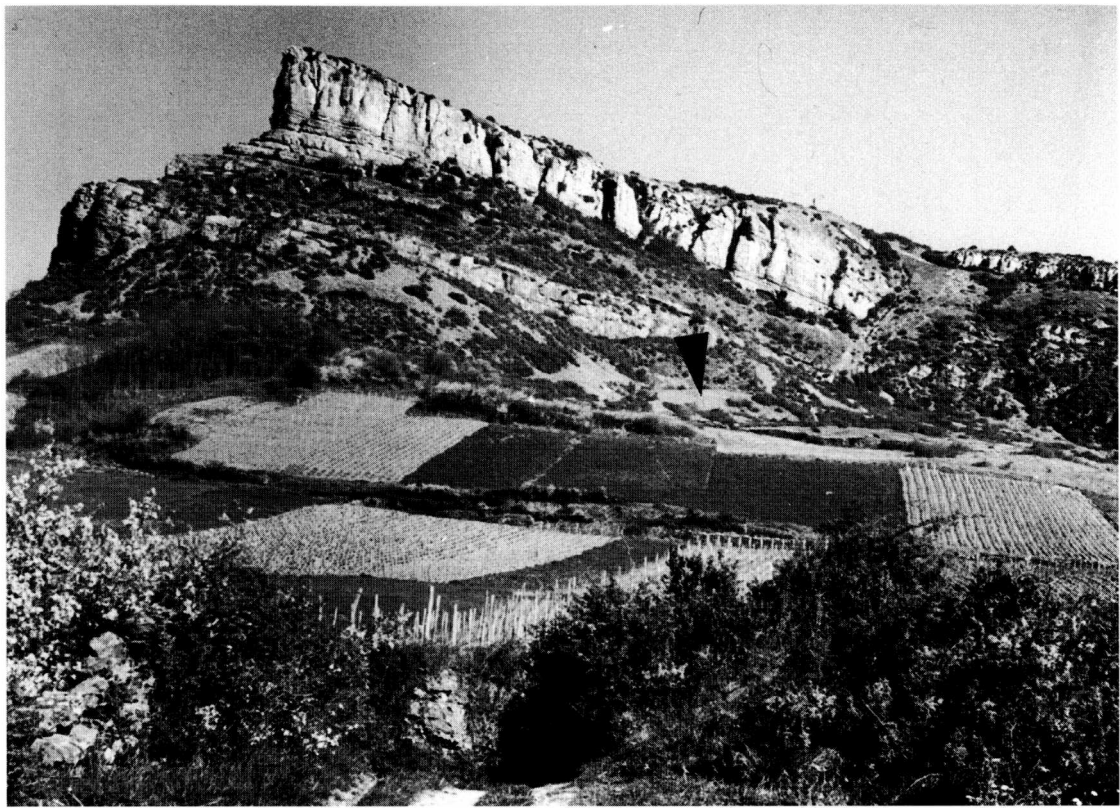


Plate 1. View of the southern cliff of the "Roche de Solutré". The site at the base of the rock is marked by an arrow.

