ELAINE TURNER

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AN ARCHEOZOOLOGICAL ANALYSIS OF THE MAGDALENIAN HORIZON

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RÖMISCH-GERMANISCHES ZENTRALMUSEUM
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Dedicated to the memory of Philippe Morel

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Elaine Turner

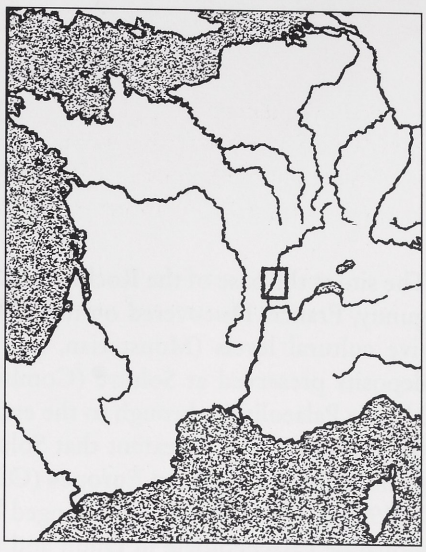
INTRODUCTION

The site at the base of the Roche de Solutré is, without a doubt, the most famous prehistoric site in Burgundy, France. Discovered on the 27th. September, 1866 by Adrien Arcelin, excavations have revealed five cultural levels (Mousterian, Aurignacian, Gravettian, Solutrean and Magdalenian) in the thick deposits preserved at Solutré (Combier 1956; 1976), reflecting repeated use of the locality from the Middle Palaeolithic through to the end of the Upper Palaeolithic. During this period, horses dominated the faunas to such an extent that Solutré has been considered the »best preserved example of a large-game kill-site in Western Europe« (Olsen 1989, p. 295).
In 1994, a joint project was arranged between the excavator of the site, Jean Combier, the Service Régional 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 characterize the type of faunal assemblage found at a Magdalenian kill and butchery site by analysing a large sample of bone material. The results of this analysis support the theory that Magdalenian people hunted mainly horses at Solutré, but also show that they took relatively high numbers of reindeer and bison. Times of death of horses, reindeer and bison suggest that the site was probably used at varying times of the year, and that groups of juvenile reindeer and juvenile bison were possibly taken on a seasonal basis. One of the characteristics of the Magdalenian faunal assemblage is the extremely low number of butchery traces and high number of carnivore gnawing traces on the remains of horse, reindeer and bison.

THE MÂCONNAIS REGION AND THE SITE OF SOLUTRÉ

Solutré is located in the Mâconnais region of Burgundy, France (fig. 1). The »Mâconnais« is a small region, some 45 kilometres long by roughly 20 kilometres wide, situated in the southern part of Burgundy in the French department of Saône-et-Loire. Bordered to the east by the Saône river, the Mâconnais comprises two hilly regions – the Mâconnais hills and the Cluny hills – extending from north to south through the region and intersected by the valley of the Grosne river. The Mâconnais hills vary between 300-600 m in height and are composed of five prinicipal chains, oriented from NNE-SSW. The longest, broadest, and geologically most intact chain, connects Fuissé in the south to Sennecy in the north of the region and consists of Middle and Upper Jurassic formations. The southern part of this formation is characterised by a series of west-east oriented ridges or »cuestas«, formed as a result of intensive tectonic movement associated with the uplift of the Alps and the Massif Central during the Tertiary period. These ridges comprise Roche de Solutré (493 m NN) (plate 1, 1), its southern neighbour, Mont de Pouilly (485 m NN) and, to the immediate north, Vergisson (485 m NN) and Montsard (406 m NN). Each cuesta is separated from its neighbour by broad valleys drained by minor streams.
The archaeological site is located on the southern slope at the base of the cuesta known as Roche de Solutré (plate 1, 2). The finds are stratified in two talus cones, which cover an area of some 10,000 m^2. Even though the continuous post-depositional movement of material down the slopes below the rock has produced a complicated stratigraphical succession, the main sequence of cultural deposits at Solutré is relatively straightforward, and can be summarised as follows beginning with the youngest horizon (Floss 1995):





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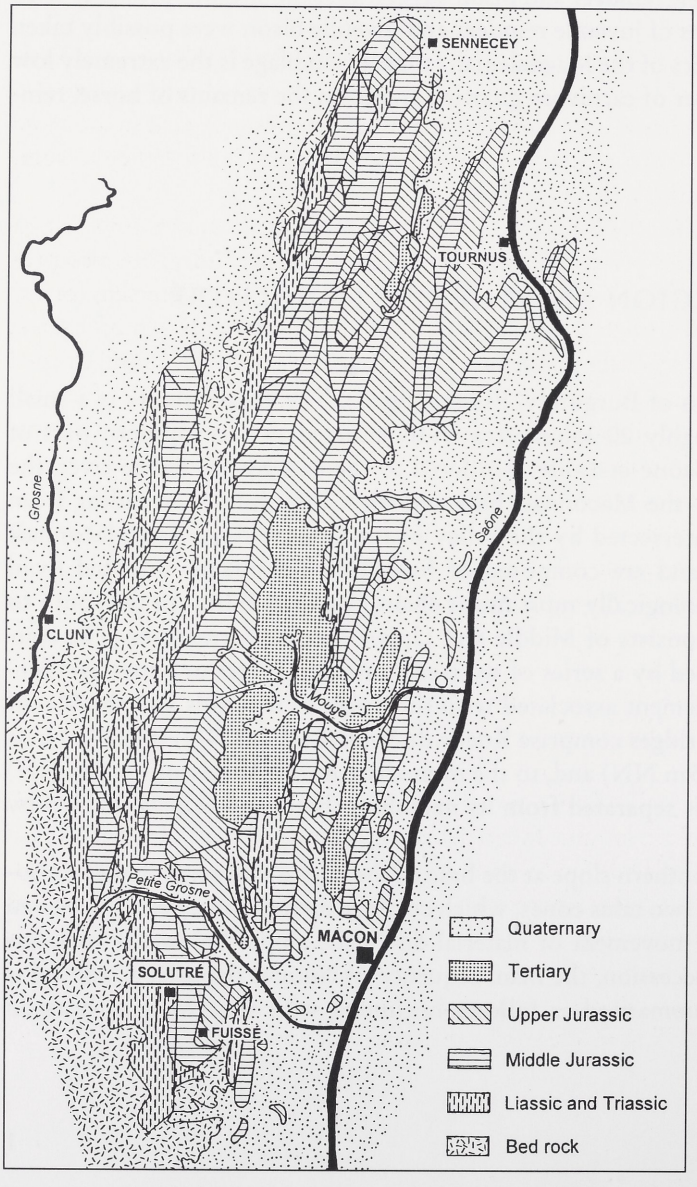


Fig. 1 Location of the site of Solutré, France. a) Main geological formations of the Mâconnais region (after Garmier 1990, p. 17). – b) Topographical map of the Mâconnais region, showing the Saône Valley and, to the west, the Mâconnais hills. To the lower left are the four »cuestas« mentioned in the text. The Roche de Solutré is marked by a circle and is flanked by Mont de Pouilly tothe south and Vergisson and Montsard to the immediate north.

- upper Magdalenian
- evolved Solutrean with small unifacial Solutrean points (pointes à face plane)
- classical middle Solutrean with leaf points
- upper Perigordian complexes with Font-Robert and Gravette points (the term Gravettian is used in this report)
- typical Aurignacian with classical lithic and bone industry
- Mousterian industry and atypical lower Perigordian industries

THE HISTORY OF FAUNAL RESEARCH AT SOLUTRÉ

At the end of the nineteenth 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 herds of up to 600 animals at a time over the precipice of the rock. The idea of Solutré as a horse »jump« site persisted well into this century even though there was no supportive evidence at the site for hunting tactics of this kind, and despite the fact that Arcelin (1872/1977) only published his theory in an adventure novel set in prehistoric times and never in his scientific works.

The turning point finally came in the 1950's when Jean Combier (1956) refuted the idea that horses plunged to their death over the precipice. He saw Solutré as a site to which hunters periodically returned to kill horses which passed through the valley between Solutré rock and the neighbouring cuesta of Mont de Pouilly, as part of their seasonal migrations from winter grazing grounds in the Saône Valley to summer grazing pastures on the higher land to the west of the site.

Systematic excavations by Combier from the 1960's to 1980's and several independent archaeozoological analyses of the fauna recovered during this period not only supported Combier's idea, but also provided insights into human hunting practices and butchering activities at Solutré. Bay-Petersen, for example, (1975) took Combier's theory a stage further and suggested that horses were driven up against the face of Solutré rock and slaughtered there as they attempted to escape. Levine (1979; 1983) studied several samples of horse remains from different cultural levels at Solutré (Aurignacian, Upper Perigordian and Magdalenian) as part of an archaeozoological analysis of Upper Pleistocene assemblages of horse bones. She came to the conclusion that Solutré was used almost exclusively as a kill-site, where horses were driven into an enclosure at the base of the cliff and slaughtered there.

In contrast to these researchers, Gordon (1988) was interested in the hunting of reindeer, a species also present in most of the levels at the site. He examined the incremental bands of cementum on a small sample of reindeer teeth (n = 14) from the Magdalenian horizon. His results showed that the hunters had taken late wintering and spring-aggregating animals.

Tretschocks (1986) studied faunal remains in two blocks of horse »magma« from the Gravettian horizon and compared Solutré with the North American bison site »Head-Smashed-In«. Tretschocks came to the conclusion that horses were driven by beaters towards Roche de Solutré into a enclosed area, where they were killed by the waiting hunters.

Olsen (1989) carried out a comparative analysis of faunal remains from several cultural levels at Solutré, including the Aurignacian, Gravettian, Solutrean and Magdalenian horizons, as part of a theoretical approach to the reconstruction of Upper Palaeolithic hunting strategies. She concluded that the most plausible hunting hypothesis was that horses were intercepted and driven up against the rock-face as they were passing Solutré in small bands of between 6 to 12 animals. Examination of cementum bands in horse teeth showed that horses died at Solutré from spring through to autumn, with the greatest concentration occurring in summer (Olsen ibid.). The low numbers of juvenile horse remains were interpreted as possibly resulting from selective killing of adults and releasing the young. Olsen also noted the

minimal utilization of horse carcasses by humans and stated that a comparable situation had also been documented at some North American bison hunting sites. In a paper published in 1995, she suggested that rather than bison jumps, bison traps or pounds may be analogous for the situation at Solutré, where a natural indentation in the southern wall of the rock may have served as a corral by enclosing its entrance with simple structures. Berke (1989) also examined finds from the Magdalenian deposits at Solutré as part of his analysis of horse remains in European Magdalenian assemblages, and concluded that the site was used predominantly as a kill-site (using similar hunting techniques as suggested above) at which there was little evidence for other activities such as the procurement of large amounts of meat or bone marrow or hides.

Research since 1994 has concentrated on two areas, sector P16 and sector I11, which have produced rich faunal assemblages associated with inventories of Magdalenian lithic tools (Combier 1976). The first site to be analysed was a small trench only 2 m^2 in size in sector I11 (Q69, 79 & 89), and the youngest level at I11, the Magdalenian horizon, was the focal point of this first study. The second site, sector P16, is a larger area totalling 95 m^2 in size, with finds dating mainly to the Magdalenian period, including material studied originally by Levine, Olsen and Berke.

DESCRIPTION OF THE SITES

THE SECTOR P16 SITE

In 1968, Jean Combier began a series of investigations and systematic excavations at the site located at the base of Solutré rock. Several areas were excavated in the first year, alongside activities such as geometric planning, aerial photographs of the whole site area, fencing off parts of the site, laying drainage gulleys and installing a wet-sieving house. One of the areas investigated in the first year was the sector P16.
Sector P16 is located in the eastern part of the area enclosed by a security fence (fig. 2). This part of the site had always been considered sterile by previous investigators at Solutré and consequently sector P16 had escaped the unsystematic excavations carried out at the end of the nineteenth and beginning of the twentieth centuries, which had destroyed deposits in other areas.
Four quarters of P16 (north-west, north-east, south-west and south-east), each 16 m^2 in size and separated by 1 m wide baulks in the form of a cross, were opened in 1968 (plate 2, 1). Later, the baulks were removed and the site was extended along its eastern and south-eastern edges by one metre. Quadrat 45 and a row of four quadrats along the south-western edge of sector P16 were not excavated (fig. 3). A total of 95 m^2 was excavated altogether.
The first finds – horse bones associated with lithic artefacts – appeared at a depth of only 5 cms. below the present-day surface (plate 2, 2) and despite their close proximity to the surface the bones appeared to be in a good state of preservation. The lithic industry with many backed blades, borers and burins and a bone industry which included a »bâton de commandement« was attributed by Combier (1976) to the »Magdalénian final«. The large amounts of bone from horse and several anatomically connected segments of carcasses of horse (eg. parts of the vertebral column) gave a general impression at the end of the first campaign that the site at sector P16 had been used primarily for butchering activities. A sondage revealed the underlying Lias marne at a depth of two metres below surface, showing that older cultural levels were not preserved *in situ* in this sector.
In his annual site report from 1968, Combier described the first appearance of a concentration of blocks of talus in the south-western corner of the site, which he interpreted as a »dallage« or pavement. Reindeer and bison bones, and a reworked Solutrean lithic inventory were apparently associated with this feature. In the report from 1970, Combier described a hearth located in the north-western corner of P16. Further excavations in sector P16 were undertaken during 1969-1974 and at the end of this period it was clear that the bulk of the finds had been deposited in the fill of an up to two metre wide channel-like feature, which ran diagonally from NW-SE through the site (plate 2, 2).
Excavations did not take place in sector P16 in 1975 or 1976, and in 1977 several urgent rescue excavations at other Palaeolithic sites in the region – Saut-de-Perron and Villerest – meant that investigations at Solutré had to be suspended altogether. Combier excavated only once more at Solutré in 1987, when the sector I11 site was investigated.

THE SECTOR I11 SITE

In 1987, sections at Solutré were prepared as part of a program of sampling undertaken by the Centre National de Préhistoire to investigate the sedimentology of the site. A small sondage in sector I11 in the

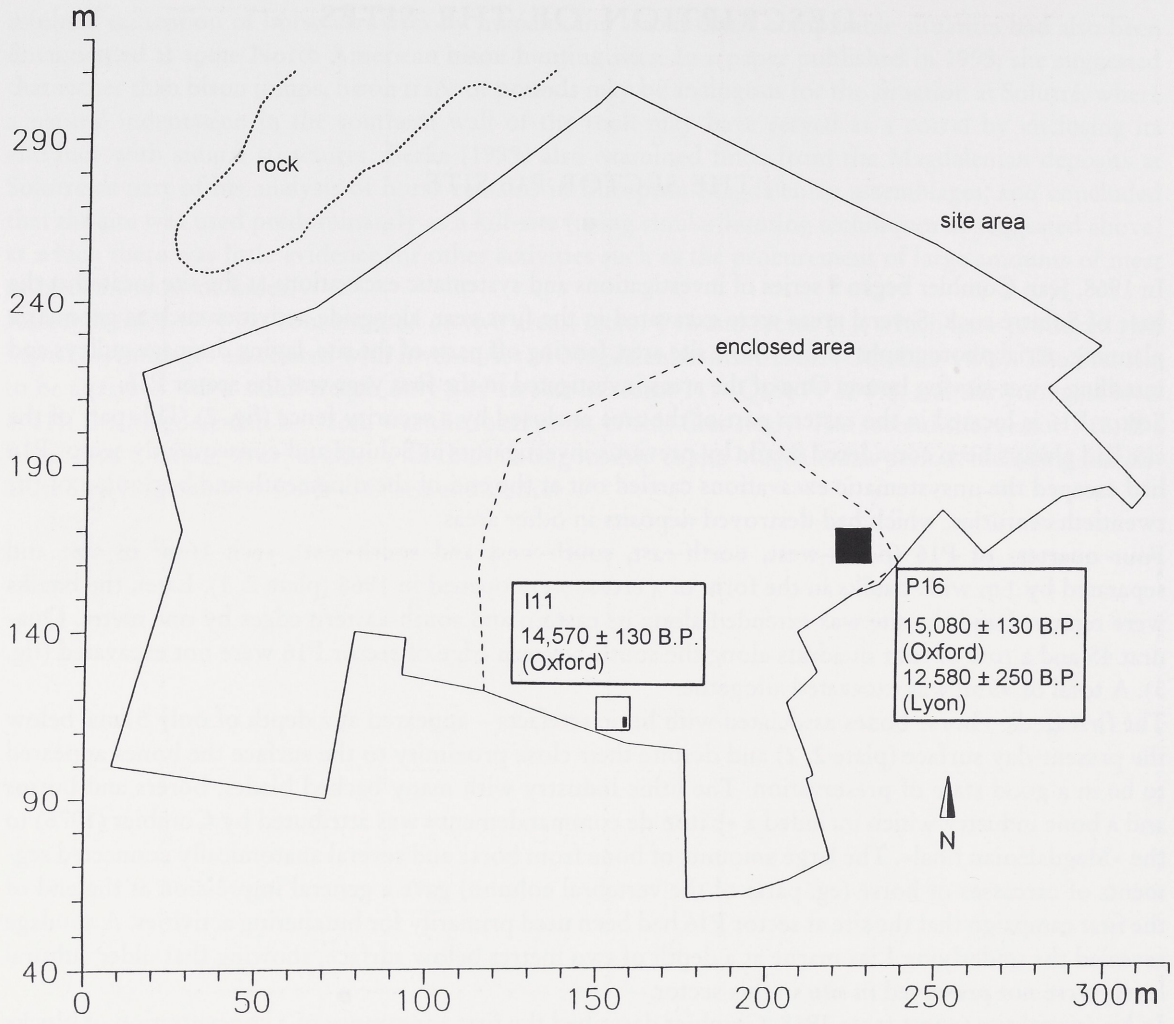


Fig. 2 Simplified map of the site at Solutré depicting the base of Solutré rock, the total area of the site, the area enclosed by a security fence and the location of the sector P16 site and the quadrats 69, 79 & 89 in sector I11. The results of C14-dating of bone samples from these areas are given in the accompanying boxes.

quadrats 69, 79 and 89 was excavated and sampled. Sector I11 is located towards the southern end of the area enclosed by the security fence, and the quadrats 69, 79 and 89 are in the south-eastern corner of this sector (fig. 2). The sondage was small, less than two square metres in size and four metres deep. The northern end of the deposits had been disturbed, presumably during earlier, pre-1960, excavations at the site. Nevertheless, two months of excavation in 1987 produced evidence of five cultural horizons at this small site comprising a »Magdalénian supérieur« horizon (Niveau 1), a small amount of finds from a horizon of unknown age, but possibly Magdalenian or Solutrean (Niveau 2), and Solutrean (Niveau 3), possibly Perigordian (Niveau 4) and Gravettian (Niveau 5) horizons (Combier 1987).
The richest level at this site in terms of numbers of finds was the Magdalenian horizon, which attained 50-80 cms. in depth and was densely packed with stone tools and well-preserved bones, mainly of horse. A fragmentarily preserved »sagaie«, needle-cores and two pieces of mobiliary art were also recovered



Fig. 3 Plan of the sector P16 site. The quadrats 45 and 91-94 were not excavated. Bold lines indicate the four quarters of the site opened in 1968.

from the Magdalenian deposits in this sector. Features such as hearths and concentrations of lithic tools and debitage or concentrations of animal bones were not observed during excavation. The location of sector I11 on the slope below the Roche de Solutré, the presence of long bones embedded vertically in the deposits and the absence of articulated bones led Combier (1987) to postulate that the finds had probably accumulated at the site as a result of solifluction and movement of material down the slope.

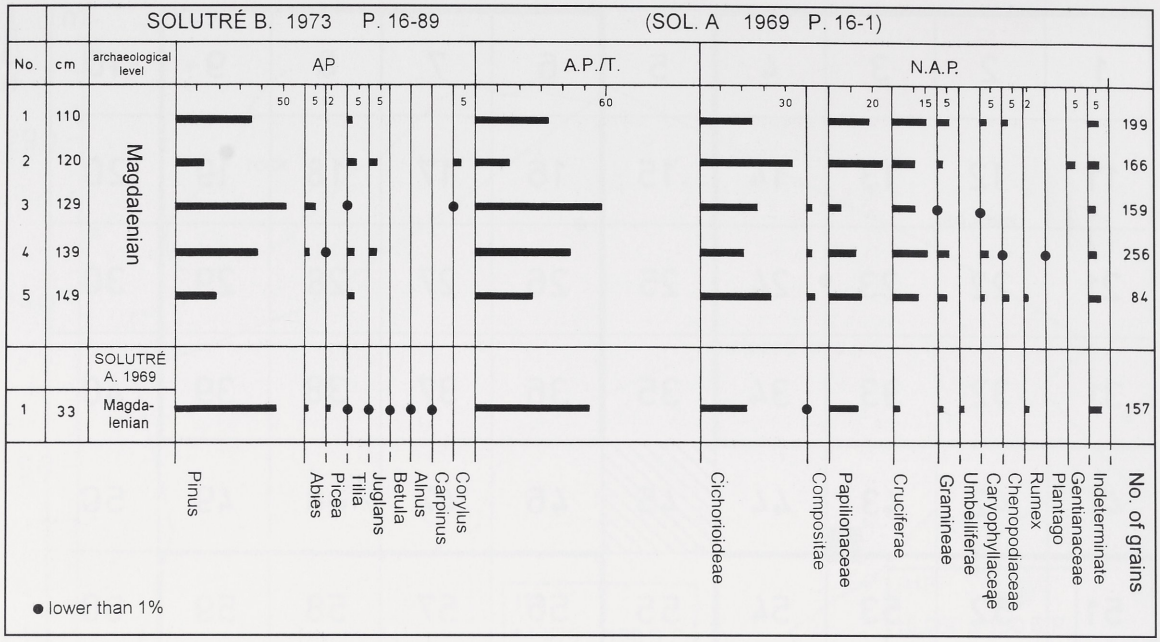


Fig. 4 Pollen diagram from deposits sampled in the sector P16 site. Taken and adapted from Argant and Argant 1985, fig. 2.

POLLEN ANALYSIS

Samples for pollen were taken from several sites during the course of Combier's excavations and analysed by Alain and Jacqueline Argant (1985). Deposits in sector P16 were sampled twice. In 1969, a column of eight samples (Solutré A) was taken through the Magdalenian deposits down to the underlying Lias marne. In 1973, five samples (Solutré B) were taken from Magdalenian deposits exposed in the southern profile in the south-eastern part of the site. The deposits in the sondage in sector I11 were not sampled.

The most significant sample, Solutré B, was described in detail (ibid.). Solutré B yielded a pollen diagram with relatively low values of aboreal pollen, which exceeded only 50% of the total pollen value in sample 3 (fig. 4). The dominance of pine (*Pinus*), associated with the low ratio of aboreal pollen, suggested predominantly cold climatic conditions in this region during the Magdalenian period. Nevertheless, low values of pollen of certain thermophilous taxa such as lime (*Tilia*), hornbeam (*Carpinus*), hazel (*Corylus*) and walnut (*Juglans*), showed that the climate was not extremely cold. Herb pollen was found in all the samples, but dominated during certain periods. Grasses (Graminae) were rare, and pollen of Chenopodia – *Rumex* and *Plantago* – indicated open terrain.

It was concluded (ibid.) that the pollen diagram could not be used to date the site. However, the more temperate character of this cold phase combined with an absolute date of 12,580 BP (see below, absolute dating) appeared to exclude deposition of the Magdalenian assemblage in sector P16 during colder stages of the Dryas, and indicated deposition during the Bölling Interstadial. However, the authors did note that the temperate conditions indicated by pollen of thermophilous taxa could have simply resulted from localised warmer temperatures at the site due to its sheltered position on the south-facing slope at the base of the Roche de Solutré.

SEDIMENTOLOGY

Two samples of deposits were studied sedimentologically during the course of excavations at sector P16. The first sample consisted of Magdalenian deposits exposed in the sections of a quadrat in the centre of the site (possibly quadrat 45 which has never been excavated); the second sample comprised deposits below the Magdalenian level, in the south-eastern corner of the site. The following is taken from an unpublished paper written by Gely, Kervazo and Porte in 1988. In general, the sediments exposed in the centre of this sector consisted of brown-grey clay at the top, yellow colluvial-like deposits below these and clay-like layers at the base. Pebbly lenses were recorded, as well as levels in which horizontally-aligned blocks of scree were observed. According to Gely, Kervazo and Porte, the alignment of the pebbles and scree blocks indicated that deposits accumulated at P16 during a series of depositionary events, rather than a single phase of deposition.

Gely, Kervazo and Porte also sampled the sections in the sondage in sector I11. The Magdalenian find assemblage from Niveau 1 was stratified in »couche 2«, which comprised two strata (2a and 2b). The bulk of the Magdalenian finds was embedded in the upper strata (2a), which had been capped during levelling for the vineyards. The base of this layer was irregular with conical cavities. Dark brown in colour and slightly clayey, this deposit included blocks of abraded scree material as well as slabs of stone and small, unabraded pebbles in a fine, well-sorted gravelly component.

Layer 2b varied in thickness and had an irregular upper boundary. Finds from the Magdalenian assemblage of niveau 1 were stratified in the upper 20cms of this layer. Yellow in colour, layer 2b had a high clay component and contained small pebbles and slabs of scree.

At first sight, the Magdalenian finds appeared to form a single, homogenous horizon of material distributed from the top of layer 2a into the upper part of layer 2b. There was no evidence during excavation of a distinct hiatus separating the finds in layer 2a from those in layer 2b. However, a vertical plotting of the lithic artefacts undertaken during preliminary analyses of the find assemblages showed that the lithics were distributed in two separate horizons, located at the top and base of niveau 1 respectively.

ABSOLUTE DATING

A bone from quadrat 88 in sector P16 was dated using the C^{14}-method by the Laboratoire de Radiocarbone in Lyon to 12,580 ± 250BP (Ly 393) (Delibras et al. 1976). During the current analysis a cut-marked upper third or fourth premolar of horse from sector P16 was submitted to the Oxford Radiocarbon Accelerator Unit in October 1996. The tooth was dated by the accelerator to 15,080 ± 130 BP (OxA-6730) (pers. comm. P. Pettitt). A cut-marked horse calcaneum from Magdalenian deposits in sector I11 (Q69, 79 and 89) was dated in Oxford at the same time as the P16 sample to 14,570 ± 130 BP (OxA-6731) (pers. comm. P. Pettitt). Both dates are substantially older than the one produced by Lyon (fig. 2). The difference in Radiocarbon ages could be due, for example, to the different laboratory methods used. If this is not the case, then the two samples from P16 indicate deposition of finds in this sector over a long period of time during the Magdalenian phase.

However, regardless of whether the differences in the C^{14}-dates relate to the laboratory method used or are the result of a long phase of deposition, none of them place accumulation of the Magdalenian horizon in sectors I11 and P16 into the brief warm phase called the Bölling Interstadial, as suggested by Argant and Argant (1985). According to a chronology of the Upper Weichselian established by Lanting and van der Pflicht (1996), the short temperate Bölling Interstadial sensu stricto begins at around 12,500 BP. A date of 12,580 BP places the bone dated by the Lyon laboratory into Lanting and van der Pflicht's older Dryas

I/»Bölling« (sensu lato). The dates produced at the Oxford laboratory, indicate deposition of cut-marked horse remains at Solutré in the period between the Pleniglacial and the Late Glacial Interstadial Complex.

LITHIC ARTEFACTS

Jean Combier (1973) described the lithic inventory from sector P16 as dominated by backed blades, borers and burins. About 1,100 lithic artefacts were recovered from the P16 site, according to lists of finds made during excavation, and the bulk of these finds are located in the south-eastern part of the P16 site. A study of the lithic inventory from this sector is currently being undertaken by Anta Montet-White of the University of Kansas.

An assemblage of Magdalenian lithic artefacts was recovered from the sondage in sector I11. The lithic industry from this site comprised 47 pieces of debitage and a few tools including 4 burins, 3 backed blades, 1 scraper, 1 truncated blade and 2 retouched blades (Combier 1987).

RECOVERY DURING EXCAVATION AND QUANTIFICATION OF THE FAUNA

RECOVERY DURING EXCAVATION

Faunal remains were classified into two categories during excavation of the sector P16 and I11 sites. The first group consisted of large or important finds which were recorded three-dimensionally and drawn on plans; the second group consisted of more fragmentary finds which were simply collected from each excavated unit and bagged together.

Three dimensionally recorded finds

This group consists of faunal material considered important enough to be recorded in detail by giving »X« (W-E) and »Y« (N-S) co-ordinates to mark the location of the find. The third, or »Z« co-ordinate, is the height of the find relative to a fixed bench height at the site. During excavation faunal remains which belonged to an individual animal but consisted of several elements – such as rows of teeth or portions of the vertebral column – were recorded together under one find-number. Although it was correct to record finds on site in this manner, it did present problems during analysis as each complete element had to be recorded individually in the data-bank. In such cases, one element retained the original find-number and the remaining finds were given provisional numbers consisting of the quadrat number and the next available find number from the site lists. The same technique was employed to correct cases where elements from different species or different elements from the same species had been inadvertently registered under the same number.

»Secondaire« finds

Fragments of bone, teeth and antler were recorded in the category »secondaire«. Secondaire finds from each quadrat were collected and bagged together during the recovery of the three-dimensionally recorded finds. Only an approximate location on site in both the horizontal and the vertical projection was recorded for this material. As part of the current analysis, these bags of material were sorted through by hand. Each bone was investigated for evidence of human modification (worked pieces, cut-marks, impact notches) and, if found, these finds were given a number and stored with the three-dimensionally recorded material. At the same time, the remains of smaller mammals (rodents), mollusc shells and lithic artefacts were separated out for future study by specialists in these fields. Fragments of charred bones were separated from the rest of the secondaire material and weighed by archaeological unit.

QUANTIFICATION OF THE FAUNAS

A total of 4,159 faunal remains from P16 was recorded during this analysis. Twenty-six of the total number of bones differed in preservation when compared to the bulk of the material. Ten of these finds are rather fresh in appearance, and may represent recent intrusive material. The remaining sixteen horse and reindeer bones are well-preserved, yellow in colour, and are covered with a thin red calcareous crust. The preservation of these 16 objects is similar to that observed on bones from the Aurignacian deposits at Solutré, which are also characterized by their reddish colouration. There was, however, no reference to Aurignacian finds in the excavation documentation from P16 and it is possible that these finds represent the reworked Solutrean fauna mentioned in early site reports. The rest of the material, a total of 4,133 faunal remains, consists of well-preserved bones, grey-yellow in colour, whose surfaces showed varying stages of root-etching and weathering. These finds represent the Magdalenian fauna from sector P16.

The Magdalenian fauna from sector P16 comprised two types of faunal remains, those which could be identified to specific level, and those which were too fragmentarily preserved for a definite identification to either species, genus or order. The latter finds were classified into the following groups based on size of the fragment and bone thickness: small (comparable to fox in size), medium (comparable to wolf or reindeer in size) and large (comparable in size to horse or bison). The counts for these fragments are listed below, along with a number of finds which were so poorly preserved that they could not be grouped according to size:

small-sized unidentified	2
medium-sized unidentified	14
large-sized unidentified	72
unidentified to size	5
total	93

Three bird bones, five bones from small carnivores (probably mustelids) and a tooth from a large carnivore, possibly lion, were also present in the Magdalenian fauna. Altogether this category of unidentifiable or less identifiable material totals 102 finds.

A total of 528 bones was recorded from the Magdalenian deposits in sector I11. 500 of these could be identified to species. Two further finds – a fragment of a metatarsal and part of a lower third molar – belonged to a cervid comparable in size to roe deer, but a definite identification to species could not be made on this material. Twelve further fragments of bone could only be grouped according to size. The remaining 14 finds belonged to birds or smaller mammals.

The faunal remains from sector I11 resemble those from sector P16 in their state of preservation. The bones are generally well-preserved, have the same grey-yellow colouration as those from P16 and the bone surfaces have similar stages of root-etching and weathering.

Counts of faunal remains from sectors P16 and I11 which could be identified to specific level are given in table 1. Horse is dominant in the faunas from both Magdalenian sites. 466 horse remains, representing 92.8% of the total number of finds identifiable to a species were recorded in sector I11. The finds represent a minimum of six individuals. At the larger P16 site 3,577 horse remains, representing a minimum of 45 horses were identified. Even though the faunas from these sites are dominated by horse, other species such as reindeer, bison, wolf, fox, bear and wolverine are also present. Typical for reindeer, bison, wolf, fox and wolverine is that they are represented by small numbers of finds and, in the case of the reindeer and bison remains from sector P16, relatively high numbers of individuals.

Faunal list P16 (95m)

archaeological fauna				background fauna			
species	NISP	%	MNI	species	NISP	%	MNI
horse	3577	88.7	45	wolverine	4	0.09	1
reindeer	271	6.6	9	fox	7	0.17	1
bison	142	3.5	5				
wolf	30	0.7	2				

Total NISP: 4031

Faunal list I11 (2m)

archaeological fauna				background fauna			
species	NISP	%	MNI	species	NISP	%	MNI
horse	466	92.8	6	bison	4	0.8	1
reindeer	29	5	3	wolf	1	0.2	1
				small cervid	2	0.3	1

Total NISP: 502

Tab. 1 Basic counts of number of specimens identifiable to a species (NISP), percentage of the total number of NISP (%) and minimum number of individuals per species (MNI) from the Magdalenian horizons in sectors P16 and I11 at Solutré.

Based on the presence or absence of traces of human butchery, such as cut-marks or hammerstone-induced impact notches, the faunas could be separated into two groups, an »archaeological« fauna and a »background« fauna. At sector I11, only the bones of horse and reindeer had been modified by humans. At sector P16, traces of human modification were observed on the bones of horse, reindeer, bison and, possibly, wolf.
Earlier faunal lists from Solutré are comparable in species composition to those in table 1. In 1881 Arcelin published the following list of fauna from the »niveaux récents« at Solutré which had been determined by Lartet: Birds, *Lepus timidus*, *Vulpes vulpes*, *Ursus arctos*, *Mammuthus primigenius*, *Equus caballus*, *Cervus elaphus*, *Rangifer tarandus* and *Bos primigenius* (bison is probably meant here).

THE SPATIAL DISTRIBUTION OF FAUNAL REMAINS AT SECTOR P16

Finds from archaeological sites situated on slopes can be affected by the post-depositional movement of material downslope during phases of solifluction or water run-off, or due to gravitation, and are often no longer *in situ*. The location of the archaeological site on the slopes below Solutré rock suggests that finds may have been affected to some extent by such processes.
At sector P16, the results of sedimentary analyses indicate several phases of deposition over a period of time during which finds accumulated in a channel which had cut through the site. Based on his field observations, Combier described the find situation in sector P16 in 1971 as, »La nappe d'ossement de chevaux du sol magdalénien, couvre l'ensemble de P16 en une large bande diagonale orientée N-W S-E. Il ne s'agit pas d'une coulée de vestiges car à l'intérieur de cette zone, qui déborde certainement la surface actuellement en cours de fouilles, on observe des localisations secondaires, telle la cuvette remplie d'ossements du secteur N-W et la surface dallée du secteur S-E«.
In an interim report dated 1973, Combier repeated his theory that the concentration of finds revealed during excavation at P16 was the result of a long phase of *in situ* deposition of material into the channel

and not the product of movement of finds down the slope. He writes »Nous sommes ici en présence d'un thalweg d'érosion dont le comblement s'est opéré progressivement au cours du Magdalénien final et n'est pas le produit d'un glissement«. Although Combier remarked on the tendency of long bones to be aligned parallel to the long axis of the channel – a feature often recorded in channel situations, where bones have been aligned due to water action – he stressed that »La présence de plusieurs séries de vertèbres ainsi connectées exclut, pour le Magdalénien, la possibilité de remaniements, de solifluxion, ou de simples glissement des vestiges sur la pente«.
It is important to clarify whether post-depositional processes had played a role in the accumulation of finds at the P16 site as the distribution of finds in this sector has often been interpreted as the *in situ* remains of a large-game butchery site. Levine, for example, described the P16 site as follows: »The distribution of horse bones in this level is as would be expected for the butchering area of a large herd-drive kill-site. Bones are found whole and sometimes in connection. Moreover, they are sometimes found grouped according to their location in the skeleton; for example, foot bones in one area and skull bones in another. It is possible that after the animals had been butchered, the discarded bones had been thrown into the solifluction channel and possibly even buried to prepare the site for the next herd drive« (1979, p. 317). Even though Olsen (1989) described solifluction as the greatest taphononic effect operating at Solutré, a detailed analysis of these effects on faunal remains at the site has not been undertaken so far.
In an attempt to assess the extent of post-depositional disturbances affecting this site and, subsequently, to see how far the remaining patterns of faunal distribution could be related to specific human subsistence activities at sector P16 during the Magdalenian phase, a series of plans depicting the general distribution of faunal remains at the site and their relationship to the channel, plots of conjoining faunal remains, distribution plans of some of the horse and bison remains and a plan of the distribution of charred bones were drawn up.

Faunal distribution and the channel feature

As the original find distribution plans made during excavation of the P16 site were not available for copying during the course of this analysis, ink drawings had to be traced from poorer-quality photocopies of the original plans kept in the museum offices at Solutré. Despite these difficulties, the resulting inked plans give a fairly reliable impression of the distribution of material at the P16 site.
The general distribution of animal remains at sector P16 as revealed by excavation is depicted in folding illustration 1. Apart from a few bones in the southern part of sector P16, the main concentration of faunal remains is located within the channel which runs from NW-SE through the site. The distribution of bone which accumulated within this feature shows that the channel was not straight but curved slightly along its length. The concentration of bone in the channel is roughly 2-2 1/2m wide increasing to almost 3m in the centre of the site, in the region of the unexcavated quadrat 45.
Apart from a general topographical plan of the whole sector, documents specific to the size or form of the channel or sections through this feature do not appear to have been recorded, and the outline of the channel depicted in figures 6-13 was extrapolated from figure 5, where the boundaries of the main concentration of finds were taken as representing approximately the »edges« of the channel.
The topography of the site appears to have been recorded after the finds had been removed (folding illustration 2). Surface heights were recorded in relation to a fixed bench level at 50cm intervals over the excavated area but not in the NE and SW parts of the site or in quadrat 1, as these areas had either been excavated deeper onto the level of the Lias Marne prior to surface heights being recorded or had functioned as test-pits. In figure 6, it can be seen that the site slopes from NW-SE, with a difference of about 85cm between the heights measured in the NW and SE corners (height of 54cm measured at top right-hand corner of the test-pit and 139cm measured outside the channel in the SE corner of the site). The channel follows the gradient of the slope.

Four sections across the site (folding ill. 2, 1-4) were reconstructed using the height data on the topographical plan. The NW part of the site is relatively level (section 1); the channel is exposed here as a narrow and shallow depression in the centre of the section. Section 2 was incomplete, as both the NE and SW parts of the site on this transect had already been excavated down onto the underlying Lias Marne before the heights had been recorded. The channel is exposed here as a rather flat and wide trough. In section 3, the channel is about 30cms deep and in section 4, the depth of the channel could be reconstructed to about 60cms.
Density of finds within the channel appears to be related more to the gradient of the slope and channel depth than Magdalenian activities. For example, in quadrats 21, 22, 31 and 32 (see fig. 3 for position of these units) 222 three-dimensionally recorded faunal remains and artefacts were listed, whereas in quadrats 78, 79, 88 and 89, 640 finds had been registered. The bulk of the finds was therefore concentrated downslope in the SE section of the channel, where the feature attained its greatest depth.

Orientation of bones

Patterned orientations of long bones are often the result of fluvial action (Lyman 1994). Although it is clear that we are not dealing with bones which accumulated in a fluvial context at Solutré, just a brief examination of the finds depicted in figure 5 reveals numerous bones with long axes parallel to the long axis of the channel – an observation which Combier had already made in the field - indicating that parts of the faunal assemblage had been oriented after deposition, probably in connection with certain natural processes taking place within the channel. In order to test this theory, the orientation of long bones at sector P16 was analysed in more detail.
One of the ways in which orientation data are typically presented is the rose-diagram (Fiorillo 1988; Toots 1965). Rose diagrams incorporate two-dimensional orientation data based on the azimuth of the long axis of the specimens and are useful indicators of random and non-random patterning in the orientation of long bones. Shipman (1981) recommends that only samples with at least 72 bones be plotted in rose diagrams as larger samples more clearly display orientation patterns, and for this reason a large sample of 342 long bones was traced from folding illustration 1 onto a separate plan (folding ill. 3). The azimuths of the bones were measured on the plan using a protractor. Bone orientation was measured in two different directions firstly, in relation to the compass azimuth and secondly, in relation to the NW-SE orientation of the channel, as bone orientation should be related to geomorphic features and not just the compass azimuth (Frostick and Reid 1983). In the first case, the 90° mark on the protractor was pointed to the north and in the second case, the 90° mark was lined up with the approximate long axis of the channel, i.e. NW-SE. The orientation data are presented in table 2 as numbers of cases observed in 10° classes, and graphed in mirror-image rose diagrams in folding illustration 3 (a and b).
In the first rose diagram (3a), the majority of the long bones are oriented in a NW-SE direction between 0° and 90°, with the highest number of observations falling into the 0°-10° and 81°-90° classes (n = 55 and 34 respectively). Only a small quantity of bones were oriented SW-NE. The diagram shows that the bulk of the long bones is oriented parallel to, or approximately parallel to, the long axis of the channel with one of the two ends of the bone oriented downslope. This phenomenon is more clearly-defined in the second diagram (3b), where bone orientation was measured in relation to channel orientation. Here, only one major orientation group – NW-SE – can be discerned. Both rose diagrams show that within the sample bone orientation is non-random and, as in the case of find-density, related to the presence of the channel and the gradient of the slope.

Compass azimuth		Channel azimuth	
Degree class	Observed frequency	Degree class	Observed frequency
0-10°	55	0-10°	20
11-20°	28	11-20°	11
21-30°	33	21-30°	11
31-40°	30	31-40°	13
41-50°	28	41-50°	27
51-60°	27	51-60°	25
61-70°	11	61-70°	37
71-80°	16	71-80°	34
81-90°	34	81-90°	36
91-100°	13	91-100°	21
101-110°	8	101-110°	31
111-120°	2	111-120°	13
121-130°	12	121-130°	12
131-140°	11	131-140°	22
141-150°	13	141-150°	11
151-160°	8	151-160°	12
161-170°	10	161-170°	2
171-180°	3	171-180°	3

Tab. 2 Observed frequencies of 342 bone specimens per 10° orientation class from sector P16 at Solutré.

Conjoining or refitting studies of bones

Bones which have been refitted during analysis are useful in reconstructing the taphonomic history of a find from the time of its arrival at a site to the time of its recovery during excavation. They contribute to the spatial analysis of the site and, more importantly in the case of sector P16, are useful tools for understanding site formational processes and the recognition of post-depositional disturbance of faunal assemblages. Attempts to conjoin, or refit back together, as many fragments of bone, teeth and antler as possible, were carried out during the course of this analysis. However, the large number of faunal remains from sector P16 meant that bones from only two neighbouring excavated units (or at the most three to four units where find-density was low) could be spread out on the tables in the laboratory at one time for refitting. Thus, the total of 312 conjoins plotted in folding illustrations 4 and 5 represents only a small percentage of the potential total number of conjoining bone fragments from the P16 site.

Three categories of bone conjoins were recorded at sector P16:

Mechanical conjoins are refits between the fragmented pieces of a single element and can consist of single conjoin sets, involving only two fragments, or multiple sets where several fragments of bone could be successfully refitted back together. Mechanical conjoins record bone fracturation which originally took place in the green or »fresh« bone condition, as a result of deliberate smashing of bone by humans to obtain marrow or carnivores cracking bones open when gnawing for example. Fresh or green bone fractures are identified by their smooth fracture surfaces with fracture planes running obliquely to the long bone axis (eg. spiral fractures). Mechanical conjoins also record fractures which took place in the dry or fossilized bone condition, usually after deposition had taken place. Dry or fossilized fractures are characterized by roughened fracture surfaces parallel and transverse to the long axis of the bone.

Anatomical conjoins are re-articulated skeletal elements and also consist of single or multiple sets of finds. Re-articulated bones record the dispersal of skeletal elements as a result of humans disarticulating

animal carcasses during butchery, or carnivores pulling apart an animal carcass during consumption, or the natural disintegration of parts of a cadaver during decomposition.

Skeletal elements from an individual animal record the spatial dispersal, or scattering, of elements from the carcass of an individual animal. Elements were attributed to the same individual animal by comparing size, bilateral symmetry, morphological details or a combination of any of these criteria. Several sets of elements, such as rows of cheek teeth from different individuals of horse, had already been found more or less in anatomical connection during excavation.

Mechanical and anatomical conjoins

Horse remains form the bulk of the conjoined bone fragments and re-articulated bones depicted in folding illustration 4, and 87 out of a total of 88 mechanical conjoins are horse bones. The majority of these (n = 84) are refitted fragments of bones which had fractured in a dry condition and illustrate the post-depositional scattering of horse remains at sector P16. Only three of the conjoining sets comprised fragments from horse bones which had been fractured in a fresh condition, but as none of these pieces bore traces of cut-marks, hammerstone-induced impact notches or carnivore tooth marks, the agent of fracturation remains unclear. One conjoin (C99) comprises fragments from the antler of a reindeer.
43 sets of re-articulated bones could be attributed to horse; two further sets belonged to the wolf (A54) and the bison (A12) respectively. None of these sets could be directly linked to the disarticulation of carcasses by humans, and these sets all appear to be the products of natural processes of disarticulation, which probably took place after deposition of the articulated bones at the site.
Except for conjoin 12 – which connected three bone fragments over a distance of about 6 m – conjoin lengths in both categories were relatively short, varying between a few centimetres to 1.5 metres in length. The predominance of short conjoins is not necessarily a characteristic of the site and conjoin 12 shows that long connections between bone fragments do exist at sector P16. The lack of other long conjoins more likely results from the technical problems encountered during refitting of the material (see page 16).
Most of these conjoins, regardless of conjoin length, follow the preferred axis of orientation already noted for the long bones – downslope and roughly parallel to the long axis of the channel. Some conjoining sets of finds in the channel and those extending over the reconstructed »edges« of the channel are transverse to the preferred axis of orientation. Such refits illustrate movement of material which probably took place within the channel and down its sides; they possibly indicate periods when the main processes of post-depositional dispersal down the slope had temporarily ceased.
Incidentally, conjoin orientation and conjoin length of the three sets of fragments from horse bones fractured in a fresh condition were found to be the same as those observed for conjoins of fragments which had fractured in the dry bone state, showing that the dispersal of freshly-broken bone fragments was also a result of post-depositional processes.