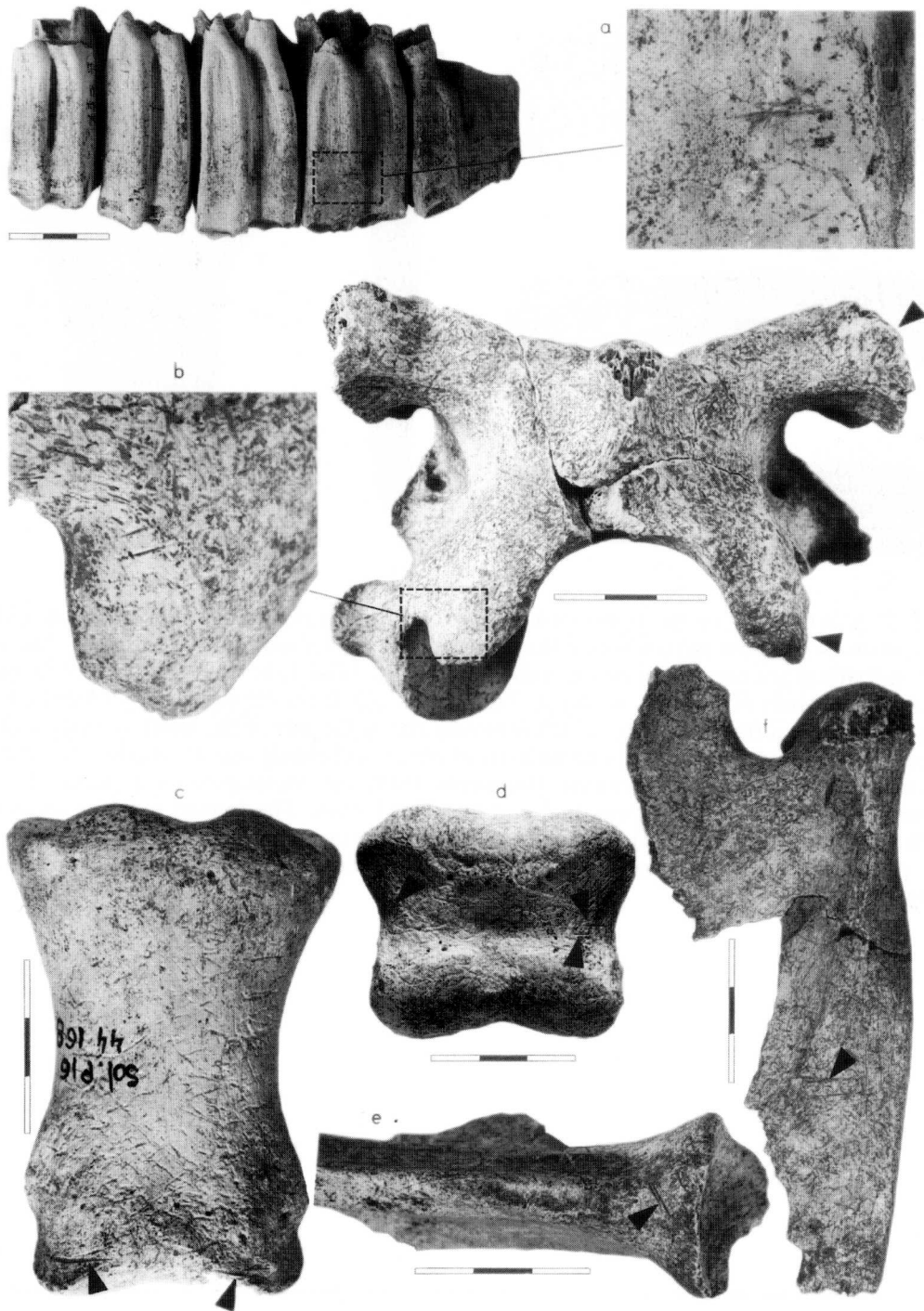


Plate 2. Cut marks on the bones of horse and reindeer. a: cut marks on the outer (buccal) surfaces of an upper P3 of horse. b: ventral face of an atlas vertebra of horse, showing traces of carnivore gnawing (arrows right) and cut marks produced during separation of the head from the neck (inset). c: cut marks produced during ?skinning or disarticulation circulating the distal end of a first phalange of horse. d: cut marks on the plantar face of a second phalange produced during tendon removal. e: cut marks around the distal end of a scapula of reindeer. f: cut marks across the ascending ramus of a mandible of horse.

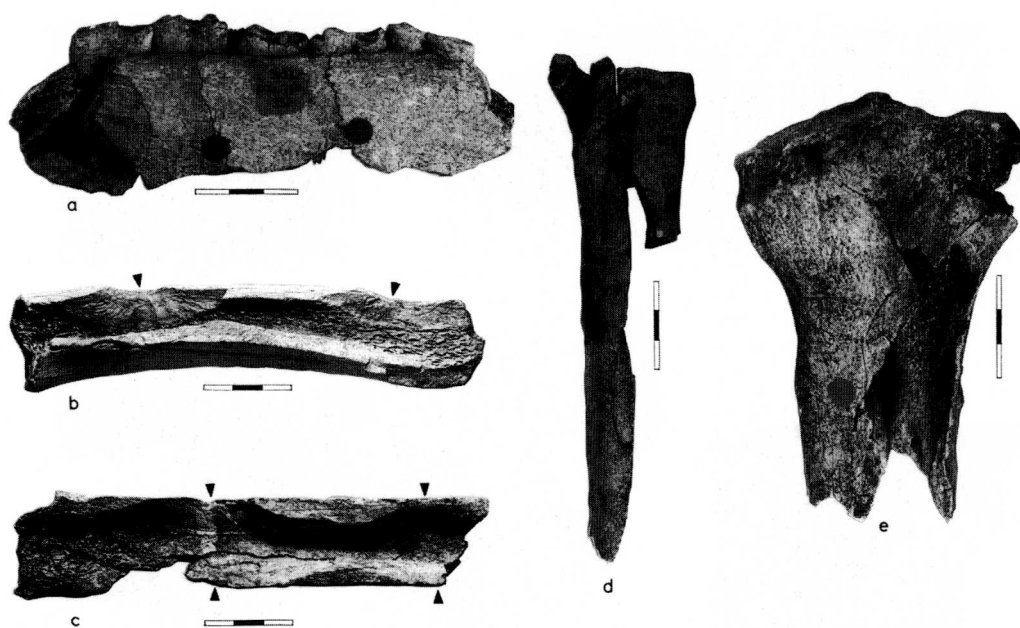
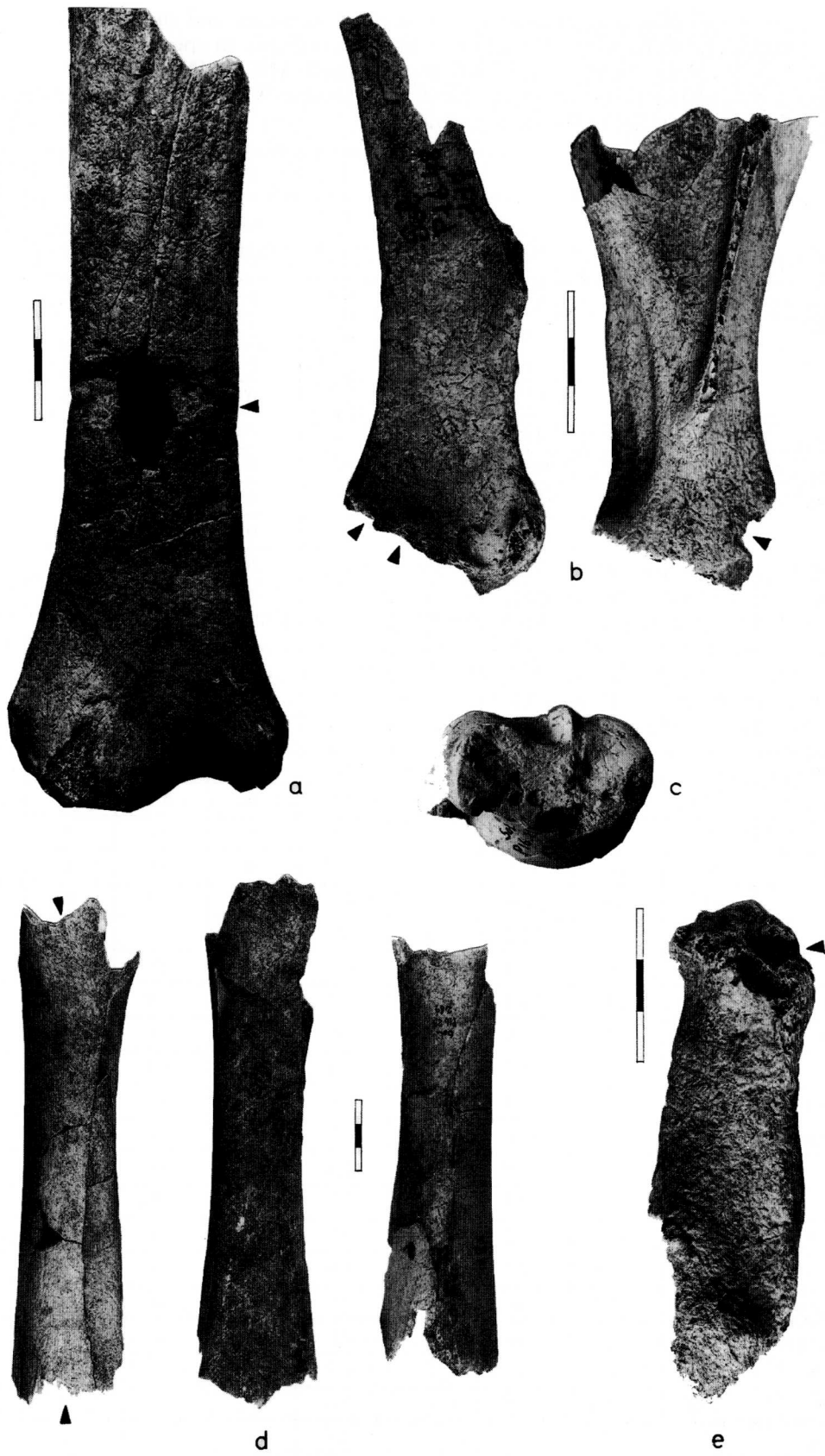