Elements from individual animals

The 179 sets of skeletal elements belonging to individual animals are plotted in folding illustration 5. Once again the bulk of these sets (n = 167) comprise horse remains. The majority of these consists of rows of upper or lower teeth, found together during excavation and indicated in the figure by symbols sized according to the numbers of teeth in each set. Whether the presence of partially-preserved rows of upper and lower horse teeth was due to the smashing of crania and mandibles during butchery episodes or simply the result of natural disintegration of thin-walled skulls and jaws is difficult to assess, as only two mandibles of horse showed traces of deliberate fracture in the form of impact notches.
Dispersal of teeth from these sets appears to have been minimal, probably due to their being contained in the crypts of the mandible or maxilla. In some cases bone disintegration had already taken place, as can be seen in examples of sets of teeth from an individual animal scattered over the site, or in cases

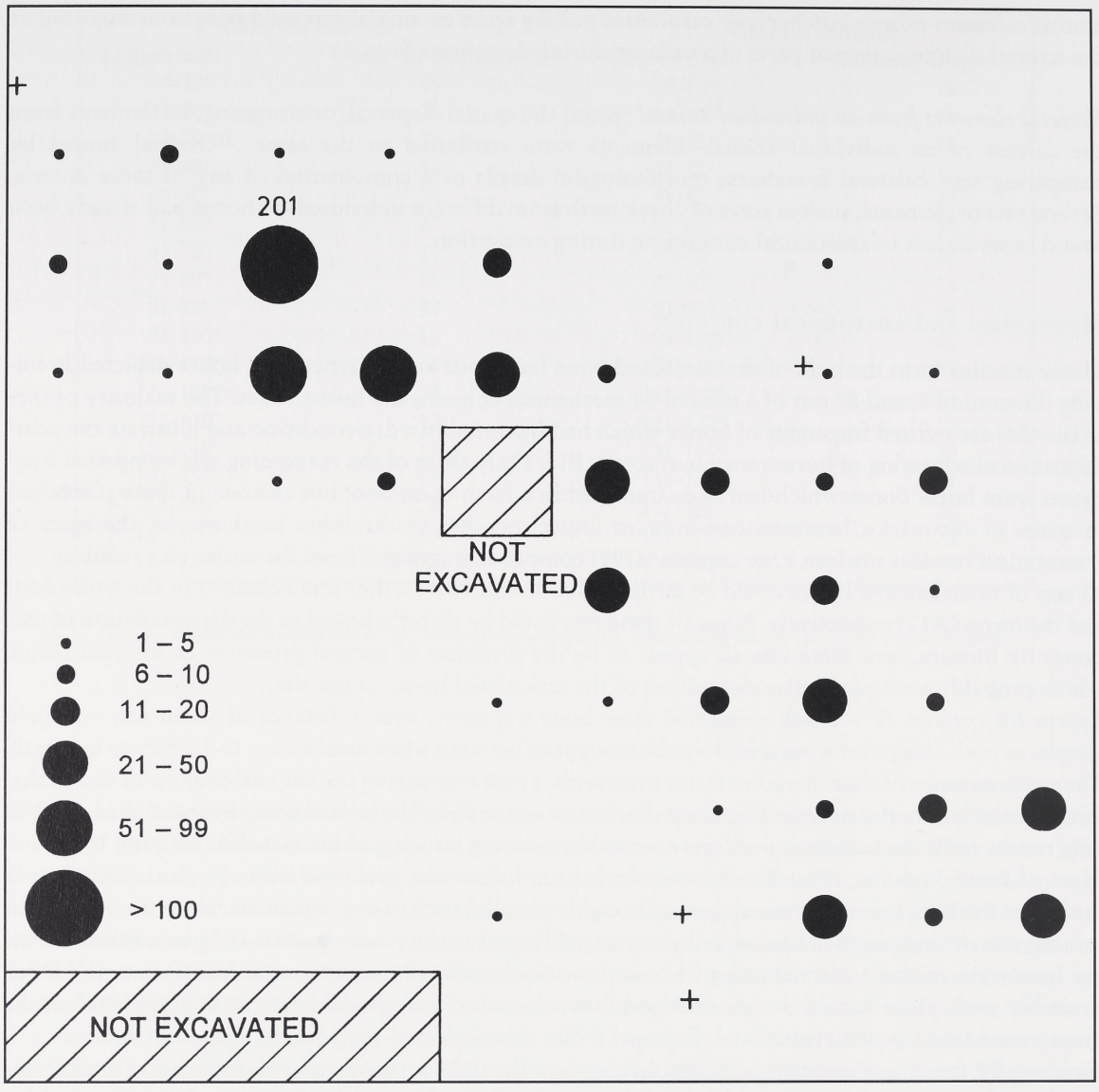


Fig. 5 Distribution of charred bone fragments by weight (grams) in sector P16. – + three-dimensionally recorded charred bones.

where a single, isolated tooth could be re-positioned in its tooth row. Seven sets of teeth of reindeer and three sets of teeth of bison were also recorded. Sets of post-cranial elements from individual animals are not as common as sets of teeth, and include bones from horse, bison and wolf.

Eight sets of finds depicted in folding illustration 4 are located just outside the channel; the remaining 172 sets are distributed within the channel. Conjoin lengths between elements belonging to individual animals were more or less the same as those connecting mechanically refitted and re-articulated finds, and showed that bones and teeth had scattered over distances between a few centimetres to about 1,5 metres apart. The only example of a longer conjoin – almost four metres in length (B60) – is located in the northern section of the channel, in an area where find-density was so low that the search for conjoining remains could be undertaken between several non-contiguous excavated units.

Although a few of the conjoins depicted in folding illustration 4 follow the preferred axis of orientation others, particularly those connecting sets of bones in the southern section of the channel, are transverse to

this. This pattern is probably related to the form and depth of the channel in the southern part of the site (folding ill. 2), where finds may have rolled down the steep channel sides, or could only disperse over short distances within the narrow confines of the base of the channel (see folding ill. 2 for cross-section of channel at this point).

To summarise, the location of the sector P16 site on a slope, the presence of a channel running parallel to the gradient of the slope, the general distribution of finds in the channel, a direct association between find-density and the depth of the channel, categories of refitted faunal remains indicating post-depositional dispersal of finds, a preferred orientation down the slope and parallel to the long axis of the channel of both some long bones and the majority of conjoined bones, all indicate post-depositional movement of faunal remains down the slope and within the channel. Conjoin lengths show movement of material up to 1,5 m; longer conjoins were observed (up to 4 m), but these were only rarely found due to technical difficulties during the refitting analysis.
Bearing these results in mind, plans were drawn plotting the distribution of selected skeletal elements of horse and the distribution of bison remains, to see if the spatial patterning of some elements from these species gave any indication of humans processing animal carcasses directly at the site. In order to assess this, the distribution of horse crania, humeri and radii, and the distribution of the remains of bison were graphed in folding illustrations 6-9. All categories of conjoins found amongst these remains were depicted and those finds with attributes such as cut-marks, hammerstone-induced impact notches or traces of carnivore attrition were marked. The distribution of charred bones, as a possible indication of the position of hearths, is shown in figure 5.

The distribution of horse crania

A concentration of horse crania had, apparently, been observed during excavation (pers. comm. J. Combier). In the site report dated 1973 this feature was described as »un ensemble arrière-crânes de chevaux«. The location of horse occipital bones is depicted in folding illustration 6. The occipital bones are spread thinly through the main zone of find distribution in the channel, with one piece located outside this area, in quadrat 4. There are no concentrations of this bone type. A single occipital bone had been modified by humans (cut marks) and this find is located in the northern section of the channel. Probably due to the very fragmentary nature of these elements, only two sets of occipital bones could be refitted (C27 and 76). These conjoins, their lengths and direction contribute very little to a further interpretation of this category of finds.

The distribution of horse humeri

A detailed depiction of the distribution of horse humeri is shown in folding illustration 7. The humeri are drawn in outline, are distinguished according to side of the body and to which portion of the bone is represented (proximal, shaft, distal), and whether they are from juvenile individuals. Circular symbols around some of the bones indicate the presence of human modifications (cut-marks/hammerstone-induced impact notches) or traces of carnivore gnawing.
Folding illustration 7 shows that humeri of horse were spread thinly throughout the main area of find distribution in the channel. There are no clear concentrations of this element, or of humeri from the left or from the right sides of the body, or of portions of this element (eg: distal ends together). There are no concentrations of humanly-modified humeri, and their pattern of distribution is otherwise not significant. Similarly, there is no patterning in the distribution of those fragments of this element with traces of carnivore gnawing; carnivores had gnawed humeri which are located on the periphery, as well as in the centre of the main distribution of horse humeri at the site.
Conjoin 94, located in the southern part of the channel, is one of only three sets of conjoins between fragments of bones fractured in a fresh condition. As discussed above, conjoin length and direction in

these three cases is comparable to that observed for conjoins of bone fractured post-depositionally, and thus cannot be interpreted as the scattering of bone fragments due to human activities.

The distribution of horse radii

The distribution of horse radii is depicted in folding illustration 8. The bones are graphed in a more simple manner than those in figure 11, and are distinguished according to body-side only. Bones with traces of human or carnivore modifications are marked with circular symbols.
Horse radii are thinly distributed throughout the channel and there are no concentrations of this element at the site. Three radii with traces of human modifications were clustered fairly close together in squares 33, 34 and 44, but on the whole the scatter of radii with cut marks or impact notches resulting from marrow fracturing could not be interpreted as reflecting Magdalenian butchering activities. The few radii modified by carnivores are located on the periphery of the main concentration of finds and in the centre.

The distribution of bison remains

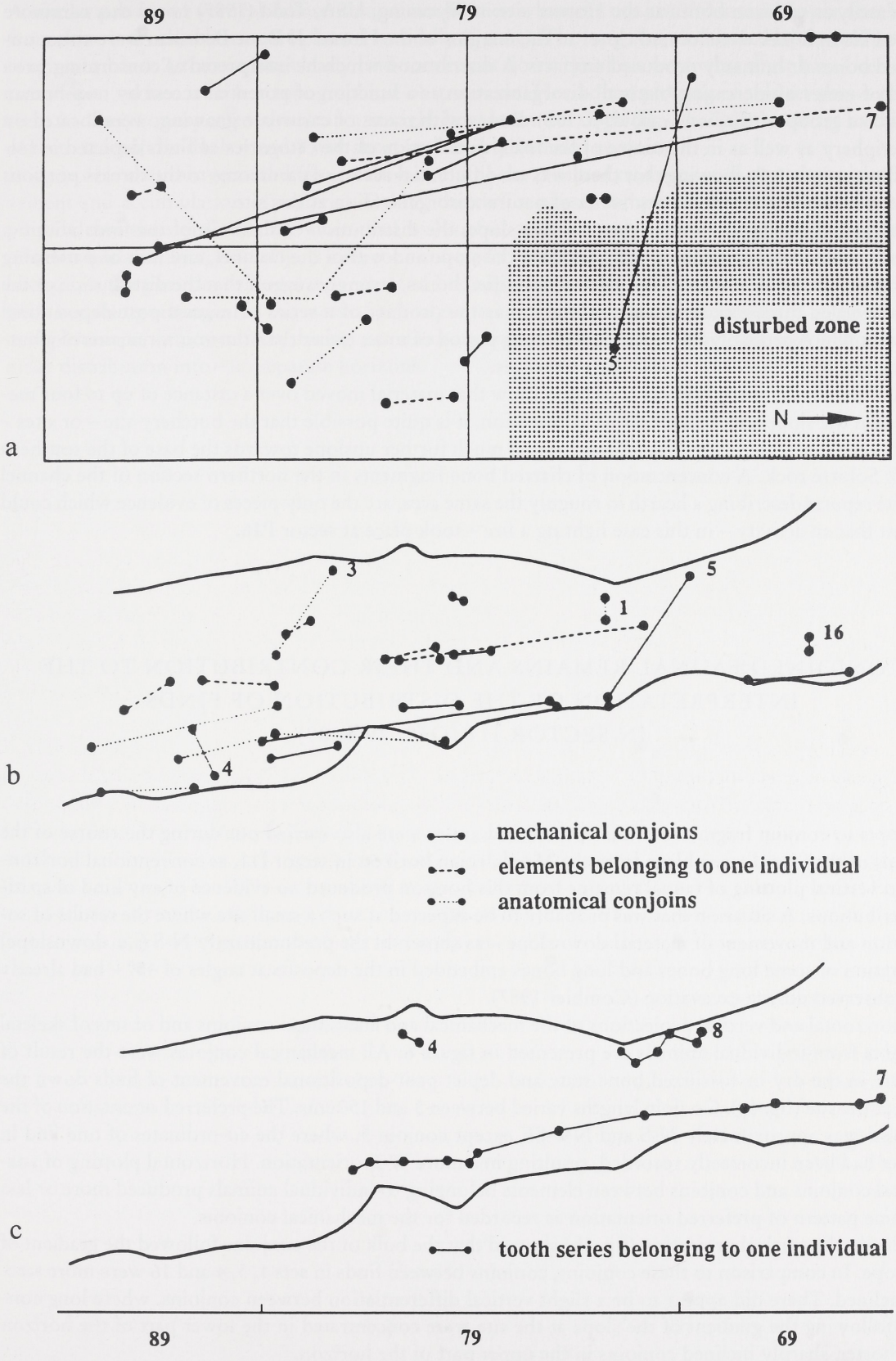
The distribution of bison bones closely follows the general pattern of faunal distribution at the site, and the bulk of the bison remains is located in the channel (folding ill. 9). Only a few bison remains were recorded outside the channel, in squares 14, 26 and 27. There are no concentrations of bison remains at the site, with the exception of some teeth preserved in tooth rows (B211, 212 and 213). The slightly higher number of bison remains preserved in the south-eastern section of the channel, probably reflects the generally higher density of finds due to the depth of the channel in this part of the site. There are no concentrations of humanly-modified bison bones and bison bones modified by carnivores are located in the centre of and on the periphery of the main distribution of finds of this species.

The distribution of charred bones

Small amounts of charred bone fragments were sorted out of the »secondaire« material and weighed during this analysis. The distribution of charred bone by weight (grams) is shown in figure 5. Four larger charred bones, two of horse, one of reindeer and one from an unidentified large animal had been recorded three-dimensionally, and the location of these pieces is also shown in figure 5.
Charred bones are spread mainly through the channel area. A few charred remains, including three of the finds recorded three-dimensionally during excavation, were recovered outside the channel feature. According to site reports, the remains of a hearth were revealed in the north-western part of sector P16 during excavation, and the »largest« amounts of charred bone are located in this area, in quadrats 23 (201 g), 33 (54.0 g) and 34 (61.0 g), providing very tentative evidence to support this observation.

In general, all categories of bones plotted in folding illustrations 6-9 showed the typical pattern of find distribution already noted in folding illustrations 1, 3, 4 and 5, in other words the faunal remains were deposited mainly in a channel. Within this feature, neither the distribution of some skeletal elements of horse or the remains of bison, or the distribution of cut-marked or marrow-fractured bones from these species could be interpreted as resulting from specific butchery activities which had taken place at sector P16.

Fig. 6 Conjoining bone fragments from the sector I11 site. a) horizontal plotting of mechanical and anatomical conjoins and elements belonging to individual animals. b) vertical plotting of mechanical and anatomical conjoins. c) vertical plotting of teeth belonging to individual animals. →


89
79
69
7
5
disturbed zone
N
a
3
5
1
16
4
b
mechanical conjoins
elements belonging to one individual
anatomical conjoins
4
8
7
c
tooth series belonging to one individual
89
79
69

In his analysis of bison bones at the Horner site in Wyoming, USA, Todd (1987) noted that carnivore gnawed bison bones were located closer to the margins of the Horner II Bone Bed than were either ungnawed bones or humanly produced artefacts. A distribution which he interpreted as conforming to »a model of zones of increasing 'natural' disorganization as a function of potential access by non-human agents to a group of carcasses« (ibid. p. 152). Bones with traces of carnivore gnawing, were located on the periphery as well as in the centre of the main distribution of the categories of finds depicted in folding illustrations 6-9, showing that there was no differential access of carnivores to the carcass portions depicted here and no evidence for zones of natural disorganization at this site.
Taken altogether, the location of the site on a slope, the distribution of the bulk of the finds within a channel, evidence of movement of finds down the slope and within the channel, and lack of patterning in the distribution of humanly or carnivore modified bones, strongly suggest that the distribution of the bones revealed during excavation at sector P16 is the product of a series of natural post-depositional processes which probably took place over a long period of time, rather than the *in situ* remains of a butchering site which was later visited by carnivores.
Conjoin lengths between fragments of bone show that material moved over a distance of up to four metres down the slope and, based on this information, it is quite possible that the butchery site – or sites – from which this material originated was located much further upslope towards the base of the southern cliff of Solutré rock. A concentration of charred bone fragments in the northern section of the channel and site reports describing a hearth in roughly the same area, are the only pieces of evidence which could suggest that an activity – in this case lighting a fire – took place at sector P16.

CONJOINED FAUNAL REMAINS AND THEIR CONTRIBUTION TO THE INTERPRETATION OF THE DISTRIBUTION OF FINDS IN SECTOR I11 (Q69, 79 & 89)

Attempts to conjoin fragments of bone, teeth and antler were also carried out during the course of the analysis of the faunal assemblage from the Magdalenian horizon in sector I11, as conventional horizontal and vertical plotting of faunal remains from this horizon produced no evidence of any kind of spatial distributions. A situation that was probably to be expected at such a small site where the results of solifluction and movement of material downslope – as shown in the predominantly N-S (i.e. downslope) orientation of some long bones and long bones embedded in the deposits at angles of 45° – had already been observed during excavation (Combier 1987).
The horizontal and vertical projections of the mechanical and anatomical conjoins and of sets of skeletal elements from individual animals are presented in figure 6. All mechanical conjoins were the result of fracture in the dry or fossilized bone state and depict post-depositional movement of finds down the slope at the site (fig. 6a). Conjoin lengths varied between 5 and 150 cms. The preferred orientation of the conjoins was approximately N-S and NW-SE except conjoin 5, where the co-ordinates of one find in this set had been incorrectly recorded, resulting in a more W-E orientation. Horizontal plotting of anatomical conjoins and conjoins between elements belonging to individual animals produced more or less the same pattern of preferred orientation as recorded for the mechanical conjoins.
Plotting in the vertical projection (fig. 6b) showed that the bulk of the conjoins followed the gradient of the slope. In comparison to these conjoins, conjoins between finds in sets 1, 3, 4 and 16 were more steeply inclined. There did appear to be a slight vertical differentiation between conjoins, where long conjoins following the gradient of the slope at the site were concentrated in the lower part of the horizon and shorter, sharply inclined conjoins in the upper part of the horizon.

A similar pattern of vertical differentiation can be seen when the conjoins of sets of upper cheek teeth from three individual horses are plotted vertically (fig. 6c). The long conjoin formed by several teeth belonging to horse 7, traces quite clearly find-movement down the slope over what must have been a relatively open surface with few topographical obstructions. Horizontal plotting of this set shows that the teeth had been transported almost in a straight line down the slope (fig. 6b, 7). In contrast to this, sets of teeth from individuals 4 and 8 had short and steeply inclined conjoins.

It is possible that this vertical differentiation could be the result of two phases of post-depositional movement and accumulation of material. During the earlier phase, comparatively more finds were transported down the slope at a time when the fossil surface was relatively clear of vegetation, talus deposits or other find-material, resulting in long conjoins closely following the gradient of the slope. During the later phase the post-depositional movement of finds appears to have been restricted, possibly due to the finds becoming entangled in the mass of animal remains which had already accumulated at the site? Vertical plotting of lithic artefacts during a preliminary analysis of the finds from this sector showed a similar distribution into two separate horizons.

THE LARGER MAMMAL FAUNA FROM SECTOR P16

HORSE

Introduction and basic data

Horse remains represent the bulk of the faunal material deposited during the Magdalenian phase at the sector P16 site. The horse from sector P16 was small in size and similar to small horse types found at many Magdalenian sites all over Europe. Prat (1968, 1969) named the horse from the Magdalenian levels at Solutré *Equus caballus arcellini*, in order to distinguish this equid from horses recovered from older levels at the site which he considered to belong to the subspecies *Equus caballus gallicus.*
The analysis of the horse remains from the Magdalenian deposits produced basic data which are presented in the following table (tab. 3). The table includes numbers of identifiable specimens (NISP) before and after refitting, minimum number of elements (MNE), minimum number of individuals (MNI), the numbers of horse bones with cut marks and hammerstone-induced impact notches and the numbers of horse bones which had been worked by humans, charred in a fire or chewed by carnivores.

NISP	NISP	MNE	MNI	carnivore gnawing	cut mark	impact notches	worked bone	charred bone
3577	3131	2672	45	262	70	44	3	2

Tab. 3 Basic data for the remains of horse with Magdalenian preservation at the P16 site.

A total of 3,577 remains with »Magdalenian« preservation could be identified to horse. Horse remains represent 88.7% of the total number of bones identifiable to a species. 2,672 elements from all parts of the skeleton were present. The highest minimum number of individuals – 45 – was recorded on the pelvis, but high numbers of individuals were also counted on many other elements of horse. Both juvenile and adult horses were present at the site. Cut marks and impact notches were observed on 114 horse remains. Part of an occipital bone and a tarsal bone (calcaneum) had been in contact with fire, and three fragments of horse bones had been used by the Magdalenians as a raw material for needle production. 262 horse bones had been chewed by carnivores.

Osteology and Palaeoecology

Osteology

The first detailed osteological descriptions of horse remains from Solutré were made by H. Toussaint and Abbé Ducrost (1873). They reckoned the wither's height of the horse from Solutré at between 1,36 -1,38 m and remarked upon the relatively large volume of the head, the large teeth and the strong muscle attachments on several elements of the skeleton, indicative of a relatively small, but robust equid. Later, François Prat undertook a study of horse remains from Solutré, and noted a significant biometrical difference between the horse remains from the older deposits at the site (»Würmiens plus anciens«) designated as *Equus caballus germanicus* (Nehring) and those from the younger deposits, which he attributed

to *Equus caballus gallicus* (Prat 1968, 1969). Nobis rejected the name *Equus caballus gallicus* in his monograph »Vom Wildpferd zum Hauspferd« published in 1971, and referred the horse from Solutré to *Equus ferus solutreensis.* However, the name *E. c. gallicus* has priority and *E. f. solutreensis* is invalid (Guadelli 1991).

The excavations undertaken by Jean Combier from 1968-1976 produced a large amount of new remains of horse and during a preliminary examination of the finds, Prat identified two horses of different size amongst the equid remains from the younger deposits at the site. In an unpublished article, J. Combier, F. Prat and J.-L. Guadelli decided to retain the name *Equus caballus gallicus* just for the larger horse from the upper Périgordian and Aurignacian levels at Solutré and named the smaller horse, found in the Magdalenian level, *Equus caballus arcelini,* in honour of the discoverer of the site. Thus two horses similar in proportion and morphology, but different in size, were described from the younger deposits at Solutré.

The holotype for *Equus caballus arcelini* is a third metacarpus from the Magdalenian deposits in sector P16. This find was, unfortunately, not available for study during the current analysis of the P16 faunal remains. The fossil (P16 34-540) was described by Guadelli (1991) in his paper on the horse remains from Solutré as a new subspecies which was probably descended from *Equus caballus gallicus.* The length of the metacarpus is 216.0 mm and the horse is described – with a withers height of 1.38 m – as smaller and less robust than *E. c. gallicus.* Its teeth possess all the typical caballine characteristics and are probably slightly smaller than those of *E. c. gallicus* (the lower cheek teeth less so) its upper molars have a relatively long protocone. Guadelli (1991) writes that the two sub-species can be distinguished biometrically on some post-cranial elements.

Basic measurements were taken on samples of equid bones and teeth from P16 during the course of the current analysis, including finds which had already been measured by Guadelli and some which were not available during his study. Some of these measurements – upper and lower P2 and M3, metacarpals and metatarsals and first phalanges – are summarised in tables 4 and 5, along with comparative measurements for *E. c. gallicus* and *E. c. arcelini* published by Guadelli in his 1991 article.

Guadelli writes that the upper premolars and molars of *E. c. arcelini* are probably smaller than those of *E. c. gallicus.* For the upper P2 the differences in mean lengths between the two sub-species given by Guadelli are very low anyway, being only 0.3 mm for the crown and 0.5 mm for the protocone (tab. 4). The mean crown length of upper P2s in the recently measured sample is smaller than the mean lengths of both sub-species, probably due to the presence of rather small P2's in the sample. The mean protocone length compares with that given for the *gallicus* form, even though the range in protocone length is greater than the ranges of both *gallicus* and *arcelini.* In the recently measured sample, mean lengths for lower P2 and M3 are comparable to those of the *arcelini* form, but the total range in length of the lower M3s compared more with the total range measured on teeth of the *gallicus* form, rather than the *arcelini* form (tab. 4).

Guadelli states that a significant difference between the sub-species can be observed in the lengths of the anterior first phalanges, those of *gallicus* being longer. The mean length of anterior phalanges in the recently measured sample is closer to that of *arcelini,* but the sample does contain some large specimens, including phalanges which even exceed the largest *gallicus* specimens in length (tab. 5). Guadelli observed that the posterior first phalanges of *arcelini* are much smaller than those of *gallicus.* The mean length of the recently measured sample of posterior first phalanges was even smaller than the mean for *arcelini,* even though the total range in length of this element is greater than that given for both sub-species (tab. 5).

The mean third metacarpal length is shorter than that given by Guadelli for both sub-species, but is closer to the mean for the *arcelini* form (tab. 5). Other measurements taken on the sample of third metatarsals – particularly metatarsal lengths and mean diaphyseal and distal breadths – compared more in size with those of *arcelini* than those of *gallicus.*

To summarise, although only a few measurements were taken recently on a selection of horse teeth and bones, these indicate that some horse remains from P16 are comparable in size to specimens described as belonging to *E. c. arcelini* – the horse thought to occur in the Magdalenian levels –, but also show that other elements are comparable in size or even larger than specimens of *E. c. gallicus,* a form thought to be pre-

	length	breadth	length protocone
Upper P 2			
P16 Magdalenian	29.7-38.8	23.4-28.0	8.1-12.6
	sd 1.92	sd 1.24	sd 1.13
	x 36.2	x 25.7	x 9.3
	n 18	n 18	n 16
E. c. arcelini	33.3-39.6	21.5-26.4	9.0-11.5
	sd 2.19	sd 1.43	sd 0.78
	x 37.1	x 24.3	x 9.8
	n 10	n 9	n 9
E. c. gallicus	35.0-38.7	23.2-26.0	8.5-10.6
	sd 1.15	sd 0.9	sd 0.66
	x 36.8	x 24.8	x 9.3
	n 8	n 8	n 8
Upper M3			
P16 Magdalenian	23.9-30.6	20.8-27.0	11.8-17.0
	sd 1.98	sd 1.50	sd 1.46
	x 26.6	x 23.1	x 14.5
	n 28	n 26	n 26
E. c. arcelini	24.4-31.0	21.0-24.0	12.3-16.8
	sd 2.22	sd 1.04	sd 1.69
	x 27.3	x 22.9	x 14.3
	n 9	n 9	n 9
E. c. gallicus	26.0-28.3	22.5-23.0	14.4-15.5
	n 4	n 4	n 4
Lower P2			
P16 Magdalenian	31.4-35.3	13.8-18.1	
	sd 1.31	sd 1.29	
	x 33.2	x 16.0	
	n 14	n 18	
E. c. arcelini	31.2-36.0	14.0-15.6	
	sd 1.79	sd 0.41	
	x 33.6	x 14.7	
	n 11	n 12	
E. c. gallicus	29.0-35.6	13.5-18.0	
	sd 1.81	sd 1.21	
	x 32.8	x 15.1	
	n 16	n 17	
Lower M3			
P16 Magdalenian	28.9-35.1	13.1-15.5	
	sd 1.67	sd 0.86	
	x 31.0	x 14.1	
	n 13	n 13	
E. c. arcelini	28.0-33.4	11.0-14.2	
	sd 1.50	sd 0.89	
	x 31.0	x 13.2	
	n 12	n 12	
E. c. gallicus	28.5-35.5	12.5-15.5	
	sd 2.19	sd 1.00	
	x 31.9	x 13.7	
	n 9	n 9	

Tab. 4 Comparative measurements of selected upper and lower premolars and molars of horse from sector P16 at Solutré. Comparative measurements (taken at the occlusal surface) for *E. c. arcelini* and *E. c. gallicus* taken from Guadelli (1991) table 1 (upper P2), table 8 (upper M3), table 10 (lower P2) and table 17 (lower M3). sd = standard deviation, x = mean, n = number of observations.

	length	proximal breadth	breadth diaphysis	distal breadth
Phalange 1 anterior				
P16 Magdalenian	77.0-93.0	50.4-59.1	32.8-40.4	45.1-51.4
	sd 3.61	sd 2.72	sd 1.69	sd 2.14
	x 82.7	x 55.6	x 36.7	x 47.6
	n 22	n 21	n 22	n 22
E. c. arcelini	75.5-90.1	52.0-62.2	32.8-39.8	43.2-50.2
	sd 2.8	sd 2.31	sd 1.24	sd 1.5
	x 82.4	x 56.5	x 36.6	x 46.1
	n 62	n 57	n 63	n 60
E. c. gallicus	74.5-92.0	52.5-62.0	35.0-40.0	43.0-54.0
	sd 3.61			
	x 83.2		x 37.4	x 46.6
	n 48	n 48	n 48	n 48
Phalange 1 posterior				
P16 Magdalenian	71.0-94.0	49.5-59.6	32.8-38.0	42.6-49.5
	sd 4.63	sd 2.83	sd 1.37	sd 2.08
	x 78.6	x 55.0	x 35.2	x 45.8
	n 33	n 34	n 32	n 34
E. c. arcelini	73.5-87.0	49.8-65.4	33.0-40.2	41.5-48.8
	sd 3.38	sd 3.04	sd 1.86	sd 1.70
	x 80.5	x 57.4	x 36.1	x 45.0
	n 57	n 53	n 57	n 55
E. c. gallicus	76.0-90.0	54.5-65.3	33.7-40.2	42.3-50.2
	sd 2.99	sd 2.44	sd 1.51	sd 1.44
	x 82.3	x 59.3	x 37.2	x 45.7
	n 61	n 54	n 63	n 58
Metacarpus 3				
P16 Magdalenian	203.5-228.2	47.8-53.3	30.6-38.6	44.4-52.5
	sd 6.20	sd 2.14	sd 3.66	sd 2.26
	x 214.1	x 49.7	x 35.2	x 48.9
	n 19	n 20	n 20	n 19
E. c. arcelini	202.5-228.0	43.1-53.5	31.0-38.0	47.2-53.7
	sd 6.34	sd 2.22	sd 1.80	sd 1.77
	x 215.7	x 49.6	x 34.5	x 49.9
	n 39	n 40	n 40	n 36
E. c. gallicus	207.0-231.5	46.5-57.0	33.5-41.8	46.0-56.5
	sd 6.32	sd 2.22	sd 1.98	sd 2.51
	x 220.2	x 51.3	x 37.4	x 51.4
	n 38	n 52	n 37	n 34
Metatarsus 3				
P16 Magdalenian	249.0-272.6	31.7-53.0	31.7-36.1	48.9-53.9
	sd 6.25	sd 7.90	sd 1.44	sd 1.61
	x 260.9	x 46.2	x 33.7	x 51.1
	n 15	n 15	n 15	n 14
E. c. arcelini	245.0-275.0	45.7-55.3	30.4-37.5	48.0-55.3
	sd 7.26	sd 2.14	sd 1.77	sd 1.74
	x 261.3	x 50.4	x 33.6	x 50.6
	n 26	n 32	n 27	n 24
E. c. gallicus	255.0-279.0	49.0-58.5	34.3-39.5	49.5-55.0
	sd 6.64	sd 2.16	sd 1.49	sd 1.18
	x 264.	x 52.82	x 36.4	x 53.4
	n 17	n 24	n 17	n 16

Tab. 5 Comparative measurements of selected post-cranial bones of horse from sector P16 at Solutré. Comparative measurements for E. c. arcelini and E. c. gallicus taken from Guadelli (1991) table 36 (phalange 1 anterior), table 56 (phalange 1 posterior), table 32 (metacarpus 3), table 53 (metatarsus 3). sd = standard deviation, x = mean, n = number of observations.

sent in the faunas from the upper Périgordian (= Gravettian) and Aurignacian levels at the site. As the aim of the present analysis was an archaeozoological and not a palaeontological assessment of the faunal remains from the site, measurements on elements which Guadelli considers to be highly significant for separating the two sub-species were not always taken. Nevertheless, the large range in size recorded on the small sample of measured horse remains from P16 is difficult to reconcile with the theory that a horse smaller in size than *E. c. gallicus*, was the only equid present in the Magdalenian levels at Solutré.
The problems involved in attempting to define species or sub-species of Pleistocene equids on size alone have been discussed elsewhere by this author (Turner 1990), and it is not necessary to repeat these arguments here. Pleistocene horses underwent an apparently gradual evolution with time: they gradually became smaller, and what we are seeing in the younger levels at Solutré is just a short episode in this evolutionary event. Whether it is possible to separate horses undergoing gradual evolution into distinct subspecies based on size alone, still remains questionable.

Palaeoecology

Equids occurred in both warm and cold stages during the Pleistocene. As far as the ecological behaviour of fossil horses is concerned, the genus appears to have preferred open grassland conditions which are essential for graze. This can be either in the form of open, herbaceous steppe, which was probably the case at Solutré, or clearings in otherwise mainly wooded conditions. That fossil horses appeared in larger numbers during periods of prevailing open, steppic conditions is indicated by the dominance of this genus in several faunas deposited during Pleistocene cold stages in the Central Rhineland area of Germany (Turner 1990).

Numbers of individuals and skeletal part representation

Counts of horse skeletal remains are listed below in table 6. Element type, body-side, the minimum number of elements and minimum number of individuals for each element are given, along with the number of elements gnawed by carnivores. For long bones of the fore and rear limbs, MNE's and MNI's are placed next to the portion of the element on which these were counted (for example, MNE and MNI

	left	*	right	MNE	MNI	number gnawed
Head						
cranium	31	48	31	31	31	3
mandible	51	25	62	69	38	6
maxillary teeth	248	5	238	491	32	0
mandibulary teeth	153	4	175	332	23	0
tooth fragments		19				
Axial						
atlas		43		33	33	6
axis		28		22	22	1
cervical		153		153	30	11
thoracic		155		153	8	12
lumbar		116		113	18	17
sacrum		11		9	9	6
caudal		4		4	1	1
unidentified vertebrae		28				
pelvis	71	3	82	81	45	20
ribs	24	67	23	38	2	5

Fore-limb						
D scapula	42	0	38	79	41	2
scapula blade	6	4	9			
humerus complete	0	0	1			
P humerus	4	0	2			
shaft	18	0	20			
D humerus	19	0	24	44	25	37
radius complete	5	0	8			
P radius	8	0	16			
shaft	9	1	12			
D radius	20	0	15	48	25	11
ulna complete	1	0	0			
P ulna	16	0	13	30	17	9
shaft	0	0	1			
D ulna	0	0	1			
carpals	47	0	42	89	16	0
metacarpal complete	20	0	16			
P metacarpal	20	0	16	71	39	10
shaft	3	3	0			
D metacarpal	17	11	11			
metacarpal 2	10	0	7	17	10	0
metacarpal 4	6	0	9	15	9	0
Rear-limb						
femur complete	0	0	1			
P femur	14	0	16			
shaft	33	0	33	42	24	30
D femur	7	0	3			
patella	13	2	9	18	13	6
tibia complete	2	0	1			
P tibia	8	0	10			
shaft	14	2	11			
D tibia	24	0	22	49	26	8
calcaneum	40	0	35	64	33	27
astragalus	48	0	39	73	39	6
tarsals	35	0	42	72	18	0
complete metatarsus	14	0	9			
P metatarsus	18	2	15	53	31	5
shaft	3	2	2			
D metatarsus	17	4	8			
metatarsal 2	9	0	7	16	9	1
metatarsal 4	11	0	6	17	11	0
phalange 1 ant	26	0	22	48	26	7
phalange 1 post.	33	11	42	78	42	
phalange 1 indet.	3	8	2	3	-	
phalange 2 ant.	34	7	29	69	34	10
phalange 2 post.	30	1	30	61	30	
phalange 2 indet.	4	8	10	18		
phalange 3		189		111	27	3
P sesamoid	11		11	2	0	
D sesamoid	8		8	2	0	
mc/mt	25				2	
Totals		**3577**		**2672**		**262**

Tab. 6 Counts of horse remains from the Magdalenian deposits in sector P16. – P = proximal, D = distal, * = indeterminate to side, mc/mt = indeterminate to third metacarpal or third metatarsal. All MNE's and MNI's are based on number of fragments after refitting. Total NISP includes two fragments of horse bones not identifiable to element and two worked fragments of horse bone which are not listed in this table. Counts of carnivore gnawing for phalanges 1 and 2 are pooled counts from anterior and posterior phalanges.

for the scapulae were counted on the distal ends of this bone); the number gnawed by carnivores refers to the total number of scapulae (distal ends and blades) which display such traces.

When examining the skeletal part representation of horse, or any of the other 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 animal remains at Palaeolithic sites simply reflect what has been found during excavation and do not necessarily represent the remains of animals left behind by the human inhabitants of the site as part of their subsistence strategies. For example, an absence of portions of the skeleton does not necessarily indicate transportation of these parts away from the site solely by humans, and gnawing by carnivores, weathering, and other post-depositional and post-burial processes can equally result in the destruction and eventual loss of bone.

It has been shown that 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, and a dominance of high-density elements is generally a good indicator that the assemblage of bones has been strongly affected by post-depositional processes of destruction (Binford and Bertram 1977; Brain 1981; Lyman 1985; Marean 1991; Marean and Spencer 1991; Marean et al. 1992). By comparing the results of bone density analyses with the horse remains preserved at sector P16, it may be possible to extrapolate some information which could be linked to the subsistence activities of humans at Solutré.

Teeth are generally the most dense elements in the animal skeleton and the post-depositional destruction of faunal remains in an assemblage leads to a reduction in the number of bones whereas numbers of teeth are less affected. This process is called differential preservation. A total of 766 horse teeth, including 19 tooth fragments, and 2,811 horse bones have been recorded at P16. Expressed as a percentage, teeth represent 21.4% and bones 78.5% of the total number of horse remains (3,577), and the dominance of bone over teeth shows that this assemblage of horse remains has hardly been affected by differential post-depositional destruction. Levine (1979) reckoned a tooth:bone ratio of 0.7:1.0 for her sample of horse remains from P16, and writes . . . »preservation in this Assemblage Unit is excellent. . . « (ibid. p. 134).

Very low numbers of deciduous teeth (tab. 7) appear to be characteristic of the bone assemblage at P16, and a similar pattern of deciduous tooth preservation has been recorded by earlier analysts in assemblages dating not only to the Magdalenian, but also to other cultural phases at Solutré. Levine (1979) suggested that this was due to the differential preservation of thinly-walled milk teeth, whereas Olsen (1989) saw this as the result of humans preferentially killing adult horses and releasing juvenile horses and foals. So far, no experimental studies have been undertaken on the differential preservation of deciduous and permanent cheek teeth from ungulates, so that Levine's argument can only be regarded as speculative for the time being. Furthermore, other lines of evidence do suggest that low numbers of deciduous teeth actually reflect the relatively low numbers of foals and juveniles which died at the site.

	dp2-4	I1-3	C	P2-4	M1-3	others	total
Maxillary teeth							
sin	25	29	2	69	68	56	248
dex	23	39	0	54	72	50	238
ind	0	2	0	0	0	3	5
Total	48	70	1	123	140	109	491
Mandibulary teeth							
sin	11	27	0	41	39	35	153
dex	17	30	1	41	32	54	175
ind	0	1	0	0	2	1	4
Total	28	58	1	82	73	90	332

Tab. 7 NISP (before refitting) of upper and lower dental elements of horse from sector P16. Numbers in the column »others« are counts of permanent upper cheek teeth approximately identifiable to position in jaw (eg. M1 or 2; P3 or 4). ind = indeterminate to side.

	cmp	pr	prs	pre	prd	sh	ds	dss	dse	dsd	total
Scapula											
sin	0	0	0	0	0	6	2	**40**	0	0	48
dex	0	0	0	0	0	9	0	**38**	0	0	47
ind	0	0	0	0	0	4	0	**0**	0	0	4
Total	0	0	0	0	0	19	2	**78**	0	0	99
Humerus											
sin	0	0	3	1	0	17	0	**19**	0	1	41
dex	1	0	1	1	0	19	3	**21**	0	1	47
ind	0	0	0	0	0	0	0	**0**	0	0	0
Total	1	0	4	2	0	36	3	**40**	0	2	88
Radius											
sin	5	0	8	0	0	7	2	**16**	2	2	42
dex	8	1	14	1	0	9	2	**8**	5	3	51
ind	0	0	0	0	0	0	0	**0**	0	1	1
Total	13	1	22	1	0	16	4	**24**	7	6	94
Ulna											
sin	1	4	**12**	0	0	0	0	0	0	0	17
dex	0	1	**12**	0	0	1	0	1	0	0	15
ind	0	0	**0**	0	0	0	0	0	0	0	0
Total	1	5	**24**	0	0	1	0	1	0	0	32
Mc3											
sin	**20**	0	**20**	0	0	2	1	15	1	1	60
dex	**16**	0	**16**	0	0	0	0	11	0	0	43
ind	**0**	0	**0**	0	0	3	2	9	0	0	14
Total	**36**	0	**36**	0	0	5	3	35	1	1	117

Tab. 8 Representation of portions of major elements from the fore-leg of horse at Sector P16. Counts are total numbers of specimens before refitting. High counts, indicating well-preserved bone portions, in bold face. – Sin = left; dex = right; ind = indeterminate to body-side; cmp = complete; pr = proximal; prs = proximal end and a portion of the shaft; pre = unfused proximal epiphysis; prd = unfused proximal diaphysis; sh = shaft; ds = distal end; dss = distal end and a portion of the shaft; dse = unfused distal epiphysis; dsd = unfused distal diaphysis.

The minimum numbers of individuals (MNI) of horse depicted in figure 7, are the highest MNI counts (from either the left or the right side of the body) for each element, and are based on data given in tables 6, 8 and 9. MNI's for teeth were assessed on the upper and lower dp2's and P2's and on the upper or lower M3's, as these dental elements are the ones that can be unequivocally identified to tooth type and position in the jaw of a horse. In the case of vertebrae, the MNI was assessed by dividing the total number of a particular vertebra by the number of that vertebrate type in the skeleton of a horse: the same method was used for the ribs. MNI's for the limb bones were counted on those portions of the bones which produced the highest number of finds. For example, MNI's for the scapula were counted on the distal end of this bone from the left side of the body. Altogether 42 left distal ends were present (2 distal ends + 40 distal ends with a portion of the shaft = 42, see table 8 for data). Two of these finds were, however, so fragmentary that they could not be assigned to separate individuals with any degree of certainty, thus bringing the total number of individuals counted on this element to 41. MNI's for all the remaining elements were counted in the same manner. Assessments of more exact numbers of individuals, such as those given for reindeer and bison, were not attempted for horse due to the large amount of remains identified to this species.

	acb	ilm	isc	pub	total
Pelvis					
sin	**41**	22	3	5	71
dex	**48**	19	9	6	82
ind	0	2	0	1	3
Total	**89**	43	12	12	156

	cmp	pr	prs	pre	prd	sh	ds	dss	dse	dsd	total
Femur											
sin	0	3	8	3	0	**33**	2	5	0	0	54
dex	1	8	5	3	0	**33**	2	1	0	0	53
ind	0	0	0	0	0	0	0	0	0	0	0
Total	1	11	13	6	0	**66**	4	6	0	0	107
Tibia											
sin	2	1	6	1	0	13	3	**19**	2	1	48
dex	1	1	8	1	0	10	2	**18**	2	1	44
ind	0	0	0	0	0	1	0	0	0	1	2
Total	3	2	14	2	0	24	5	**37**	4	3	94
Mt3											
sin	14	0	**18**	0	0	3	1	16	0	0	52
dex	9	0	**15**	0	0	2	0	8	0	0	34
ind	0	0	**2**	0	0	2	0	4	0	0	8
Total	23	0	**35**	0	0	7	1	28	0	0	94

Tab. 9 Representation of portions of the pelvis and of major elements from the rear-leg of horse at Sector P16. Counts are total numbers of specimens before refitting. High counts, indicating well-preserved bone portions, in bold face. – Sin = left; dex = right; ind = indeterminate to body-side. Pelvis: acb = acetabulum; ilm: ilium; isc = ischium; pub = pubis. Rear-leg: cmp = complete; pr = proximal; prs = proximal and a portion of the shaft; pre = proximal epiphysis; prd = unfused proximal diaphysis; sh = shaft; ds = distal end; dss = distal end and a portion of the shaft; dse = distal epiphysis; dsd = unfused distal diaphysis.

Practically all skeletal elements of horse were recovered at sector P16, even if some bones were better represented than others. The highest MNI for horse – 45 – was recorded on the pelvis. 42 individuals were counted on the posterior first phalange, and relatively high numbers of individuals were observed on elements of the head (mandible MNI = 38), fore-leg (scapula MNI = 41; metacarpal MNI = 39, phalange 2 MNI = 34), and rear leg (astragalus MNI = 39; calcaneum MNI = 33; metatarsal MNI = 31) (fig. 7). In the majority of cases, counts of elements from the left or from the right sides of the body were either equal or more or less so (tabs. 8 and 9 and see figs. 9 and 10), indicating that there had been no deliberate selection of body side.

The MNI's for the upper and lower dentition were established on deciduous and permanent second premolars (dp2 and P2) and on permanent third molars (M3), as these teeth can usually be identified with some certainty. Similar numbers of individuals were obtained for the upper second premolars (32) and the upper third molars (29), showing no differentiation in preservation of anterior as opposed to posterior portions of the upper dentition. A greater differentiation was observed between anterior (23 individuals) and posterior (15 individuals) portions of the lower dentition.

MNI counts for the cranium were based on the occipital region of the skull and counts for the mandible on the mandibular hinge, as both of these anatomical regions are relatively sturdy parts of the head and the jaw. Low numbers of other bones of the skull and certain portions of the mandible were certainly due to post-depositional fragmentation and disintegration of these thin-walled bones a process which, at least for the mandibles, may have been exacerbated by humans smashing horse jaws into smaller pieces in order to obtain marrow. Only twelve mandibular symphyses were recorded: this is unusual as

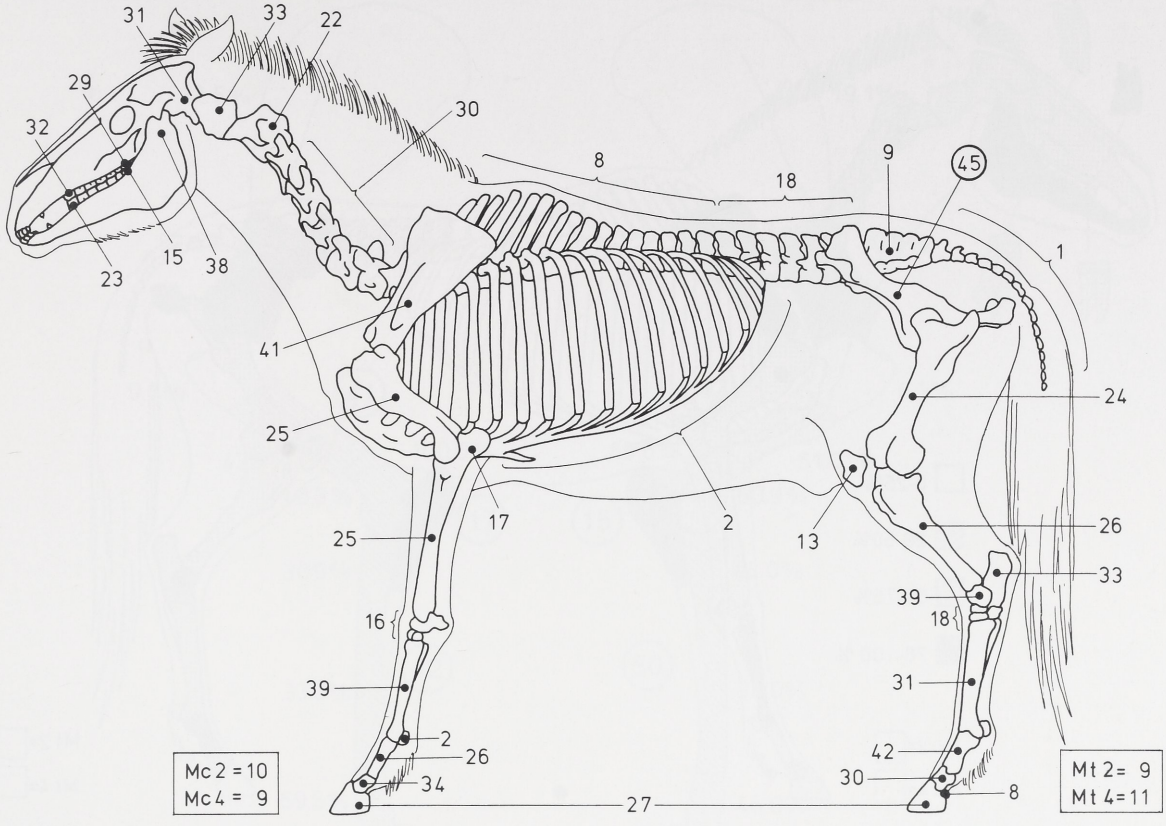


Fig. 7 Horse skeletal representation at sector P16 depicting counts of minimum number of individuals (MNI) for each element.

the symphysis is a robust part of the jaw, and the low numbers of this portion may also relate to human modification of horse mandibles, along with the differential preservation observed between anterior and posterior mandibulary cheek teeth. Low MNI's were counted on axial elements such as ribs, thoracic and caudal vertebrae, sacrum, and on elements small in size, such as the sesamoids and vestigial metapodia. To some extent, the low numbers of ribs is certainly due to the fragility of this element, as testified by numerous rib shaft fragments in the »secondaire« category of finds. According to horse bone density data recently published by Lam et al. (1999), cervical vertebrae are more robust than other vertebrae of the back and tail of horse (thoracic, lumbar and caudal vertebrae and the sacrum), which probably accounts, to some extent, for the extreme differential preservation between these elements shown in figure 7. However, the possibility that the extreme differential preservation of the horses back could also reflect transportation of these skeletal parts away from the site by humans, for example, cannot be excluded.