Plate 3. Impact notches on the bones of horse. a: two impact notches produced during extraction of marrow (marked by circles on the photograph) on the mandible of a horse. The teeth of this individual are very worn down, indicating an old animal. b: two well-preserved impact notches on the shaft of a radius of horse. The impact notch on the right side of the bone has been truncated by a fracture plane which removed the distal part of the shaft. c: opposing sets of impact notches on the shaft of a metatarsus of horse, indicating use of an anvil as a support (reflective percussion). d: conjoining fragments from the metatarsal of a horse showing fracture planes which split the proximal end into two halves. The impact notch is located on the left side of the shaft (circle). e: impact notch (circle) on the dorsal face of a radius, close to the proximal end. A large portion of the shaft has been removed in order to expose the marrow cavity.



Plate 4. Traces of carnivore gnawing on the bones of horse, reindeer and bison. a: distal tibia of horse showing tooth furrows (arrow) and an opening – latter probably caused by the bone collapsing under pressure of the teeth – on the shaft. b: distal end of two scapulae of reindeer with tooth notching traces on the distal edge (left specimen) and on the tuber scapulae (right specimen). c: astragalus of reindeer with well-preserved tooth puncture marks (arrow). d: three femurs of bison showing typical traces of gnawing on the proximal and distal ends (arrows on left specimen) resulting in the “bone cylinder” form commonly found after the intensive carnivore gnawing of long bones. e: calcaneum of reindeer with tooth furrows at tip of corpus calcanei.



Appendix 1. Counts and percentages of skeletal elements and modifications of horse remains from sector P16. NISP = number of finds identifiable to species; MNI = minimum number of individuals; % MNI reckoned from highest MNI (MNI 45 = 100%); % cut, % impact and % gnawed reckoned from NISP per element. NISP counts in this table do not include fragmentary pieces eg. tooth fragments.

	1	2	3	4	5	6	7	8	9
Skeletal element	NISP	MNI	% MNI	N Cut	% Cut	N Impact	% Impact	N Gnawed	% Gnawed
cranium	110	31	68.8	1	0.9	0	0	3	2.7
mandible	138	38	84.4	7	5.0	2	1.8	6	4.3
max. teeth	491	32	71.0	8	1.6	0	0	0	0
man. teeth	332	23	51.1	2	0.6	0	0	0	0
atlas	43	33	73.3	4	9.3	0	0	6	13.9
axis	28	22	48.8	0	0	0	0	1	3.5
cervical	153	30	66.6	0	0	0	0	11	7.1
thoracic	155	8	17.7	0	0	0	0	12	7.7
lumbar	116	18	15.5	0	0	0	0	17	14.6
sacrum	11	9	20.0	0	0	0	0	6	54.5
caudal	4	1	25.0	0	0	0	0	1	25.0
pelvis	156	45	100.0	1	0.64	0	0	20	12.8
rib	114	2	4.4	10	8.7	0	0	5	4.3
scapula	99	41	91.9	5	5.0	0	0	2	2.0
humerus	88	25	55.5	4	4.5	10	11.3	37	42.0
radius	94	25	55.5	2	2.1	6	6.3	11	11.7
ulna	32	17	37.7	2	6.2	0	0	9	28.1
carpals	89	16	35.5	1	1.1	0	0	0	0
mc 3	117	39	86.6	5	4.2	5	4.2	10	8.5
mc 2	17	10	22.2	0	0	0	0	0	0
mc 4	15	9	20.0	1	6.6	0	0	0	0
femur	107	24	53.3	4	3.7	3	2.8	30	28.0
patella	24	13	28.8	0	0	0	0	6	25.0
tibia	94	26	57.7	3	0.3	8	8.5	8	8.5
calcaneum	75	33	73.3	0	0	0	0	27	36.0
astragalus	87	39	86.6	2	2.2	0	0	6	6.8
tarsals	77	18	40.0	2	2.5	0	0	0	0
mt 3	94	31	68.8	1	1.0	10	10.6	5	5.3
mt 2	16	9	56.2	0	0	0	0	1	6.2
mt 4	17	11	64.7	1	5.8	0	0	0	0
P sesamoid	11	2	4.4	0	0	0	0	0	0
D sesamoid	8	2	4.4	0	0	0	0	0	0
phalange 1	147	42	93.3	2	1.3	0	0	7	4.7
phalange 2	153	34	75.5	1	0.6	0	0	10	6.5
phalange 3	189	27	60.0	1	0.5	0	0	3	1.5