Olsen (1989) postulated that low numbers of small bones could be due to the excavation techniques employed at Solutré, but the lack of such material in the secondaire category indicates that this was probably not the case at sector P16. The low numbers of sesamoids and vestigial metapodia may be due to the activities of carnivores, as small bones such as these are easily swallowed by carnivores when they chew on animal carcasses after which they disintegrate in the gut or are passed as scat at, or away from, the site.

Figure 8 depicts the numbers of individuals for each element as a percentage of the highest MNI (MNI 45=100%). The percentages were divided into four main groups, 0-25%, 26-50%, 51-75% and 76-100% in order to show broad differences in skeletal representation more clearly.

High-ranking percentages were recorded on portions of the limbs which are referred to as »high-utility

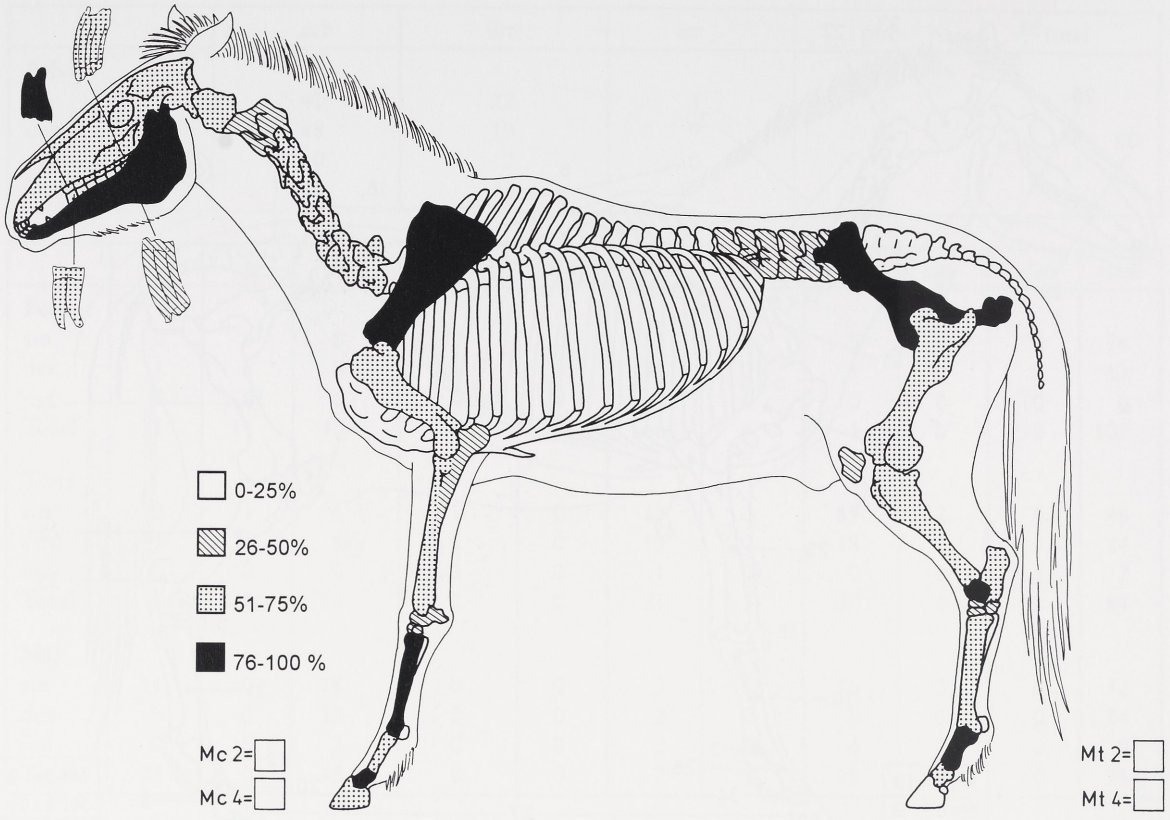


Fig. 8 Horse skeletal representation at sector P16 with MNI's depicted in figure 16 expressed as percentages of the highest minimum number of individuals (MNI 45=100%).

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 on parts of the limbs which are usually considered low in utility (carrying no meat) such as the metacarpals and first and second phalanges. In other words there seemed to be no indication of a deliberate selection of high or of low-utility parts of the horse in the assemblage of horse bones at P16.

Interesting is the representation of major leg bones (humerus, radius, femur and tibia), – which all have ratings of 51-75% [fig. 8] and are more or less equal in terms of MNI (humerus MNI 25; radius MNI 25; femur MNI 24; tibia MNI 26 [fig. 7]) – when compared to ratings for some of their immediate neighbours in the horse skeleton. The femur, with an MNI of 24, is almost 50% less well-represented than its skeletal neighbour the pelvis, which has a MNI of 45. The same pattern of differentiation between neighbouring elements can be seen in the ratings for the scapula/humerus, radius/third metacarpus and, to a lesser extent, tibia/third metatarsal. Analyses of bone preservation have shown that on the whole, scapulae, pelves, metacarpals and metatarsals do have better chances of survival than major leg bones, and the lower ratings for leg bones at Solutré obviously reflect this to some extent. However, the possibility that the strong differential preservation between parts of the horses limbs could be due to transportation of some major leg bones away from the site by humans cannot be excluded.

Some portions of horse limb and foot bones were better-represented at P16 than others. Detailed counts (before refitting) of portions of major elements of the fore legs, rear legs and pelves of horse from P16 are listed in tables 8 and 9. Counts for proximal, shaft and distal bone portions are depicted as percentages of the total number of finds of a particular element from the left and from the right side of the body

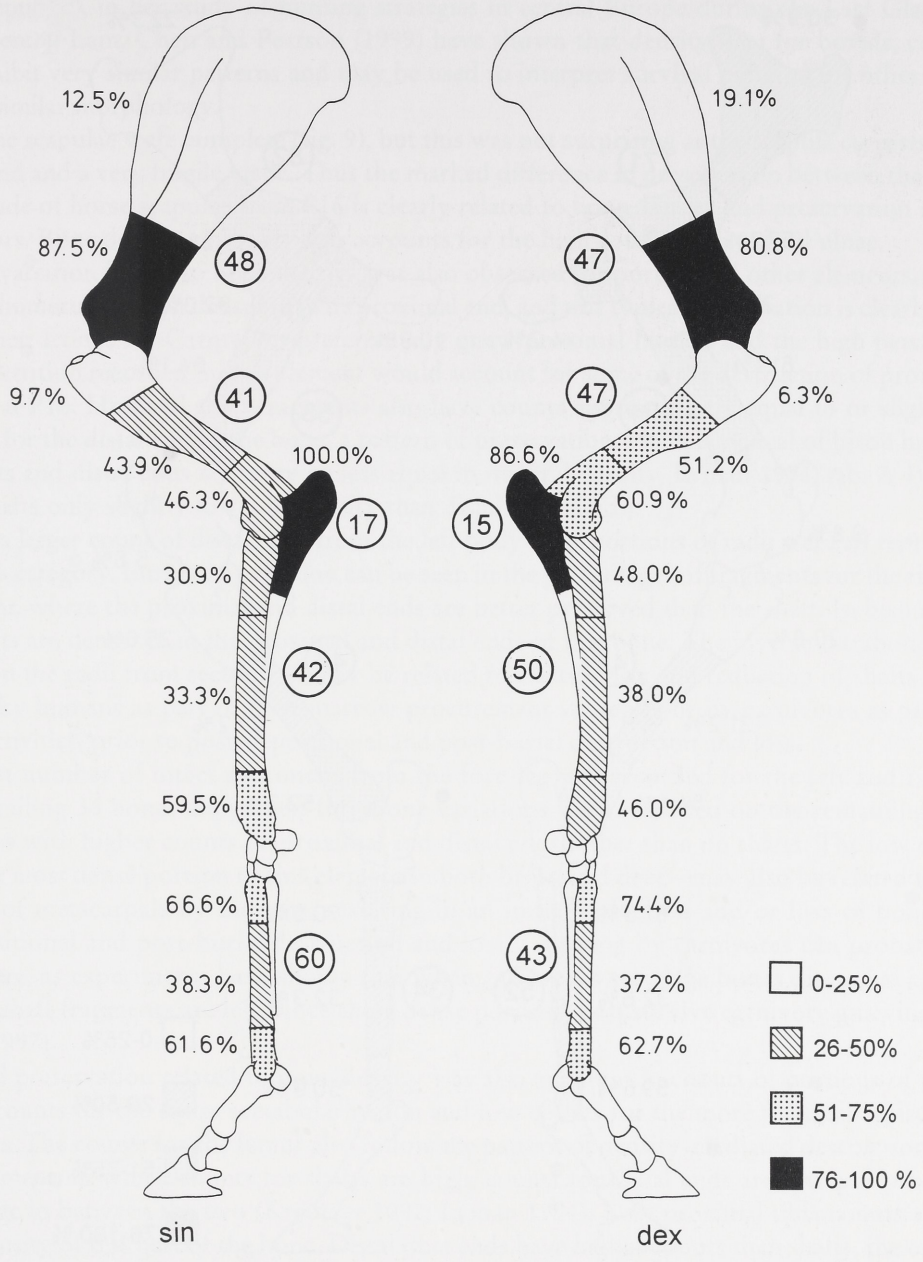


Fig. 9 Representation of portions of fore-leg long bones of horse from sector P16. Percentages of all carpals, phalanges, vestigial metapodials (Mc 2 and 4) and sesamoids not indicated. Numbers in circles are total numbers of a particular element (eg. 48 left scapulae), from which the percentages were 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.

and presented in figures 9 and 10. In these figures, the proximal portion includes all proximal (=pr; prs; pre; psd) categories and distal all distal (ds; dss; dse; dsd) categories as listed in the tables; intact bones were recorded as one count each to the proximal, shaft and distal portions of the element.

In the following discussion, reference is made to structural densities of bones given by Brain (1981) for example, and to more detailed bone mineral density analyses. In the latter case, bones are scanned at specific sites and the mineral density measured using photo densitometry techniques. Bone mineral densities have been measured for a number of animals, including deer, pronghorn antelope, domestic sheep,

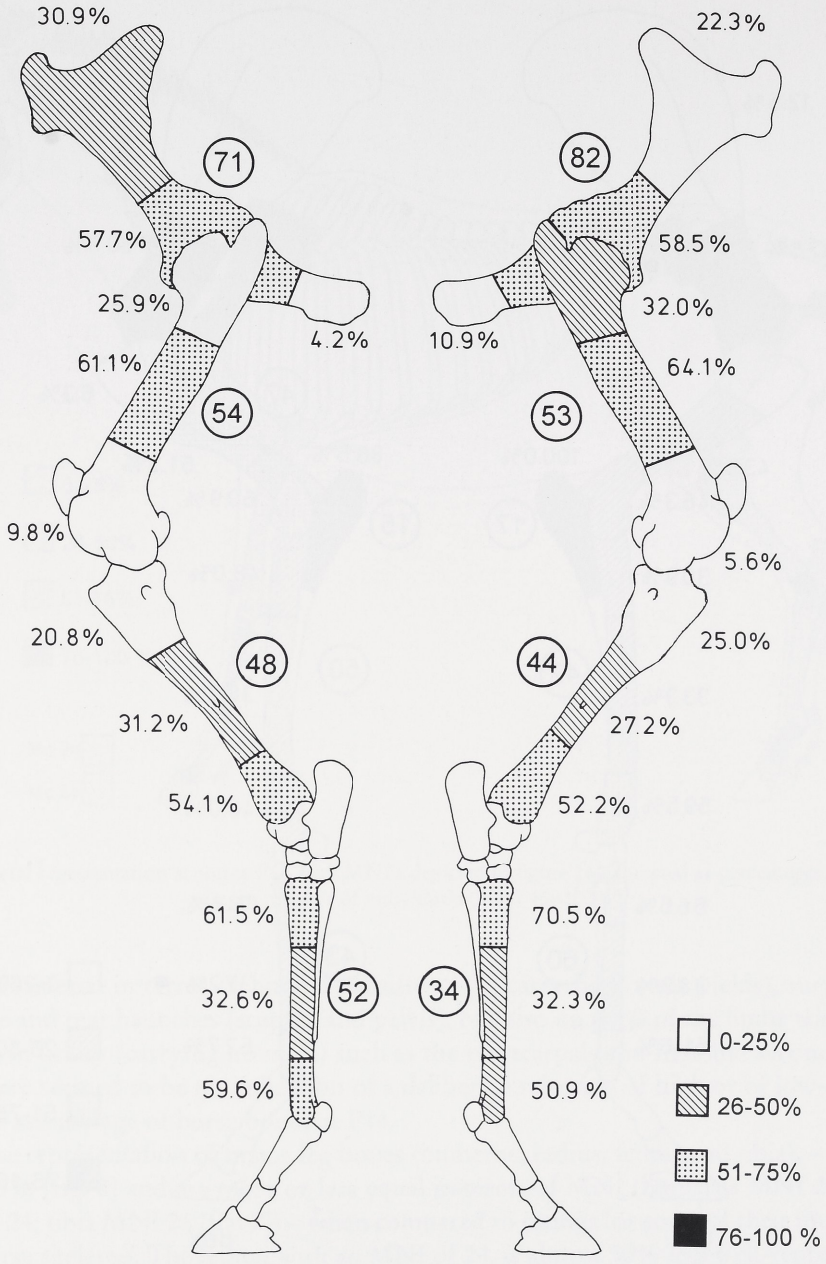


Fig. 10 Representation of portions of the pelvis and rear-leg long bones of horse from sector P16. Percentages of all tarsals, phalanges, vestigial metapodials (Mt 2 and 4) and sesamoids not indicated. For explanation to numbers in circles and percentages see figure 9.

seal, North American bison and marmots, and South American vicuna and guanaco (Lyman 1994) but, until recently, not for horse. In order to provisionally interpret the differential preservation of some horse bones at P16, tentative comparisons were made with bone mineral densities given by Kreutzer (1992) for bison and by Lyman for deer (Lyman 1994, table 7. 6 summarizing all bone mineral densities published to date), as these species represent animals larger (bison) and smaller (deer) in body-size than the small horse from Solutré. West (1997) also used bison and deer bone mineral densities to assess the preservation of horse remains from the sites of Grubgraben (Lower Austria) and from Stránska Skála IV

(Czech Republic), in her study of hunting strategies in central Europe during the Last Glacial Maximum. Recently, Lam, Chen and Pearson (1999) have shown that density data for bovids, cervids and equids exhibit very similar patterns and may be used to interpret survival patterns for other species of generally similar morphology.

None of the scapulae were complete (fig. 9), but this was not surprising as the scapula consists of a sturdy distal end and a very fragile blade. Thus the marked difference in preservation between the distal end and the blade of horse scapulae from P16 is clearly related to bone density and preservation and not to other factors. Bone density probably also accounts for the high counts of proximal ulnae.

Intrabone variation linked to bone density was also observed for portions of other elements. The distal end of the humerus is much denser than its proximal end, and this typical preservation is clearly reflected in the humeri from P16. Carnivores preferentially gnaw proximal humeri and the high percentages of carnivore attrition recorded on this element would account for some of the destruction of proximal horse humeri at P16. Humeral shaft fragments also have counts approximately equal to or slightly lower than those for the distal end of the bone, a pattern of preservation which is typical of bison humeri (humeral shafts and distal ends are more or less equal in mineral density, Lyman 1994, tab. 7. 4), and deer humeri (shafts only slightly lower in density than distal ends, ibid.).

Excepting a larger count of distal ends from the left body-side, portions of radii were all represented in the 26-50% category. Intrabone variation can be seen in the percentages of fragments for the right radius in particular, where the proximal and distal ends are better preserved than the shaft. In bison and deer, radius shafts are denser than the proximal and distal ends of this bone. The inverse intrabone variation observed on the radii from sector P16 may be related to fracturation and reduction of shafts to smaller fragments by humans as part of their marrow procurement strategies or by carnivores as part of their gnawing activities, prior to post-depositional and post-burial destruction and loss.

The highest number of intact specimens from the fore-leg was recorded for the left and right metacarpals, totalling 36 bones altogether. Intrabone variations were recorded on the remaining metacarpal portions with higher counts on proximal and distal ends rather than on shafts. The low counts for shafts – the most dense portion of this element in both bison and deer – may also be related to marrow fracturing of metacarpals by humans, resulting in an initial reduction and/or loss of bone prior to post-depositional and post-burial destruction and loss. Gnawing by carnivores can probably be eliminated here, as experiments have shown that when carnivores scavenge bones discarded by humans numerous shaft fragments are left, since these dense portions best survive carnivore gnawing (Marean and Frey 1997).

Differential preservation related to bone density was also apparent in counts of portions of the pelvis, with high counts for the dense acetabular region and low counts for the more fragile iliac, ischium and pubis bones. The counts for the femur also follow the pattern of density-mediated destruction recorded for this element, in which counts for shafts are high, counts for distal ends are low and proximal end counts range in between the two (Kreutzer 1992; Lyman 1994). Low proximal tibia counts also reflect the low-density of this part of the bone. Distal tibia ends have higher counts than shafts, the opposite of what is to be expected according to comparative density values for this bone in bison and deer. Once again this pattern may result from the initial smashing of tibias by humans during marrow procurement, reducing shafts into smaller fragments. The same has been suggested to explain inverse ratings between shafts and ends of metacarpals.

Counts of intact bones from the rear-leg were low, with the exception of the metatarsals – a pattern already observed in the corresponding elements of the fore-leg. Altogether 23 intact metatarsals were recovered. Typical patterns of density-mediated destruction for metatarsals are reflected in higher counts for the denser proximal ends than the less dense distal ends of this bone, particularly on the right body-side. The low counts for metatarsal shafts could also reflect initial human modification and reduction of this element.

The bulk of the phalanges was intact: only rarely did fragmentary pieces of these elements occur. Counts for posterior first phalanges were higher than those for the anterior first phalanges; anterior and posterior second phalanges were more or less equally represented (tab. 6).

To summarise, the high number of individuals, presence of pratically all skeletal parts in large numbers at the site, lack of evidence of deliberate selection for high or for low-utility parts of the carcass and lack of evidence of selection of a particular side of the body, suggest that numerous, intact horse carcasses were originally present at the site below Roche de Solutré. Although death of perhaps one or two horses at the site due to natural causes (eg. old age, disease) cannot be excluded, the location of the site precludes mass deaths of ungulates by drowning, as observed at river crossings (Behrensmeyer 1975) or during episodes of seasonal flooding (Voorhies 1969), deaths at waterering-holes (Haynes 1991), or death due to bogging down in quagmires (Berger 1983). Olsen came to the same conclusions in her 1989 paper. In this analysis, the bulk of the horse remains at the sector P16 site are interpreted as resulting primarily from the hunting activities of the Magdalenians.

The presence of numerous less dense post-cranial bones among the horse remains at sector P16 indicates that the effects of density-mediated bone destruction on this assemblage was minimal. The extremely low numbers of ribs and some axial elements are certainly related to some extent to the fragility of these bones. However, the possibility that the differential preservation of parts of the horses back, as well as variations between ratings for leg bones (humerus, radius, femur and tibia) and their skeletal neighbours (scapula, pelvis and metapodials) could reflect transportation of these skeletal parts away from the site by humans for example, cannot be excluded.

The frequencies of portions of bones such as the scapula, humerus, pelvis and femur, show a positive correlation with intrabone variations in density recorded for these elements in other large-medium sized ungulates. Negative correlations were observed for the shafts and ends of radii, tibiae, metacarpals and metatarsals of horse. The low counts for the shafts of these bones may be related to the initial fracture of these elements by humans, resulting in a reduction or loss of bone prior to subsequent post-depositional and post-burial destruction. Similarly, low numbers of some portions of the mandible, including the robust mandibular symphysis, and the differential preservation observed between anterior and posterior mandibulary cheek teeth may also be the result of humans initially smashing horse jaws into smaller pieces in order to obtain marrow.

The bone assemblage is further characterized by portions of horse carcasses recovered in anatomical connection. Several sections of connecting vertebrae of horse were recorded during excavation and some post-cranial bones could also be re-articulated during analysis of the bone assemblage. Upper and lower cheek tooth rows or portions of these were often recorded in connection during excavation and are also characteristic of the assemblage of horse bone from sector P16.

Determination of horse age, sexual demography and season of death on certain skeletal elements

The age structure of the horse population from sector P16

Cheek tooth height and wear ageing

Although a rough correlation between horse age and premolar and molar tooth heights had already been established by Cornevin and Lesbre as early as 1894, Levine (1979; 1982; 1983) was the first researcher to apply these data to large assemblages of fossil horse teeth. Solutré was one of nine archaeological sites she chose to study for her archaeozoological analysis of Upper Pleistocene horse bone assemblages in western Europe. Using tooth eruption and wear sequences and crown height-wear curves, Levine interpreted fossil horse population structure and mortality models. By referring to data from several workers including Cornevin and Lesbre (1894) Barone (1954), Axe (1905) and Küpfer (1937) and including her own data from a series of New Forest Pony skulls, she compiled a series of tables in which the erup-

tion-wear stages of deciduous and permanent upper and lower premolars, molars, and incisors and the crown height-wear of permanent upper and lower cheek teeth, adapted to the limits of the fossil material, were listed (Levine, 1979, Appendix III; 1982, Appendix 1).
I used the data in Levine's tables to age 232 upper and lower deciduous and permanent horse cheek teeth from the sector P16 site. Levine (1982) states that horse teeth cannot be accurately aged if they cannot be precisely identified and for this reason, my sample comprises only those teeth which could be definitely identified to tooth type and position in jaw. Following these criteria, the crown-heights of 58 lower and 145 upper, identifiable, permanent cheek teeth (P2-M3) were measured following the method described in Levine's work (1979, fig. 21; 1982, fig. 2), and aged using data in her comparative crown-height tables. Deciduous teeth were aged using comparative wear-stages in Levine's tables. These elements are underrepresented at P16, and the wear stages of only six lower and 23 upper deciduous premolars could be assessed.
The results of the current analysis of the P16 horse teeth are shown in figure 11. Each age-class represents 10% of the natural ecological longevity of the horse. The natural longevity was set at 20 years (Klingel and Klingel 1966). The numbers of teeth in each age-class were 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). A similar percent (29%) is in age-class 5 (8-10 years). 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, prime adult and old – for her assessments of mammalian mortality patterns. She defines »juveniles« as from birth to the age at which a particular taxon-dependant deciduous tooth is shed (approximately the first 20% of the natural longevity according to Lyman [1994]). »Prime adult« is the breeding age and »old« are past their prime adults (approximately the last 30% of the natural longevity [Lyman 1994]). These criteria were applied to the age-classes from the P16 sample. The juvenile class was defined as from birth to the age at which the last deciduous cheek tooth in the horse, the dp4, is lost. According to Levine this tooth is shed at between $3^1/_2$-4 years from the upper jaw and at between $3^1/_2$-$4^1/_2$ years from the mandible; a time-range of $3^1/_2$-$4^1/_2$ years. Using Lymans method of calculation, the first 20% of the natural longevity of horse used here is four years, which compares well with the range given by Levine for the dp4. Thus, the boundary from the juvenile to the prime adult age-class was placed between age-classes 2 and 3 (2-4 and 4-6 years) for the horses from P16. Prime adults range from age-class 3 to age-class 7 (4-6 and 10-12 years). Old animals, representing the last 30% of the natural longevity, occupy the age-classses 7-10 (12+ years). Using this method, teeth from juveniles can be seen to form about 15% and old horses only about 13% of the sample from P16. The bulk of the teeth, some 76%, are in the prime-adult group.

Incisor tooth ageing

Horse incisors are also useful for ageing due to the presence of a deep opening, called the infundibulum, which runs through the middle of the tooth from the occlusal surface to almost half-way down the crown. On the occlusal surface, the form of the infundibulum changes as the tooth becomes worn down. In very worn teeth, the tip of the pulp cavity appears as a small mark on the occlusal surface next to the infundibulum and after the infundibulum disappears, the pulp cavity is the only characteristic observable (Levine 1982, fig. 3).
Major changes in infundibulum form – termed »unworn«, »oval« and »round«, and the appearance of the pulp cavity - called the »star« –, have been recorded and approximately aged by several researchers (see for example Habermehl 1961). Levine (ibid.) states that this method of ageing can be used quite accurately up to eight years, and is less accurate after this time. However, age-ranges attributable to changes in infundibulum form are usually very long, and this also appears to be the case for incisors from horses younger than eight years of age. For example, the third permanent upper or lower incisor can be in the oval infundibulum stage for anything between 5 to 9 years (Levine 1979; 1982). Because of this, and due to the fact that the bulk of the permanent incisors from P16 had already reached the oval infundibulum stage, I recorded infundibulum form only on a small sample of 47 permanent horse incisors,

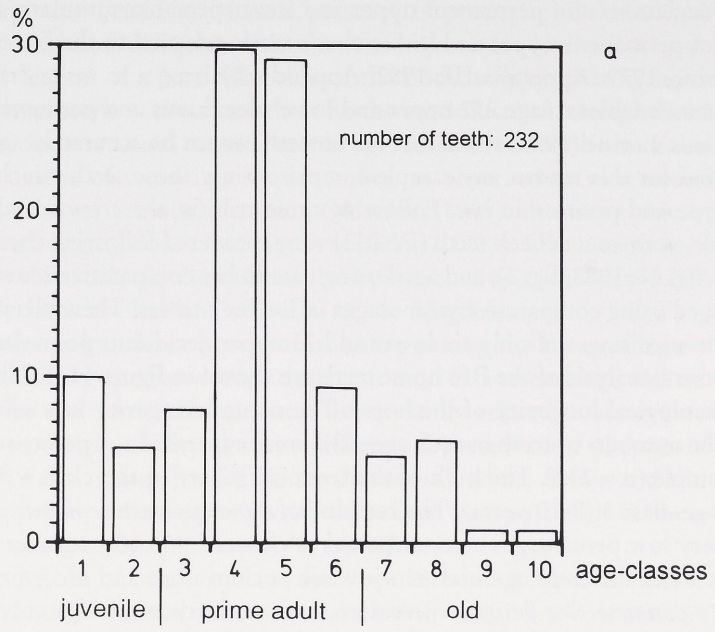


Fig. 11 The age-structure of the horse population from sector P16 at Solutré based on cheek teeth crown heights and wear stages. Each age-class represents 10% of the natural longevity of the horse, which was set at 20 years in this study.

not with the intention of approximately ageing each specimen, but to see if clusters of incisor occlusal patterns produced a population structure different to that produced by ageing cheek teeth.
Counts of permanent incisor teeth with a particular infundibulum form/presence of pulp cavity are listed below in order of increasing age from the youngest (unworn) to oldest (star):

unworn	oval	round	star
2	29	9	7

The majority of the teeth, 29 finds or 61.7% of the sample, have oval infundibulums, a stage reached at any time between three and nine years of age. Nine teeth (19.1%) have round infundibulums, a stage reached at between 5-11$^1/_2$ years. These age-ranges comprise the older part of the juvenile group and the prime adult group as established on the horse cheek teeth. Very young animals, represented by the unworn specimens, formed only 4.2% and old animals, represented by the star, form 14.8% of the sample. The bulk of the incisors sampled here belongs to older juveniles and prime adults. Very young and old horses are represented by lower percentages. This pattern is similar to that observed in the population structure established on the cheek teeth (fig. 11).

Epiphyseal fusion stages of post-cranial bone

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 and mostly by 3$^1/_2$ years (Levine 1982), the use of epiphyseal fusion is restricted mainly to the juvenile group. Thus epiphyseal fusion stages were used here in an attempt to extract more details about the number of juvenile horses and their ages at death, than could be obtained from the tooth crown height and wear analysis.
Epiphyseal fusion stages were recorded on several skeletal elements of horse, but not on the cranium as these bones were too fragmentarily preserved to be of use. The elements used, the portion of the bone

bone	portion of bone	fusion stages observed	number of bones in fusion stage	number of individuals (MNI) in fusion stage
Fore limb				
humerus	proximal epiphysis	unfused	2	1
	distal diaphysis	unfused	1	1
ulna	proximal diaphysis	unfused	5	4
radius	proximal epiphysis	unfused	1	1
	distal diaphysis	unfused	6	3
	distal epiphysis	unfused	7	5
metacarpus 3	distal diaphysis	unfused	1	1
	distal epiphysis	unfused	1	1
Rear limb				
femur	proximal epiphysis	unfused	6	3
tibia	proximal diaphysis	unfused	2	1
	distal diaphysis	unfused	3	2
	distal epiphysis	unfused	3	2
calcaneum	tuberositas calcanei	unfused	8	4
	as above	fusion line visible	1	1
Feet				
phalange 1	proximal diaphysis	unfused	1	1
	proximal epiphysis	fusion line visible	1	1
	proximal diaphysis/epiphysis	fusion line visible	2	1
phalange 2	proximal diaphysis	unfused	2	1
	proximal epiphysis/diaphysis	fusion line visble	3	1

Tab. 10 Epiphyseal fusion stages of horse limb and foot bones from sector P16 at Solutré.

bone	portion of bone	fusion stage observed	number of bones in fusion stage	number of individuals (MNI) in fusion stage
Vertebra				
axis	caudal plate	unfused	7	6
other cervicals	cranial plate	unfused	4	1
	caudal plate	unfused	19	4
	cranial and caudal	unfused	11	2
	cranial	fusion line visible	4	1
	caudal	fusion line visible	5	1
thoracic vertebra	cranial plate	unfused	1	1
	caudal plate	unfused	32	2
	cranial and caudal	unfused	9	1
	corpus caudal	fusion line visible	9	1
lumbar vertebra	caudal plate	unfused	27	7
	cranial and caudal	unfused	22	4
	corpus cranial	fusion line visble	1	1
	corpus caudal	fusion line visible	7	2
caudal vertebra	corpus caudal	fusion line visible	1	1
	cranial and caudal	fusion line visble	1	1
sacrum		unfused	4	1
pelvis	acetabulum	unfused	4	4

Tab. 11 Epiphyseal fusion stages of axial elements of horse from sector P16 at Solutré.

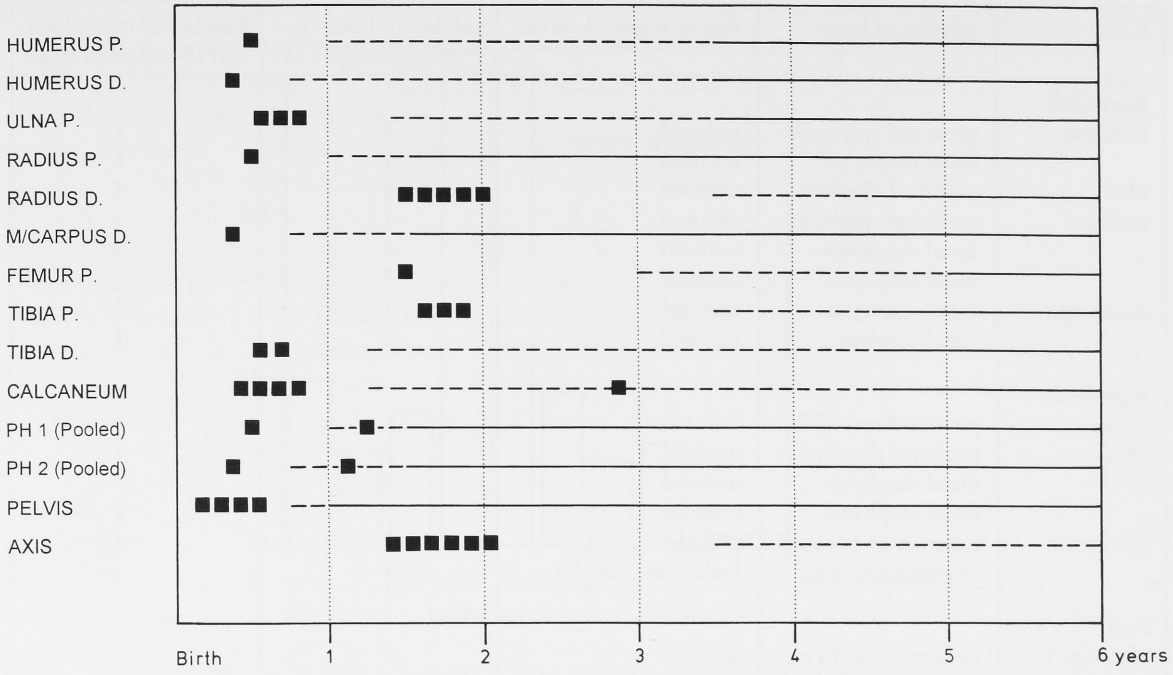


Fig. 12 Epiphyseal fusion stages of post-cranial horse bones from sector P16 at Solutré. Black squares each represent one individual (MNI) in a particular fusion stage. Three main fusion stages were plotted from birth-6 years of age: unfused = without line; fusing, but not fully ossified = discontinuous line; fused = continuous line. For example, six individuals have unfused caudal plates on their axis vertebrae (bottom line) ageing them to anytime between birth and $3^1/_2$ years when fusion begins in this element. Fusion stages based on data given in Levine (1979) and Schmid (1972). P = proximal; D = distal. PH = phalanges, data pooled from anterior and posterior specimens.

and its fusion stage, the number of times this fusion stage was recorded, and the minimum number of individuals in a particular fusion stage are listed in tables 10 and 11.

Axial elements, such as cervical, thoracal, lumbal and caudal vertebrae, and the sacrum, all fuse relatively late in mammals, and the horse is no exception to this. More information about the ages of young horses at P16 was therefore obtained from the fusion stages of fore and hind limb bones, bones of the foot, the pelvis, and the axis vertebra. The fusion times of these elements and the number of individuals in each fusion stage are depicted in figure 12. Approximate ages of fusion were based on published data taken from Levine (1979) and Schmid (1972). Fusion times are depicted from birth up to six years of age, and three major stages of fusion are shown: the unfused stage, the stage where the epiphyses are fusing, i.e. the epiphyses are attached to the bone, but not completely ossified, and the stage where the epiphyses are completely ossified with the bone.

Three individuals were recorded on unfused epiphyses of the proximal tibia and the proximal ulna, and four individuals on the pelvis and the calcaneum. Five individuals were represented by unfused distal epiphyses of the radius. However, the highest minimum number of six juvenile individuals at P16 was recorded on the unfused caudal plates of the axis vertebrae. These six individuals were younger than $3^1/_2$ years of age at death, this being the time when fusion of the vertebral plate to the corpus or vertebral body begins in the axis. Unfused elements such as the second phalange and the distal humerus show that some horses could have been as young as 9 months of age at the time of their death. The highest minimum number of six juvenile individuals represents 13.3% of the minimum number of 45 individuals of horse from the P16 site. This percentage is slightly less than the percentage of juveniles assessed on cheek teeth (fig. 11).

Sexual demography

Two main features can be used to distinguish male and female horses (Levine 1979), the presence or absence of canines and the shape of the pelvis. The latter is only rarely used for fossil remains as pelves are almost always fragmented in fossil assemblages (Sisson and Grossman 1953).
Although canine teeth have been observed in female horses, they are more commonly found in the jaws of stallions. Sisson and Grossman (1953) report on observations of canine presence undertaken in 8,000 horses which showed that about 2-3% of the mares had canines in both jaws and 20-30% had canines in the lower jaw. A total of only three canines, one upper, one lower and a third unerupted in a mandible symphysis was recorded from sector P16. Although canines are usually underrepresented in fossil assemblages, the extremely low representation of this tooth in the P16 assemblage, which was relatively well preserved and where even fragile elements such as foetal bones (see below) were recovered, suggests that low numbers of canines are related to the dominance of females among the horses which died at the site.

Season of horse death using foetal bones and tooth increment analysis

Four bones from horse foetuses were present in the bone assemblage from the sector P16 site. Foetal bones were easily recognisable by their extremely small size, the presence of unfused diaphyses and a highly corroded state of bone preservation observable only on these finds. The remains represent two foetuses, one of which was about 36 weeks (about 9 months) at the time of death of the mare and one in which the foetus was in a slightly younger stage of development when its mother died. In the following description, identification to species of the foetal skeletal elements was carried out using criteria published by Prummel (1987), and the developmental age of two of the bones was established using comparative measurements given by Habermehl (1961) for foetus bones of domestic animals.
– a right humerus, with unfused proximal and distal ends, epiphyses missing (P16 33-447).
This bone was identified as horse by its pronounced *tuberositas deltoidea* – a morphological feature which is already well-pronounced in horse foetuses at 230 days – and the presence of a foramen nutritica on the medial side of the bone towards the distal end, which is absent in the humeri of other large mammals of comparable body-size such as bovids. The humerus measured 102.9 mm long, which places age at death of this foetus at around 36 weeks (humerus length at 35 weeks: 95.0 mm and humerus length at 37 weeks: 112.0 mm, Habermehl 1961, Tab. 2).
– a right femur, proximal and distal ends missing (P16 89-591).
This bone was identified as horse due to the deep *Fossa plantaris*, the presence of a pronounced *trochanter minor*, and a well-developed third trochanter (*trochanter tertius*) which is developed in the horse foetus from day 230. The shaft measured 121.1 mm in length which, allowing for its incompleteness, places the death of this foetus at around 36 weeks (mean femur length at 35 weeks: 118.0 mm and at 37 weeks: 140.0 mm, Habermehl ibid.).
– a left femur shaft, proximally unfused, distal part of shaft missing (P16 79-611).
The shape of the bone and the presence of a *foramen nutriticum* mid-shaft on the caudal face indicate that this poorly-preserved find is a femur. The length of the bone could not be measured, but the specimen was slightly smaller in size than the right femur described above, and is from a second foetus whose development terminated at an earlier stage.
– a fragment from the right pelvis, including part of the acetabulum and the base of the ilium (P16 78-606). The slender form of the ilium is typical of horse; the ilium bone from bovid foetuses are thicker. The ilium, ischium and pubis bones fuse together in the acetabulum after birth (Habermehl 1961).
Thus, skeletal elements from two horse foetuses could be identified at P16. One foetus was about 36 weeks old when the mare died. The femur from the second foetus was slightly smaller in size, possibly from a foetus which was two weeks younger. As horse gestation lasts for almost one year (345 or 348 days [Berger 1986]), the two mares at Solutré died about $2^1/_2$ 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 between February and March.
A more reliable method of determining season of death is the analysis of incremental bands of tooth cementum. During her study of faunal remains from Solutré, Sandra Olsen submitted a sample of 75 horse teeth from the Aurignacian and Magdalenian levels to Margaret Beasley at the University of London for tooth increment analysis. Included in the sample were six teeth from Magdalenian deposits in sector J10 at the site. Beasley's results were published in Olsen's article about Upper Palaeolithic hunting strategies (1989, Tab. 3), and approximate season of death for the sample from the Magdalenian deposits in J10 was given as spring/early summer for two teeth. Two further specimens were from horses that had died in summer and two teeth from animals that had died in winter. Similar results, including specimens from horses which had died in autumn, were obtained from the sample of teeth in the Aurignacian deposits (sectors M12 and L13). Olsen concluded that »... horses were hunted from the spring through the fall, with the greatest concentration occurring in the summer months« (ibid. p. 303).

Ecology and Behaviour of the Horse

There has been relatively little systematic collection of data concerning equid behaviour in the wild (Levine 1989). Interest in such studies developed at a time when wild horse populations were already on the verge of extinction or were managed in, for example, zoological gardens under circumstances which disturbed their natural social patterns (ibid.). Extant equids can be separated into two main groups, territorial and non-territorial, based on their social organisation. The Plains zebra, Mountain zebra, Przewalski horses, feral and domestic horses are non-territorial and some comparative ethological data can be gleaned from the behaviour of the Plains zebras and from historic records of Przewalski horses in the wild. The following is taken mainly from Levine's (1979) description of non-territorial horse ethology which includes information from Klingel's detailed studies of Plains zebra (Klingel 1965; 1969a; 1969b).
Wild equids occur together in two different types of groups, the bachelor group and the family group. The bachelor group consists, as its title suggests, only of male horses. Young males generally leave their family groups when they reach 2-4 1/2 years of age and become part of a bachelor group. They may stay in this group for the rest of their lives or leave when physically and psychologically mature at around 5-6 years, to establish their own harems. Stallions which have lost their harems of females due to ill health or old age may also attach themselves to bachelor group and a bachelor group may be led by an older male. Up to 15 individuals have been observed in bachelor groups of Plains zebra, more commonly there are 2-3 horses in the group.
The family group consists of several mares, their foals and a stallion. Thus, a family group can consist of all age categories including very young foals, sexually mature young adults, prime adults and old individuals. The mares form the stable core within this group, and if the stallion is displaced or lost, another male can take the group over as a unit. The mares are held together by personal bonds and have a hierarchical order, with the most dominant mare leading the group. Stallions do not try to abduct adult females, but will abduct young mares between 1-2 1/2 years of age. At this age, young mares adopt a certain posture during oestrus, which is highly attractive to mature males. Young mares are often abducted several times and move from family group to family group, until they are about 2-2 1/2 years old, at which time they no longer display during oestrus and simply stay with the group that they happen to be in at that time as the least dominant mare. Mares as young as 3 1/2 years have been observed with foals, and were probably 2 1/2 years old at the time of conception. The mare gives birth within the vicinity of the family group with the stallion remaining close by, probably as a protector against predators. After the foal is born, the mare returns to the group, but does not allow any other members of the group to approach the foal too closely for a number of days.
Horses often move in single file with, in the case of family groups, the dominant mare and her foal leading and the remaining members following her trail. The stallion generally walks at one side of the mares or follows at the rear (Olsen 1995, fig. 6). One of the stallion's main roles is the protection of the

family group, and in dangerous situations the stallion initiates flight and sometimes stands between the agressor and the mares (Olsen ibid.; Klimov 1986).
Groups of horses migrate seasonally through their ranges, and in regions with marked topographical relief, equids inhabit plains and river valleys in winter, moving up into the hills in spring where they remain during the summer months, and returning to lower-lying lands in autumn (Olsen 1995). Horses undertake seasonal movements for a number of reasons, but mainly to prevent depletion of grazing land, to have access to water in winter in lower-lying areas, where they can also avoid deep snow-cover; in the summer, temperatures are cooler in higher lying areas than in the valleys and there are fewer biting insects (Olsen ibid.).

Summary

Information about the age-structure and sexual demography of the horse population from sector P16, and evidence of seasonality of death of the population was gleaned from cheek tooth heights, tooth wear stages, incisor tooth ageing, epiphyseal fusion stages of post-cranial bone, numbers of canine teeth, stages of foetal development and the results of an incremental analysis undertaken during an earlier analysis (Olsen 1989) on a sample of horse teeth from Magdalenian deposits in sector J10.
The bulk of the teeth (30%), sampled in the current analysis, was aged to between 6-8 years. A similar percent (29%) was aged to between 8-10 years. Very low percentages were recorded for older horses aged 16-20 years. The remaining age-classes are represented by 10% or less of the teeth sampled. When this mortality pattern is expressed in terms of broader age-classes – juvenile, prime-adult and old – teeth from juveniles form about 15% of the sample and old horses only about 13%. The bulk of the teeth, a total of about 76%, is in the prime-adult group.
Similar results were obtained from incisor tooth ageing; the majority of the incisors in the sample belonged to older juveniles and prime adults. The presence of six horses younger than $3^1/_2$ years of age at death, was established using post-cranial epiphyseal fusion stages. Unfused elements such as the second phalange and the distal humerus show that some of these horses could have been as young as 9 months of age at the time of their death.
On the whole, the large number of individuals, presence of very young horses and a dominance of prime-adults in the population, suggest that several family groups of horses died at the site. However, as it is impossible to separate faunal remains from P16 into discrete depositional events, the possibility that males from a bachelor horse group also died at the site cannot be excluded, as the inclusion of a few males from a bachelor herd would not drastically alter the age-profile shown in figure 11, and may even explain the high percentages of prime adults. An important, final role is therefore played by the extremely low numbers of canines recovered at the site, indicating that the population consisted mainly of mares. This, combined with the presence of horses as young as nine months at death and pregnant mares, indicates that the bulk of the horse remains recovered at sector P16 originated from horses living together in family groups.
According to foetal bone development, two mares died sometime between February and March. 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). Analysis of incremental bands of tooth cementum shows that horses died in spring/early summer, summer and winter (Olsen 1989). These results indicate that horses were killed during periods when both males and females are in poor condition (spring/early summer), in periods when their condition is improving (summer) and in periods when their condition is declining (winter) (West ibid.).

Evidence of human modification of horse bones

Cut marks

The surfaces of all the bones, including those of horse, were inspected for traces of cut marks. Bones were inspected by holding them under a bright lamp, using a hand-held magnifier (x8). During the course of this analysis a number of surface marks other than cut marks, were observed on the finds. These include surface marks produced during excavation and curation, as well as multiple, fine, parallel striations across a broad area of bone probably caused by the post-depositional movement of finds down the slope at the site, and U-shaped scratches produced by the teeth of carnivores and rodents. Cut marks produced by stone tools were identified by their V-shaped grooves. These appear on the P16 bones as groups of parallel marks, groups of superimposed marks and as isolated marks. They vary in length, thickness and depth. The antiquity of these marks was often shown by root-etching superimposing the cut marks and/or the presence of manganese staining in the cut mark groove.
After analysis, marks on only 70 horse bones could, in some cases tentatively, be attributed to human activities (see Olsen 1989 and Berke 1989 for descriptions of humanly modified bones from sector P16 seen during the course of their analyses). Some of the marks recorded during the current analysis as cut marks and described below are very superficial, mainly due to weathering of the bone surfaces, and it is possible that these marks were produced by other agents. But even when these more ambiguous marks are included in the count, the total number of 70 horse bones with cut marks is still low. Despite the low numbers, cut marks produced during evisceration, carcass disarticulation or dismemberment, filleting, tendon removal and, possibly, skinning, could be identified on the horse bones. Cut marks produced during dismemberment and filleting of horse carcasses are comparable with Binford's (1981) description of cut marks made by Nunamiut Eskimo during butchery of caribou and Dall sheep.

Head (fig. 13, 1)

Cut marks were observed on only one bone from the skull, the fragment of an occiput (P16 22-163) (plate 3, 1). Two sets of cut marks were recorded on this find, one set on the left and one set on the right side of the exocranial face of the bone. The cut marks are located on the bony ridges of the bone and consist of medium to long grooves of varying depth, positioned parallel to each other and transverse across the bone. When the head of an animal is dismembered from the neck, cut marks are usually found on the condyles of the occiput. The cut marks described here are placed higher, but probably resulted from the same disarticulation process.

Mandibles (fig. 13, 2)

Sets of cut marks were recorded on the ascending ramus of two left and three right mandibles (plate 4, 1-5). The sets consisted of parallel cut marks (up to 10-11 in one set) of varying length, transverse to the long axis of the ramus and located on the lateral face of the bones. Only in one case (P16 46-177) were cut marks also recorded in this position on the inner or medial face of the jaw. Transverse cuts across the masseteric fossa are usually produced when the masseter muscle is cleaned off the jaw, a process termed filleting in situ by Binford (1981, p. 109). Marks located towards the base of the ramus on the medial side of one mandible, may be related to removal of the tongue. Traces of carnivore gnawing were found on only one mandible with cut marks (P16 47-102) (plate 4, 1. 3).
Cut marks were also observed in the area of the mandible symphysis. One fragment bore a set of eight cut marks on the left side of the inner, or lingual, face of the symphysis (P16 79-217), which again may be related to removal of the tongue (plate 3, 2-3). A set of ambiguous surface marks on the lateral face of a right mandible from a juvenile horse (the remains of the alveola for the first deciduous tooth was

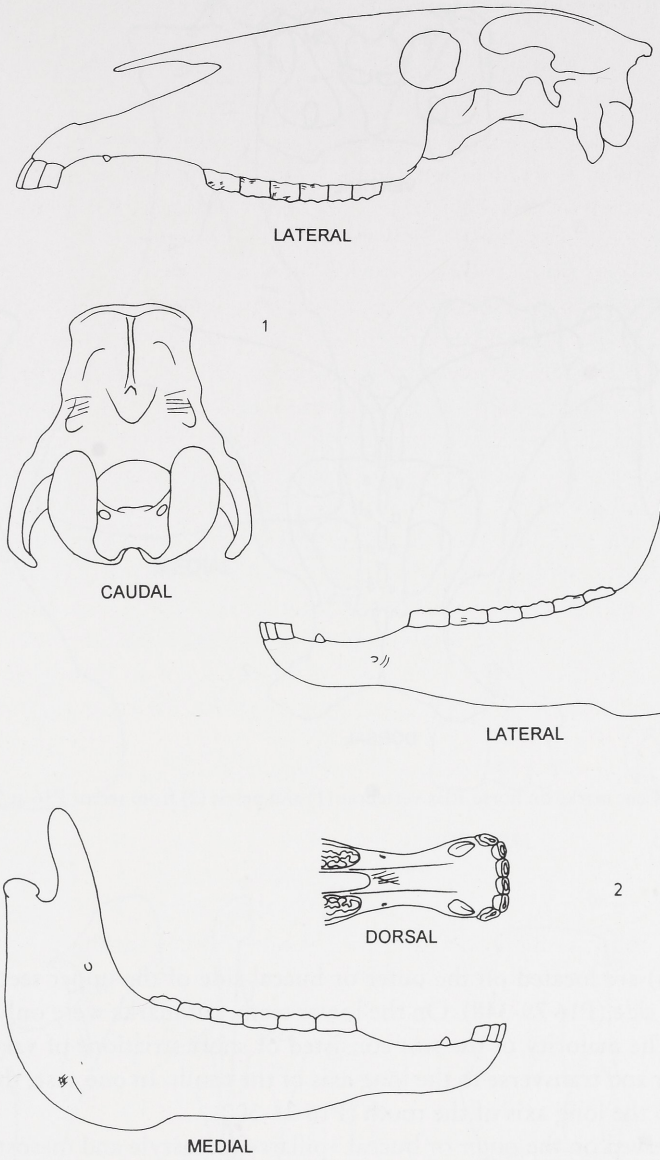


Fig. 13 Location of cut marks on horse crania (1), mandibles (2) and teeth (top figures in 1 and 2) from sector P16 at Solutré.

still preserved) was difficult to determine, as the mandible was highly weathered. These marks may have been caused by non-human agents, but did not resemble those produced by carnivores.

Teeth (fig. 13, 1 and 2)

Sets of cut marks were recorded on the crowns of six isolated, permanent upper cheek teeth and on three teeth which formed part of a permanent upper cheek tooth row. An isolated upper dp3 also bore traces resembling cut marks on its crown. Two lower permanent cheek teeth had cut marks located in a similar position to those on the upper dental elements.

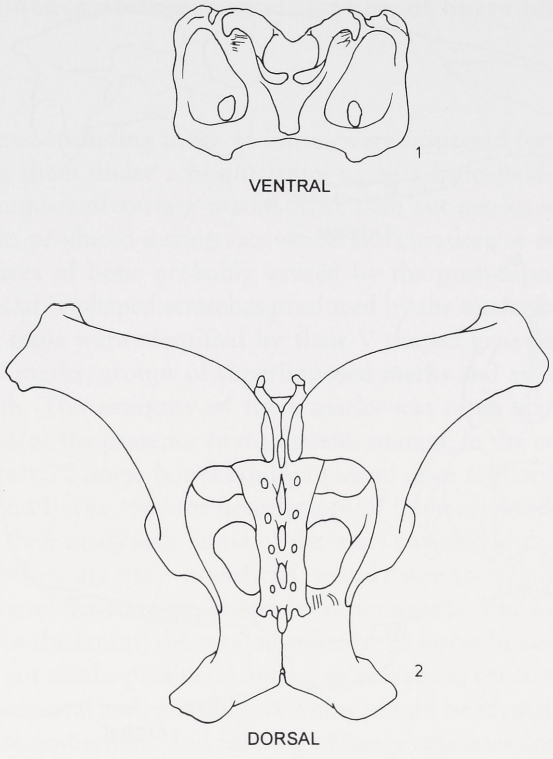


Fig. 14 Location of cut marks on horse atlas vertebrae (1) and pelvis (2) from sector P16 at Solutré.

The cut marks (plate 3, 4-5) are located on the outer or buccal side of the upper teeth and, in one instance, on the lingual tooth side (P16 79-348). On the lower teeth, cut marks were only observed on the buccal side of the crown. The majority of the sets consisted of short striations of varying depth, positioned parallel to each other and transverse to the long axis of the tooth. In one case, the cut marks were positioned perpendicular to the long axis of the tooth (P16 24-500).
Usually the marks are preserved on the outer or buccal »pillars« (parastyle and mesostyle) of the upper teeth and the buccal »lobes« of the lower teeth (protoconid and hypoconid), these being the parts of the crowns which protrude outwards, and would be nicked by stone tools passing over the buccal surfaces while cutting parallel to the edges of the maxillary and mandibulary bones. Cuts were positioned either close to the edge of the occlusal surfaces, or about 10 mm below. Those placed lower down on the crown of the tooth are at the same level as the bony edge of the jaws (plate 3, 5). All these marks were probably produced when the gingival tissue was cut away from the jaws.

Cervical vertebrae (fig. 14, 1)

Transverse cuts across the ventral surfaces on the cranial ends of three atlases were recorded (plate 4, 6-7). These cut marks were produced during dismemberment of the head from the cervical column. Their occurrence shows that at least three heads were processed in this manner. One of these finds (P16 44-196) has been gnawed by carnivores.
Superficial marks were observed on the left side of the caudal end of a fourth atlas, their location indicates separation of segments of the neck.

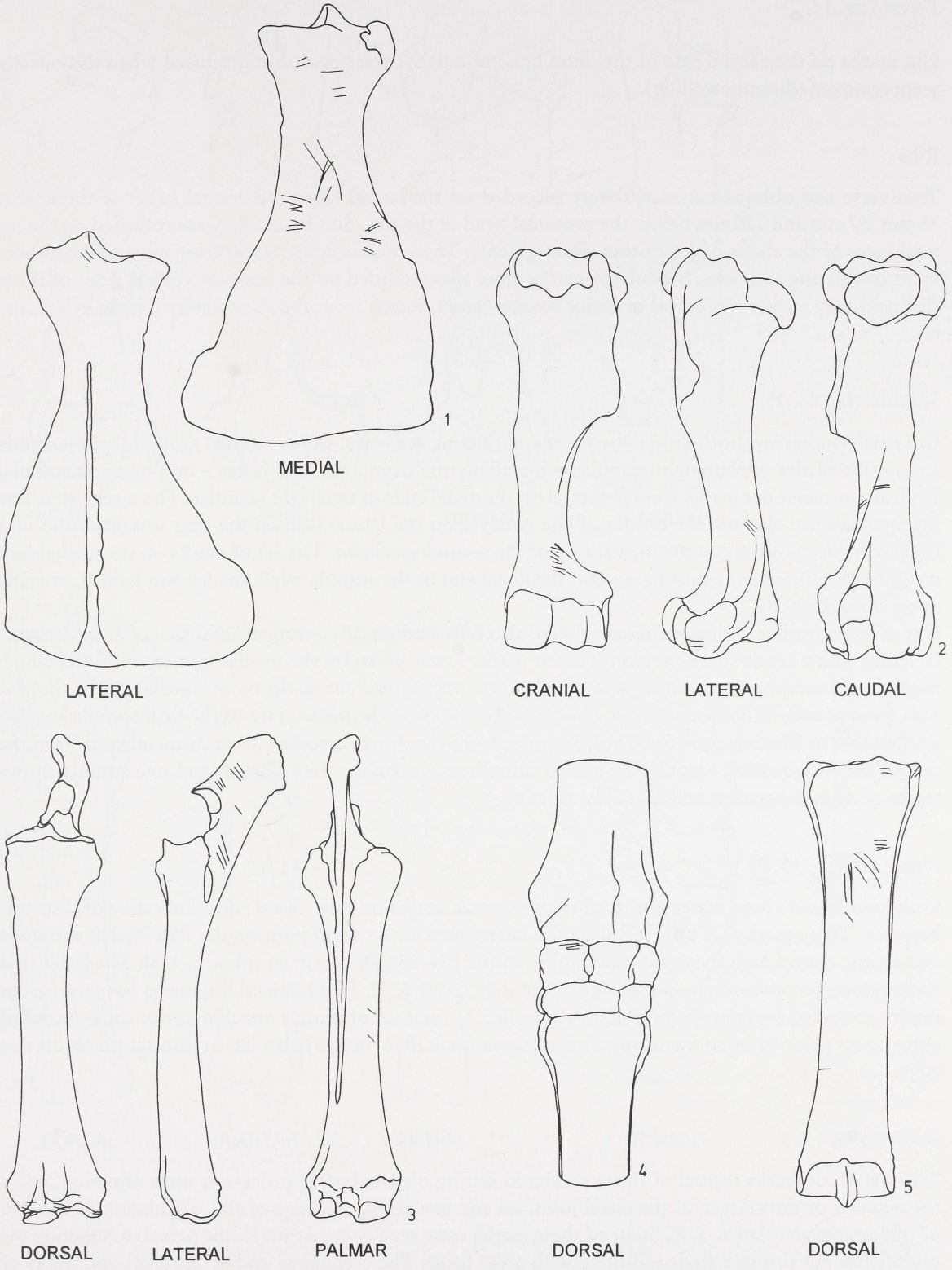


Fig. 15 Location of cut marks on fore-limb bones of horse from sector P16 at Solutré. – 1 Scapula, lateral and medial views; 2 humerus, cranial, lateral and caudal views; 3 radius and ulna, dorsal, lateral and palmar views; 4 carpals, dorsal view; 5 metacarpus 3 and 4, dorsal view.

Pelvis (fig. 14, 2)

Cut marks on the ventral side of the ilium bone of a pelvis were probably produced when the entrails were removed (disembowelling).

Ribs

Transverse and oblique cut marks were recorded on the lateral faces and cranial edges of three ribs, 35 mm, 57 mm and 120 mm below the proximal head of the ribs. Similar marks were recorded on the lateral faces of the shafts of four other rib fragments. These marks could result from either dismemberment or filleting activities. Sets of cut marks were also recorded on the inner or ventral sides of three ribs, and may attest to removal of major organs (heart, lungs) from the chest cavity during evisceration.

Scapula (fig. 15, 1)

Cut marks indicating both dismemberment and filleting activities, were recorded around the distal ends and on the blades of four right scapulae – including one from a juvenile horse – and on a left scapula. Typical transverse cut marks were observed on the distal ends of two right scapulae. The marks were positioned close to the inferior border of the condyle on the lateral face on the first specimen and in a slightly higher position on the medial face of the second specimen. The set of marks on the medial face could have resulted from cutting around the distal end of the scapula while the leg was held at an angle away from the body.
Cut marks attesting to dismemberment were also observed distally on the medial face of a third scapula, along with a set of short chevron-like cut marks lower down on the medial face of the blade, which might have been produced during filleting. A set of longitudinal cut marks on the medial face of the scapula from a juvenile horse and short, chevron-like marks on the medial face of the fifth scapula are also attributable to filleting activities Thus, scapulae from two horse carcasses were dismembered from the rest of the fore-quarter, scapulae from two other horse carcasses were filleted, and one scapula shows traces of dismemberment and, possibly, filleting.

Humerus (fig. 15, 2)

Only two humeri bore traces of sets of transverse cut marks on their distal ends, indicative of dismemberment. These marks are positioned on the lateral face of the distal joint on the P16 79-242 specimen and on the cranial face above the distal joint on the P16 66-228 specimen (plate 5, 1-3). The latter find has a carnivore tooth notch on the edge of the shaft (plate 5, 2). Two humeral fragments have sets of cut marks preserved on their shafts probably attesting to removal of muscle attachments or the removal of periosteum prior to bone fracturing: one of these finds (P16 46-179) also has an impact notch on one edge.

Radius (fig. 15, 3)

Transverse cut marks typical of those produced during dismembering processes, were observed across the anterior or dorsal face of the distal joint, on and just above the edge of the articulation of the P16 67-115 specimen (plate 6, 1-2). Some of these marks were very deep as though the person butchering the carcass had cut through flesh and bone with great force. The crenulated end of the shaft and traces of gouging in the spongiosa of the joint show that carnivores had also modified this bone (plate 6, 2, arrow at top of picture). Two isolated, oblique cuts on the dorsal face of a second radius probably result from filleting.

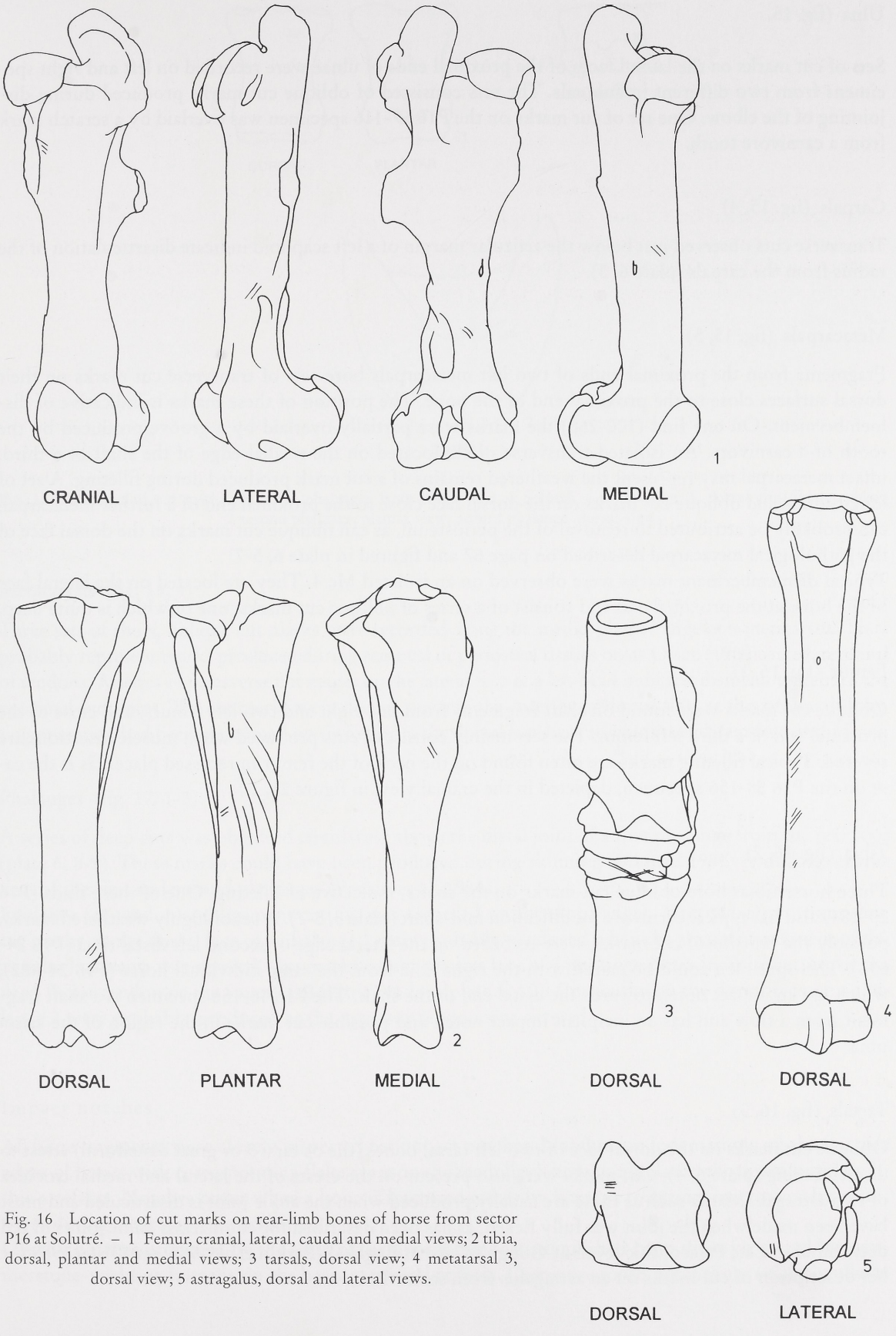


Fig. 16 Location of cut marks on rear-limb bones of horse from sector P16 at Solutré. – 1 Femur, cranial, lateral, caudal and medial views; 2 tibia, dorsal, plantar and medial views; 3 tarsals, dorsal view; 4 metatarsal 3, dorsal view; 5 astragalus, dorsal and lateral views.

Ulna (fig. 15, 3)

Sets of cut marks on the lateral faces of the proximal ends of ulnae were recorded on left and right specimens from two different individuals. The sets consisted of oblique cut marks produced during disjointing of the elbow. One set of cut marks on the P16 67-116 specimen was overlaid by a scratch mark from a carnivore tooth.

Carpals (fig. 15, 4)

Transverse cuts observed just below the articular margin of a left scaphoid indicate disarticulation of the radius from the carpals (plate 6, 3).

Metacarpals (fig. 15, 5)

Fragments from the proximal ends of two left metacarpals bore sets of transverse cut marks on their dorsal surfaces close to the proximal end of the bone. The position of these marks is indicative of dismemberment. On one find (100-268) the marks were partially overlaid by a groove produced by the tooth of a carnivore. An isolated transverse mark, located on the medial edge of the shaft of a third, intact metacarpal may represent the weathered remains of a cut mark produced during filleting. A set of longitudinal and oblique cut marks on the dorsal face close to the proximal end of a further metacarpal, can probably be attributed to removal of the periosteum, as can oblique cut marks on the dorsal face of the pathological metacarpal described on page 67 and figured in plate 6, 5-7.
Typical dismemberment marks were observed on an isolated Mc 4. They are located on the lateral face of the bone at the proximal end and consist of a series of oblique cut marks, one of which is quite deep.

Femur (fig. 16, 1)

Oblique cut marks were found on shaft fragments from one right and two left femurs, and close to the proximal end of a third left femur. The sets mainly consist of cuts produced when muscle insertions are severed. Typical filleting marks are often found on the neck of the femur in recessed places, as is the case on the P16 88-156 specimen, depicted in the cranial view in figure 25, 1.

Tibia (fig. 16, 2)

Three horse tibias bore oblique cut marks on the shafts, indicative of filleting. One of these finds (P16 23-184) also has typical carnivore modification mid-shaft (plate 5, 5-7). A set of highly weathered marks, possibly the remains of cut marks, were recorded on the lateral edge of second left distal tibia (P16 24-536). This specimen could be paired with the right tibia from the same individual horse (P16 24-482), which has an impact notch towards the distal end of the shaft. The P16 46-156 specimen is a shaft fragment from a tibia and has an incipient impact notch and possible cut marks in the region of the crista tibia.

Tarsals (fig. 16, 3)

Oblique cut marks on the dorsal face of two left tarsal bones (the os tarsi 3 or great cuneiform) attest to dismembering (plate 6, 4). Cut marks were also present on the crests of the lateral and medial trochlea of two astragali. Marks such as these are usually produced when the ankle joint is disarticuled and must have been made when the joint was fully flexed, as has been described for cut marked ankle joints of red deer found in Late Palaeolithic levels at Gough's Cave in England (Parkin et al. 1986; see Olsen 1989 for her description of cut marks on an astragalus from sector P16).

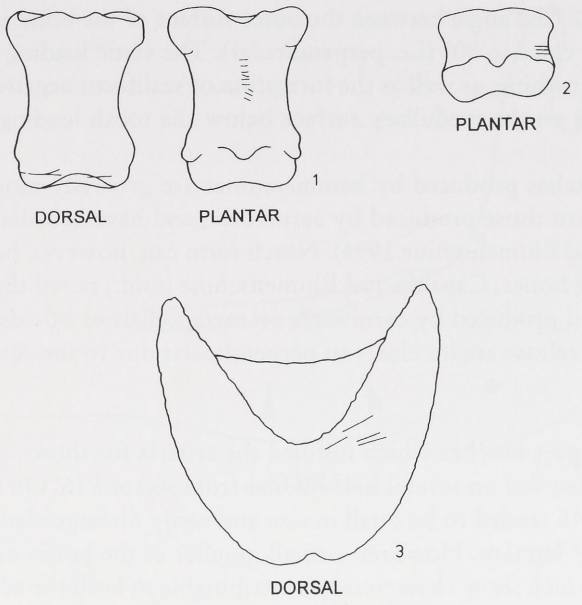


Fig. 17 Location of cut marks on horse phalanges from sector P16 at Solutré. – 1 Phalange 1, dorsal and plantar views; 2 second phalange, plantar view; 3 third phalange, dorsal view.

Metatarsals (fig. 16, 4)

Three sets of short, oblique cut marks were recorded along the medio-plantar edge of a metatarsus. They probably represent marks produced during removal of periosteal tissues or, as Olsen (1989) stated, removal of tendons. A series of transverse cut marks on the lateral face of a left Mt 4 indicates dismemberment of the proximal foot joint. The cut marks were deeper towards the anterior or dorsal side, as though the disjointing operation had been performed by slicing from the dorsal face back towards the plantar face of the joint.

Phalanges (fig. 17, 1-3)

A series of deep cuts was observed circulating above the distal joint of a first phalange from the rear foot (plate 6, 8-9). These marks could have been produced during skinning (Binford 1981) or during separation of the first and second phalanges (Parkin et al. 1986).
Evidence for tendon and ligament cutting was recorded on three phalanges. Multiple, short, transverse cut marks on the dorsal face of a phalange 1 were probably produced when the area of attachment of the annular ligaments was severed. Cut marks on the plantar face of a phalange 2 may indicate cutting of the deep flexor tendon or the superficial flexor tendon (plate 6, 10). Cut marks on the dorsal face of a phalange 3 were probably produced as the extensor tendon was severed.

Impact notches

All bone fragments were closely inspected for impact notches. Notches are indentations on the fracture edges of bones with corresponding flake scars on the medullary surface, similar to those produced on lithic artefacts. Notches occur when a bone is fractured either by humans to extract marrow or by carnivores during their gnawing activities.
Usually notches produced by the teeth of carnivores can be distinguished from those produced by hammerstone-wielding humans on the basis of several criteria. Carnivore tooth notches are semi-circular in

form and the release angle (the angle between the outer surface of the bone and the surface of the flake on the medullary side) is close to 90° (i.e. perpendicular). The static loading of a carnivore tooth leads to surface or subsurface crushing, as well as the formation of scaliform negative flake scars on the bone's thickness (or profile) and on the medullary surface below the tooth loading point (Capaldo and Blumenschine 1994).
Impact or percussion notches produced by hammerstones are generally more arcuate. In other words broader and shallower than those produced by carnivores, and have broader flakes with release angles less than 90° (Capaldo and Blumenschine 1994). Notch form can, however, be affected by the cross sectional shape of some long bones. Capaldo and Blumenschine (ibid.) noted that notches produced experimentally by humans and produced by carnivores on metapodials of bovids (ranging in size from less than 115 to 340 kg), have release angles closer to perpendicular due to the square section of the diaphyses of these elements.

Excellent examples of impact notches which fulfilled the criteria for those produced by hammerstone-wielding humans were observed on several horse bones from sector P16. On the whole, carnivore tooth notches on bones from P16 tended to be small in size and easily distinguishable from impact or percussion notches produced by humans. However, a small number of the bones described below bore ambiguous notches, some of which show characteristics attributable to both the activities of humans and carnivores. Other notches similar in morphology to notches produced by hammerstone blows, were located close to notches more typical of carnivore gnawing activities, so that it was difficult to identify the notch producer with any great degree of certainty.
Altogether 44 bones with impact notches, including the more ambiguous ones, were recorded on horse bones from sector P16. Hammerstone-induced notches were present on the bones of both juvenile and adult horses.

Mandibles (fig. 18, 1)

Notches attributed to the deliberate smashing of horse mandibles by humans can be seen on the P16 79-351 specimen (plate 7, 2). Two notches are located on the medial face of the mandible, just below the tips of the roots of the teeth which are still in their bony sockets. The first notch is arcuate, the second notch more semi-circular in form but the release angle of both notches is acute. A third notch is located at the same height on the buccal face of the jaw. This particular mandible was from a very old horse whose lower teeth were worn down to the base of their crowns. Similar impact notches were also present on a second mandible fragment (P16 68-451).
The low number of impact notches recorded on mandibles is probably due to the preservation of this element. All mandibles at P16 are very fragmentarily preserved, probably due to post-burial sediment compaction. Although some mandibles of horse had been restored as part of laboratory work undertaken during early excavation campaigns, the bulk of the horse mandibles from P16 are still stored in a fragmentary state, making a study of fracture patterns on these elements impossible. That many more mandibles were broken open to obtain marrow than just the two described above, is also indicated by numerous lower premolar and molar teeth with artificially fractured roots. The find depicted in plate 7, 1 (P16 46-229), gives us an impression of how horse mandibles may have looked after marrow extraction, even though impact notches were not preserved on this particular piece.
The lack of any form of observable notches on horse cranial bones is probably due to the thin walls of these elements, and to factors of preservation and curation described above.

Humerus (fig. 18, 2)

Impact notches were observed on shaft fragments from ten humeri. The notches are located mid-shaft on the cranial, lateral and latero-caudal faces of the bones. The majority of the notches and their flakes

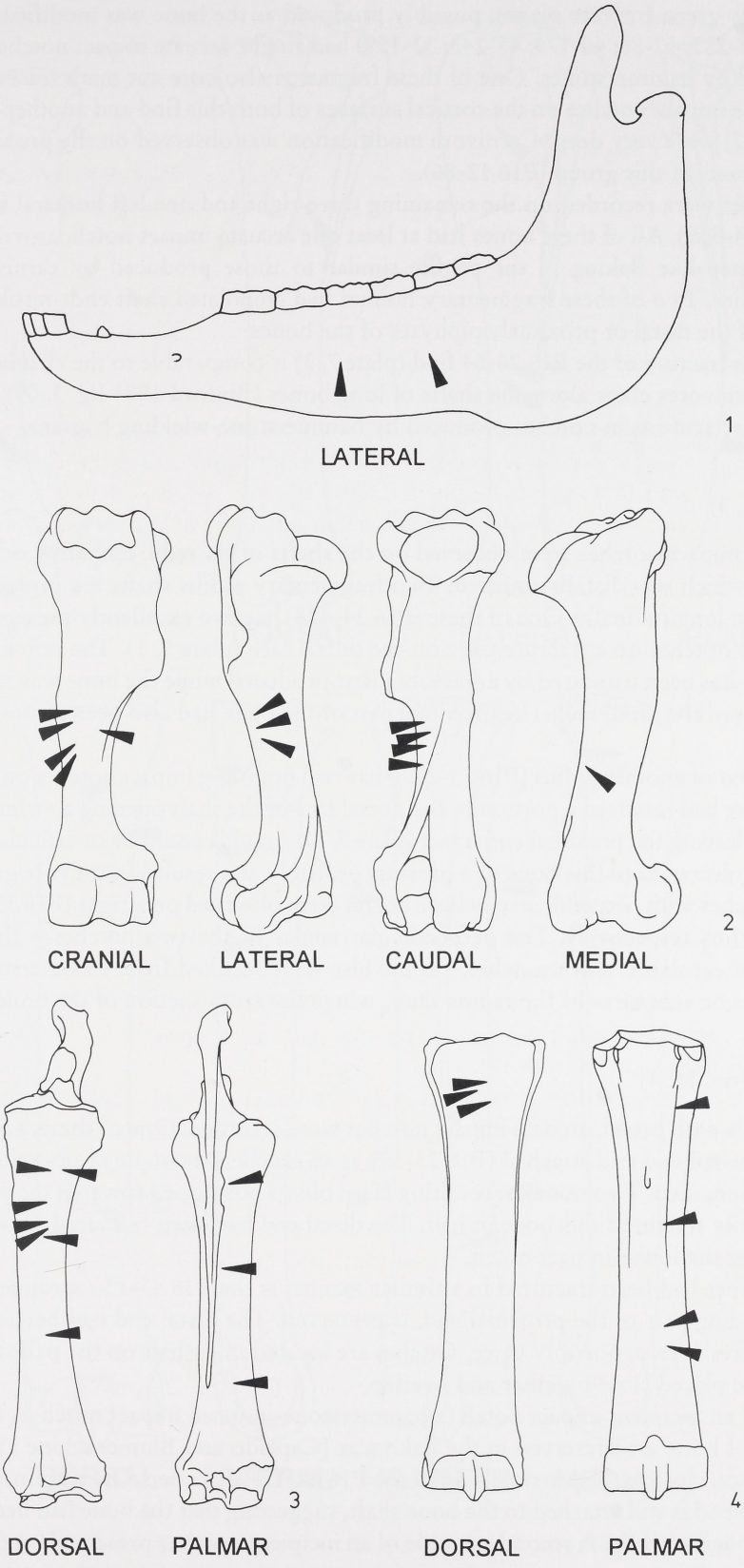


Fig. 18 Location of impact notches on the mandible and fore limbs of horse from sector P16 at Solutré. – 1 Mandible; 2 humerus; 3 radius and ulna; 4 metacarpal.

are truncated by green fracture planes, possibly produced as the bone was modified further. Six bones (P16 67-919; 35-283; 12-86; 46-179; 47-243; 33-159) had single, arcuate impact notches, characteristic of those produced by hammerstones. One of these fragments also bore cut mark traces on the shaft (P16 46-179), and the impact notches on the cortical surfaces of both this find and another specimen (P16 47-243; plate 8, 1-2) were very deep. Carnivore modification was observed on the proximal end of one of the shaft fragments of this group (P16 12-86).
Multiple notches were recorded on the remaining three right and one left humeral shafts (P16 36-137; 21-89; 26-64; 24-539). All of these bones had at least one arcuate impact notch, as well as one or several notches with step-like flaking in the profile similar to those produced by carnivores during their gnawing activities. Two of these fragmentary humeri had crenulated shaft ends resulting from carnivores gnawing off the distal or proximal epiphyses of the bones.
The form of the fracture of the P16 26-64 find (plate 7, 3) is comparable to the channeled breakage produced when carnivores chew along the shafts of long bones (Binford 1981 fig. 3. 09), even though their release angles are acute as in notches produced by hammerstone-wielding humans.

Radius (fig. 18, 3)

Broad, arcuate impact notches were observed on the shafts of six radii, including one specimen from a juvenile horse which was distally unfused. Two fragmentary radius shafts are probably the remains of bones split open longitudinally. One of these (P16 34-428) has two excellently preserved, hammerstone-induced impact notches on a fracture edge on the dorsal face (plate 9, 1). The notch towards the distal end of the shaft has been truncated by a fracture plane produced while the bone was still fresh and which probably removed the distal end. The proximal part of the bone had also been removed in the fresh bone state.
The proximal end of another radius (P16 23-289), has two opposing impact notches on its dorsal face. The resulting fracture had removed a portion of the dorsal face of the shaft opening a »window« into the marrow cavity but leaving the proximal end intact (plate 7, 4). An ulna could be re-articulated with the radius and part of the olecranon of this bone was missing, probably as a result of carnivore gnawing activities.
Two broad notches with perpendicular release angles were observed on a right (P16 33-389) and on a left (P16 44-47) radius respectively. The perpendicular angles of the two notches – thought to be more characteristic of carnivore tooth notches – could also have resulted from hammerstone blows striking the lateral edges or »corners« of the radius shaft, where the cross-section of the bone is right-angled.

Metacarpus 3 (fig. 18, 4)

Five metacarpals with broad, arcuate impact notches were recorded. One of these, a shaft fragment with part of the proximal end still attached (P16 25-59), is an excellent example of intentional splitting of the bone along its long axis. Two notches, resulting from blows positioned towards the proximal end of the shaft, successfully fractured this bone in half. The distal end had been fractured off while the bone was fresh, truncating the lower impact notch.
A metacarpus that had been fractured in a similar manner is the P16 43-156 specimen. Roughly half of the shaft, including part of the proximal end, is preserved. The distal end had been removed when the bone was still fresh. Two, possibly three, notches are located mid-shaft on the palmar face of the bone. The notches are placed close together and overlap.
The remains of an incipient impact notch (a hammerstone-induced impact notch in which one or more nesting flakes of bone are preserved in the flake scar [Capaldo and Blumenschine 1994]) are preserved on the dorsal face, close to the proximal end of the P16 48-154 specimen. Once again, approximately half of the proximal end is still attached to the bone shaft, suggesting that the bone had been opened by splitting the shaft longitudinally. A second example of an incipient notch is preserved on the P16 36-122 specimen.

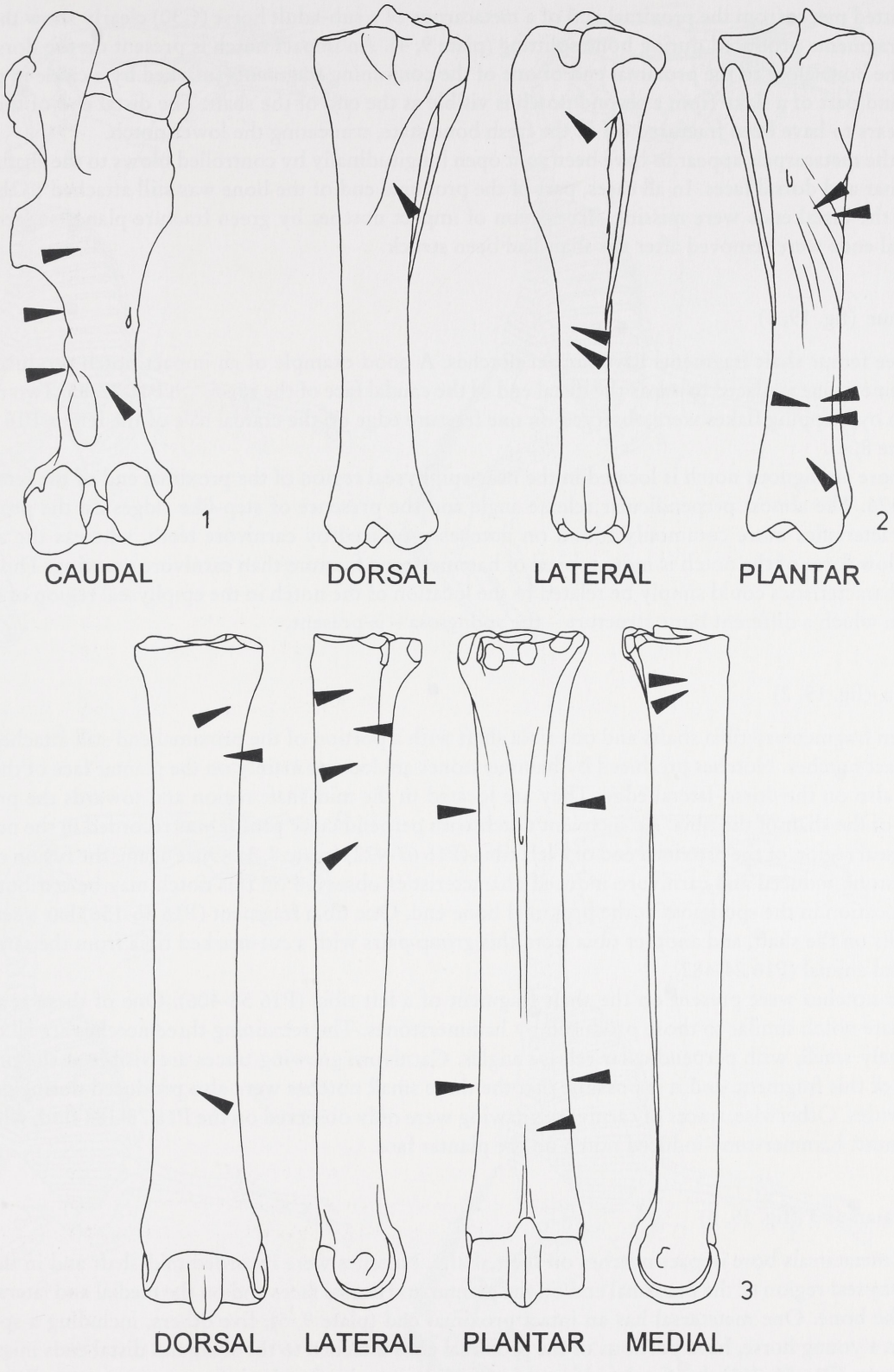


Fig. 19 Location of impact notches on the rear limbs of horse from sector P16 at Solutré. – 1 Femur; 2 tibia; 3 metatarsal.

Refitted pieces from the proximal end of a metacarpus of a sub-adult horse (C30) clearly show the form of fragments produced during bone splitting (plate 9, 4). An impact notch is present on the dorsal face of the bone close to the proximal end of one of the conjoining fragments (marked by a circle in plate 9, 4), and part of a flake from a second notch is visible at the end of the shaft. The distal end of this bone appears to have been fractured off in the fresh bone state, truncating the lower notch.
All the metacarpals appear to have been split open longitudinally by controlled blows to the shaft on the palmar and dorsal faces. In all cases, part of the proximal end of the bone was still attached to the shaft and the distal ends were missing. Truncation of impact notches by green fracture planes suggests that distal ends were removed after the shaft had been struck.

Femur (fig. 19, 1)

Three femur shaft fragments have impact notches. A good example of an impact notch produced by a hammerstone is placed towards the distal end of the caudal face of the specimen P16 77-85. Two notches with overlapping flakes were observed on one fracture edge on the cranial face of the femur P16 57-571 (plate 8, 4).
A more ambiguous notch is located in the near-epiphyseal region of the proximal end of the femur P16 79-576. The almost perpendicular release angle and the presence of step-like ridges on the profile are characteristics more commonly found on notches produced by carnivore teeth, whereas the arcuate, shallow form of the notch is more typical of hammerstone fracture than carnivore gnawing. This fusion of characteristics could simply be related to the location of the notch in the epiphyseal region of the bone in which a different bone structure – the spongiosa – is present.

Tibia (fig. 19, 2)

Seven fragmentary tibia shafts and one tibia shaft with a portion of the proximal end still attached, bore impact notches. Notches produced by hammerstones are located mainly on the plantar face of the bone, but also on the dorso-lateral edge. They are located in the mid-shaft region and towards the proximal end of the shaft of the tibia. An incipient notch with perpendicular profile was recorded in the near-epiphyseal region of the proximal end of a left tibia (P16 67-422) (plate 8, 3). Once again, the fusion of hammerstone-induced and carnivore-induced characteristics observed on this notch may be attributable to its location in the spongiosa at the proximal bone end. One tibia fragment (P16 46-156) has a set of cut marks on the shaft, and another tibia from this group pairs with a cut-marked tibia from the same individual animal (P16 24-482).
Four notches were present on the shaft fragment of a left tibia (P16 58-406). One of these is a broad arcuate notch similar to those produced by hammerstones. The remaining three notches are all comparatively small, with perpendicular release angles. Carnivore gnawing traces are visible at the proximal end of this fragment, and it is possible that the three small notches were also produced during gnawing activities. Otherwise, traces of carnivore gnawing were only observed on the P16 78-184 find, which has an intact hammerstone-induced notch on the plantar face.

Metatarsus 3 (fig. 19, 3)

Ten metatarsals bore impact notches on their shafts. Notches were recorded mid-shaft and in the near-epiphyseal region of the proximal end on the plantar and dorsal faces and on the medial and lateral edges of the bone. One metatarsal has an intact proximal end (plate 9, 5); five others, including a specimen from a young horse, have portions of the proximal ends attached to the shaft and distal ends missing. In one case (P16 58-213) the distal end is present and the proximal end missing.
An excellent example of the intentional reflective fracture of a metatarsus was observed on the shaft fragment P16 24-50 (plate 9, 2). Two sets of opposing notches on the lateral and medial sides showed that

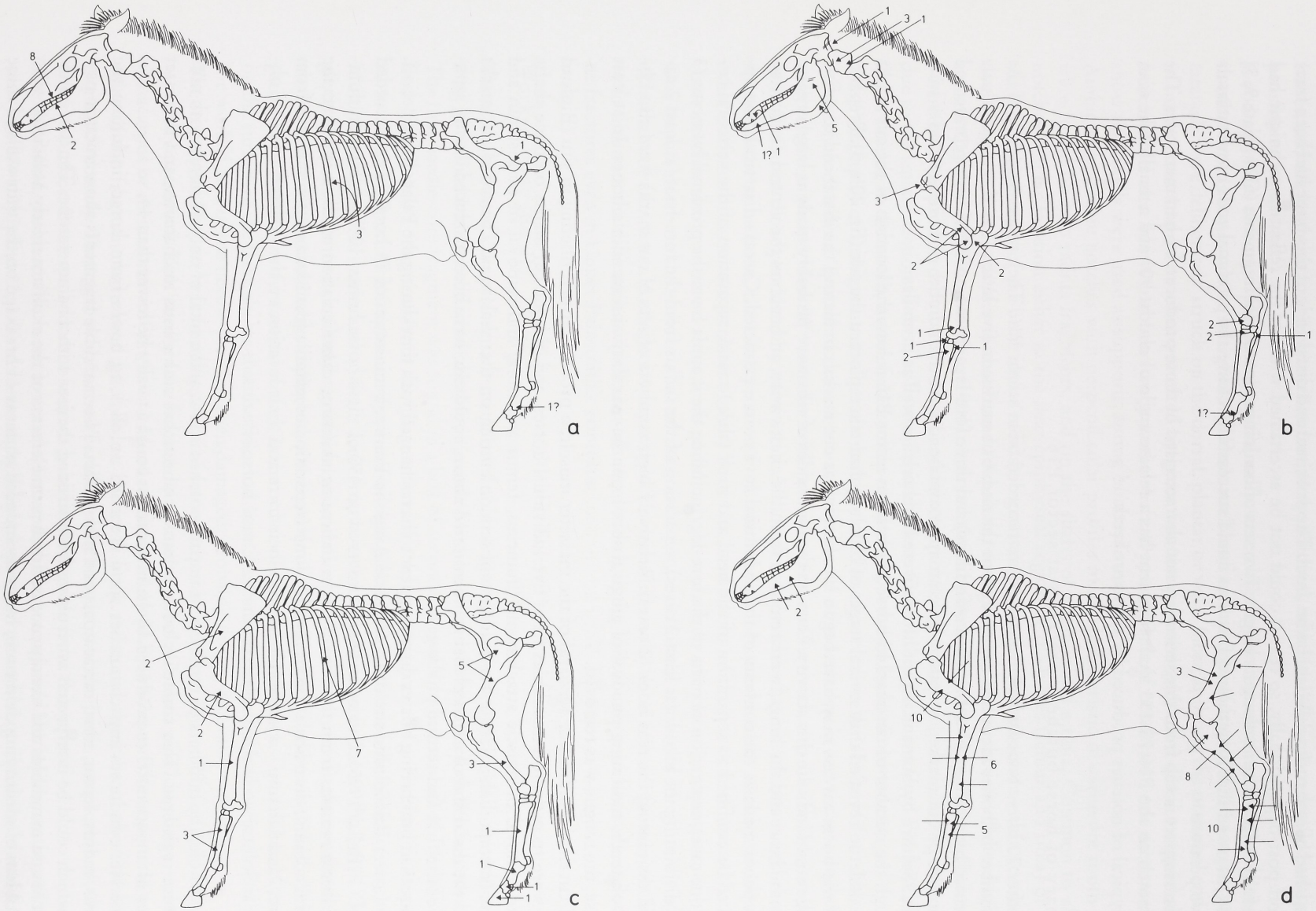


Fig. 20 The various stages of horse carcass butchery recorded at sector P16 at Solutré. – a Preparation of the carcass, including disembowelling, removal of large organs in the chest cavity and possibly skinning. – b Dismemberment or disarticulation. – c Filleting. – d. Marrow fracture. – a-c: arrows with numbers indicate the approximate location and number of times cut marks were observed in these locations. d: arrows and numbers indicate the approximate location of impact notches and the total number of times impact notches were observed on each element.

the bone had been struck while laid on an anvil. The proximal and distal ends of this bone had been fractured off post-depositionally, so that it could not be ascertained whether the reflective technique had successfully split the bone along its length. Two sets of conjoining metatarsal fragments (C29 [plate 9, 3] and C54) showed that longitudinal fractures could successfully cleave the proximal ends of metatarsals into two portions.
Only one impact notch from this series was not characteristic of those produced by hammerstones. The single notch on the P16 78-193 shaft fragment has a release angle of almost 90° and a small flake scar, more typical of notches produced by carnivore teeth.

Summary of horse butchery practices at sector P16

Altogether 70 horse bones with cut marks were recorded from sector P16. They represent 1.9% of the total number of bones identified as horse from the site. Cut marks on five heads (based on individuals represented by numbers of cut marked mandibles) and three fore-legs (based on individuals represented by numbers of cut marked scapulae) give an approximate idea of the number of horse carcasses butchered at Solutré by humans. Adult horses were butchered as well as juveniles.
Although the number of cut-marked horse bones from sector P16 is low, the location of the cut marks on the skeleton revealed that several stages of butchery had taken place at the site (fig. 20 a-d). Preparation of the horse carcass may have begun by skinning as cut marks circulating the distal end of a first phalange could indicate this activity. Cuts on the inner sides of ribs were probably made as large organs, such as the heart and the lungs, were removed from the chest cavity, and cuts on the ventral or inner side of a pelvis made as the contents of the abdominal cavity were extracted. Carcass disarticulation appeared to be confined to separation of the head and neck (three cases), separation of the vertebral column (one case), separation of parts of the fore-leg, including the scapula from the proximal humerus (3 cases), disjointing the elbow (at least 2 cases), separation of the radius from the fore-foot (at least 2 cases) and disjointing the rear hock (2 cases). Relatively high numbers of sets of cut marks were also observed on teeth, indicating removal of gingival skin from the maxillary and mandible bones. In at least one case, the tongue was removed.
Sets of cut marks indicating removal of the masseter muscle, a process termed filleting in situ (Binford 1981), were recorded on mandibles from five individual horses, and oblique cut marks on bone shafts indicate removal of muscle attachments (humerus, femur and tibia) and removal of periosteum and tendons (metapodials). There was evidence of tendon cutting on the phalanges. The set of cut marks around the distal end of a first phalange, mentioned above, could also have been produced during separation of the first and second phalanges.
Techniques of butchering horses do not appear to have changed with time during the Palaeolithic period. At the Lower Palaeolithic site of La Caune d'Arago in France, a minimum of 74 horses were recorded in level G (Bellai 1995). Cut marks were observed on 450 of these horse bones, 10% of the total number of horse remains from this level. Marks indicating skinning, disarticulation of the head from the vertebral column, disarticulation of the fore-limb (separation of scapula from humerus and radius from humerus) and filleting – comparable in both their form and their location on the skeleton to those observed at Solutré – are also present on the La Caune horse remains.

On the whole, the numbers of instances of impact notches is low, and a total of only 44 bones with notches were registered. This count includes a number of notches ambiguous in character, and the exact number of impact notches produced by hammerstones could actually be lower than 44.
Hammerstone-induced impact notches were recorded on all long bones from horse, including the humerus, radius, femur, tibia, metacarpals and metatarsals. Two mandible fragments show fracture patterns which could be interpreted as resulting from striking the jaw with a hammerstone. The low count of notches on mandibles and the absence of notches on elements of the skull are clearly associated with the problem of identifying deliberate, humanly induced patterns of breakage on the thin walls of these

bones, and the fragmentary, unrestored nature of the material, which makes a more detailed analysis impossible to undertake.
Good examples of bones split open longitudinally were observed on metacarpals, metatarsals and radii, in other words bones whose straight form lends itself well to this type of fracture. Metacarpals and metatarsals were deliberately struck on the dorsal, plantar or volar faces, splitting the proximal end in half in many cases. Impact notches truncated by green fracture planes suggest that distal metapodials were fractured off after blows had been made to the shaft. Opposing sets of notches on one metatarsal shaft show that anvils were used as supports during bone splitting.
Ambiguous arcuate notches with perpendicular profiles more characteristic of carnivore tooth marks, were found on two radius fragments, and on the shafts of a femur and a tibia. Common to all these notches is their location either in the near-epiphyseal region of the bones (femur and tibia) or on the sharply-angled edges of the bone shaft (radius), regions in which the bone structure – thin cortical bone overlying spongiosa – differs to that found mid-shaft, or regions where the section of the diaphysis is square. Capaldo and Blumenschine (1994) observed similar phenomena on metapodials in their samples where notches produced by both humans and by carnivores had release angles closer to perpendicular due to the square section of the diaphysis of this element. One of the specimens from P16 had incipient flakes nesting in the notch, more characteristic of notches produced by hammerstones.
Other examples of ambiguous notches are multiple notches observed on the shafts of four humeri and on the shaft of a tibia. Typical of these sets was the presence of at least one broad arcuate impact notch with release angle less than 90°, together with one or several notches with step-like flaking on the profiles, similar to those produced by carnivores. Although it is possible that both humans and carnivores fractured the same bone, the close proximity of notches possibly produced by carnivores along with other evidence of carnivore attrition of these bones (eg. crenulation of the bone ends), meant that the arcuate notches also present on these finds could only be tentatively attributed to the action of humans. One impact notch on the shaft of a metatarsus could not be definitely attributed to either the activities of humans or carnivores. Ambiguous impact notches recorded on the horse remains from sector P16 serve to illustrate the difficulties which are still encountered in the identification of humanly-induced bone fractures even in Upper Palaeolithic contexts.