Appendix 2. Counts and percentages of skeletal elements and modifications of reindeer remains from sector P16. NISP = number of finds identifiable to species; MNI = minimum number of individuals; % MNI reckoned from highest MNI (MNI 9 = 100%); % cut, % impact and % gnawed reckoned from NISP per element. NISP counts in this table do not include fragmentary pieces eg. tooth fragments.

[illegible]

Appendix 3. Counts and percentages of skeletal elements and modifications of bison remains from sector P16. NISP = number of finds identifiable to species; MNI = minimum number of individuals; % MNI reckoned from highest MNI (MNI 5 = 100%); % cut, % impact and % gnawed reckoned from NISP per element. NISP counts in this table do not include fragmentary pieces eg. tooth fragments.

	1	2	3	4	5	6	7	8	9
Skeletal element	NISP	MNI	% MNI	N Cut	% Cut	N Impact	% Impact	N Gnawed	% Gnawed
cranium	2	1	40.0	0	0	0	0	0	0
mandible	3	2	40.0	0	0	0	0	0	0
max. teeth	14	4	80.0	0	0	0	0	0	0
man. teeth	13	3	60.0	0	0	0	0	0	0
atlas	2	2	40.0	0	0	0	0	0	0
axis	4	3	80.0	0	0	0	0	0	0
cervical	2	1	20.0	0	0	0	0	0	0
thoracic	1	1	20.0	0	0	0	0	0	0
lumbar	3	1	20.0	0	0	0	0	1	33.3
sacrum	0	0	0	0	0	0	0	0	0
caudal	0	0	0	0	0	0	0	0	0
pelvis	8	3	60.0	0	0	0	0	2	25.0
rib	2	1	40.0	0	0	0	0	0	0
scapula	2	1	20.0	0	0	0	0	0	0
humerus	9	4	80.0	1	11.1	2	22.2	4	44.4
radius	3	2	40.0	0	0	0	0	2	66.6
ulna	4	1	20.0	0	0	0	0	0	0
carpals	9	2	40.0	0	0	0	0	0	0
metacarpal	8	5	100.0	0	0	1	12.5	0	0
femur	7	2	40.0	1	14.2	0	0	4	57.1
patella	1	1	20.0	0	0	0	0	0	0
tibia	5	3	60.0	0	0	1	20.0	0	0
os mall	0	0	0	0	0	0	0	0	0
calcaneum	2	1	40.0	0	0	0	0	1	50.0
astragalus	4	3	60.0	0	0	0	0	0	0
tarsals	5	3	60.0	0	0	0	0	1	20.0
metatarsus	5	2	40.0	0	0	0	0	1	20.0
sesamoids	1	1	20.0	0	0	0	0	0	0
phalange 1	8	1	20.0	0	0	1	12.5	2	25.0
phalange 2	5	1	20.0	0	0	0	0	1	20.0
phalange 3	7	1	20.0	0	0	0	0	1	14.2