Worked bone (fig. 21)

Three horse bones, comprising two metapodial shaft fragments and a fragment from an unidentifiable long bone, had been modified further by humans. All three finds had been used as needle-cores.
The first needle-core fragment was found in a box of secondaire faunal remains, marked P16 69-SE. The find (fig. 21a) is a fragment from the planter face of a left metacarpus shaft. The fragment measures 92.5 × 33.6 × 13.6 mm. It is fragmentarily preserved and parts of the surface of the bone are also missing. Multiple, oblique cut marks and a single deep groove are preserved on one side of the bone. The deep groove indicates that the bone had been utilised as a needle-core. Fresh fractures on the proximal end and along the two longitudinal edges indicate that the needle-core broke after it had been worked. A flake negative was observed on the cortical surface in the centre of the cut marked area. The absence of cut marks on the surface of the flake shows that the flake had been removed after the find had been worked. Part of the worked area of the needle core has been damaged, probably during excavation or lifting.
The second needle-core was found in a box of secondaire material from square 79 (fig. 21b) and is fragmentarily preserved. This needle-core has been prepared on part of a shaft of a long bone – possibly a metacarpus or metatarsus – of horse and measures about 67.4 × 26.8 × 19.2 mm. The upper end and both sides of the fragment have been fractured in the fresh bone state, and the base of the find has been damaged recently. Three grooves, incised parallel to the long axis of the bone, are present on the outer cortical surface. Bone spalls do not seem to have been removed from this core.
The third find, an intact left metacarpus of a horse, had been recognized during excavation of the P16 site (P16 67-419) (plate 20, 1-2). At least eight deep grooves were counted on the dorsal face of the bo-

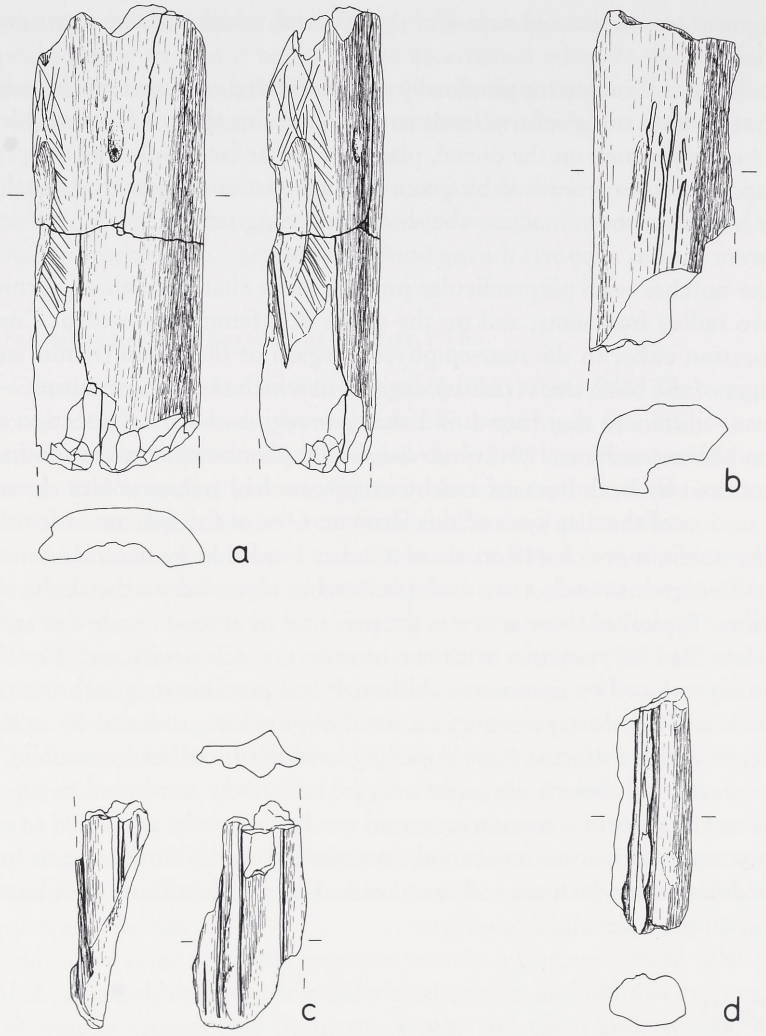


Fig. 21 Bone needle cores from sector P16 at Solutré. a and b prepared on horse metapodials (P16 69-SE and P16 79), c and d made from bones of large, unidentified mammals (P16 100-566 and P16 99-565).

ne, demonstrating the intensive use of this particular find as raw material. The grooves had been incised down the full length of the shaft of the bone and attain some 130 mm in length. Unfortunately, the find had been preserved by covering it with a thick coat of varnish, obliterating many details. The find is on permanent exhibition in the museum at Solutré.

The following fragments of worked bone are described in this section, but could not be definitely identified as horse bones and are therefore not included in the counts for horse remains.
A small fragment of bone was found in secondaire material from quadrat 100 (P16 100-566) (fig. 21 c). The find is a fragment from the shaft of a bone, possibly a radius, which could not be identified to a species. The remains of four grooves were observed on the cortical surface, parallel to the long axis of the bone. The bone appears to have been fractured after it had been worked, but while it was still in a fresh state. The fragment measures 43.9 × 20.9 × 14.3 mm.
A needle-core (P16 99-565) (fig. 21d) was recovered from secondaire material lifted in square metre 99. The piece is an incomplete core made out of a long bone shaft, which has been recently damaged in several places. The width of the shaft indicates that the bone is from a large mammal, comparable in size

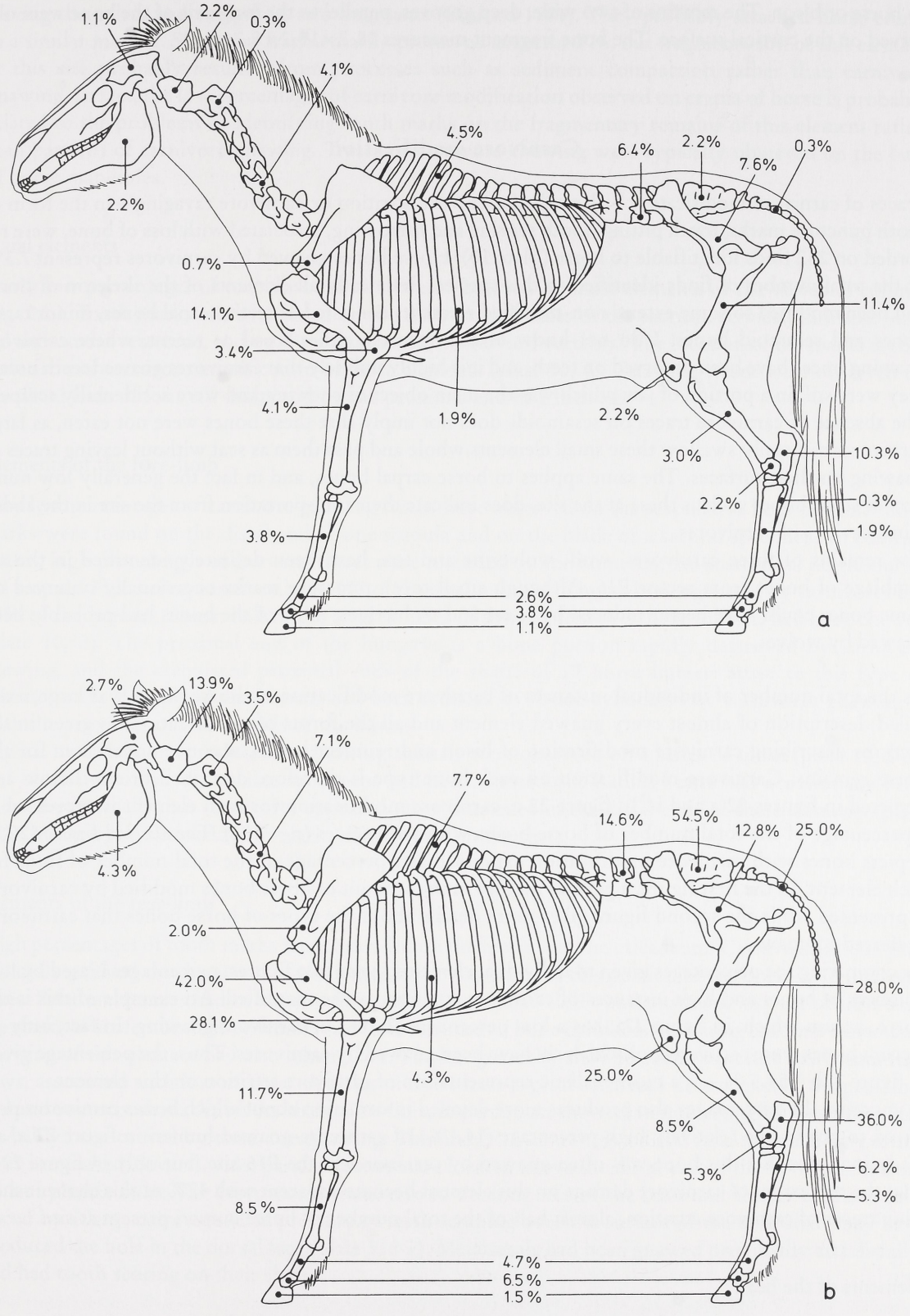


Fig. 22 Carnivore modification of the horse bones from sector P16 at Solutré expressed as a) percentage of the total number of horse bones with traces of carnivore attrition (n=262) and b) percentage of the total number of finds for each element.

to horse or bison. The remains of two wide, deep grooves, parallel to the long axis of the bone were observed on the cortical surface. The bone fragment measures 18.2 × 15.2 × 9.7 mm.

Carnivore modification

Traces of carnivore modification – also called carnivore attrition or carnivore ravaging – in the form of tooth puncture marks, tooth pitting, tooth scoring and furrowing, associated with loss of bone, were recorded on 262 finds identifiable to horse (plate 10). Horse bones gnawed by carnivores represent 7.3% of the total number of finds identified to this species. Practically all elements of the skeleton of horse had been modified to some extent; non-modified elements consisted of teeth, carpal bones, minor tarsal bones and sesamoid bones. I do not know of any records, either fossil or recent, where carnivore gnawing traces have been observed on teeth, and it is highly unlikely that carnivores gnawed teeth unless they were still in a portion of jaw which was the main object of chewing and were accidentally scraped. The absence of carnivore traces on sesamoids does not imply that these bones were not eaten, as large carnivores can easily swallow these small elements whole and pass them as scat without leaving traces of gnawing on their surfaces. The same applies to horse carpal bones, and in fact the generally low numbers of small bones such as these at the site, does indicate their transportation from the site in the abdominal cavities of carnivores.
The remains of three carnivores, wolf, wolverine and fox, have been definitely identified in the assemblage of bones from sector P16. Although small tooth puncture marks occasionally observed on some bones could have been produced by foxes and wolverines, most of the bones had probably been gnawed by wolves.

As the total number of individual instances of carnivore modification on horse bones was large, a detailed description of almost every gnawed element and all the forms of modification, as given in the sections describing carnivore modification of bison and reindeer bones, was not undertaken for the horse remains. Carnivore modification on each bone type is therefore described briefly below and depicted in figures 22 a and b. In figure 22 a, carnivore modification for each element is expressed as a percentage of the total number of horse bones with such traces (n = 262). The second figure (22 b) depicts bones with carnivore modification expressed as a percentage of the total number of finds for each element. In the first figure, a general picture of the amount of horse bones modified by carnivores is presented while the second figure gives more details about the types of horse bones that carnivores preferred to gnaw.
By comparing the percentages given to individual elements in the two figures, percentages biased by low numbers of bones and high instances of carnivore attrition can be identified. An example of this is the horse sacrum which, in figure 22a, has a low percentage (2.2%) of carnivore gnawing. In fact, only 11 sacrum bones were recovered, of which six have been gnawed by carnivores. Thus, the percentage given in figure 22b – 54.5 % – is a more realistic representation of carnivore attrition on this element.
Comparing the percentages also produces more detailed information about which bones carnivores preferred to gnaw. The relatively high percentage (14.1%) of carnivore-gnawed humeri in figure 22 a, already indicates that this bone was often gnawed by carnivores at the P16 site, but only in figure 22 b does the real extent of carnivore damage on this element become apparent with 42% of this element showing traces of carnivore attrition, almost half of the total number of horse humeri present at site.

Elements of the head

Traces of gnawing were observed on two occipital bones and one temporal bone. Carnivores typically gnaw crania of medium-sized ungulates from the nose inwards, collapsing the face of the skull and

leaving the palate and occiput in two fragments (Binford 1981). They probably attacked horse crania in a similar manner. Skulls are fragmentarily preserved at sector P16, but fragmentation of this element at this site probably resulted from processes such as sediment compaction rather than carnivore gnawing. In fact, the low percentages of carnivore modification observed on crania of horse is probably related to the problems of identifying tooth marks on the fragmentary remains of this element rather than patterns of carnivore gnawing. Traces of carnivore chewing were typically observed on the base of horse mandibles.

Axial elements

Fairly low percentages of carnivore attrition were observed on most elements of the vertebral column (fig. 22a). Tooth marks were recorded on the centrum or bodies of the sacrum, cervical, thoracic, lumbal and caudal vertebrae, and on the dorsal spine of a cervical vertebra. The location of the marks is characteristic of carnivore modification of these elements (plate 10, 4). Gnawing traces were observed on the distal ends of four rib shafts and on the proximal end of a fifth rib.

Elements of the fore-limb

Very low percentages of carnivore gnawing traces were observed on the scapulae in both figures. Tooth marks were found on the distal end of one scapula and on the blade of a second specimen. In contrast to this, high percentages of gnawing traces were recorded on the humerus, the anatomical neighbour of the scapula. Humeri represent only 14.1% of the total number of horse bones gnawed by carnivores but 42% of the humeri, almost half of the total number of this element present at the site, had been chewed (plate 10, 2). The proximal end of the humerus is a bone portion rapidly destroyed by carnivore chewing, and the crenulated proximal ends of the shafts of 17 horse humeri attest to this type of destruction at P16. Six of the humeri had been reduced to »bone cylinders« by carnivores gnawing at both the proximal and distal ends of the bone.
Typical modifications produced by gnawing animals were observed on a series of ulnae (plate 10, 5-6). The olecranon on all of the nine specimens had been chewed off. Radius bones had occasionally been chewed proximally, but carnivores appeared more interested in the distal ends of these elements (plate 6, 2). Metacarpals showed tooth marks distally and on the shaft.

Elements of the rear-limb

High percentages of tooth marks were recorded on the femur and the calcaneum. Carnivores at P16 preferntially gnawed the distal end of the femur, removing parts of this portion of the bone in 13 different cases. Proximal femurs had been gnawed in seven cases (plate 10, 1), and tooth marks were observed on the shafts of six femurs. Three femurs had been reduced to bone cylinders indicating that more intensive gnawing of this element had also taken place. Patellas generally showed tooth puncture marks and furrows, associated with loss of bone. A series of tibias have typical carnivore destruction of the proximal end and some tooth marks on the shaft. One tibia, in particular, showed an interesting feature which had probably been caused by carnivore gnawing. The find (P16 23-184) is a distal tibia to which part of the shaft is attached. Several wide, parallel furrows are located above the distal end of the bone on the dorsal and plantar faces. The furrows are transverse to the long axis of the bone and similar to those produced by a large carnivore. The pressure of teeth scraping over the surface of the tibia shaft may have produced the hole in the dorsal face (plate 5, 6-7). Metatarsals had been gnawed proximally and distally, and had tooth scoring on their shafts.

Phalanges

Relatively low percentages of modification were observed on the phalanges. Carnivore gnawing traces were observed on proximal ends, distal ends and shafts of the phalanges.

Summary

Carnivores were attracted to parts of the carcass which are usually described as »meaty« parts, such as the humerus and the femur; less meaty parts, such as the radius and the tibia, were less attractive. Certain skeletal regions appear to have been gnawed more than others, and high percentages of gnawing were recorded in the hind-quarter region (lumbar vertebrae, pelvis and femur) and the fore-quarter region (humerus).

The high percentage of tooth marks on the calcaneum was mainly observed on the end of the tuber calcis (plate 10, 3). A relatively high percentage of modification on the olecranon part of the ulna is only expressed in figure 22 b. Carnivores tend to chew the ends of both calcaneum and ulna, since these bony protruberances are easily gnawed even when articulated with other bones. Several of the calcanei from P16 could be re-articulated with astragali, and none of the astragali showed traces of gnawing.

Interesting are the high percentages of gnawed humeri in both diagrams, and the extremely low percentages recorded on its anatomical neighbour, the distal scapula. Gnawing of the proximal humerus was often observed, and if the bones had still been articulated during gnawing then an equally high percentage of such traces would be expected on the distal scapulae. This was not the case, and only 2.0% of the total number of scapulae, representing 0.7% of the total number of gnawed horse bones, had been modified by carnivores. The lack of carnivore modification of the distal scapulae is not due to poor preservation of this element, as this part of the shoulder-blade is well-represented in the assemblage of horse bones (fig. 9). Therefore, it could be speculated that the difference in percentages between the two elements indicates that the bones were already disarticulated before gnawing took place. However, large numbers of cut marks indicating the large scale disarticulation of the fore-quarter region by humans were not observed at P16. Only five scapulae bore cut mark traces and of these, only three had cut marks around the distal end of the bone indicating dismemberment. Other reasons have to be found to explain the difference in percentages of carnivore attrition.

Traces of gnawing on horse bones decribed above and depicted in figures 22 a and b, show that carnivores had access to and gnawed many horse bones. Wolves were probably mainly responsible for these gnawing patterns, reflecting all stages of carcass utilisation from light through to heavy, along with the preferential chewing of bones such as humerus, femur and calcanuem. Heavy carcass utilisation suggests that carnivores were able to spend relatively long periods of time gnawing horse bones undisturbed, during the periods when humans were not present at the site (cf. Olsen 1989, p. 322). Although the interpretation of carnivores as oppurtunistic scavengers of the remains of horses killed by the Magdalenian hunters is probably correct, the evidence of intensive carnivore attrition does not exclude the possibility that some horse bones were the remains of carnivore kills.

Horse bone and oral pathologies

One horse tooth with abnormal wear and nine horse bones with pathological or non-pathological deformations were recorded from sector P16 at Solutré. Localized lesions on the surface of the bone were observed on the lateral sides of the ischium bones just below the rim of the acetabulum (plate 12, 1-2) on the left and right halves of a pelvis from an individual animal, and on the dorsal surface of a third phalange (plate 11, 3). These lesions are typical of osteoperiostitis, an inflammatory condition of the bone caused by bacteria or viruses, which starts in the periosteum in comparison to other bone inflammations such as osteomyelitis, where the disease begins in the marrow cavity and the rarer osteitis, which originates in the soft tissues within the compact tissue of the bone (Baker and Brothwell 1980).

A slight swelling was noted on the medial side of a shaft of a left third metatarsus. The swelling did not have the open, porous nature typical of lesions caused by osteoperiostitis, and smooth swellings such as this one often persist at sites where a draining sinus has broken through to the outside of a bone affected by osteomyelitis.
Exostoses (abnormal outgrowths from the surface of the bone) were recorded on the peri-articular regions of a first and a second phalange. In the case of the first phalange, a small outgrowth is present on the dorsal side of the proximal end. The bony outgrowth on the second phalange is located on the medial side towards the distal end (plate 11, 4).
A more extensive exostose had fused a left vestigial, second metacarpal to the third, major metacarpal (plate 6, 5-7). The articular surfaces of the bones had not been affected. Cut marks were observed on the shaft of the third metacarpus. Bony outgrowths were also present around the caudal articulation of a lumbal vertebra.
According to Baker and Brothwell (ibid.), depressions or lesions in the articular surfaces of bones are probably non-pathological variations from the normal. A non-pathological lesion can be seen on the proximal articular surface of a horse radius from sector P16. An abnormal opening through the centre of a left tarsal bone (Os tarsale 3) of horse (plate 11, 2) may likewise be non-pathological in origin.
Only one oral pathological specimen was found. The upper right P2 could be reconnected to a row of cheek tooth from an individual animal. The tooth is abnormally worn down, as the slope of the occlusal surface shows (plate 11, 1).

Summary of the horse remains from the Magdalenian deposits at Sector P16

The remains of a small horse, often referred to as *Equus caballus arcelini*, represent the bulk of the faunal material from the Magdalenian deposits at sector P16. A total of 3,577 remains could be identified to horse. They form 88.7% of the total number of bones identified to a species. The highest minimum number of individuals – 45 – was recorded on the pelvis.
The large number of skeletal remains, the presence of practically every part of the horses skeleton, high numbers of individuals recorded on different parts of the skeleton, lack of evidence of deliberate selection for a particular part of the body, more or less equal numbers of elements from the right and the left sides of the body, all indicate that intact horse carcasses were originally present at the site below Roche de Solutré. Although death due to natural causes cannot be excluded for one or two of the horses, the location of the site precludes mass deaths such as those observed at river crossings or during flooding, or deaths of animals at water-holes and due to bogging down in quagmires. 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.
In general, the effects of density-mediated bone destruction on this assemblage were minimal, as shown by high counts for less dense post-cranial bones and relatively low counts for dense teeth. Although the extremely low numbers of ribs and some axial elements are certainly related to some extent to the fragility of these elements, the differential preservation of parts of the horses back, as well as variations between ratings for leg bones (humerus, radius, femur and tibia) and their skeletal neighbours (scapula, pelvis, major metapodials), could reflect transportation of these skeletal parts away from the site by humans. Low numbers of small-sized bones (eg. sesamoids) on the other hand, are probably attributable to carnivore attrition.
The differential preservation of portions of long bones was related in the majority of the cases to the density of the bone and post-depositional attrition, with frequencies of portions of scapulae, humeri, pelves and femurs showing a positive correlation with intrabone variations in density recorded for these elements from other large-medium-sized ungulates. In the case of tibias, metacarpals and metatarsals low frequencies for the bone shafts, usually regarded as high-density portions of these bones,

may be related to the initial fracture of these elements by humans as they obtained bone marrow, resulting in the reduction and possible loss of shaft pieces prior to post-depositional and post-burial destruction of bone. The relatively high percentage of hammerstone-induced impact notches on horse metapodials (18.4%) supports this theory to some extent. Low numbers of portions of the mandible, including the robust mandibular symphysis, and differences in counts between anterior and posterior mandibulary cheek teeth may also be a result of humans smashing jaw bones into small pieces to obtain marrow.

The bone assemblage is characterized further by portions of horse carcasses recovered in anatomical connection. Sections of connecting vertebrae and intact or partially preserved rows of upper and lower cheek teeth were revealed during excavation, and during analysis some isolated teeth could be refitted into their tooth-rows and some post-cranial elements could be re-articulated.

Of 232 upper and lower deciduous and permanent cheek teeth aged according to cheek tooth height or tooth wear stages, 76% were animals in their prime, reproductive years. Only 15% were juveniles and old or senile animals represented only 13% of the horse population from this site. Ageing of a small sample of incisors by wear-stages produced results similar to those already observed for the cheek teeth. The highest number of juvenile individuals recorded from epiphyseal fusion stages of post-cranial bones was six. All of these animals were younger than 3 1/2 years at death, and some may have been only 9 months old when they died. They represent 13.3% of the highest MNI (=45) for the horse and the percentage is slightly less than that assessed on the cheek teeth (15%).

Only three canine teeth were recovered from the site. Although canines are often underrepresented in fossil assemblages, their almost complete absence at this site suggests that the population consisted mainly of females.

The stage of development of bones from two horse foetuses shows that the mares died during the period February to March, shortly before they were due to give birth. An earlier analysis of incremental bands of tooth cementum indicates that horse were hunted in spring/early summer, summer and winter. A dominance of prime adults, probably females, in the age-structure, the presence of young foals and pregnant mares, suggest that mainly family groups of horses were being hunted at the site as they were undertaking seasonal migrations in their ranges.

Evidence for human modification of horse bones was minimal. Only 70 horse bones bore traces of cut-marks and impact notches were only observed on 44 bones. Despite the low numbers, several stages of horse butchery at Solutré were recognised. These included removal of gingival tissues, removal of large organs, dismemberment or disarticulation, filleting, tendon cutting, removal of the periosteum and, possibly, skinning. Impact notches were recorded on several types of long bones and on mandibles. Parallel-sided bones such as the radius and metapodials, were split open by a series of blows placed longitudinally along the shafts, and opposing sets of notches on one metatarsal indicate the use of an anvil as a support. Three metapodials of horse had been utilized as needle-cores.

Carnivore modification of bone was observed on 262 finds representing 7.3% of the bones identifiable to horse. Practically all parts of the horse skeleton had been altered by carnivores. In typical carnivore manner, they preferentially chewed parts of the skeleton such as the humerus and the femur. All stages of carcass utilisation from light through to heavy were recorded on the horse remains. Carnivores were obviously able to spend relatively long periods of time chewing horse bones undisturbed, during the periods when humans were not present at the site. Although the interpretation of carnivores as oppurtunistic scavengers of the remains of horses killed by the Magdalenian hunters is probably correct, the evidence of intensive carnivore attrition cannot exclude the possibility that some horse bones were the remains of carnivore kills.

Pathological and non-pathological deformations were recorded on nine horse bones. The Solutré horses suffered from osteoperiostitis, possibly osteomyelitis, and had abnormal bony outgrowths and non-pathological lesions on some elements. An upper second premolar showed traces of abnormal wear.

REINDEER

Introduction and basic data

The remains of a medium-sized cervid, identified on morphological characteristics of the cheek teeth and some post-cranial bones as reindeer (*Rangifer tarandus*), were present at the sector P16 site.
The 271 reindeer remains with Magdalenian preservation represent 6.6% of the total number of bones identifiable to a species from the Magdalenian deposits at P16.
The following table presents basic data resulting from the analysis of the reindeer remains, including the number of identifiable specimens (NISP) before and after refitting, minimum number of elements (MNE) and individuals (MNI), counts of bones with traces of carnivore modification, cut marks and impact notches, and numbers of worked and charred remains.

NISP	NISP after refitting	MNE	MNI	carnivore gnawing	cut marks	impact notches	worked bone/antler	charred bone
271	265	216	9	18	10	2	8	2

Tab. 12 Basic data for the remains of reindeer with Magdalenian preservation at the P16 site.

The finds represent a minimum of 216 elements from this species. The highest minimum number of individuals – nine – was counted on astragali from the left side of the body. Remains from both juvenile and adult reindeer were present. Cut marks and impact notches were observed on a total of only twelve reindeer bones. Two carpal bones had been in contact with fire. Six pieces of antler, one incisor tooth and one bone fragment had been deliberately worked by humans. Eighteen reindeer bones had been modified by carnivores.

Osteology and Palaeoecology

Osteology

Little is known about the evolution of European reindeer, and attempts to describe sub-species have not been successful (Lister 1986) [1]. Delpech (1983) compared the sizes of skeletal elements of reindeer from Upper Palaeolithic sites in south-west France, and came to the conclusion that for this region at least, reindeers underwent a reduction in body-size during the latter phases of the Last Cold Stage (Würm III, III-IV and the beginning of Würm IV), a tendency which was particularly marked during the third phase of Würm IV. She suggested that the reduction in body-size was due to climates unfavourable to this species, with cold, humid phases resulting in thick snow cover impeding reindeer in their search for forage. The phases of favourable climatic conditions which followed were too short to enable reindeer to re-attain the dimensions they had previously grown to. One of the measurements that Delpech con-

1 Weinstock's (2000) study of Late Pleistocene reindeer populations in Middle and Western Europe appeared after completion of this report.

sidered to be significant in demonstrating body-size reduction is the lateral height of the astragali, and 13 astragali from the P16 assemblage were measured and compared to lateral heights given for this element from the French sites (Delpech 1983, tab. 88, p. 421).

Lateral height of reindeer astragali:

	min-max	x	n
»Würm III«	42.3-48.0	44.5	11
»Würm III-IV«	43.1-49.0	44.8	10
sector P16	41.9-48.8	44 3	13

The mean lateral heights of reindeer astragali from the Magdalenian deposits at sector P16 are marginally smaller than those recorded on samples from French sites dating to Würm III and Würm III-IV. On the whole, the reindeer from Solutré are comparable in size to the group of smaller-sized reindeer Delpech describes for the Würm III-IV period in the south-west regions of France.

Palaeoecology

Reindeer were common elements of Late Pleistocene cold stage faunas throughout Europe. This species occurs throughout most of the tundra and taiga of Eurasia and North America and also ranges into boreal forests today, but during Pleistocene cold stages reindeer were found as far south as northern Spain (Altuna 1972). Often found in association with other mammals typical of open steppe tundra environments, such as mammoth and woolly rhinoceros, reindeer have also been recorded in interstadial phases in association with boreal forest (Stuart 1982; Mania and Toepfer 1973).

Number of individuals and skeletal part representation

In table 13, the skeletal remains of reindeer are listed by element and body-side. Minimum numbers of each element (MNE) and minimum numbers of individuals for each bone (MNI) are given, along with the numbers of bones gnawed by carnivores. For long bones of the fore and rear limbs, MNE's and MNI's are placed next to the portion of the element on which these were counted (for example, MNE and MNI for the scapulae were counted on the distal ends of this bone); the number gnawed by carnivores refers to the total number of scapulae (distal ends and blades) which bear such traces.
Reindeer skeletal part representation is shown in figure 23 where minimum numbers of individuals, taken from table 13, are depicted for the portions of reindeer skeletal elements present at the site. Reindeer remains are highly underrepresented in the bone assemblage from sector P16, considering that at least nine animals (based on numbers of left astragali) were present. As already suggested for some of the horse remains, the presence or absence of the skeletal parts of reindeer appears to be strongly related to the structural densities of bones or portions of bones and bone preservation, and possibly carnivore activities. Thus, high numbers of individuals were recorded on robust elements of the reindeer skeleton such as the astragalus and calcaneum and on high density portions of reindeer bones such as the acetabular part of the pelvis and distal ends of scapula, humerus, radius and tibia. Fragments of fragile bones, such as ribs, are absent, and extremely low individual counts were recorded on all types of reindeer vertebrae. Small bones, such as some of the carpals and tarsals, and the sesamoids, are absent. These elements are also rare amongst the horse remains and their loss may be the result of carnivores digesting these elements.
But even when factors such as differential bone preservation and carnivore attrition and their effects on the remains of a medium-sized cervid are taken into account, it is still very difficult to interpret the small assemblage of reindeer remains from sector P16. Reindeer belongs to the archaeological fauna at this site,

	left	*	right	MNE	MNI	number gnawed
Head						
pedicles/cranium	7		3	9	6	1
antler fragments	14					
shed antler	1		2			
worked antler bases		2				
mandible	2		0	1	1	0
maxillary teeth	19	3	24	46	5	0
mandibulary teeth	15	6	20	41	3	0
Axial						
atlas	0		0	0	0	
axis	2		2	2	0	
cervical	2		2	1	0	
thoracic	2		2	1	0	
lumbar	1		1	1	0	
sacrum	5		5	5	0	
caudal	0		0	0	0	
pelvis	6	1	9	10	7	2
ribs	0		0	0	0	
Fore-limb						
D scapula	5		6	11	5	5
P humerus	0		0	–	–	–
shaft	2		1	–	–	
D humerus	2		4	8	5	4
P radius	0		2	–	–	–
shaft	0	1	0	–	–	–
D radius	0		5	5	5	1
P ulna	0		1	1	1	0
carpals	2		2	4	2	0
P metacarpal	0		0	–	–	–
shaft	0		1	–	–	–
D metacarpal	3		3	7	4	0
Rear-limb						
P femur	1	2	3	7	3	1
shaft	1	1	0	–	–	–
D femur	0		1	–	–	–
patella	0		0		0	0
P tibia	0		1	–	–	–
shaft	0	1	2	–	–	–
D tibia	5		3	10	5	0
os malleolare	0		1	1	1	0
calcaneum	4		5	9	5	3
astragalus	9		7	16	9	1
tarsals	1		1	2	1	0
P metatarsus	3		1	5	3	0
shaft	0		0	–	–	–
D metatarsus	1		2	–	–	–
mc/mt shaft/distal		12				
phalange 1	4 complete, 3 proximal, 4 distal			8	1	0
phalange 2	1 complete, 1 proximal, 2 distal			3	1	0
phalange 3	0			0	0	0
sesamoid	0			0	0	0
Totals	**270**			**216**		**18**

Tab. 13 Counts of reindeer remains from the Magdalenian deposits in sector P16. – P = proximal, D = distal, * = indeterminate side, mc/mt = indeterminate to metacarpal or metatarsal. All MNE and MNI numbers are based on numbers of fragments after refitting. MNE for mandibles and pelves is based on halves.

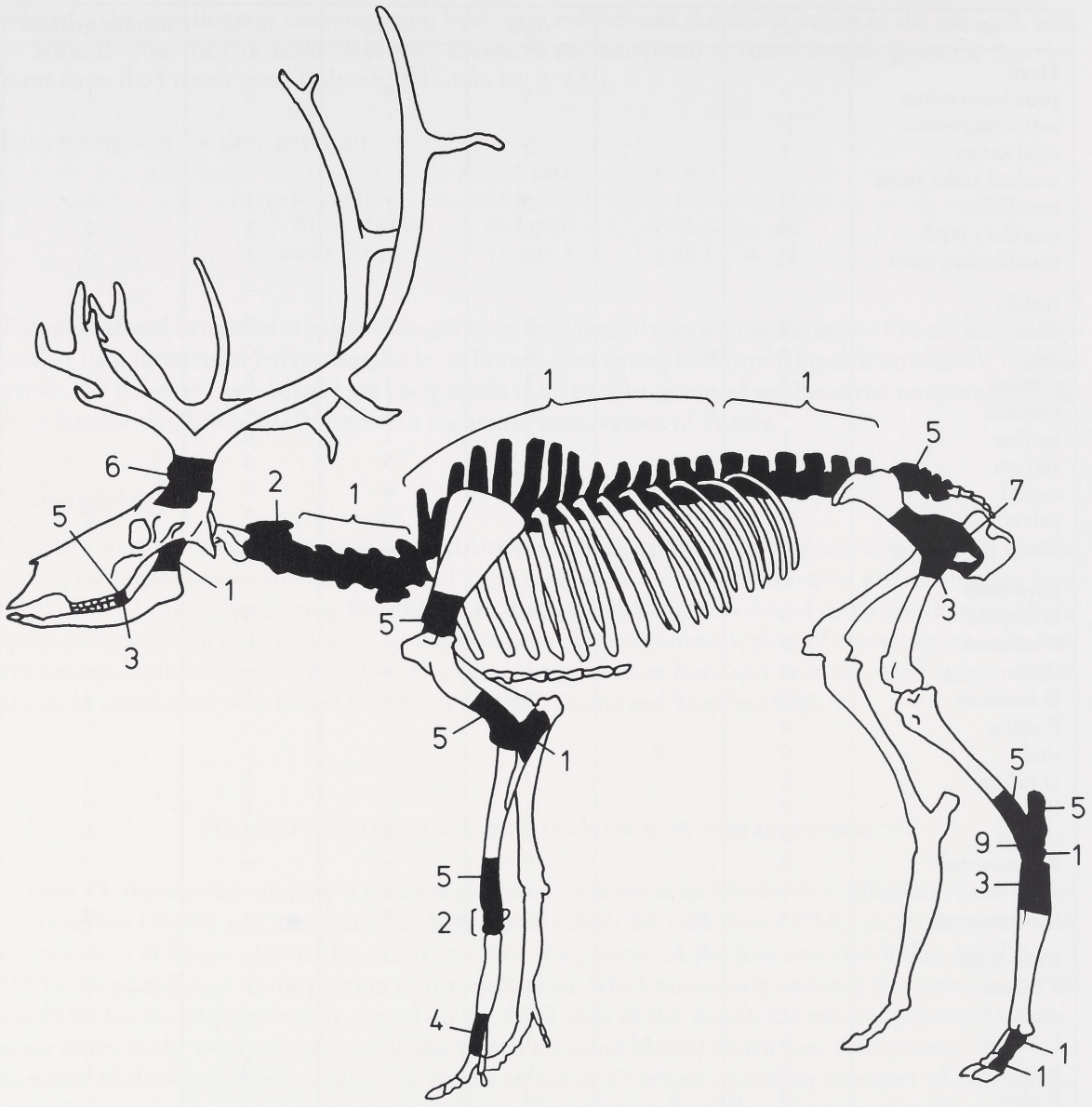


Fig. 23 Reindeer skeletal representation at sector P16 depicting the minimum number of individuals (MNI) for each element. Black areas on elements of the head, legs and on the pelvis indicate those portions of the bones which were preserved in the assemblage.

but if humans were the ones mainly responsible for the representation of reindeer remains, they appear to have shown no interest in selecting particular parts of the carcasses as can be seen, for example, in the relatively high individual counts from both high and low-utility parts of the fore and rear limbs. From the point of view of human procurement tactics, the post-cranial bones of reindeer give little indication as to whether these elements represent the remains of intensively processed, whole carcasses of reindeer hunted close to the sector P16 site, or portions of carcasses of reindeer hunted elsewhere, which were transported back to Solutré by the hunters.

Determination of reindeer individuals, reindeer age, and season of death on certain skeletal elements

In this section, the small assemblages of reindeer antler and teeth from the sector P16 site were analysed in detail, to see if numbers of individuals, their age at death and the season in which they died, could be defined and interpreted in terms of patterns of reindeer procurement by the Magdalenian hunters at Solutré. Epiphyseal fusion stages on some post-cranial bones were also studied with the same goal in mind. Attempts to determine the sexual demography of the reindeers from sector P16 using, for example, mandibular measurements (Spiess 1979; Morrison and 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 sample of measurable reindeer bones recovered at the site.

Numbers of individuals, individual age and season of death using antler

A total of 29 antlers and pedicles from sector P16 could be identified as reindeer. Two of the antler finds are worked objects, comprising a bâton percé and an almost intact antler beam along which a spall of antler has been removed by the groove and splinter technique. Both finds are on permanent exhibition in the museum at Solutré. Three other fragments of worked antler were discovered during this analysis. These finds are described in detail in the worked antler and bone paragraph towards the end of this section.

Two shed antler bases, an antler frontlet, a frontlet from a second individual which was just about to shed its antler, antler pedicles from seven individuals which had shed their antlers, and 13 isolated beam or tine fragments comprise the assemblage of non-worked reindeer antler. Two of the beam fragments could be refitted onto their antler bases (C31 and C99). The two antler frontlets are both from the left side of the body, and together with four pedicles from the left body side, give a minimum count of six individuals. However, as it was not possible to pair any of the left pedicles with those from the right body side, a higher number of nine individuals (six left pedicles plus three right pedicles) could be postulated.

The antler bases, frontlets and pedicles could be divided into two groups based on their size:

1. large robust antlers probably from adult males (plate 13, 1).
   Only two specimens belonged to this group and both of these are shed antlers. The base of the left shed antler (P16 78-440) is concave and the base of the right antler (P16 58-180) is flat or slightly concave. Bouchud (1966) claimed that the sex of reindeer could be determined by observing the form of shed antler bases; antler from males having concave shed bases and antlers from females (or castrated domesticate reindeers) having convex shed bases. Spiess (1979) pointed out that in his observations of collections of recent shed antlers from reindeer, concave bases were predominantly associated with very large antlers which obviously belonged to males, but that this characteristic should not be considered as a consistent sex indicator.
2. weakly-built antlers and thin, short pedicles probably from young animals of either sex (plate 13, 2-7).
   The remaining finds (9 pieces) fall into this category. This group consists of seven pedicles, some of which have small portions of the skull attached to the pedicle base. All of the pedicles are similar in size.
   The left antler frontlet (P16 34-526) consists of the pedicle and a portion of a thin antler beam without tine development, preserved to a length of about 20 cm. This specimen showed no sign of incipient shedding (plate 13, 2). A left antler frontlet from a second individual consists of the pedicle with a fragment of the cranium at its base (P16 46-272). Its beam is preserved to a length of about 28 cm, and the base of a single tine is located on the anterior side. This frontlet is interesting because of the bone reduction between the pedicle and the burr, a state usually observed in reindeer antler just before shedding (plate 13, 3).

The shed antlers in group 1 are not good indicators of season. Much more important are the antlers from group 2 which, based on their size, are probably from sub-adult individuals (3-4 years) of either sex. The specimens included in the second group represent eight young animals which died during the period of antler regeneration. One reindeer from this group was just about to shed its antler, and seven other animals were represented by pedicles from which the antler had been shed, but regrowth had not begun. As the period between the shedding of antler and antler re-growth in two and three-year old males and females comprises only a few days within the month of May (Miller 1974; Spiess 1979), the state of antler regeneration indicates that eight reindeer from sector P16 died during this period.
The single frontlet (P16 34-526) was more difficult to place seasonally. Antler growth in young reindeers begins in the second half of May to June and antlers are carried until the following May. There was no trace of a resorbtion line below the burr indicating incipient shedding, which would have been the case had this individual also died in May, just before shedding its antler. Thus this animal may have died any time between November (after the velvet has worn away) and March/April (assuming that resorbtion begins about $^1/_2$-1 month before shedding takes place in May).
To summarise, the seven pedicles and the pedicle with antler just about to be shed, indicate May as the month in which eight of the animals in group 2 died. The reindeer carrying the antler frontlet with no traces of incipient shedding could have died anytime between November and May.

Season of death using tooth increment analysis

Gordon (1988) examined incremental bands of cementum on a small sample of reindeer teeth (n = 14) from the Magdalenian horizon at Solutré and established that 52.3% were the result of winter kills (December-March) and 47.6% had been killed in spring (April-May).

Numbers of individuals and individual age at death using the upper and lower cheek teeth

41 mandibulary cheek teeth and 46 maxillary cheek teeth were identified to reindeer. Some of the elements from this sample provided additional information about numbers of individuals and their approximate ages at death.
Counts of minimum numbers of individuals showed that a minimum of five reindeer were represented by permanent upper M3's from the right body-side, and three reindeer were represented by permanent lower M3's from the right side of the body. However, the low total number of premolars and molars of reindeer allowed a more detailed analysis to be undertaken, and higher counts of eight individuals for the upper cheek teeth and six individuals for the lower cheek teeth could be extrapolated by using a combination of tooth eruption stages, differing crown-heights and different body-sides (figs. 24 and 25).
Ageing these individuals was more problematic as there is no published information about the timing of tooth eruption and wear stages of upper cheek teeth and, with the exception of fairly complete mandibles from reindeer of less than 2 years old, mandibular tooth eruption and wear are not considered to be a precise enough indicator of age or season of death (Spiess 1979 for criticism of Bouchuds (1966) method; Morrison and Whitridge 1997). Some of the problems involved are individual variation in diet and rates of wear, the slowing down of tooth and mandible growth during winter and individual variation in eruption dates. Also the span of time in which a particular tooth erupts can be long; the eruption of the lower M3 of reindeer can take up to 15 months, for example.
However, reindeer mandibles are still considered useful in establishing the season of death in very young animals and constructing demographies of kill by broad age class. The second category – demographies of kill by broad age-class – was more relevant for the sample of reindeer teeth from P16, as there was not much evidence for the presence of very young reindeer at the site since the bulk of the upper and lower reindeer cheek teeth in the sample consisted of permanent premolars and molars in varying stages of wear.

Miller's method (1974, p. 17-18) of grouping teeth into rough age classes was employed. Miller described wear patterns of cheek teeth from reindeer culled from the Kaminuriak herd of barren ground caribou (*Rangifer tarandus groenlandicus*). These animals were of known age at death, or had been aged by tooth sectioning. Spiess (1979) subsequently divided Millers descriptions into five age-classes or cohorts comprising 2 year olds, 3-5 year olds, 6-9 year olds, 10 year olds and reindeers older than 10 years as follows:

2 years	– all premolars and molars full erupted
	– sharp-edged, high buccal cusps on M1-M3 with light wear on all except M1
	– premolars with very light wear
3-5 years	– wear on premolars advances to point where the dentine exposed on each cusp is wider than each bordering piece of enamel
	– molars and premolars still retain sharp lingual cusps noticeably higher than buccal ones
6-9 years	– lingual and buccal cusps worn to even height although wave-form relief of cusps still visible
	– premolars blunted
	– exposed dentine has widened from thin crescentic or tear-drop shape to broad quarter or half moon form
10 years and older	– molars very worn and flat (maximum lifespan in wild caribou is about 18 years)

Individuals based on mandibulary teeth

The mandibular teeth are represented by a total of 41 elements, comprising isolated incisors, premolars and molars and several incomplete mandibulary cheek tooth rows. Body-side of the most common dental elements in this category – the lower M2 and M3 – was used as the basis for initial sorting to individual animal, and decreasing crown height - measured on the lingual side of the lower teeth from the base of the crown to the tip of the highest cusp - as an approximate guide to increasing age. The six individuals established on the mandibular cheek teeth are depicted in figure 24, beginning with the youngest reindeer at the top and described below.

Reindeer 1: The youngest reindeer in this series is represented by an isolated, unworn lower right M3 (P16 89-59).

Reindeer 2: Three lower molars – M1-M3 – from the right body-side represent reindeer 2. All the teeth are worn and the peaks of the cusps on the M1 are almost even. The posterior lobe of the M3 is just showing the first traces of wear. The crown-height of the M3 measures 16.1 mm.

Reindeer 3: This animal is represented by an isolated lower right M3 (P16 63-128) with anterior cusps in wear and wear on the posterior third lobe just beginning. The crown height is 14.9 mm.

Reindeer 4: A left lower M2 and M3 represent the fourth reindeer. The cusps on both teeth are in wear and still peaked with lingual cusps higher than buccal. Half of the surface of the third lobe of the M3 is in wear. The crown height of the M3 is 14.7 mm and the M2 is 14.5 mm high. A mandible fragment encasing the M2 is cut-marked (plate 13, 9).

Reindeer 5: This individual is represented by the lower right P2-M2. All teeth are in wear; the cusps of the M2 are peaked with lingual cusps fused. Its crown height measures 15.0 mm. The cusps on the M1 are almost even; on the M2 they are higher lingually. This animal is probably older than reindeer 4, even though the height of the common element, the M2, is slightly less worn down in this individual. The P3 and P4 have blunted cusps and the dentine on the occlusal surface is wider than the surrounding enamel. Wear on the P2 was restricted to the posterior part of the tooth.

Reindeer 6: The oldest individual is represented by a series of lower premolars and molars from the left body-side (P3-M3). The M3 is well worn and the peaks of the cusps are flattened, but the wave-form relief is still visible. The height of the M3 measures 10.3 mm.

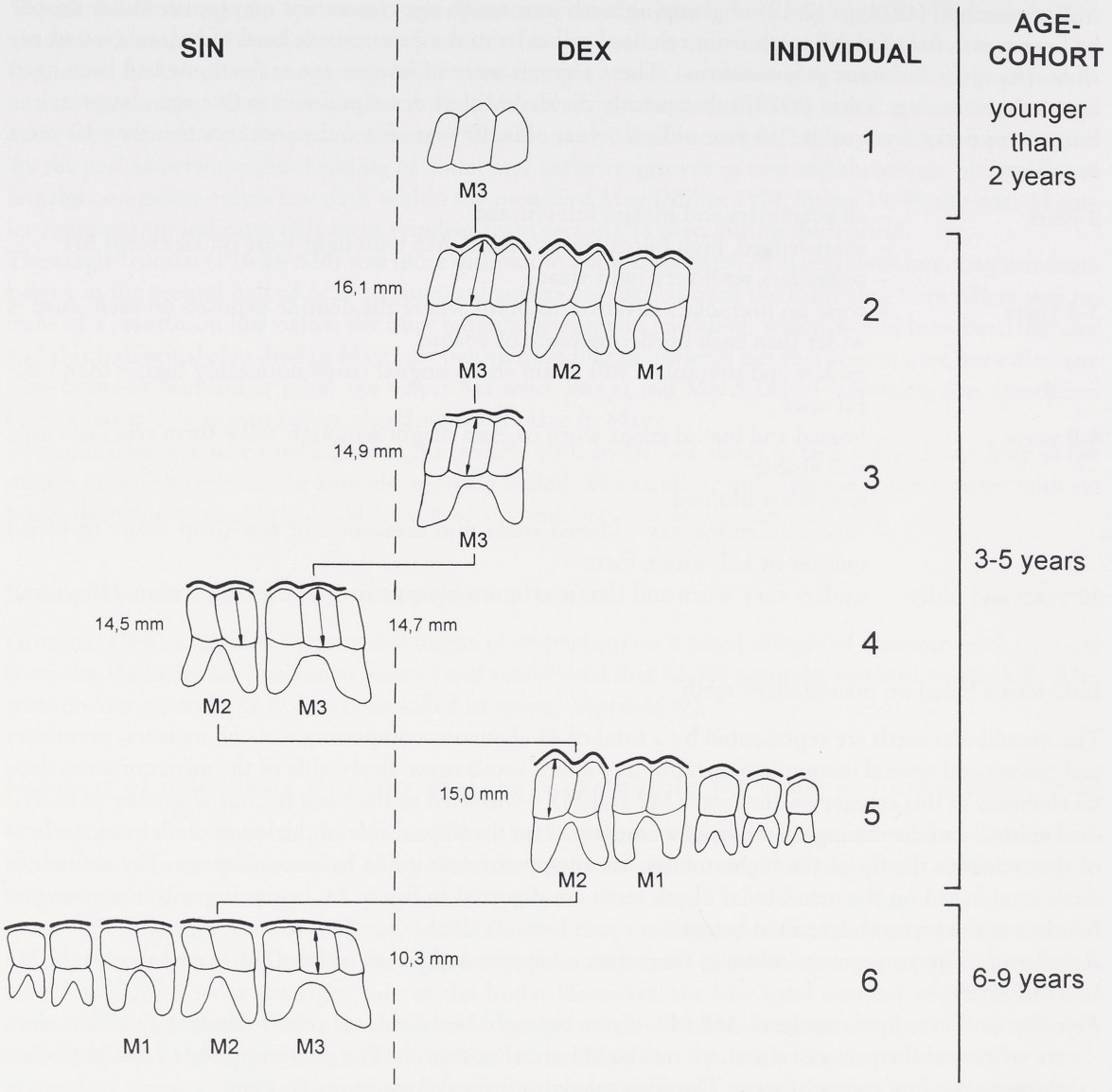


Fig. 24 Numbers of individuals and their age-cohorts established on reindeer mandibulary cheek teeth.

Individuals based on maxillary teeth

The sample of maxillary teeth from reindeer comprised 46 premolars and molars. A larger number of isolated elements were present in this sample, more so than in the sample of reindeer mandibulary teeth. The youngest individuals in this series were identified using two upper deciduous teeth (dp4) from the left body-side. A tooth row in which one of the dp4's and a permanent third molar (M3) were present, was used as the »bridging element« between the dp4s used to identify the younger reindeer and the M3s used to identify the older individuals. Decreasing crown-height in the M3 was taken as an approximate indication of increasing age. Crown heights were measured on the buccal side of the tooth from the base of the crown to the tip of the highest cusp. Eight individuals could be tentatively identified using this method and these are depicted in figure 25 and described below.

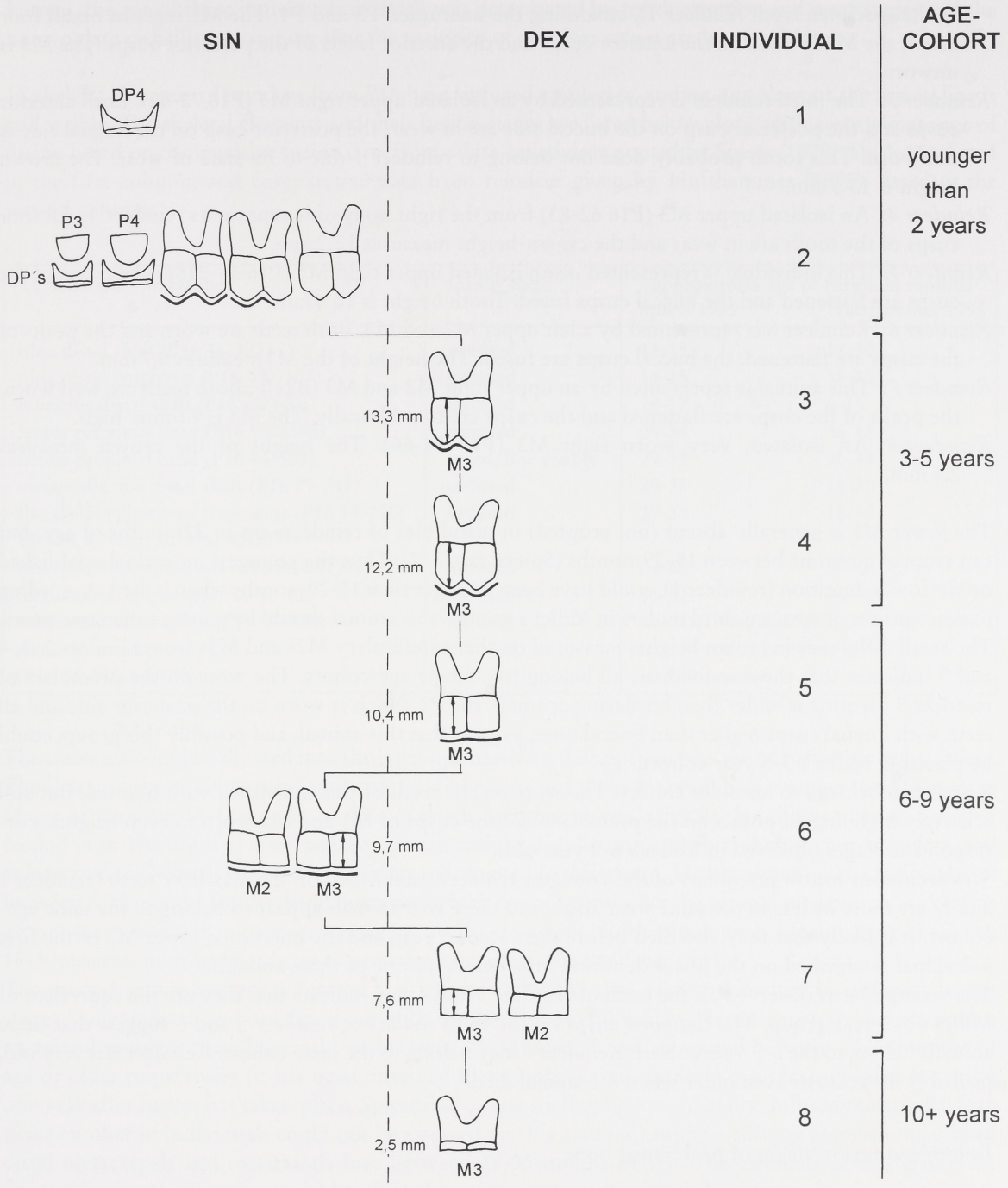


Fig. 25 Numbers of individuals and their age-cohorts established on reindeer maxillary cheek teeth.

Reindeer 1: The youngest individual in this series is represented by an isolated left deciduous premolar (dp4) (P16 47-394). The tooth is in the very last stage of wear, the roots are almost fully resorbed.

Reindeer 2: This animal is represented by a series of upper deciduous and permanent premolars and molars from the left body-side, including a very worn dp3 and dp4 (latter tooth in the same wear stage

as the specimen from reindeer 1), straddling the unerupted P3 and P4. The M1 is worn on all four cusps; the M2 is worn on the anterior cusps and the anterior facets of the posterior cusps. The M3 is unworn.

Reindeer 3: The third reindeer is represented by an isolated upper right M3 (P16 72-42). Both anterior cusps and the posterior cusp on the buccal side are in wear; the posterior cusp on the lingual side is not worn. This tooth probably does not belong to reindeer 1 due to its state of wear. The crown height is 13.3 mm.

Reindeer 4: An isolated upper M3 (P16 62-83) from the right body-side represents reindeer 4. All four cusps of the tooth are in wear and the crown-height measures 12.2 mm.

Reindeer 5: This individual is represented by an isolated upper right M3 (P16 35-218). The peaks of the cusps are flattened and the buccal cusps fused. Tooth height is 10.4 mm.

Reindeer 6: Reindeer 6 is represented by a left upper M2 and M3. Both teeth are worn and the peaks of the cusps are flattened; the buccal cusps are fused. The height of the M3 measures 9.7 mm.

Reindeer 7: This animal is represented by an upper right M2 and M3 (B215). Both teeth are well worn, the peaks of the cusps are flattened and the cusps are fused bucally. The M3 is 7.6 mm. high.

Reindeer 8: An isolated, very worn right M3 (P16 54-66). The height of the crown measures 2.5 mm.

The lower M3 is generally absent (not erupted) in mandibles of reindeers up to 22 months of age, but can erupt at any time between 15-29 months (Spiess, tab. 3. 7). Thus the youngest individual established on the lower dentition (reindeer 1), could have been younger than 15-29 months when it died. According to descriptions of wear on third molars in Miller's groups, this animal should be younger than two years. The small difference in crown heights measured on the mandibulary M2s and M3s from reindeer 2, 3, 4 and 5 indicates that these individuals all belong to a single age-cohort. The wear on the premolars of reindeer 5 (dentine is wider than bordering enamel), the P2 which is worn on the posterior side and all teeth with lingual cusps higher than buccal ones, suggest that this animal, and possibly this group, could be placed in Miller's 3-5 year cohort.

Reindeer 6 belongs to an older cohort. The wear on the teeth of this individual with blunted, but still relatively high lingual points on the premolars and the cusps of M1 and M2 worn to even heights, correspond to stages observed in Miller's 6-9 year olds.

The deciduous fourth premolars of the youngest reindeer established on the maxillary teeth (reindeer 1 and 2) are more or less in the same wear stage, and these two animals appear to belong to the same age-cohort. It is likely that they also died before their second year, and the unerupted lower M3 of the first individual established on the lower dentition may belong to one of these animals.

The wear patterns observed on the teeth of reindeer 3 and 4 may indicate that they are the equivalent of Miller's 3-5 year group. The flattened cusps on the third molars of reindeer 5 and 6 suggest that these animals belong to the 6-9 year cohort. Reindeer 7 may belong to the same cohort. Reindeer 8 is very old, probably 10 years or even older when the animal died.

Epiphyseal fusion stages of postcranial bone

According to Spiess (1979), the ages of epiphyseal fusion of reindeer postcranial bones are either unknown or unpublished. In his discussion of epiphyseal closure sequences, Spiess (ibid, tab. 3. 15) used known comparative data from white-tailed deer (*Odocoileus virginiatus*) in North America, which are close relatives of reindeer and are similar in body-size. Approximately the same times of epiphyseal-fusion were observed in the skeleton of a male reindeer of known age from Labrador and the skeleton of the white-tailed deer, and Spiess concluded that white-tailed deer bone fusion data can be reasonably used for analysis of reindeer archaeological samples.

In an article published recently, Hufthammer (1995) observed epiphyseal fusion stages in the skeletons of 35 wild reindeer killed at Hardengervidda in southern Norway. As the year of their birth was un-

known, the age of these individuals at death was determined by tooth eruption and wear stages and the known date of culling, assuming that the majority of reindeer calves are born in May.

15 skeletal elements of reindeer from P16 have unfused epiphyses, and on one element the fusion line is still visible. The skeletal elements and their fusion stages are listed below along with approximate age of fusion based on comparative fusion data from white-tailed deer quoted by Spiess (1979, tab. 3. 15), listed in the first column, and comparative data from reindeer given by Hufthammer (1995), listed in the second column:

Element and site cat. no.	fusion stage	approximate age of fusion in months	
		Spiess 1979	Hufthammer 1995
tibia distal shaft (P16 46-393)	unfused	14-15	18-30
tibia distal epiphysis (P16 100-307)	unfused	14-15	18-30
humerus distal shaft (P16 80-100)	unfused	14-17	6-15
femur proximal head (P16 100-560)	unfused	29-34	36-48
femur proximal head (P16 46-309)	fused, line visible	29-34	36-48
metapodia one distal shaft (P16 79-741)	unfused	29-35	18-30
five distal epiphyseal fragments (P16 49-100; 48-398; 67-913; 80-326; 90-327	unfused	29-35	18-30
tibia proximal epiphysis (P16 68-621)	unfused	34-60	36-48
femur distal epiphysis (P16 85-12)	unfused	35-52	36-48
calcaneum tuber calcis (P16 99-458)	unfused	no data, irregular fusion	
thoracic vertebra corpus (P16 34-586; 67-480)	unfused	late, anything between 35 and 60 months	

The elements could be divided into three groups based on the approximate age of fusion given by Spiess. The first group comprises the distally unfused humerus and tibias from animals younger than 14 months of age or between 14-17 months at time of death. In other words, animals that did not live to see their second year. The unfused distal tibial epiphysis and the distally unfused tibial shaft do not articulate, and at least two individuals of reindeer are thus represented in this group. Hufthammer gives a fusion age of between 6-15 months for the distal humerus, which doesn't contradict the general interpretation that this group was younger than two years of age at death. However, Hufthammer gives a fusion age of between 18-30 months, in other words up to just over two years, for the distal tibia.

The second group comprises femurs and metapodials. The two proximal femurs in different fusion stages – one unfused and one fused but with the fusion line still visible – represent, according to Spiess, an animal younger than 29 months or between 29-34 months, and an animal between 29-34 months of age or older respectively (it has been observed that epiphyseal fusion lines can remain visible for up to one year after fusion has taken place, Spiess ibid.). The six fragmentary, distally unfused metapodials (an exact number of individuals could not be assessed on this material) support this age assessment, as both distal metacarpals and metatarsals fuse between 29-35 months of age. The elements in this group are from animals which were not older than three years when they died. Hufthammer gives a younger fusion age, between 18-30 months, for the distal metapodials which, if correct, would place these elements into the category younger than two years.

The third group consists of bones which fuse at around three years of age or later. The unfused proximal tibia and distal femur can be placed into this group, being elements from animals younger than 34 months or between 34-53 months at death. Hufthammer also gives dates of between 36-48 months for the fusion of the proximal tibia and the distal femur.

Fusion times of the remaining elements give no clear indications of reindeer age. The vertebral plate fuses onto the vertebral corpus after 35 months and up to as late as 60 months. The fusion of the calca-

near epiphysis is, according to Spiess, too irregular to be of use in ageing, and Hufthammer indicates much the same.
It should be pointed out that the three age-groups described above are classified only according to their approximate fusion ages and are completely abitrary for a number of reasons. This becomes clear when the ages of fusion published by Hufthammer and Spiess, which differ quite considerably in some cases, are compared. Using Hufthammer's data, only two age-groups would be present in the P16 sample, animals which were not older than 2 1/2 years at death – including the distal tibias and metapodials – and a second group aged at around three years at time of death, which includes the rest of the bones. Spiess gives no indication as to whether his comparative data from white-tailed deer was from animals of known age at death, or whether age was also assessed using tooth eruption and wear, as in the case of Hufthammer's sample. Ageing animals on tooth eruption and wear can only be approximate, and it may be that the differences in the two sets of comparative data are simply based on fusion stages from the bones of more accurately aged deers (Spiess' sample) and fusion stages from the bones of less accurately-aged reindeers (Hufthammer's sample).
Furthermore, the fusion ages of the proximal and distal epiphyses of some bones often straddle two age-groups. Due to the fragmentary nature of the reindeer remains from P16, where only distal or proximal epiphyses ends or distal ends of the shafts were preserved, it was impossible to determine whether the distal end of a bone with an early fusion age belonged to an unfused proximal end which fuses at a much later date. If the unfused distal and proximal epiphyses of the tibia belonged to the same bone, then the proximal epiphysis would be automatically included in the younger age-group due to the early fusion date of the distal tibia (14-15 months) despite the late fusion date (34-60 months) for the proximal end of this bone.
Due to small sample size, differences between comparative fusion data and the fragmentary state of the material, the unfused skeletal elements from reindeer allow no definite assessments of demographic data of the population of this species found at the P16 site. The unfused elements can only indicate the presence of at least two animals (two unfused distal tibias) younger than 14 or 18 months of age at the site.

Ecology and behaviour of reindeer

Reindeer is a strongly social species with long-term social bonds that maintain certain groupings. Miller (1974) considers that unity in these groups is maintained by the formation of post-calving aggregations providing, as its primary function, socialization and the favourable situations required for regrouping of previous winter bands. Reindeer occur in groups of various kinds of which the »band« is the primary distinguishable social group. Miller categorized bands of barren-ground caribou according to the representation of the sex and age of the animals within them. He determined age and sex from collections of mandibles of animals culled in the groups, and supplemented this information with data from observations of animals left behind in the sampled groups. Seven bands could be identified including cow bands, bull bands, subadult bands, juvenile bands, cow-juvenile bands, cow-juvenile-bull bands and bull-cow-juvenile bands.
The following description of reindeer annual migration and changing social units is based on observations of the Kaminuriak barren-ground caribou west of Hudson Bay (Spiess 1979). The first sign of spring migration to calving grounds appears in late April, as cow and yearlings begin to move northwards to the limit of the taiga, joining into larger groups called »premigratory concentrations«. Adult males are distributed further south at this time. Non-pregnant females and young males drop behind due to antagonism of pregnant females as these large groups leave the treeline and head towards the calving ground, which is generally chosen for its sheltered terrain. After calving, females and calves form into core units or »nursery bands« with limited movement, called postcalving aggregations. Yearlings, juveniles, other cows and, rarely, males move around periphery of the core units. Agglomeration of these bands begins about late June. Herds of about 1000-5000 animals move across the calving grounds at the beginning of July. By mid-July, postcalving aggregations have reached up to tens of thousands of animals and have been joined by the male bands. Southward movement takes place in the third week of July.

Large groups disperse after travelling about 160 km to the south. In late September cows initiate the movement to the breeding areas and the bulls catch up rapidly. The rut takes place in late October and autumn migration begin around the 1st. of November in a westerly direction to taiga. The animals concentrate into winter groups with males in deeper snow areas than females and young. These concentrations last until the spring migrations begin.

Summary

Analysis of more exact numbers of individuals, reindeer antler regeneration, eruption and wear-patterns on reindeer teeth, the results of reindeer tooth incremental analysis and epiphyseal fusion stages on reindeer bones, produced some information on possible patterns of reindeer procurement during the Magdalenian period at Solutré.

Nine reindeers are represented by antler frontlets and pedicles. The weakly-built antlers and the small size of the pedicles suggest the remains belonged to young, possibly sub-adult, animals of either sex. One reindeer was just about to shed its antler, and seven other animals were represented by pedicles from which the antler had just been shed, but regrowth had not begun. As the period between the shedding of antler and antler regrowth in young reindeer comprises only a few day in May, the state of antler regeneration indicates that eight reindeers from sector P16 died during this short period. A single antler frontlet without any trace of a resorbtion line is probably from an individual which died sometime between November and March-April. Incremental analysis on a sample of teeth indicates reindeers dying in the periods November to March and April to May, supporting the small amount of seasonal information derived from reindeer antler regeneration.

Counts of individuals higher than those produced by the minimal number of individuals (MNI) method were determined by a more detailed analysis of reindeer lower and upper cheek teeth. Six individuals were recognised on mandibular, 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. 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 (adults). 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). Unfused reindeer skeletal elements provide supportive evidence for the presence of two juvenile reindeers younger than 14 or 18 months at the site.

Approximate ages of reindeer from sector P16 based on tooth eruption and tooth wear show that low numbers of animals younger than two years and old animals were present at the site. Sub-adult and adult reindeers between 3-9 years of age appear to have been the preferred prey of the Magdalenian hunters.

If all of the eight individuals, represented by the antler frontlets and pedicles, died during the same event, they may have belonged to a single sub-adult band. Sub-adult bands are usually composed of three year olds of both sexes or of one sex, and may contain a few older four-year olds. These bands occur at all times of the year, but are most obvious in spring and autumn. During spring, when the cows and yearlings begin to move towards the calving grounds, young males and non-pregnant females drop behind due to the antagonistic nature of the pregnant cows. Sub-adult groups, moving on the periphery of the larger premigratory concentrations, may have been easy pickings for the Magdalenian hunters.

If the seasonal information is correct, then reindeers were being taken 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).

Evidence of human modification of reindeer bones

Three categories of human or cultural modification – cut marks, impact notches produced during bone-smashing activities and worked pieces – were observed amongst the reindeer remains. Ten bones bore traces of cut marks, one bone had been deliberately smashed open and one bone had cut marks and an impact notch. Reindeer remains were also used as raw materials and the assemblage of worked antler comprises a bâton percé, an antler beam from which a long spall had been removed using the groove and splinter technique, a broken double bevel-based point, and two fragments of antler debitage. An incisor tooth had been deliberately worked as well as a small fragment of bone from an animal comparable in size to reindeer.

Cut marks

Surface marks, similar to those produced by stone tools, were observed on ten bones from reindeer, and their location on the reindeer skeleton is depicted in figures 26 and 27. Cut marks on three scapulae show that the fore-leg portions from three reindeer carcasses had been processed by the Magdalenians. One of these was from the carcass of a sub-adult or juvenile reindeer, as the distal end of the scapula (P16 57-499) has the porous bone structure characteristic of young animals. Despite the low number of cut-marks, four stages of reindeer carcass processing are apparent.

Cut marks on the maxillary tooth and on the mandible fragment (and see Olsen 1989, fig. 10) were probably associated with the removal of skin and flesh around the mouth (plate 13, 9). Other initial butchery marks include those recorded on the distal end of the humerus. Binford (1981) refers to cut marks in this location as Hd-2, the most common mark produced on or across the distal humerus during dismemberment, and the first of a series of cuts designed to dislocate the humerus from the radio-cubitus. He describes this action in recent reindeer butchery scenarios as »The knife is run transversely into the joint and turned inward across the medial face of the distal humerus, sometimes even penetrating to the medial face of the olecranon. This is generally done with the leg fairly well extended or straight« (ibid. p. 124). Typical dismemberment cut marks were observed on the distal metacarpus (Mtd-1) and on the medial face of the astragalus (Ta-2). Cut marks located around the glenoid cavity were recorded on the three distal scapulae (plate 13, 8). Such marks are produced during disarticulation of the distal scapula from the proximal humerus. 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.

The remaining marks are located on the shafts of the humerus and on two femur shaft fragments and were probably produced during removal of the periosteum.

Traces of carnivore gnawing were also recorded on two cut marked scapulae (P16 56-899 and P16 68-247), and on one of the femur shafts (P16 34-665) which also has a hammerstone-induced impact notch on one long side.

Impact notches

Hammerstone-induced impact notches observed on reindeer bones were identified using the same criteria described in the chapter on humanly-modified horse bones, and are depicted in figures 26 and 27. Single impact notches were recorded on only two reindeer bones, a shaft fragment from a femur and a shaft fragment from a metacarpus. Cut marks were also present on the femur shaft, along with carnivore tooth pitting. Both bones were too fragmentarily preserved to ascertain whether they belonged to adult or to juvenile animals.

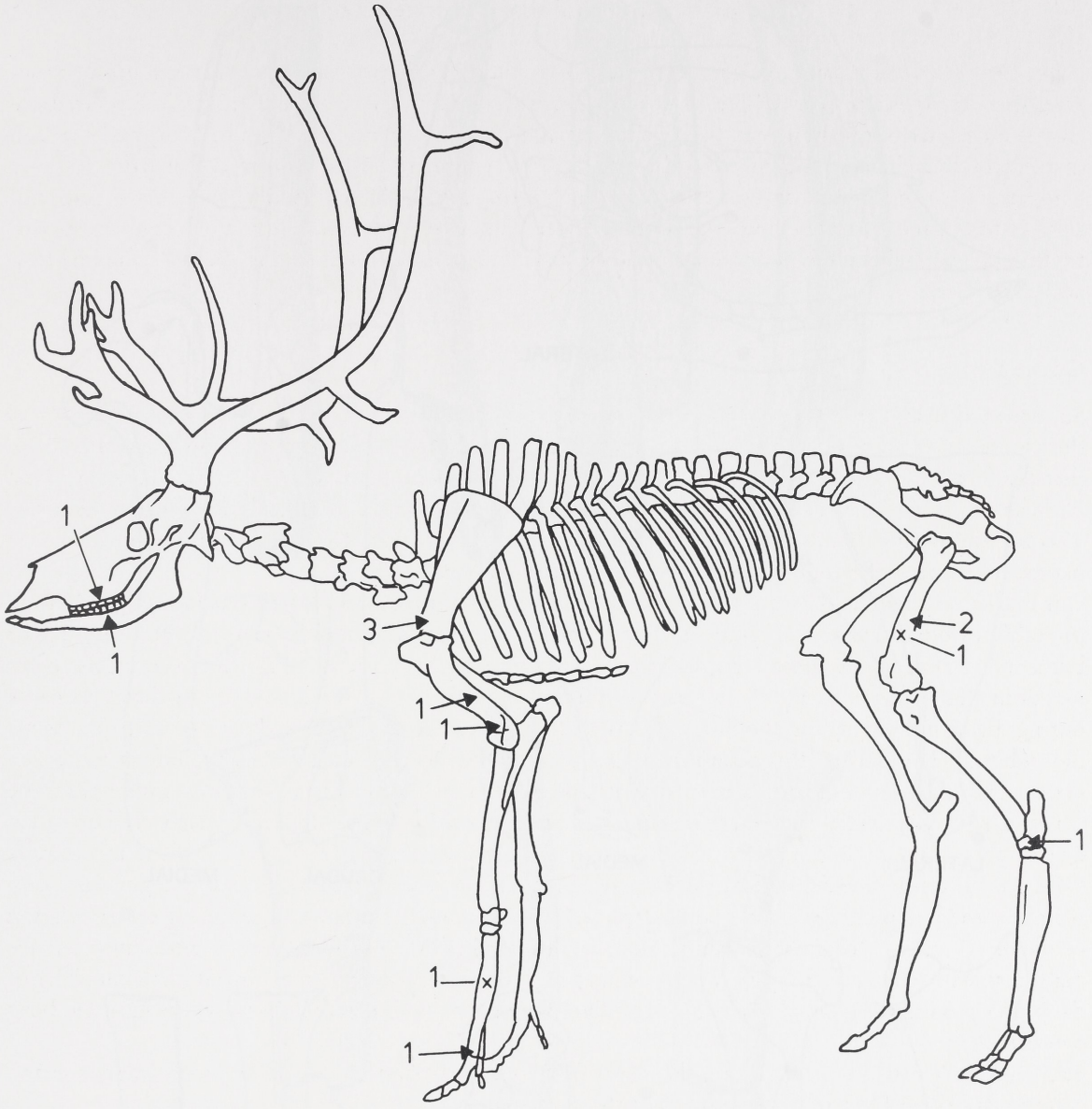


Fig. 26 Location of cut marks and hammerstone-induced impact notches on reindeer remains from the sector P16 site at Solutré. Arrows with numbers indicate the location of cut marks and the number of times cut marks were observed in a particular location. Crosses with number indicate the location of impact notches and the number of times impact notches were observed on the element.

Worked antler and bone

Five antler finds from sector P16 had been worked. A single reindeer incisor tooth bore cut marks across the root, and was probably intended for wear as a pendant. A bone fragment, possibly from a reindeer, bore multiple cut mark traces along one edge.

The most important piece of worked antler is an incomplete bâton percé made of reindeer antler (P16 23-379) (plate 20, 3). The find comprises the base of the antler, a portion of the pedicle and part of the beam preserved to a length of about 220 mm. The beam has been fractured post-depositionally. The

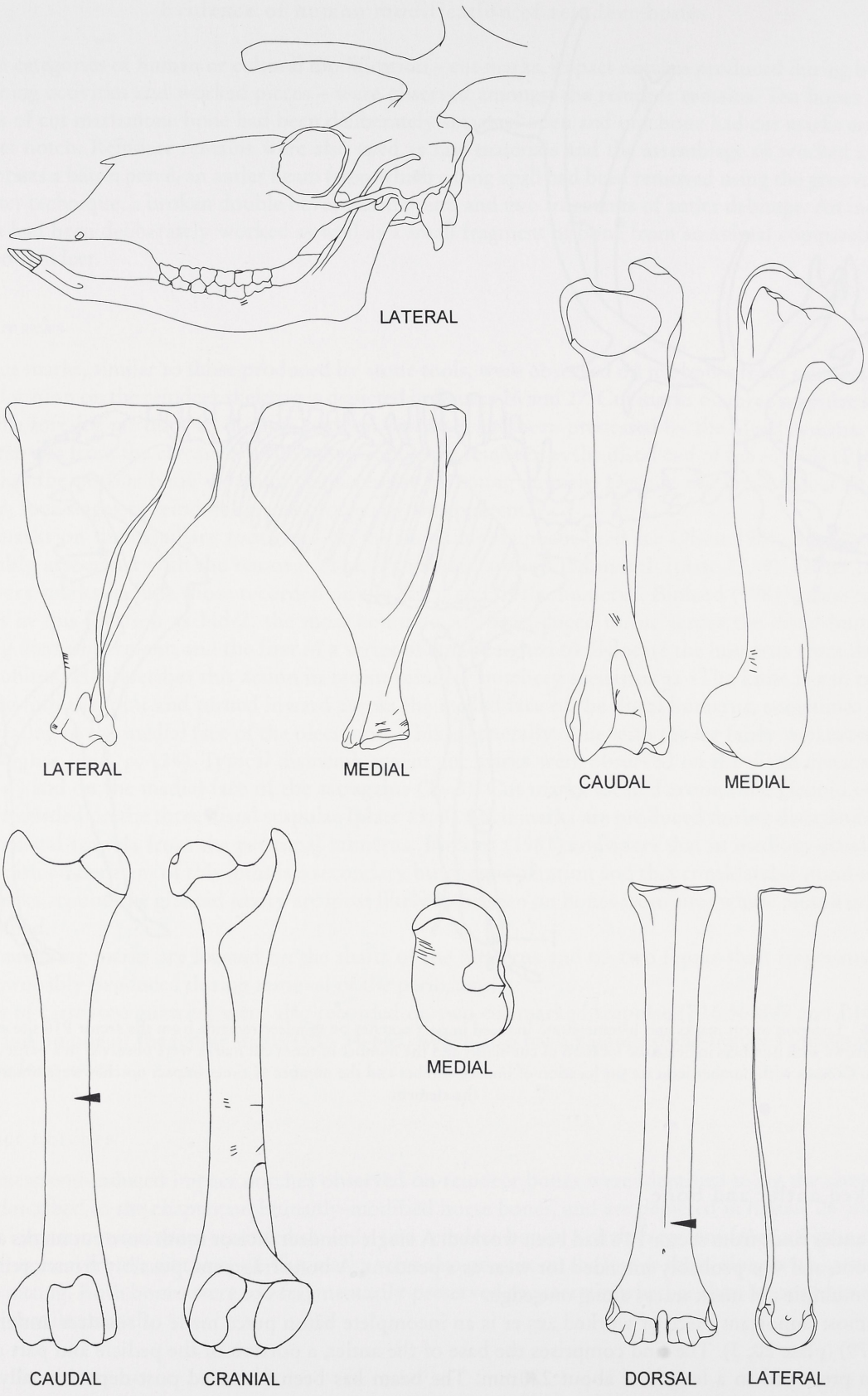


Fig. 27 Details of cut marks and impact notches on reindeer remains. Top row: cranium and mandible; middle row left to right: scapula, humerus; bottom row left to right: femur, calcaneum, metacarpus. Arrows mark location of impact notches.

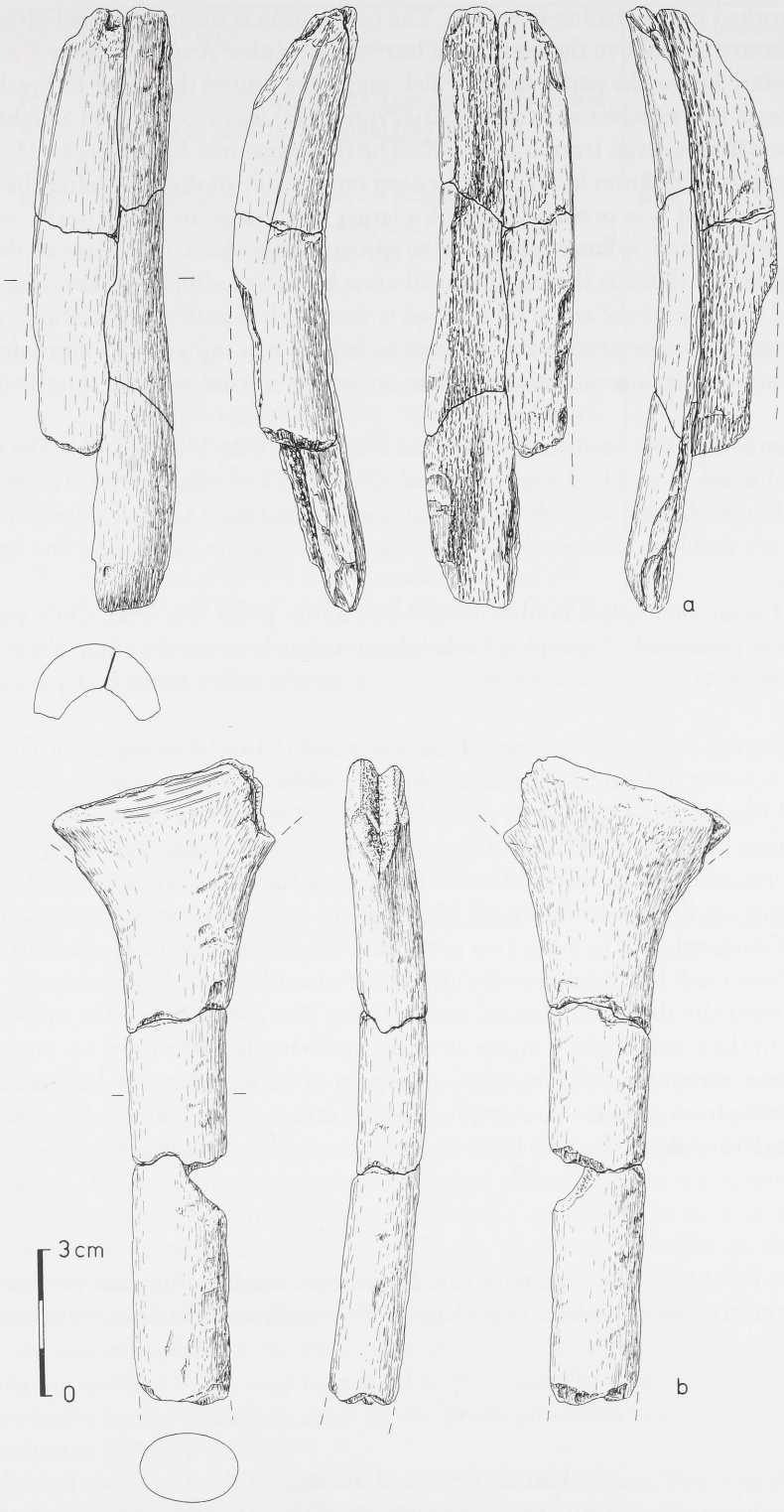


Fig. 28 Worked reindeer antler from sector P16 at Solutré.

pedicle has been worked into a phallus-like form. The perforation is incomplete and placed towards the base of the shaft about 4 cms above the weathered burr of the antler. A spall of bone has been removed from the beam directly below the perforation, which may have caused the antler to break.
A portion of the beam of a reindeer antler (P16 90-329; fig. 28a) was recovered in a highly fragmentary state amongst secondaire material from quadrat 90. The find measures 123.1 × 26.0 × 15.7 mm. The end of a single, deep cut mark (43.8 mm long) could be seen on one side of the beam after the fragments had been refitted. The fragment was probably part of a larger portion of an antler beam, which had been worked using the groove and splinter technique to obtain antler spalls. The base of the find appears slightly rounded. Whether this was the result of deliberate human modification, abrasion or simply preservation of part of the base of the antler (if the find is from a shed antler) was difficult to ascertain on this fragmentary piece. That the groove and splinter technique was utilized at Solutré during Magdalenian times, can be seen on an almost intact reindeer antler beam from which a long spall of antler has been removed.
A fragment of an antler tine was recovered during excavation (P16 24-547; fig. 28b). The find comprises the base and part of a tine, possibly the second basal tine, from a reindeer antler. The tine has been removed by cutting longitudinally on both the medial (inner) and lateral (outer) sides of the beam. Well-defined cut marks are visible at the base of the tine on one side of the beam. The tine has been broken post-depositionally.
The find P16 26-71 is an incomplete double bevel-based antler point (fig. 29a). Only part of the bevel base and the shaft are preserved. The find is broken longitudinally along the shaft; the point is missing. The fragment measures 11.2 × 20.9 × 10.5 mm. A second, simple antler point is depicted in figure 28b (P16 99-240).
Cut marks were observed on one incisor tooth from a reindeer (P16 57-518, fig. 29c). The tooth is a first lower incisor from a young individual. The incisor had probably erupted, but had not been brought into wear at the time of the animals death. Five, possibly six, short transverse cut marks, are located on the buccal side of the root just below the base of the crown. This tooth could have been part of a series of incisor teeth from reindeer which were intended for decorative wear. Rows of reindeer incisor teeth worked into pendants are known from several Magdalenian contexts (Poplin 1983). A row of reindeer incisor teeth from Gönnersdorf (Germany) is a good example of this form of Magdalenian pendant. The roots of the six incisor teeth had been cut off close to the mandible by a lithic tool, and the teeth were held together afterwards by dried out gingival tissue (ibid.). The cut marks on the incisor from P16 are located at the neck of the tooth, slightly higher than the point at which the roots on the specimens from Gönnersdorf had been removed. The Magdalenian visitors to the P16 site may have started to produce a similar pendant made from reindeer incisors, but for some reason did not complete their task.
The bone fragment (P16 67-921, fig. 29d) bears traces of multiple cut marks along one long edge.

Charred bone

Two reindeer bones had been in contact with fire. Both bones are from the fore-foot joint (carpal bones) of the animal and comprise a right scaphoid and a left cuneiform. The finds were both recovered in square metre 97.

Carnivore modification

Traces of carnivore gnawing were observed on 18 reindeer bones. The specimens comprise 6.6% of the total number of finds identified to reindeer. These elements are listed and described below, and depicted in figure 30. The percentages are the number of gnawed bones out of the total number of finds for each element:

	%	damage type	carcass utilization
Cranium			
antler pedicle	10.0	tooth puncture mark (∅3.3) in cranium fragment at base of pedicle on caudal side (58-209)	
Axial			
pelvis	12.5	isolated puncture marks on ischiac bones (67-522, ∅2.9 and 79-429, ∅6.7) associated with loss of bone in iliac and pubis regions resulting in bony stumps	light to heavy carcass utilization
Fore-limb			
scapula	45.4	removal of acromion and scalloping of spine (90-268; 56-899). Removal of coracoid process (68-247, 24-312, 48-117). Puncture mark on 48-117 specimen (∅2.6). Cut marks on 68-247 and 56-899 specimens.	typical carnivore modification of shoulder blade. Heavy carcass utilisation
humerus	44.4	series of tooth notches on caudal face of shaft (54-458), single puncture mark medial side distal end ∅2. 2 (47-83). Gnawing and bone loss on distal end (54-67) and end of distal shaft (57-494)	full to heavy carcass utilization
radius	12.5	two tooth notches on proximal near-epiphyseal region (35-286) of radius	probably produced during gnawing of proximal end
Rear limb			
femur	11.1	pitting on proximal part of a shaft fragment (34-665). Cut marks and hammerstone-induced impact notch on shaft.	heavy carcass utilization
astragalus	6.2	two puncture marks (∅2.5 and 3.3) on medial face (21-184), associated with small area of bone loss	
calcaneum	33.3	gouging and loss of bone on tuber calcis (47-35; 67-491; 69-87)	most common form of carnivore modification on this element

Carnivore modification was observed on 18 reindeer bones, including a fragment of a cranium, two bones from the pelvic girdle, five scapulae, four humeri, a femur, a radius, an astragalus and three calcanei (plate 14, 1-5). One specimen, a distal humerus (P16 47-83), retained the porous bone structure typical of sub-adult animals. None of the more intact bones had unfused epiphyses. Carnivores had gnawed mainly on reindeer scapulae and humeri. Typical carnivore modification such as the removal of the coracoid process on the scapula and removal of the tip of the tuber calcis on the calcaneum were recorded on reindeer remains. Patterns of modification on the pelvis, scapulae and humeri indicate heavy utilization of reindeer carcasses by carnivores. Tooth notches on humeral shafts attesting to the cracking of these bones are also exemplary of the final stages of carnivore bone processing. The ample evidence of shaft cracking on reindeer bones may be related to the relatively small size of the bones of this cervid, which were easier for carnivores to crack open. Tooth punctures were observed on several bones and these range in size from 2.2-6.7 mm.

Three bones showed traces of both cultural and carnivore modification. Two scapulae – one specimen with cut marks around the distal end (P16 56-899) produced during carcass dismemberment, and a second specimen with a series of cut marks on the cranial edge (P16 68-247) – had been gnawed along the spine and at the distal end. Cut marks on a femur shaft (P16 34-665) are probably attributable to periosteum removal and the bone was subsequently smashed open leaving an impact notch. The shaft of this particular specimen also has traces of pitting, probably produced by carnivore teeth.

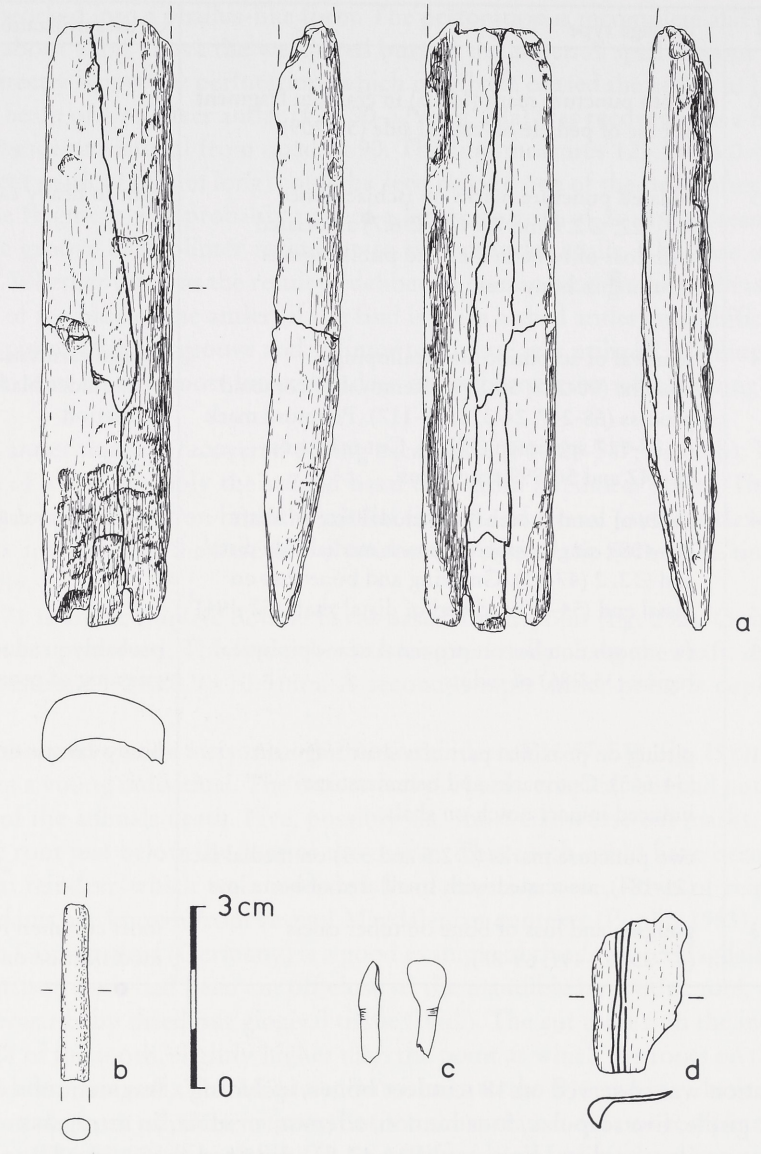


Fig. 29 Worked reindeer antler, teeth and bone from sector P16 at Solutré.

Summary of the reindeer remains from the Magdalenian deposits at sector P16

The remains of a medium-sized cervid, identified as reindeer, were recovered from the sector P16 site. The reindeer are comparable in size to a small form of this species noted at south-western sites in France dating to the latter part of the Upper Pleistocene.

Reindeer remains are clearly underrepresented in the P16 assemblage, considering that a minimum of nine individuals of reindeer were identified. As with horse bones, the absence of some reindeer skeletal parts could be related to bone preservation and bone density: high numbers of reindeer individuals being re-

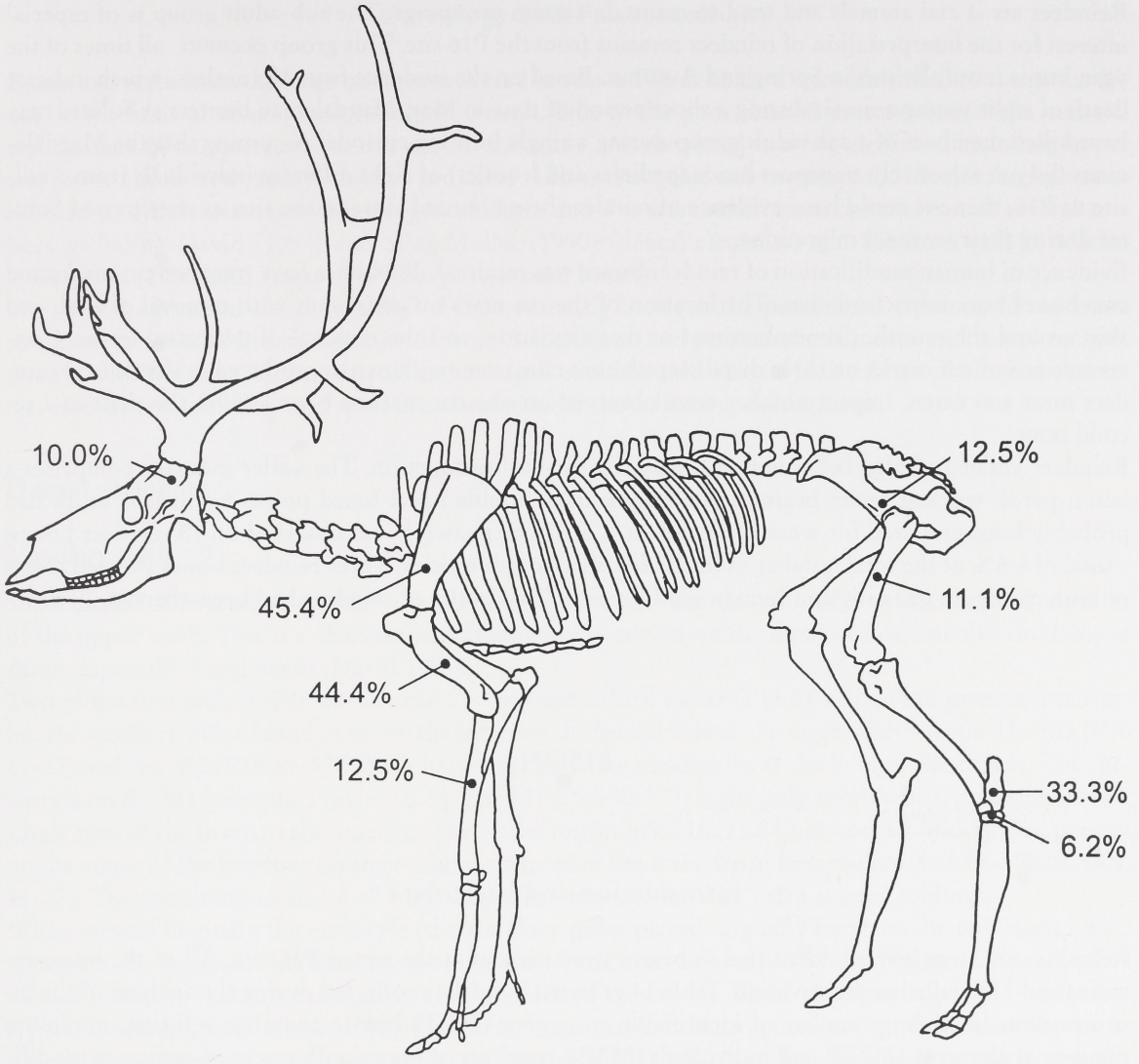


Fig. 30 Carnivore modification of the reindeer bones from sector P16 at Solutré expressed as a percentage of the total number of finds for each element. Arrows indicate position of gnawing traces on the elements.

corded on high-density bones; more fragile bones, in particular those from the axial skeleton, having very low ratings or are absent. There was little difference in numbers of individuals counted on high-utility and on low-utility body-parts. Reindeer are part of the archaeological fauna at the site, but reindeer skeletal part representation gives no clear indication as to whether these body parts are the remains of intensively processed whole carcasses of reindeer which had been killed at the site, or the remains of carcasses of reindeer which had been killed elsewhere and transported to the site as carcass portions.

The stage of antler shedding and regrowth of seven pedicles and an antler frontlet from sub-adult reindeer, indicate that these individuals died during the month of May. Incremental analysis of a sample of teeth indicated reindeer dying between November to March and April to May.

Approximate ages of reindeer show that two individuals less than two years of age and one old adult were present at the site. Sub adult and adult reindeer appear to have been the preferred prey of the Magdalenian hunters, and six individuals (counted on maxillary teeth) and 3-4 individuals (counted on mandibulary teeth) were represented in these age-cohorts.

Reindeer are social animals and tend to maintain certain groupings. The sub-adult group is of especial interest for the interpretation of reindeer remains from the P16 site. This group occurs at all times of the year, but is most obvious in Spring and Autumn. Based on the evidence from the antlers, which indicate death of eight young animals during a short period of time in May, Magdalenian hunters at Solutré may have killed members of a sub-adult group during a single hunting episode. Assuming that the Magdalenians did not selectively transport heads (pedicles and frontlet) of eight different individuals from a kill-site to P16, then we could have evidence of reindeer being hunted close to the site, as they passed Solutré during their seasonal migrations.
Evidence of human modification of reindeer bones was minimal. Ten bones have traces of cut marks and two bones bore impact notches. The location of the cut marks is consistent with removal of flesh and skin around the mouth, dismemberment or disarticulation, and the removal of periosteal tissue. Concentrations of cut marks on three distal scapulae are consistent with marks produced at sites where reindeer meat was eaten. Impact notches were observed on one cut-marked bone and on the shaft of a second bone.
Reindeer antler had also been used as a material for tool production. The antler industry comprises a bâton-percé, worked antler beams and a fragmentary double bevel-based point. An incisor tooth had probably been prepared for wear as a pendant. Carnivore gnawing was observed on 18 reindeer bones, a total of 6.6% of the total number of finds identified to this species. Three reindeer bones showed traces of both carnivore gnawing and human modification. Two bones of reindeer had been charred.

BISON

Introduction and basic data

Remains of a large bovine, identified as bison, were present at the sector P16 site. All of the bison remains had Magdalenian preservation. Table 14 presents basic data collected during the analysis of the bison remains, including number of identifiable specimens (NISP) before and after refitting, minimum number of elements (MNE) and individuals (MNI), numbers of bones with traces of carnivore modification, cut marks and impact notches and numbers of worked and charred bones.

NISP	NISP after refitting	MNE	MNI	carnivore gnawing	cut marks	impact notches	worked bone	charred bone
142	137	119	5	20	2	6	0	0

Tab. 14 Basic data about the remains of bison at the sector P16 site at Solutré.

142 remains could be identified to bison and they represent 3.4% of the total number of bones identifiable to a species. 119 elements are present. Five individuals were counted on the metacarpals. Juvenile and adult bison are present. Cut marks and impact notches were observed on a total of eight bison bones, but there was no evidence that bison remains were deliberately worked by humans or came into contact with fire. In contrast to the evidence of minimal human modification, a relatively high number of bison bones had been modified by carnivores.

Osteology and Palaeoecology

Bones and teeth from the large bovine recovered in sector P16 at Solutré were identified to the genus *Bison* on the basis of several morphological criteria. Due to the poor state of preservation of the material and the lack of complete crania, this part of the study was restricted to a few elements, including upper and lower cheek teeth, axis vertebrae, proximal radius, astragalus and metacarpals. Morphological criteria used to differentiate between the genera *Bison* and *Bos* were taken from the analyses of several authors including David (1994) and Slott-Moller (1990) (dental elements) and Bibikova (1958), Martin (1987), Sala (1986) and Stampfli (1963) (post-cranial bones).
Gee (1993) addressed the difficulties of differentiating between the postcranial elements of the often abundant remains of Pleistocene bovids from British sites, and presented qualitative and morphometric criteria with which radii, metacarpals and astragali could be told apart. He listed morphological characters in order of reliability and these are referred to in the following descriptions.

Dental elements

Maxillary teeth

Small circles of enamel or enamel »islands« are present between the two lobes on the occlusal surfaces of the upper teeth. This is a characteristic frequently observed on the teeth of *Bos*, but also on those of *Bison*, especially fossil bison (David 1994).
Two of the first molars (P16 68-473 and 21-166) and a third molar (P16 54-79) do not possess mesostyles, the auxillary pillar found between the lobes on the buccal side of the upper cheek teeth. The M1 (P16 11-22) and the M2 (P16 69-377) both have tiny, bud-like mesostyles at the base of the crown. The mesostyle on the M1 is crooked (plate 16, 3). The M1 (P16 80-202) is the only tooth which possesses a high, single mesostyle, fused to the anterior lobe of the tooth (plate 16, 2). Minor enamel foldings are present on the edges of the fossettes on the occlusal surfaces of the three worn first molars (P16 68-473, 80-202, 11-22). The remaining teeth are all very simple in form and have no extra enamel foldings.
When viewed lingually the entostyle (the auxillary pillar placed lingually between the two main lobes) appears to be »pinched« between the lobes on one of the first molars (P16 68-473) (plate 16, 5) and, when viewed mesially, does not protrude beyond the side of the crown. These characteristics are described as typical for *Bison* (Slott-Moller 1990). However, these characteristics appear to be low in reliability as the entostyles on a second molar from the same individual (P16 69-377) (plate 16, 4) and on the first molar from a second individual (P16 80 202) are not pinched between the lobes. In the case of the M2, the entostyle protrudes beyond the side of the crown.
All of the entostyles on the sample of upper molars from P16 were single ones with the exception of the M2 (P16 69-377), which has a multilobed entostyle (plate 16, 4). On this tooth, a main pillar is flanked by a shorter pillar fused to the protocone, which continues down onto the root of tooth in the form of a ridge. A third bud-like pillar at the base of the crown on the posterior lobe is also present on this tooth. Multilobed entostyles are more typical of *Bison*. The crowns of the upper molars have sub-parallel (convergent) sides when viewed mesially or distally, a characteristic also considered to be more typical of *Bison* (Slott-Moller 1990).

Mandibulary teeth

The only specimens of lower M2 and M1 in the sample are from the same animal (plate 17, 1-2). Both have wide, parallel-sided, in section U-shaped, lingual grooves (the groove separating the two main lobes of the tooth), a trait often observed in *Bison* teeth. On both teeth, the bases of the ectostylids are flared as depicted for *Bison* (Slott-Moller 1990) rather than straight as in *Bos*.
Morphological attributes could only be observed on two out of a total of three lower third molars. The

third specimen is unerupted. One specimen (79-738) has the open, U-shaped lingual groove thought to be characteristic of *Bison* (plate 17, 4). The lingual groove on the second specimen (33-369) was V-shaped in profile, but open at its base (plate 17, 3). This specimen also resembles to some extent teeth described by Slott-Moller as »M2's onto which a third lobe has been attached« (1990:46), which he considers to be characteristic of *Bos*. When viewed occlusally, the third lobe on both specimens appeared to be placed in the same axis as the two main lobes, a characteristic of *Bos* rather than *Bison*. None of the third molars possessed an auxillary column between the second and third lobe on the buccal side (plate 17, 5-6).

Post-cranial bones

Axis or Epistropheus

Only the cranial ends of three axis vertebrae are preserved (P16 31-107, 47-124 56-157). The dorsal edge of the odontoid process is low in all three specimens, a characteristic described by Stampfli (1963) as typical of *Bison*.

Proximal radius

The form of the proximal end of the radius, and in particular characteristics of the articular surface, are considered by many authors to be important distinguishing criteria between the two genera (Martin 1987 [including references to other authors], Sala 1986, Stampfli 1963) Only one proximal radius was recovered, and unfortunately the proximal end of this find was so poorly-preserved that only two characteristics could be referred to. The radius possesses a swelling just below the proximal edge on the lateral side of the bone. This swelling is irregular and very pronounced in *Bos*, less pronounced and steeply inclined in *Bison*. The swelling on the specimen from sector P16 compared more with criteria described for *Bison*. The medial edge of the proximal surface has a well-defined lip which is again considered to be typical of *Bison* (Martin 1987).

Astragalus

Altogether four astragali were recovered (P16 58-293, 58-129, 33-440, 88-444). Gee (1993) and Stampfli (1963) describe two morphological traits of the astragalus as potentially useful when distinguishing between the two genera. In *Bison*, there is a prominent laterally directed flange which curves medially and distally around the nutrient foramen on the posterior edge of the articulation facet for the calcaneum. A prominent, medially curving flange is present on the 33-440 find; flanges observed on the other finds, although less well-defined due to weathering, have the same form. In *Bos*, the flange is reduced, angles at 90° above the foramen, or is absent (Gee 1993; Stampfli 1963).
The lateral articular facet for the calcaneum is longer in *Bison* and not as tall as in *Bos*. This facet was preserved on only one of the specimens (P16 33-440). A facet-index of 49.8 was reckoned for this find (breadth of facet x 100/length of facet) comparable with indices for *Bison* (41.6-56.6 x = 45.9) given by Stampfli (1963, p. 150). According to Bibikova (1958), facet indices for *Bos* usually range above 58.0. A third characteristic, but one which ranks low in reliability (Gee 1993), is the form of the posterior lateral edge of the astragalus which is straight in *Bison*, but curved in *Bos*. All three specimens from sector P16 are straight-sided.

Metacarpal

Metacarpals are one of the most commonly preserved bones at archaeological sites and, in the absence of skulls, probably one of the most useful from a taxonomical aspect. A total of four intact bovine metacarpals were found at the P16 site (46-411, 32-41, 12-64, 34-534). All four specimens have the same form

and size, and only very minor differences in morphology were observed, as was to be expected of bones from several individuals of the same species. One specimen (46-411) is distally incompletely ossified.
The metacarpals of *Bos* are more angular in proximal view than *Bison* metacarpals. The four metacarpals from P16 are less angular as in *Bison*. Particularly noticeable on all four specimens is the more or less straight palmar edge of the proximal articulation when viewed from above.
However, the most reliable characteristic is the articular facet for the vestigial 5th metacarpal, which is more pronounced in *Bos* than in *Bison*, as noted by Brugal (1984). This articular surface could only be observed on the well-preserved 32-41 specimen (plate 18, 2). It is less pronounced, and compared well in size and shape with the articular surface for the vestigial metacarpal on a metacarpus from recent European bison (*Bison bonasus*) in the comparative bone collection (plate 18, 1). The facet for the unciform is triangular as in *Bison* (Bibikova 1958). The depression median on the palmar edge is not as marked as in *Bos*.
Two differentiating features were noted on the distal ends of the metacarpals from P16. Both are described as moderately reliable criterias by Gee (1993). Firstly, the anterior vascular groove is weakly developed as in *Bison* (Bibikova 1958) (plate 18, 3-4). Secondly, the metacarpals have a pronounced »kink« or shouldered appearance in the region of the distal diaphysis which is considered typical of *Bison*, and which was also observed on the recent comparative specimen (plate 18, 1-4). This morphological characteristic was not so well-developed on the metacarpal from the juvenile animal, probably due to the less robust form of this specimen.
On the whole, morphological criteria observed on the four metacarpals are characteristic of *Bison*. An isolated distal metacarpus (89-548) showed some differences to the specimens mentioned above. The bone was very large and probably belonged to a male individual. The characteristic »kink« in the distal region was not as pronounced on this specimen.

The remains of a large bovine from sector P16 at Solutré were studied in an attempt to define the finds to one of the genera of Pleistocene bovids, *Bison* or *Bos*. The skull is the element which can be most reliably used to differentiate between the genera. At Solutré, only fragmentary parts of the cranium had been preserved, so that an identification to genera was undertaken using morphological criteria observed on dental elements (cheek teeth) and post-cranial bones.
The post-cranial bones described above (with the possible exception of the isolated distal metacarpus) could be identified to *Bison* using morphological criteria. Two of the mandibulary cheek teeth have criteria considered to be more typical of the genus *Bos*, whereas morphological characters observed on the upper cheek teeth have been described as typical of *Bison*. As the majority of the elements in this small sample showed morphological criteria comparable to *Bison* rather than *Bos*, all large bovine remains from P16 were attributed to the genus *Bison*.

In his revision of Pleistocene European bison Brugal (1984) demonstrated the presence of three sub-species: *Bison priscus priscus* from early Middle Pleistocene sites such as Mosbach and Mauer in Germany, *Bison priscus mediator* represented at sites dating to the Saalian Glaciation, such as Châtillon-Saint-Jean in France and dating to interglacials within the Saale phase, such as Weimar-Ehringsdorf in Germany, and a new subspecies, *Bison priscus* subsp. nov., found at sites dating to the last warm and last cold phases, such as Roterberg (Germany) and Windy Knoll (England). The three subspecies are characterized by a gradual decrease in body-size from the large *B. p. priscus* to the smaller, new subspecies which approached the living European bison (*Bison bonasus*) in size. According to Brugal the metacarpals play a significant role in this evolution, becoming shorter and stockier as evolution progressed.
The lengths of four measurable metacarpals from sector P16 were compared with data given by Brugal (ibid. fig. 2, p. 673) for bison metacarpals from the site of Roterberg (Germany) and for metacarpals of living European bison. The comparative sample includes measurements taken on metacarpals from males and females, the four specimens from P16 are from female bison only.

Comparative measurements of metacarpal length (min-max in mm):

Roterberg, *Bison priscus* nov. subsp.	210-240
Bison bonasus	202-225
sector P16 specimens	218-226

The bison metacarpals from P16 compare with the smaller end of the size range given for bison from Roterberg, as was to be expected considering that female bison are smaller than male bison. They are also comparable in size to those of *Bison bonasus*. In other words, they represent a relatively small form of bison, which Brugal sees as typical for the youngest part of the Pleistocene period.

Palaeoecology

Bison is known to have occurred in faunas from both cold and warm stages during the Pleistocene. Usually associated with an open environment and regional herbaceous vegetation during the cold stages, its remains have also been recorded in interstadial contexts in association with boreal forests and in interglacial contexts in association with locally deforested areas (Stuart 1982).

Numbers of individuals and skeletal part representation

In table 15, the skeletal remains of bison are listed by element, body-side, minimum number of element and individuals for each bone and number gnawed by carnivores. For long bones of the fore and rear limbs, MNE's and MNI's are placed next to the portion of the element on which these were counted (for example, MNE and MNI for the humeri were counted on the shafts of this bone); the number gnawed by carnivores refers to the total number of humeri which bear such traces.

The highest minimum number of bison individuals – five – was counted on the metacarpals (fig. 31). Considering that we are dealing with a minimum of five bison at P16, their remains are underrepresented. In the skeletal representation of bison, axial elements are rare. Only one rib fragment and one vertebra from the cervical, thoracic and lumbal regions of the spine could be identified to this species.
High counts of four bison were recorded on maxillary cheek teeth and the shaft and distal end of the humerus, and counts of three bison on the acetabular region of the pelvis, distal tibia, astragalus and axis vertebrae. All of the elements with high individual counts are high density or sturdy bones, including for bison the first two cervical vertebrae (Kreutzer 1992). Carnivore attrition was relatively high for bison remains and the absence of articular ends, such as proximal humerus and proximal and distal femur, is very likely due to carnivore modification of bison bone.
As with reindeer remains, there was little indication of a particular selection for high or low-utility bison body parts. Three individuals being recorded on the high-utility pelvic region and also on the low-utility astragalus; four individuals on the high-utility humerus and five on the low-utility metacarpal. Despite differences in body-size and numbers of individuals, both bison and reindeer have a similar skeletal representation. The remains of bison represented at sector P16 could represent carcass parts which were either transported to the site, or parts of carcasses of animals killed close to the site which had been intensively processed by the Magdalenian hunters.

	left	*	right	MNE	MNI	number gnawed
Head						
cranium	1	1	0	1	1	0
mandible	2		1	3	2	0
maxillary teeth	5		9	14	4	0
mandibulary teeth	10	1	2	13	3	0
Axial						
atlas	2		2	2	0	
axis	4		3	3	0	
cervical	2		2	1	0	
thoracic	1		1	1	0	
lumbar	3		3	1	1	
caudal	0		0	0	0	
sacrum		0		0	0	
pelvis	4		4	5	3	2
ribs	2		1	1	0	
Fore-limb						
D scapula	1		1	2	1	0
P humerus	0		0	–	–	–
shaft	5		2	7	4	4
D humerus	1		1	–	–	–
radius complete		2	–	–	–	
P radius	0		0	–	–	–
shaft	0		1	2	2	2
D radius	0		0	–	–	–
P ulna	1		1	2	1	0
shaft	1		1	–	–	–
carpals	5		4	9	2	0
metacarpal, complete	0		4	–	–	–
P metacarpal	0		1	5	5	0
shaft	0	1	0	–	–	–
D metacarpal	1		1	–	–	–
Rear-limb						
P femur	1		1	–	–	–
shaft	2		2	4	2	4
D femur	1		0	–	–	–
patella	1		0	1	1	0
P tibia	0		0	–	–	–
shaft	2		0	–	–	–
D tibia	3		0	3	3	0
os malleolare	0		0	0	0	0
calcaneum	1		1	2	1	1
astragalus	3		1	4	3	0
tarsals	2		3	5	3	1
P metatarsus	2		2	4	2	1
shaft	0	1	0	–	–	–
D metatarsus	0		0	–	–	–
mc/mt shaft	0	2	0	–	–	0
sesamoid		1		1	1	0
phalange 1	6 complete, 2 fragments			8	1	2
phalange 2	4 complete, 1 fragment			5	1	1
phalange 3	5 complete, 2 fragments			7	1	1
Totals	**142**			**119**		**20**

Tab. 15 Counts of bison remains from the Magdalenian deposits at the sector P16 site at Solutré. – P = proximal, D =distal, * = indeterminable to body-side, mc/mt = indeterminable to metacarpal or metatarsal. MNE for mandibles and pelves is based on halves. Fragment of an unidentifiable long bone included in total count, but not in table.

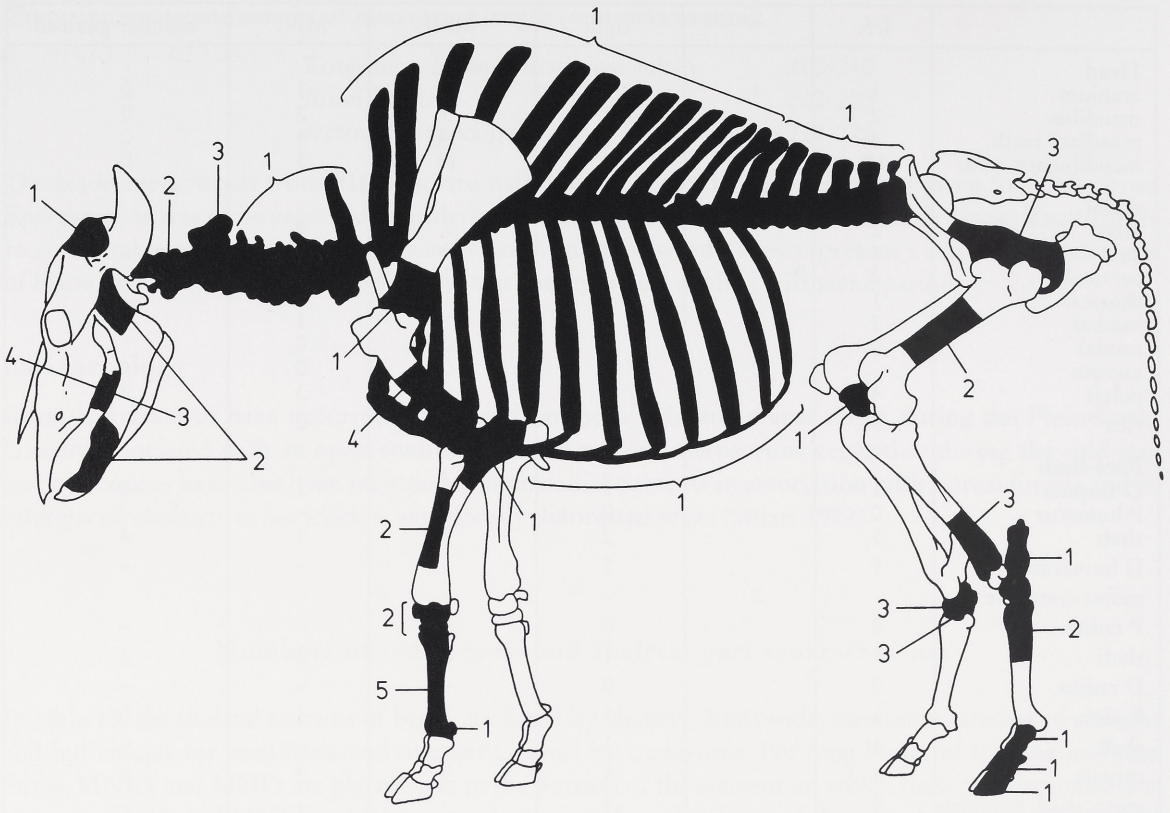


Fig. 31 Bison skeletal representation at sector P16 based on the minimum number of individuals (MNI) for each element. Black areas on elements of the head, legs and on the pelvis indicate those portions of the bones preserved at the site.

Determination of number of bison individuals, bison age and season of death on certain skeletal elements

Numbers of individuals and individual age using the upper and lower cheek teeth

A total of 23 cheek teeth were identified to bison. Although very small in size, the sample provided information about the numbers of individuals and, on a more tentative basis, their ages at death and seasons in which they died. The small size of the sample from sector P16 allowed a detailed analysis to be undertaken, and it was possible to distinguish a total of at least four individuals of bison on both the upper and the lower cheek teeth using teeth in different wear and eruption stages from the right and left sides of the body. Conventional counts of minimum numbers of individuals gave a total of four bisons for the upper teeth, but only three for the lower teeth.

Bison are a seasonally birthing taxon, in other words their calves are born in annually consistent, short seasons, which in recent North American bison is a two-week period in the latter part of April and the beginning of May or, in the case of European bison, mainly in May to the beginning of June (Heptner, Nasimovich and Bannikov 1989). Bisons born in the same season belong to a single age-cohort sharing a pattern of tooth development and wear which is distinct from other age-groups in the herd (Todd and Hofman 1987). Patterns of dental development and wear observed on the lower dentition of bison from sector P16 were compared with dental development in age-groups described in detail by Todd and Hofman (ibid.) in their analysis of fossil bison mandibles from the Horner and Finley sites in the northern

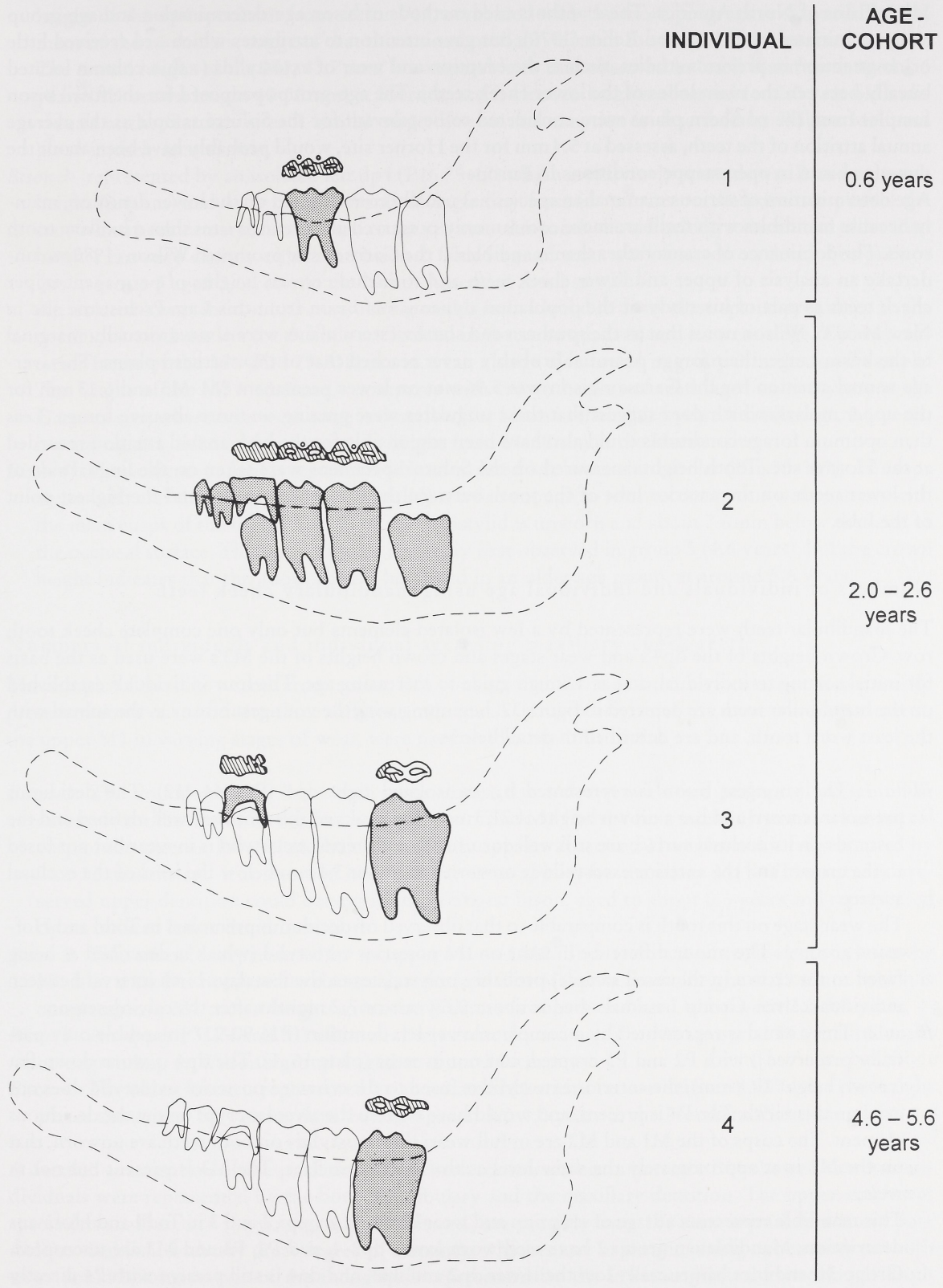


Fig. 32 Numbers of individuals and their ages based on mandibulary cheek teeth.

High Plains of North America. These authors used methods of bison age-determination and age-group analyses initiated by Frison and Reher (1970), but gave attention to attributes which had received little or no attention in previous studies, such as the eruption and wear of extostylids (a thin column located bucally between the main lobes of the lower cheek teeth). The age-groups proposed for the fossil bison samples from the northern plains were considered to be relevant for the Solutré sample as the average annual attrition of the teeth, assessed at 5.4 mm for the Horner site, would probably have been about the same for bison in open steppe conditions in Europe.

Age determination of various mammalian species has usually concentrated on the lower dentition, mainly because mandibles with teeth are more commmonly preserved at excavated sites than maxillary tooth rows. The dominance of crania rather than mandibles at the Garnsey site prompted Wilson (1980) to undertake an analysis of upper and lower cheek teeth and to include crown heights of permanent upper cheek teeth as part of his study of the population dynamics of bison from this Late Prehistoric site in New Mexico. Wilson notes that as the southern and southwestern plains were always virtually marginal to the bison range, their forage potential probably never reached that of the northern plains. The average annual attrition for the Garnsey bison was 5.96 mm on lower permanent M1-M3 and 6.13 mm for the upper molars, which does suggest that these ungulates were grazing on more abrasive forage. Less than optimum forage conditions could also have been responsible for the high annual attrition recorded at the Horner site. Tooth heights measured on the Solutré specimens were taken on the lingual side of the lower teeth, on the anterior lobe of the tooth between the base of the crown and the highest point of the lobe.

Numbers of individuals and individual age using mandibulary cheek teeth

The mandibular teeth were represented by a few isolated elements but only one complete cheek tooth row. Crown heights of the dp4's and wear stages and crown heights of the M3's were used as the basis for initial sorting to individual, and as a rough guide to increasing age. The four individuals established on the mandibular teeth are depicted in figure 32, beginning with the youngest bison i.e. the animal with the least worn tooth, and are described in detail below.

Bison 1: The youngest bison is represented by an isolated right dp4 (P16 44-212). The deciduous premolar is worn and has a crown height of 21.3 mm. The peaks of the tooth are well-defined and the fossetids on its occlusal surface are still well-formed. The posterior extostylid is in wear but not fused to the crown, and the anterior extostylid is unworn and about 3.4 mm below the level of the occlusal surface.

The wear stage on this tooth is comparable to that observed on deciduous premolars in Todd and Hofmans group 1. The minor difference in wear on the posterior extostylid (which is described as being fused to the crown in the fossil sample) probably only relates to the few days birth interval between individual calves. Group 1 animals died at about 0.6 years or 7.2 months after the calving season.

Bison 2: This animal is represented by a complete lower left dentition (P16 90-237 [mandible only partially preserved]) with P2 and P3 erupted, but not in wear (plate 16, 1). The dp4 is worn down flat (crown height 10.8 mm), the anterior extostylid is fused to the crown; a posterior extostylid does not exist on this tooth. The P4 is present, and would have been in the alveolar crypt below the deciduous element. The cusps of the M1 and M2 are in full wear; the extostylids on both teeth are unworn, that on the M1 is at approximately the same level as the occlusal surface. The M3 is present but not in wear.

This mandible represents a stage of eruption and wear between groups 2 and 3 in Todd and Hofmans description. Mandibles in group 2 have well worn lower dp2-4, and P2, P3 and M3 are unerupted. Group 3 mandibles have usually lost the lower dp2 and dp3, and dp4 is still present with P4 directly below it. P2 and P3 are not in wear. The third molar is erupted and the anterior portion is already in wear. Group 2 is aged at about 1.6 years and group 3 at about 2.6 years. However, the low crown

height of the dp4 specimen from sector P16, combined with the more progressive stage of replacement of the premolars, suggests that this animal probably died in the range 2.0-2.6 years.
The crown height of the M1, 43.7 mm, is comparable to that observed in fossil bison teeth aged 1.6 years (M1 crown height 40-50 mm) at Horner, and is close to heights observed for 2.0 year old individuals at the Garnsey site. A similar stage of wear and eruption is described by Wilson for fossil bison in their second year.

Bison 3: represented by an isolated left dp4 (P16 79-17) which is extremely worn down. Based on tooth height (8.4 mm) and wear pattern – only a single tiny fossetid remains on the posterior part of the crown and both extostylids are fused to the crown – this tooth should belong to an animal older than bison 1 but only slightly older than bison 2. This stage of wear was observed on deciduous premolars in group 3 aged 2.6 years in the North American fossil sample.
An isolated lower third molar may belong to this individual due to its close spatial proximity to the deciduous tooth on site (both finds are located in the same quadrat) and its wear stage. The two anterior facets of the M3 (P16 79-738) are in wear, a stage also found in group 3 in the fossil sample. The height of the M3 – 63.6 mm – compares with crown heights of teeth aged to two years at the Garnsey site, whereas its wear stage is described for bison in their third year. A similar age, 2.6 years, is attributed to third molars ranging in height from 64-68 mm at the Horner site.

Bison 4: The »oldest« animal is represented by an isolated left lower third molar (P16 33-369). All cusps are in wear and the third cusp (hypoconulid) is worn enough to form a continuous wear pattern with the main cusps of the tooth. The tip of the extostylid is unworn and about 7.6 mm below the level of the occlusal surface. This stage of wear is usually first observed in group 5 (4.6 years), but the crown height indicates that this tooth should be placed in an older age group, at around 5.6 years.

Numbers of individuals and individual age using maxillary cheek teeth

The sample of maxillary teeth from sector P16 consists mainly of isolated elements, but also partially preserved rows of teeth from three different individuals. Crown heights of the most common element, the upper M1 in varying stages of wear, were used to identify four bison.

Bison 1: The youngest bison has a dp3 worn almost flat and dp4 with two peaks still present. The entostyle on the dp4 is in the first stage of wear. The M1 has the first traces of wear on the buccal cusp of the anterior lobe. Mandibular M1 usually appears at around 3 months and is fully erupted by 9 or 12 months and it is assumed here that the same applies for maxillary M1's. This partially preserved upper dentition could belong to the youngest bison, aged to about 0.6 years and represented by an isolated lower deciduous tooth.

Bison 2: This animal is represented by an upper M1 and M2. Both teeth are worn; the entostyle on the M1 is in wear but not fused to the occlusal surface. The M1 has a crown height of 39.6 mm, which is comparable to M1 crown heights given for Wilson's groups 3 or 4 aged to between 2.0-3.0 years.

Bison 3: An upper P3, P4 and M1 all in wear represent this animal. The M1 measured 34.9 mm in height corresponding to Wilson's group 4 aged at about 3.0 years.

Bison 4: The oldest bison is represented by an isolated M1 with a crown-height of 30.7 mm. This height places the animal between groups 4 and 5 aged at 3.0-4.0 years in the Northern Plains sample.

A detailed examination of the small sample of cheek teeth from bison in sector P16 showed that four individuals were represented by the both mandibulary and the maxillary dentition. The upper and lower specimens attributed to the youngest bison (bison 1) are possibly from the same animal. It was not possible to establish, with any great degree of certainty, whether any of the remaining upper teeth or tooth rows could belong to one of the individuals represented by the lower dentition, even though tooth height and/or wear pattern was comparable in most cases.
Teeth from foetal and neonatal individuals with no dental wear or only very slight wear on the deci-

duous premolars are absent in the P16 sample. Extremely worn teeth from very old or senile individuals were also not observed. The bison population recovered at P16 consisted of a calf (bison 1) which died in its first year during either late autumn/early winter according to Todd and Hofman. The mandibulary teeth provide further information (fig. 32). Bisons 2 and 3 are juveniles. Although the state of eruption of the third molars suggests some differences in age between these animals, the similarity in the heights of the dp4's indicates that both bison could have been born during the same calving period. Their provisional ages are assessed as 2.0-2.6 years. According to eruption and wear recorded on fossil bison from the Vore site (Reher and Frison 1980), mandibulary M3 first appears at 2.1-2.2 years and the first two cusps are in wear a few months later during autumn. This state of wear and eruption is comparable to that found on the M3's from bisons 2 and 3. Bison 4 is an almost fully mature animal slightly older than 4.6 years when the animal died.

Epiphyseal fusion stages of postcranial bone of bison

The timing of epiphyseal fusion stages of postcranial bone observed in domestic cattle by Habermehl (1961), Silver (1963), Ellenberger-Baum (1943) (a useful summary of the results of these studies is given by Grigson (1982, p. 22, Appendix 3) and by Schmid (1972) was used to establish the approximate age at death of juvenile bison from sector P16. A total of twelve elements from bison have unfused or partially fused epiphyses and diaphyses. The elements are listed in table 16, along with their fusion stage, approximate age of ossification of the element based on a compilation of data given by the authors mentioned above, and the minimum number of individuals (MNI) represented in a particular fusion stage.
The bones with unfused epiphyses and diaphyses could all belong to a single individual of bison. In this group of bones the proximal epiphysis of the phalange 1 has the earliest fusion date, and gives an age at death for this animal of younger than 20 months to one year (Habermehl 1961; Silver 1963) or younger than $1^1/_2$-2 years according to Schmid (1972). Four elements, a first phalange, a metacarpus and a proximal and a distal femur were incompletely fused and the fusion line was still visible. Spiess (1979) reports that epiphyseal fusion lines can remain visible for up to one year after fusion has taken place. These four incompletely fused elements could represent the remains of a second juvenile bison at the site. This animal could have been as young as three years of age (oldest age for phalange 1 fusion plus one year) or as old as five years (oldest age of fusion for proximal femur plus one year) at the time of death.

In addition to these unfused or partially fused elements, a series of 17 bison bones were observed which, although fused, showed the porous bone structure of the joint typical of sub-adult animals. Some of these bones, such as the astragalus and carpal and tarsal bones, do not fuse anyway and could belong to the same individual represented by the unfused long bones. However, among the remaining long bones is a right metacarpus (P16 12-64) which duplicates the right metacarpus with a visible distal fusion line listed in table 16. The second metacarpus possibly represents a third young bison at the site.

To summarise, the unfused and partially fused elements from juvenile bison recorded at the P16 site, indicate that at least one animal died before it reached an age of 20 months to one year or $1^1/_2$-2 years, depending on which comparative ageing data is referred to. A second, older bison is represented by three partially fused elements with fusion lines still visible. This animal was between three and five years at the time of death. One of the elements from the second individual, a right metacarpus, is duplicated by a fused metacarpus from the same body-side which retains the porous structure indicative of sub-adult animals. This bone tentatively represents a third young bison of approximately the same age as the second individual.
Three young bisons were also identified using crown heights and tooth wear patterns of mandibulary and maxillary teeth. The group of unfused postcranial elements listed in table 16 may belong to bison 1, which according to tooth wear was about six months old when it died. Postcranial remains from a

element and site cat. no.	fusion stage	approximate age of fusion in years	MNI
phalange 1 (55-109)	unfused proximally	20 months to 1 year or 1 1/2-2 (Schmid)	1
metacarpus or metatarsus dex (99-417 and 99-439)	unfused distal epiphyses	2-3	1
metatarsus sin (89-294)	distal diaphysis unfused	2-3	1
metatarsus (33-12)	distal diaphysis unfused	2-3	–
calcaneum dex (79-451)	tuber calcis unfused	3-3 1/2	1
ulna dex 69-235	proximal diaphysis unfused	3 1/2-4	1
cervical vertebra (34-463)	corpus unfused caudally	4-8 or more	1
lumbar vertebra (100-325)	corpus unfused	2 1/2-5 or 7-9 (Schmid)	1
phalange 1 (78-423)	fused proximally, line visible	20 months to 1 year or 1 1/2-2 (Schmid)	1
metacarpus dex (46-41)	fused distally, line visible	2-2 1/2	1
femur sin (48-51)	fused proximally, line visible	3 1/2-4	1
femur sin (90-273)	fused distally, line visible	3 1/2-4	1

Tab. 16 Bison epipyseal fusion stages at sector P16.

second, somewhat older, juvenile and from a possible third, sub-adult, individual could not be assigned to one of the remaining bisons identified on the teeth. They simply support the evidence from the dental elements that at least two (bison 2 and 3 on mandibulary teeth) and possibly three (bison 2, 3 and 4 on maxillary teeth) individuals of bison younger than 4 years of age were present at the site.

Sexual dimorphism in the bison from Solutré

Sexual dimorphism is particularly marked in both the genera *Bos* and *Bison*. In modern North American bison, the average weight of mature bulls is in the region of 1600-1800 pounds. Female bisons weigh only half this weight (Todd 1987). Similar weights have been recorded for European bison, and females are also much smaller than the males. This overall difference in body-size is also reflected in the size of the bones from adult individuals. 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 recording of five metacarpals. Four of these specimens, including the incompletely ossified metacarpal and the metacarpal which retained the porous bone structure typical of sub-adult animals, were more or less equal in length, proximal width and distal width. A fifth metacarpus was much larger, and even though only the distal end of this bone was preserved, it surpassed 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 in figure 33 against the depth of the medial part of the trochlea (David 1994). The metacarpals clearly divide into two groups in the graph, with the single

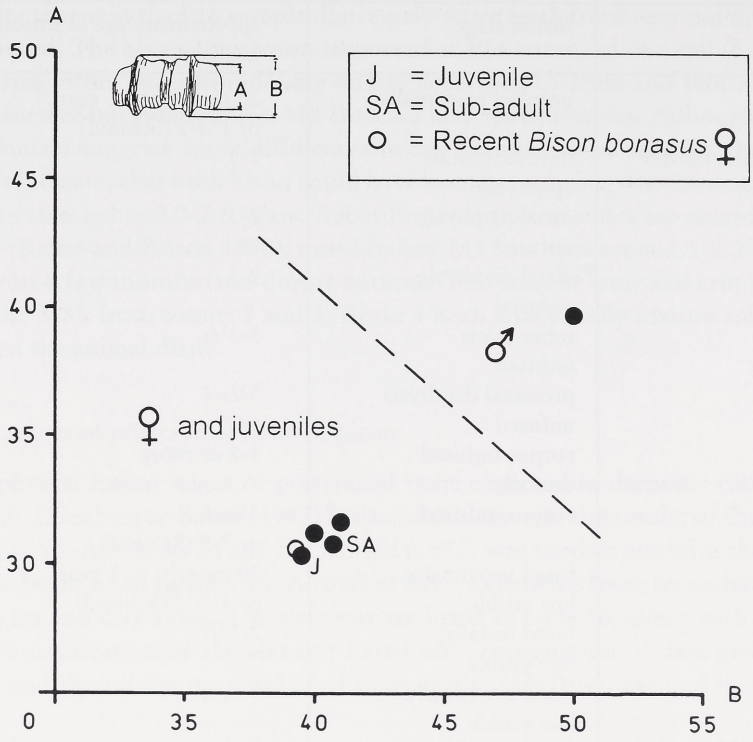


Fig. 33 Sexual dimophism in the bison population from the sector P16 site.

large specimen probably representing a male and the four other metacarpals representing two adult females and two younger animals. It could be postulated that the juvenile and sub-adult specimens are also females, since both finds fall within the female size range.

Ecology and behaviour of bison

Three basic kinds of herds have been observed for American bison (Olsen 1995, referring to Reynolds et al. 1982). These consist of the cow-calf group (or nursery group), the bull group and large herds composed of congregations of both groups. Cow-calf groups usually consist of several cows with their calves and some yearlings. An elder, experienced cow usually leads the group which can include some bulls. Bull groups are usually composed of bachelor males, although cows, in particular those which for some reason have not calved, may also join the bull group. The breeding season, or rut, takes place between July to September, and during this phase cow-calf and bull groups often congregate together forming large herds. After the rut, the large herd disintegrates into the smaller core groups.
Bison are a migratory species and in regions with pronounced local topography, graze in summer on pastures on higher lands, moving into the lowlands in winter (Olsen 1995).
Limited observations on the variability of the nutritional condition of male and female American bison suggest that seasonal changes in bison conditions parallel reasonably well those described for other mammals, and Speth (1983) describes a general pattern for bison as follows. Male condition improves during late spring-early summer, as the bulls prepare for the rut by building up fat reserves. Male condition peaks at the onset of the rut and declines sharply during and after the rut. Bulls may loose up to

10% of their body-weight at this time (Lott 1979) and this may be sufficient to cause marrow fat mobilisation (Brooks 1978). In late autumn-winter male condition begins to improve, but many males are in a comparatively poor nutritional condition as they go through the winter months. Overall condition may decline through late winter into spring especially if nutrition is sparse during winter. Male condition improves rapidly as new forage appears in spring and, with this, the annual cycle begins again.
Female condition is low during the calving season in spring. After calving, female condition improves gradually throughout the summer and autumn, during which time the cows build up fat reserves for winter and the calving season of the following year. In late spring, pregnant or lactating females are poor in condition, probably reaching a level lower than that of males during this period. On the other hand, females enter winter with greater reserves than males and thus may be in better condition in spring.

	calf	juvenile/sub-adult			adult		
mandibular teeth	bison 1 c. 6 months	bison 2 2.0-2.6 years	bison 3 2.6 years		bison 4 5.6 years		
maxillary teeth	bison 1 c. 6 months	bison 2 2.0-3.0 years	bison 3 3.0 years	bison 4 3.0-4.0 years			
postcranial bone	unfused bones younger than 20 months		incompletely ossified bones 3-5 years, probably female	bone with »porous« structure sub-adult, probably female	female	female	male

Tab. 17 Summary of data describing numbers of individuals, age of the individuals and sexual demography of bisons from the Magdalenian deposits at sector P16.

Summary

Table 17 attempts to summarise all the data about numbers of bison individuals, their ages and their sex as described and discussed in the sections above.
The deciduous teeth and the unfused postcranial bones could all belong to one bison, a calf which may have been as young as 6 months of age at death. The remaining juvenile animals identified on teeth (bison 2 and 3 based on mandibulary teeth and bison 2-4 based on maxillary teeth) are more difficult to associate with the postcranial bones. However, an incompletely ossified metacarpal and an ossified metacarpal retaining the porous bone structure typical of sub-adults, show that postcranial remains of one juvenile older than the calf and one sub-adult are present, and that both of these individuals were females according to bone-size. Two adult females and an adult male complete the population of bison recovered at the P16 site. Altogether, one calf of unknown sex, two juveniles including one female, a sub-adult female, two adult females and an adult male form the P16 bison »herd«.
The dominance of females associated with a single calf and two individuals in the juvenile/sub-adult category suggests that if these animals died during a single event, the age and sex-structure of the group

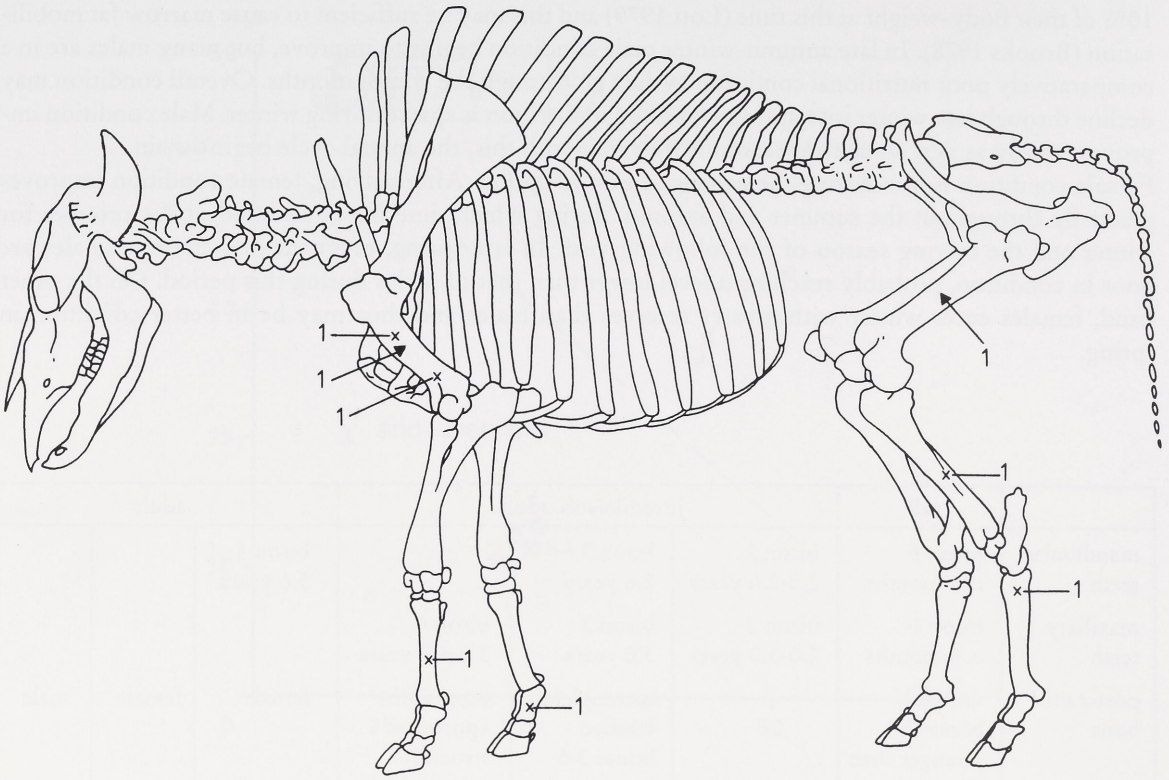


Fig. 34 Location of cut marks and hammerstone-induced impact notches on bison remains from the sector P16 site at Solutré. Arrows with numbers indicate the location of cut marks and the number of times cut marks were observed in a particular location. Crosses with number indicate the position of impact notches and the number of times impact notches were observed in a particular position.

would compare closely with that described for cow-calf groups. The presence of a single male is not unusual, as males have also been observed attached to cow-calf groups. The time of death established for the calf (bison 1) and for the two juveniles (bison 2 and 3) suggests that some bisons were hunted during autumn/winter. At this time, females are probably in a relatively good condition as this is the period when they are building up or have built up their fat resources. The single bull, would be in a relatively poor condition if this animal had died alongside the calf and the juveniles.

Evidence of human modification of bison bones

Two categories of human modification – cut marks and hammerstone-induced impact notches – were observed on bison remains from sector P16. A total of six bones bore impact notches, and marks possibly produced by stone tools are present on two bones. Altogether eight bones representing 5.9% of the total number of bones identified to this species show possible evidence of human modification. Bison bones do not appear to have been used as a raw material for bone tools and none of them are charred.

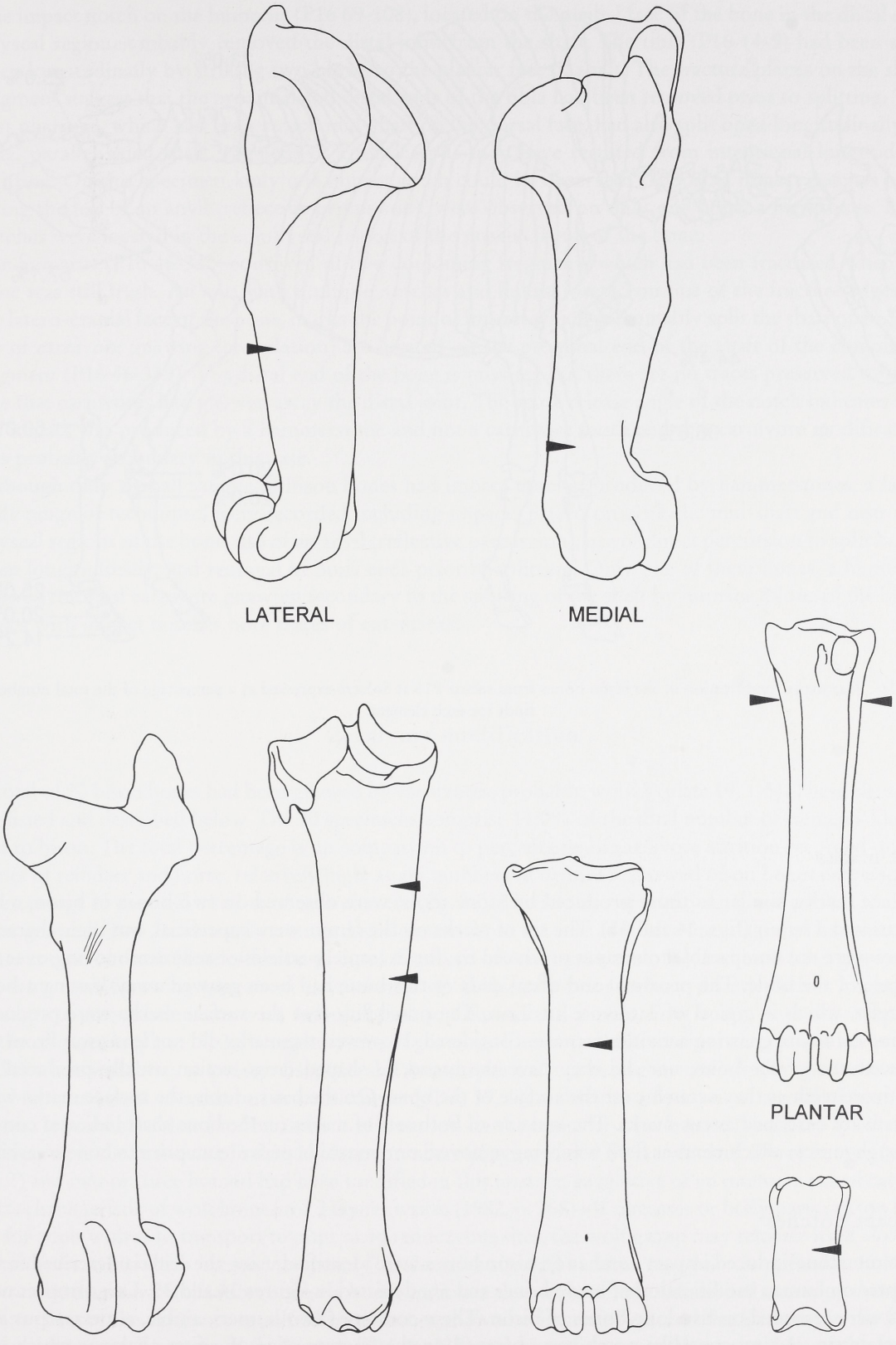


Fig. 35 Details of cut marks and impact notches on bison remains. Top row; humerus; bottom row from left to right: femur, tibia, metacarpus, metatarsus and phalange. Arrows mark locations of impact notches.

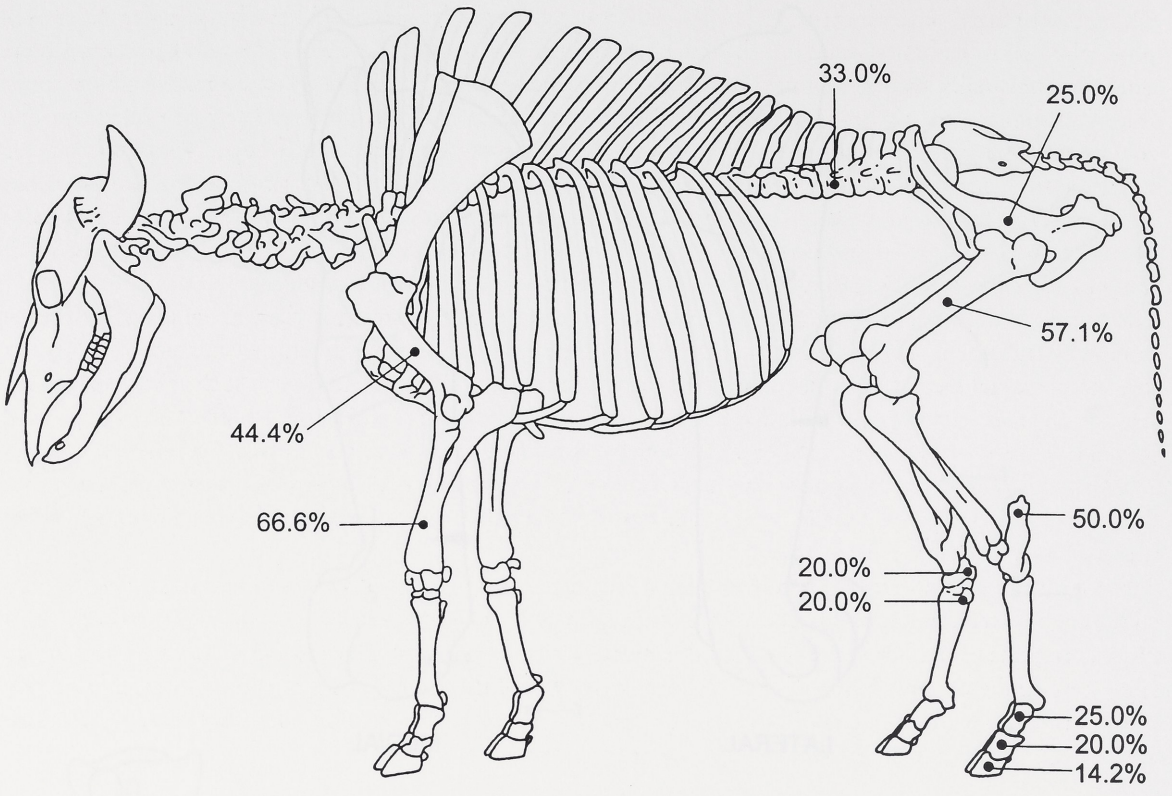


Fig. 36 Carnivore modification of the bison bones from sector P16 at Solutré expressed as a percentage of the total number of finds for each element.

Cut marks

Surface marks, similar to those produced by stone tools, were observed on two bones of bison, a humerus and a femur (figs. 34 and 35). The set of marks on the femur were superficial, but their characteristics were not comparable to scrapes produced by, for example, particles of sediment moving over the surface of the bone. The proximal and distal ends of this bone had been gnawed away leaving a bone cylinder, which is typical of carnivore attrition. The possibility that the surface marks were produced during carnivore gnawing activities was also considered. However, the marks did not lead away from the gnawed end of the bone, nor did they have the broad, U-shaped cross-section usually produced by carnivore teeth as they scratch over the surface of the bone. On the basis of this, the surface marks were tentatively described as cut-marks. The location of both sets of marks on the bone shaft indicates cutting through muscle attachments as flesh was being removed, or removal of periosteum prior to bone smashing.

Impact notches

Hammerstone-induced impact notches on bison bones were identified using the criteria described in the chapter on human modification of horse bones and are depicted in figures 34 and 35. Large impact notches were recorded on five long bones of bison. These consist of two humeri, a tibia, a metacarpus and a metatarsus. A tiny cone-like notch was observed on the fracture edge of a first phalange which had been split open longitudinally.

The impact notch on the humerus (P16 69-108), located on the medial face of the bone in the distal epiphyseal region, probably removed the distal joint from the shaft. The tibia (P16 14-9) had been split open longitudinally by striking two blows to the plantar face of shaft. The fracture planes on the shaft fragment suggest that the proximal and distal ends of the tibia had been removed prior to splitting. The first phalange, which had been struck mid-shaft on the dorsal face, had also split open longitudinally. A long, parallel-sided shaft fragment of a metacarpus may have resulted from intentional longitudinal splitting. On this specimen, only one impact notch could be observed. Opposing impact notches indicating the use of an anvil (reflective percussion), were observed on only one bone, a metatarsus. Both notches were located in the epiphyseal region of the proximal end of the bone.
The humerus (P16 46-340) consisted of two conjoining fragments which had been fractured when the bone was still fresh. An area with multiple notches and flakes, located on one of the fracture edges on the latero-cranial face of the bone, marks the point of impact which presumably split the shaft open. Traces of carnivore gnawing (crenulation) are located on the proximal end of the shaft of the conjoining fragment (P16 46-339). The distal end of the bone is missing, but there are no traces preserved to indicate that carnivores had gnawed away the distal joint. The acute release angle of the notch indicates that the impact was produced by a hammerstone and not a carnivore tooth and that carnivore modification was probably secondary in this case.
Although only a small sample of bison bones had impact notches produced by hammerstones, a fairly wide range of techniques were recorded including impacts placed on both the mid-shaft and near epiphyseal regions of the bone, use of an anvil (reflective percussion), use of direct percussion to split bones open longitudinally, and removal of bone ends prior to splitting. Only one of these bones, a humerus, showed traces of carnivore gnawing secondary to the splitting of the shaft by humans. None of the bison bones with impact notches bore traces of cut-marks.

Carnivore modification

A total of 20 bison bones had been gnawed by carnivores, probably wolves (plate 19, 1-5). These elements are listed and described below. The 20 specimens comprise 14.0% of the total number of elements identified to bison. The total percentage is, in comparison to percentages of carnivore attrition recorded on the bones of reindeer and horse, relatively high, as are numbers of carnivore gnawed bison bones expressed as a percentage of the total number of each element (fig. 36). The remains of both young and adult bison had been gnawed. Two anatomically connecting elements from the rear foot of a bison aged at less than 2-3 years at time of death (time of fusion of distal diaphysis of metatarsus, table 16), had both been gnawed in the same area. Gnawing appears to have taken place in this case prior to bone disarticulation. High percentages of gnawed elements were recorded on bison humeri and femurs. Foot bones, with the exception of the calcaneum (plate 19, 3), bore less traces of gnawing. Elements of the cranium and mandible, cervical and thoracic vertebrae, scapulae, ribs, tibias and metacarpals had not been gnawn. Carnivore preference for the humerus (4 out of a total of seven elements [plate 19, 1]) and femur (three out of a total of four elements) 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 bone cylinders. Three femurs (plate 19, 2) and two or three humeri had been modified in this manner, suggestive of an intensive use of carcass parts characteristic of 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. Certainly, the heavy utilization of bison bones indicates that wolves had undisturbed access to these remains. Two of the carnivore-modified bison bones showed evidence of cultural modification in the form of an impact notch on one of the humeri (P16 46-339) and a possible cut mark on the shaft of the femur (P16 23-269):

	%	damage type	carcass utilization
Axial			
lumbar vertebra	33.0	furrowing and loss of bone on cranial end (100-325)	typical carnivore modification
pelvis	25.0	pitting and furrowing on pubis bone, crenulated ischium (56-375, 90-292)	light to heavy carcass utilization
Fore-limb			
humerus	44.4	two bone »cylinders« (100-313, 34-525) with both proximal and distal ends missing, ends of shafts crenulated. One incomplete bone cylinder (46-339) with crenulation preserved on proximal end only. One distal end and shaft (78-379 with furrowing on medial edge of distal end. Hammerstone-induced impact notch on 46-339 find.	heavy carcass utilization. Gnawing of distal condyles typical of scavenging.
radius	66.6	proximal end gnawed off (22-65). Gnawing marks on medial edge of distal end (32-80).	typical carnivore modification
Rear-limb			
femur	57.1	Gouging on proximal femur head (22-66) three bone cylinders with proximal and distal ends gnawed away, crenulation on shaft ends (23-269, 46-239, 66-398). Possible cut-marks on shaft of 23-269 find.	light to heavy utilization
calcaneum	50.0	furrowing on end of tuber calcis (89-296)	most common form of modification on this element
os centrotarsale	20.0	furrowing and loss of bone on plantar edge (90-190)	
metatarsus	25.0	furrowing and loss of bone on plantar part of proximal end. This element could be re-articulated with the os centrotarsale (above). Gnawing traces on both bones are located in the same area and took place before the bones became disarticulated	
phalange 1	25.0	Puncture marks on one specimen (89-582). Second specimen (78-423) gnawed distally	typical minor damage resulting from chewing up through phalanges
phalange 2	20.0	multiple punctures (57-355)	as above
phalange 3	14.2	(33-444)	as above

Pathological bones

A single element from bison showed evidence of a pathological growth. The find is a portion of the symphysis of a left mandible (P16 90-218). The symphysis is unfused and exhibits excessive bony growth (exostose) on its inner, lingual side.

Summary of the bison remains in the Magdalenian deposits at the Sector P16 site

Remains of a large bovine, identified on morphological criteria as bison, were also present at the sector P16 site. The remains are comparable in size with those of a new subspecies of *Bison priscus* which

occurred during the last Interglacial and Last Cold stage in Europe. A total of 142 bison remains were counted, representing 3.4% of the remains identified to a species at this site. Five individuals of bison were counted on the metacarpals. Considering that we are dealing with at least five individuals of bison, their remains are underrepresented. Axial elements are rare. High counts of individuals were recorded for high density or sturdy bones, including for bison the first two cervical vertebrae. The total percentage of carnivore attrition was relatively high for bison remains and the absence of articular ends on bison bones, such as proximal humerus and proximal and distal femur, is very likely due to carnivore modification. Bison skeletal part representation is similar to that of reindeer, despite the great differences in body-size between these species. As with reindeer there was little indication of a particular selection for high or low-utility bison body parts. The remains of bison preserved at sector P16 could represent carcass parts which were either transported to the site, or parts of carcasses of bisons which had been killed and intensely processed close to or at the site.

A detailed comparison of numbers of individuals and their ages showed that one calf of unknown sex, two juveniles (one of which is female), a subadult female, two adult females and an adult male form the P16 bison »herd«. The dominance of females associated with a single calf and two individuals in the juvenile/subadult category suggest that if these animals died during a single event, the age and sex-structure of the group would compare closely with that described for cow-calf groups. The time of death established for the calf and for the two juveniles suggests that bisons were seasonally hunted during autumn/winter. The time of death of the young bison indicates that these animals, and possibly the group, had died during migration into the valley in order to shelter from the harsher climes prevailing in higher altitudes during the winter. During autumn/winter, nutritional condition is poor in male bison but relatively good in female bison.

A total of only eight bison bones bore traces of human modification. The location of cut marks on the shafts of two bones could be related to either cutting through muscle attachments or removal of periosteal tissue. Six bones bore impact notches. One specimen had been fractured on an anvil (reflective percussion) and another specimen had been split open longitudinally. There was evidence of removal of articular ends prior to bone cracking.

Twenty bones or 14.0% of the total number of bison remains had been gnawed by carnivores. When compared to those of horse and reindeer, the proportion of carnivore chewed bison bones is relatively high. This, and the high number of bison bone cylinders suggest that for some reason, carnivores utilized bison carcass parts more intensively than carcass parts of horse and reindeer.

WOLF

Introduction

Thirty finds were identified to the wolf, *Canis lupus*. These represent a minimum of two animals. Two mandible halves, some isolated teeth fragments and post-cranial bones could be attributed to two adult wolves. Two elements, a distal humerus and a distal femur, were unfused and represent the remains of a young wolf, possibly a third individual, at the site.

One of the radii has an isolated, superficial cut mark on its shaft. Five wolf bones show traces of carnivore gnawing and one bone has been pathologically altered. None of the bones had been charred. The basic data for the wolf from sector P16 is summarised below in table 18.

NISP	NISP after refitting	MNE	MNI	carnivore gnawing	cut marks	impact notches	worked bone	charred bone
30	30	30	2	5	1	0	0	0

Tab. 18 Basic data for the remains of wolf from the Magdalenian level at the P16 site.

Osteology and Palaeoecology

Only a few remains from wolf were measurable. These finds include the teeth preserved in the left mandible (P16 36-74) and the distal end of a radius (P16 23-72).

mandible (P16 36-7)	length	breadth
P4	16.7	8.6
M1	29.4	11.4
M2	12.6	9.3
length of molar row	47.5	
height of mandible behind M1	32.7	
radius (P16 23-72)		
breadth distal end	23.1	

Argant (1991) only mentions fragmentary wolf remains from Solutré in his study of Quaternary carnivores from Burgundy, so that a comparison in size between the remains identified here and those found earlier at the site was not possible. The length of the lower M1 is comparable with the range in size of M1's in the living wolf (27.0-31.0mm) given by Bonifay (1966, tab. XX).

The wolf is a ubiquitous carnivore. This species is known to have occurred in both cold and warm stages during the Pleistocene, and the presence of its preferred prey, medium-sized to large-sized herbivores, dictated its range more than climatic conditions. Living wolves are found in various habitats including forested regions, mountainous areas, flat, open plains and in areas with dense vegetational cover.

Skeletal part representation

In table 19, the skeletal elements of wolf are listed by element and body-side and depicted in figure 37. Because of the small amount of finds from wolf, details concerning number of individuals and number of bones chewed by carnivores are given in the following sections and not in this table.

Elements of the head (upper and lower teeth, mandibles), axial elements and bones from the legs and feet of wolf were present in low numbers at the P16 site. Ribs, thoracic and lumbar vertebrae, and sacrum were not preserved. One caudal vertebra is the only element from the tail. Bones from the fore limbs are better represented than those of the rear limbs (fig. 37).
Some wolf remains appear to have been deposited as anatomically connected portions. Several cervical vertebrae (B28) were recovered more or less in anatomical connection during excavation. The two mandible halves (B27) (plate 15, 1-2) were located together on site and close to the cervical vertebrae as

	left	*	right	MNE
Head				
mandible	1		1	2
maxillary teeth	2		1	3
mandibulary teeth	0	1	2	3
Axial				
atlas	1		1	
axis	1		1	
cervical	4		4	
thoracic	0			
lumbar	0			
sacrum	0			
caudal	1		1	
pelvis	0			
ribs	0			
Fore-limb				
D humerus	0		2	2
P radius	1			1
D radius	1		0	1
P ulna	0		1	1
metacarpus 3	1		0	1
metacarpus 5	0		2	1
Hind-limb				
D femur	1		0	1
D tibia	1		1	2
astragalus	1		0	1
calcaneum	2		0	2
phalange 1		1		1
Totals		30		30

Tab. 19 Counts of wolf skeletal elements from sector P16. P = proximal, D = distal, * = indeterminate to side. MNE for mandibles and pelves based on halves.

though part of the head and the neck of an adult wolf had been deposited together (folding ill. 4). Bones from a fore-leg joint of a young wolf, recorded in squares 99 and 100 (humerus and ulna; A54; folding ill. 4), could be reconnected during analysis. Conjoins between post-depositionally fractured bones were not observed among the wolf remains.

Number of individuals and their ages

The two left calcanei, two left radii and two right lower P4's show the presence of two adult wolves at the site. Two bones, a proximally unfused humerus and an unfused distal epiphysis from a femur could be aged. According to Habermehl (1961) the distal femur of domestic dog fuses at between 6-8 months and the proximal humerus at about 10 months. Assuming that fusion stages in wolf bones are similar to those of the domestic dog, this wolf died between 6 and 10 months of age. Whether this animal represents a third individual is difficult to ascertain. The more complete of the other post-cranial bones all have fused epiphyses. However, the proximal humerus is one of the last epiphyses to

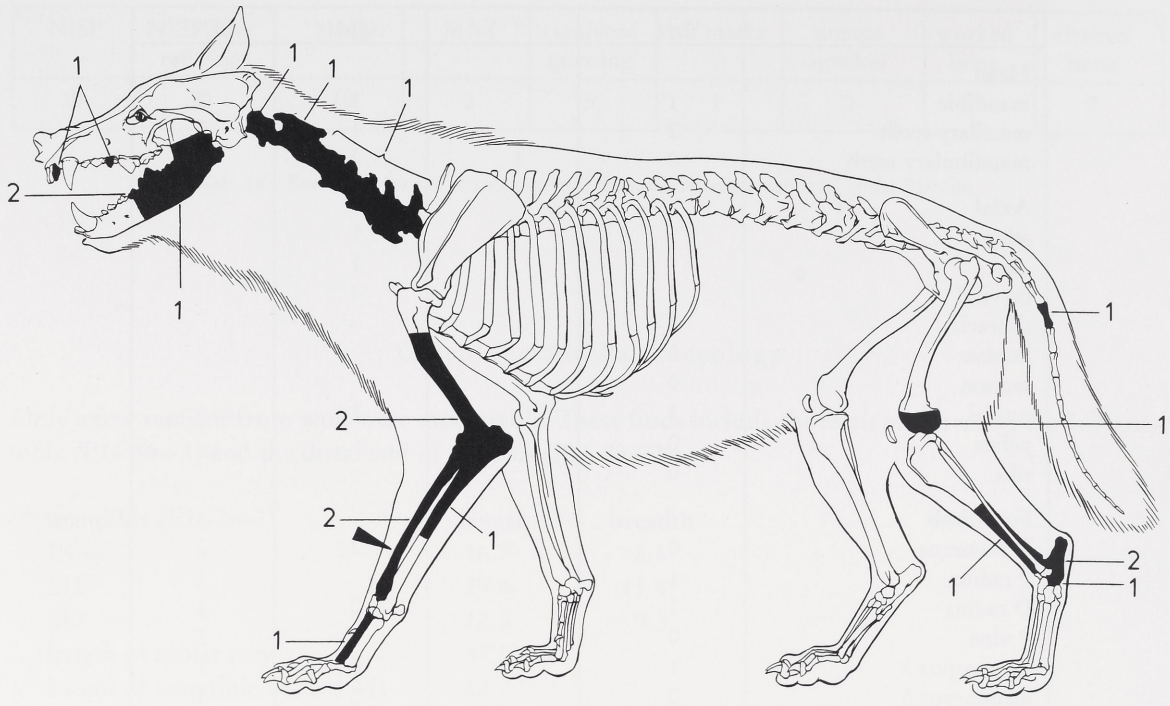


Fig. 37 Wolf skeletal representation at sector P16 at Solutré based on the minimum number of individuals (MNI) for each element. Black areas indicate those portions of the bones preserved at the site.

fuse in canids and it is possible that some long bones, such as the distal tibia or distal radius which fuse at between 6-9 months, could be in a fused condition alongside an unfused humerus in the same skeleton.

The wolf teeth from P16 are all permanent ones. Habermehl (ibid.) writes that the full permanent dentition in domestic dogs is erupted at any time between 6 months to one year, approximately the same time period when the bones fuse. Thus the permanent teeth from P16 cannot offer any further information about numbers of individuals. The minimum number of wolf individuals remains at two.

Evidence of human modification of wolf bones

Only one bone from wolf, the distal end and part of the shaft of a left radius (P16 100-278), bore traces of modification by humans. A single, short, transverse cut mark was observed on the medial edge of the dorsal face of this bone (fig. 37) (plate 15, 4). If the wolf had been skinned, cut marks would usually have been located around the distal end of the radius or around the bones of the feet. The location of this cut mark in the middle of the shaft of the bone is therefore unusual. Usually superficial cut marks on the shafts of limb bones of ungulates are interpreted as resulting from filleting.

Cut marks on wolf bones not associated with skinning activities have been observed on the bones of wolves and other carnivores recovered at Moravian Upper Palaeolithic sites assigned to the Pavlov culture (Soffer 1990). Numerous carnivore remains from the site at Dolni Vestonice bear extensive cut and filleting marks (on scapulae and mandibles) analogous to those found on the bones of large herbivores, suggesting that carnivore flesh was also consumed. Ethnographic data indicate that carnivores were consumed either as ritual foods or in times of seasonal subsistence stress as part of the subsistence practices

of northern hunter-gatherers. However, food stress and ritual hypotheses are difficult to explain at the Moravian sites where large quantities of mammoths, providing the hunters with much meat protein, were also found, and where the consumption of carnivores as ritual food is unlikely, given the same disposal patterns for herbivore and carnivore remains (Soffer ibid.).

Carnivore modification

Traces of carnivore gnawing were found on five wolf bones. These remains represent 6% of the total number of wolf bones. Tiny pitting marks were observed around the distal end of a left radius (P16 23-72) and on the distal end of the left radius which had possibly been cut by a stone tool (P16 100-278) (plate 15, 3. 5). Two tooth puncture marks were found towards the distal end of the tibia (P16 58-44). The fore-limb elements which could be anatomically re-connected during analysis bore traces of gnawing around the joint of the humerus (P16 100-272) and the ulna (P16 99-337). Loss of bone on both the proximal end of the ulna (olecranon) and the distal end of the humerus shows that gnawing took place when the joint was still anatomically connected. Dispersal of these bones took place after disarticulation which may have been caused by carnivores gnawing through the joint.

Bone pathologies

The cut marked and gnawed radius (P16 100-278) also has a pathological alteration. A small lesion on the lateral edge of the bone shaft probably results from an inflammatory condition of the bone (plate 15, 6). The bony growth appears to be restricted to the outer bone surface and was probably caused by osteoperiostitis, an inflammatory disease of the periosteum often brought about infections of overlying or adjacent tissues (Baker and Brothwell 1980). This wolf may have had an open wound on its fore-leg.

Summary of the wolf remains from the Magdalenian deposits at sector P16

Thirty finds were identified as the remains of wolf. The finds represent a minimum of two adult individuals. Various elements from this species were present in low numbers. One bone, a radius, appears to have been modified by humans, and a single cut-mark was observed on the shaft of the bone. The location of the cut-mark is unusual since skinning of a wolf for its pelt would produce marks around the distal end of the radius or around the bones of the foot. On the other hand, the number of anatomically connected wolf elements, including the bone with the cut-mark, is suggestive of the remains of an animal that had been skinned. Traces of carnivore gnawing were observed on five wolf bones, representing 6% of the assemblage of wolf remains. The cut-marked radius also had a small pathological lesion, probably caused by osteoperiostitis.

FOX AND WOLVERINE

Introduction

Two other species, red fox and wolverine, were identified amongst the remains of larger mammals from the sector P16 site. Both species have been identified during earlier studies of carnivore remains from Solutré (Argant 1991). Tables presenting basic data were not prepared for the remains of fox or wolverine, as neither of these species produced large amounts of material and none of the remains showed any form of modification made by either humans or carnivores. None of these remains were charred.

Red fox

A total of seven finds was identified to fox. The fox remains comprise a first phalange, fragment of a proximal tibia and a distal femur, part of a second metatarsal and three teeth, a lower P4, M1 and M2. The size of the teeth from this animal indicates the genus *Vulpes*, the red fox. Measurements taken on the lower M1 (given below) show that this tooth belonged to a large individual:

	length	breadth
P4	9.1	3.4
M1	16.7	6.5
M2	7.0	5.7

Fox remains were spread thinly throughout the main find distribution area at sector P16. None of the finds could be anatomically connected. The remains represent a minimum of one, adult individual.
The red fox lives in a variety of habitats today. Principally it is found in areas of dry terrain, close to forests, scrubland or places where tall grasses are growing. Its presence in pleistocene contexts simply implies the existence of local vegetational cover.

Wolverine

Only four finds, conjoining fragments (C51) of a right mandible (plate 14, 6), the proximal end of a right femur (plate 14, 7) and a first phalange could be attributed to the wolverine. The finds represent a single adult individual.
The mandible had been fractured post-depositionally. Conjoin length between the two fragments is about one metre and conjoin direction is roughly parallel to the main NW-SE axis of the channel (folding ill. 4). One of these finds (P16 33-589) comprises the base of the ascending ramus and a portion of the jaw with fragments of the M1 in its alveola. The circular alveola for the M2 is also visible, but the tooth is missing. The second find (P16 44-288) consists of part of the jaw in which a fragment of the P2 is preserved; the alveola for the P3 is present but the tooth is missing.
The P4 is the only tooth which was preserved well enough to be measured. Argant (1991) mentions a mandible from wolverine found in the older levels (niveaux anciens=Aurignacian) at Solutré, which was described originally by Chantre (1901), and the size of the P4 in that mandible was used for comparison:

P4	length	breadth
Magdalenian sector P16	13.9	8.9
Aurignacian (Argant 1991 tab. 59, page 155)	14.0	9.0
recent wolverine (ibid.)	11.0-12.3	6.6-8.0

The mandible is from a large individual, comparable to but slightly larger in dental size, than the living wolverine. The lower P4 from sector P16 is comparable in size to the P4 in the mandible from the Aurignacian level at Solutré and, like this find, is slightly larger than the range in size of P4's given for recent wolverines. The wolverine from P16 was also a large individual.

Wolverines inhabit boreal regions; they live in or close to marshy areas and amongst rocky outcrops in mountain forests. Its habitat today corresponds to cold climatic regions, although in Scandinavia the wolverine has been known to spread south into belts of mainly coniferous woodland mixed with some deciduous trees. The presence of this species is often taken as an indication of cold climatic conditions, even though some researchers see the wolverines present-day distribution in boreal regions as a recent adaptation. Argant (ibid.) interprets the presence of the wolverine at Solutré as indicating periods of cold climatic conditions, but perhaps less cold than its present distribution suggests. He suggests that wolverines probably inhabited this part of France during Pleistocene cold stages in slightly temperate periods associated with mixed coniferous forests as well as colder periods associated with extensive herbaceous steppe and some wooded areas.

THE LARGER MAMMAL FAUNA FROM SECTOR I11 (Q 69, 79, 89)

HORSE

Introduction and basic data

Horse dominates, with 92.8% of the total number of remains identifiable to a species, the fauna from the Magdalenian horizon in sector I11. Basic data for horse from this sector are presented in table 20.

NISP	NISP after refitting	MNE	MNI	carnivore gnawing	cut marks	impact notches	worked bone	charred bone
466	457	364	6	60	24	5	4	0

Tab. 20 Basic data for the remains of horse from the sector I11 site.

A total of 466 identifiable specimens (NISP) and 364 elements (MNE) of horse were present at this site. The highest minimum number of six individuals was recorded on upper third molars of the right body-side. Both juvenile and adult horses were present at the site. Cut marks and impact notches were observed on a total of 29 horse remains. Four horse bones had been utilised by the Magdalenians as raw material for needle production, but none of the horse remains were charred. 60 horse bones had been chewed by carnivores.

Numbers of individuals and skeletal part representation

Counts of horse skeletal remains are listed in table 21. Element type, body-side, the minimum number of elements and minimum number of individuals for each element are given, along with the number of elements gnawed by carnivores. For long bones of the fore and rear limbs, MNE's and MNI's are placed next to the portion of the element on which these were counted (for example, MNE and MNI for the scapulae were counted on the distal ends of this bone); the number gnawed by carnivores refers to the total number of scapulae (distal ends and blades) which bear such traces.

A total of 139 horse teeth and 327 horse bones have been recorded at the sector I11 site. Expressed as percentages, teeth represent 29.8% and bones 70.1% of the total number of remains identified to this species. The dominance of bones over teeth shows that this assemblage was well-preserved and, as in the case of the horse remains from sector P16, had hardly been affected by differential post-depositional destruction.

As in the sample from P16, upper deciduous cheek teeth were underrepresented in the I11 sample, and only five deciduous teeth out of a total of 59 upper cheek teeth were recorded. The opposite appeared to be the case among the lower cheek teeth from sector I11, where deciduous molars represented almost one fifth of the total number of identifiable mandibular cheek teeth (7 deciduous teeth out of a total of 36 teeth).

Tab. 21 Counts of horse remains from sector I11. – P = proximal, D = distal, * = indeterminable to body-side, indet = not determinable to fore or rear limb (phalanges), mc/mt = not determinable to metacarpus 3 or metatarsus 3. All MNI's and MNE's are based on number of fragments after refitting. Counts of carnivore gnawing for phalange 2 are pooled counts from anterior and posterior second phalanges. →

Element	left	*	right	MNE	MNI	number gnawed
Head						
cranium	3	3	6	3	3	0
mandible	5	2	5	3	3	0
maxillary teeth	44	0	35	78	6	0
mandibulary teeth	18	3	21	42	5	0
tooth fragments	18					
Axial						
atlas		5		4	4	0
axis		2		2	2	0
cervical		14		13	3	1
thoracic		26		25	2	11
lumbar		20		19	3	7
sacrum		2		2	2	0
caudal		0		0	0	0
unidentified vertebrae		4				
pelvis	10	3	5	10	5	5
ribs	8	10	8	14	1	2
sternebra	0	1	0	1	1	0
Fore-limb						
D scapula	4	0	1	5	4	2
scapula blade	0	1	0			
humerus complete	0	0	1			
P humerus	1	0	0			
D humerus	3	0	5	8	5	5
P radius	2	0	2			
shaft	0	2	0			
D radius	3	0	1	4	3	4
ulna	2	0	3	5	3	4
carpals	7	1	11	19	4	1
metacarpal 3, complete	0	0	3			
D metacarpal 3	0	0	2	5	5	3
metacarpal 2	0	0	1	1	1	1
metacarpal 4	1	0	2	3	2	1
Rear-limb						
P femur	6	0	2			
shaft	4	0	1			
D femur	6	0	1	6	4	5
patella	1	0	0	1	1	1
tibia shaft	1	0	1			
D tibia	1	0	4	4	3	1
calcaneum	2	0	4	6	4	2
astragalus	4	0	3	7	4	0
tarsals	8	0	6	14	4	0
metatarsal 3, complete	1	0	3			
P metatarsal 3	1	0	1			
shaft	0	0	1			
D metatarsal 3	0	0	1	7	5	1
metatarsal 4	1	0	4	4	3	0
phalange 1 ant.	2	1	2	4	2	
phalange 1 post.	1	0	5	6	3	0
phalange 1 indet.	0	1	0			
phalange 2 ant.	2	0	1	3	2	
phalange 2 post.	2	0	3	5	2	3
phalange 2 indet.	1	3	2	3	1	
phalange 3		14	0	14	3	0
sesamoids		14		14	2	0
mc/mt		4				
Totals		**466**		**364**		**60**

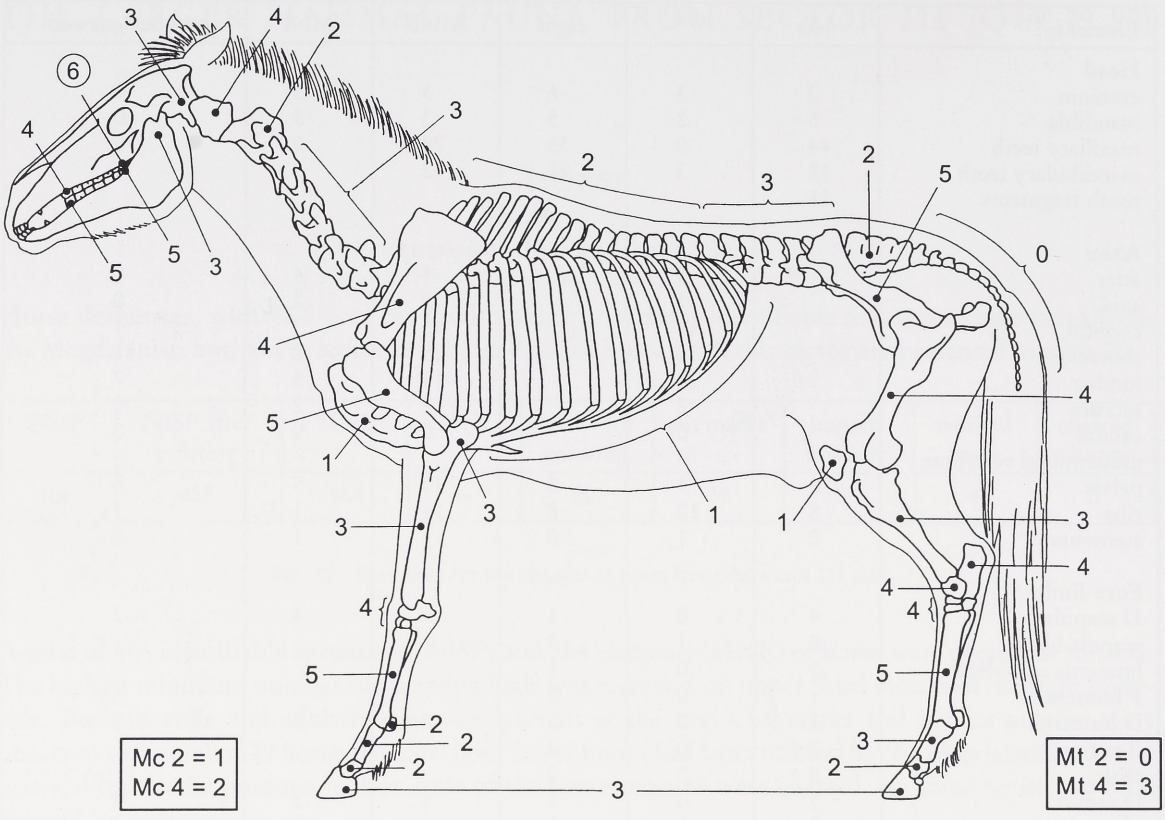


Fig. 38 Horse skeletal representation at sector I11 depicting counts of minimum number of individuals (MNI) for each element.

All skeletal parts of horse were recorded from the I11 site, except caudal vertebrae and second metatarsals. The highest minimum number of six individuals of horse was counted on upper third molars from the right side of the body (fig. 38). Five individuals were recorded on lower third molars from the right body side, on the pelvis, humerus, third metacarpals, and third metatarsals.

Low counts of individuals were recorded on ribs, sternebrae and the patella, and also on the sesamoids. A similar situation was observed in the assemblage of horse bones from sector P16, where the low numbers of these elements was attributed mainly to bone fragility (ribs), bone porosity (patella) and carnivore attrition (sesamoids).

There was no differentiation between the anterior and the posterior portions of the lower dentition of horse at sector I11, and five individuals were recorded on the second premolars and on the third molars. Similarly, there was only a difference of one individual between counts on the anterior and on the posterior portions of the upper dentition. The strong differential preservation between cervical vertebrae 3-7 and vertebrae from the thoracic region of the spine, noted for the axial assemblage of horse from sector P16, was also absent in the assemblage from I11.

In figure 39, the numbers of individuals for each element are expressed as percentages of the highest MNI (MNI 6 = 100%) and further divided into four main groups (0-25% etc.). High-ranking percentages were recorded on high-utility (pelvis, humerus) as well as on low-utility portions (metapodials) of the limbs. At sector I11, there was no apparent selection of high or low utility body parts of horse, and a comparable situation was recorded at sector P16.

Equally comparable was the role that bone preservation played in the representation of portions of horse bones at sector I11. High numbers of individuals were counted on parts of elements which are less likely to be destroyed by carnivore attrition or weathering processes. Thus, the minimum of five indi-

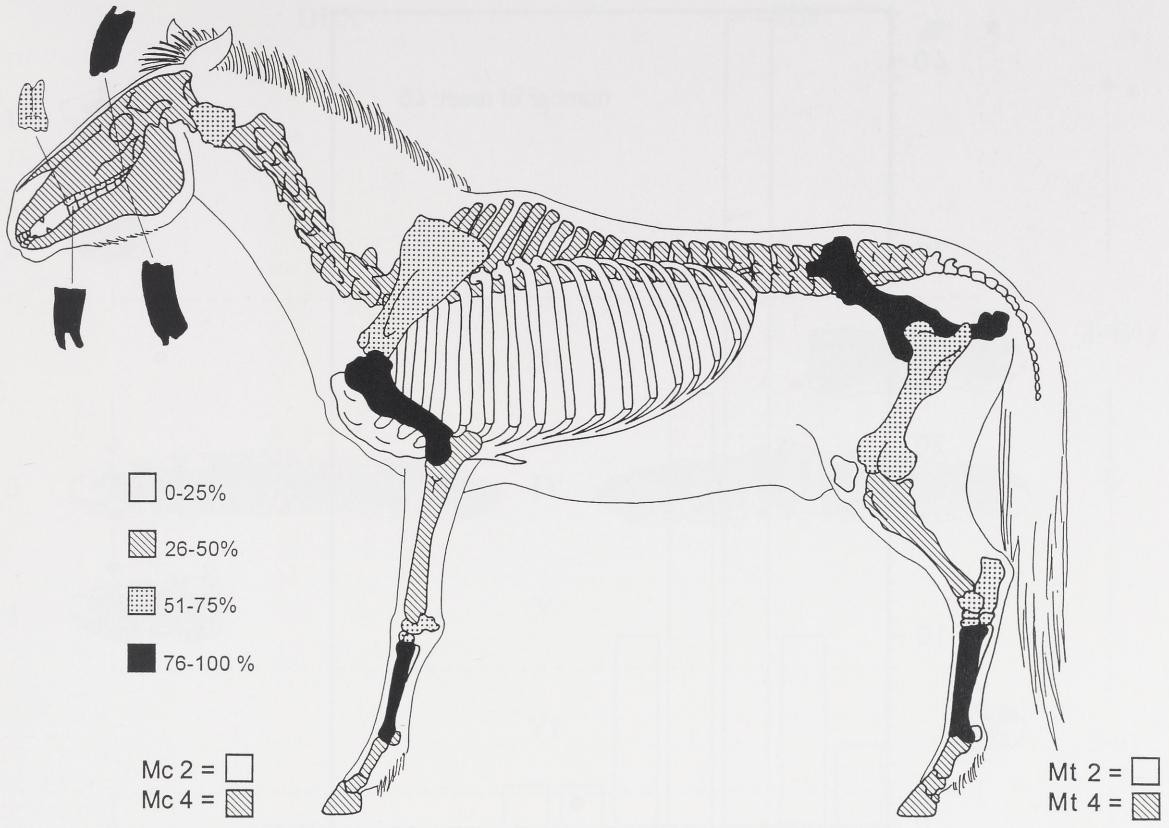


Fig. 39 Horse skeletal representation at sector I11 with MNI's depicted in figure 38 expressed as percentages of the highest minimum number of individuals (MNI 6 = 100%).

viduals recorded on the pelvis was counted on the acetabulum, this being the sturdiest part of the pelvic girdle. Similarly robust portions of bones, such as distal scapula, distal humerus, proximal ulna, tarsal bones and metapodials, had relatively high individual counts.

On the whole, horse skeletal part representation from the sector I11 site was comparable to that observed at the P16 site. Minor differences, including the absence of a strong differential preservation between bones of different regions of the spine, are probably related to the relatively small total amount of horse remains recovered at the sector I11 site and the chance sampling bias that is always associated with assemblages from small sites such this one, rather than indications of Magdalenian butchery activities at Solutré.

Determination of horse age and sex demography on certain skeletal elements

The age structure of the horse population from sector I11

Cheek tooth height and wear ageing

The crown-heights of 32 upper and seven lower permanent premolars and molars were measured following Levine's method (1979; 1982), and aged using data in her comparative tables. The three upper and four lower deciduous teeth included in this sample were aged using comparative wear-stages in Levine's

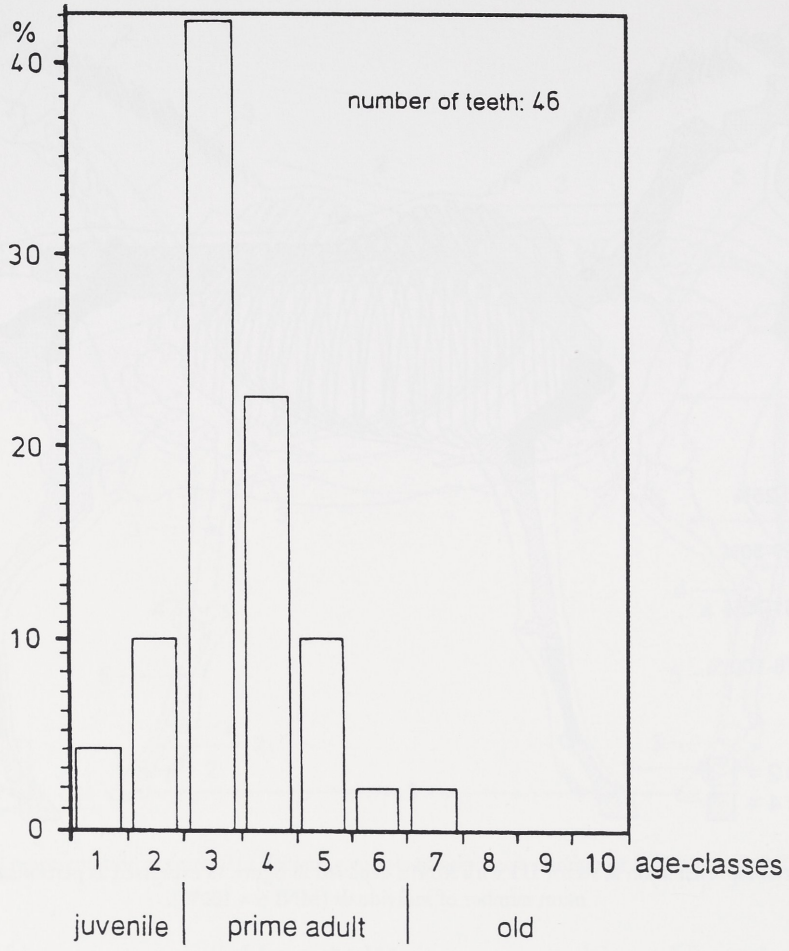


Fig. 40 The age-structure of the horse population from sector I11 at Solutré based on cheek teeth crown heights and wear stages. Each age-class represents 10% of the natural longevity of the horse, which was set at 20 years in this study. For definition of juvenile, prime adult and old classes see page 39.

tables (ibid). The results of the analysis are shown in figure 40, expressed as percentages of the total number of teeth in the sample (see page 39 for explanation of age-classes used in the analysis). Horse incisor teeth from sector I11 were not aged.
The resulting mortality-profile is dominated by horses in the age-classes 3 (5-6 years) and 4 (6-8 years). These are prime adult animals. Approximately 14% of the population were juveniles and only one tooth, or 2% of the sample, was from an old horse. A similar mortality structure with low numbers of juveniles and old horses and a dominance of prime adults was established for the sample of aged horse teeth from sector P16. In contrast to the sample from sector P16, slightly higher percentages of prime adults and a lower percentage of old individuals were recorded for I11. In order to test whether these differences were due to biasing because of the small amount of teeth in the I11 sample, a more detailed analysis of numbers of individuals and their ages was undertaken on the upper premolars and molars.

The minimum number of six individuals was based on the upper third molar of horse, of which there were six from the right and from the left sides of the body respectively. By sorting this total of twelve teeth to body-side, and by comparing their individual tooth morphology and wear stages, nine indivi-

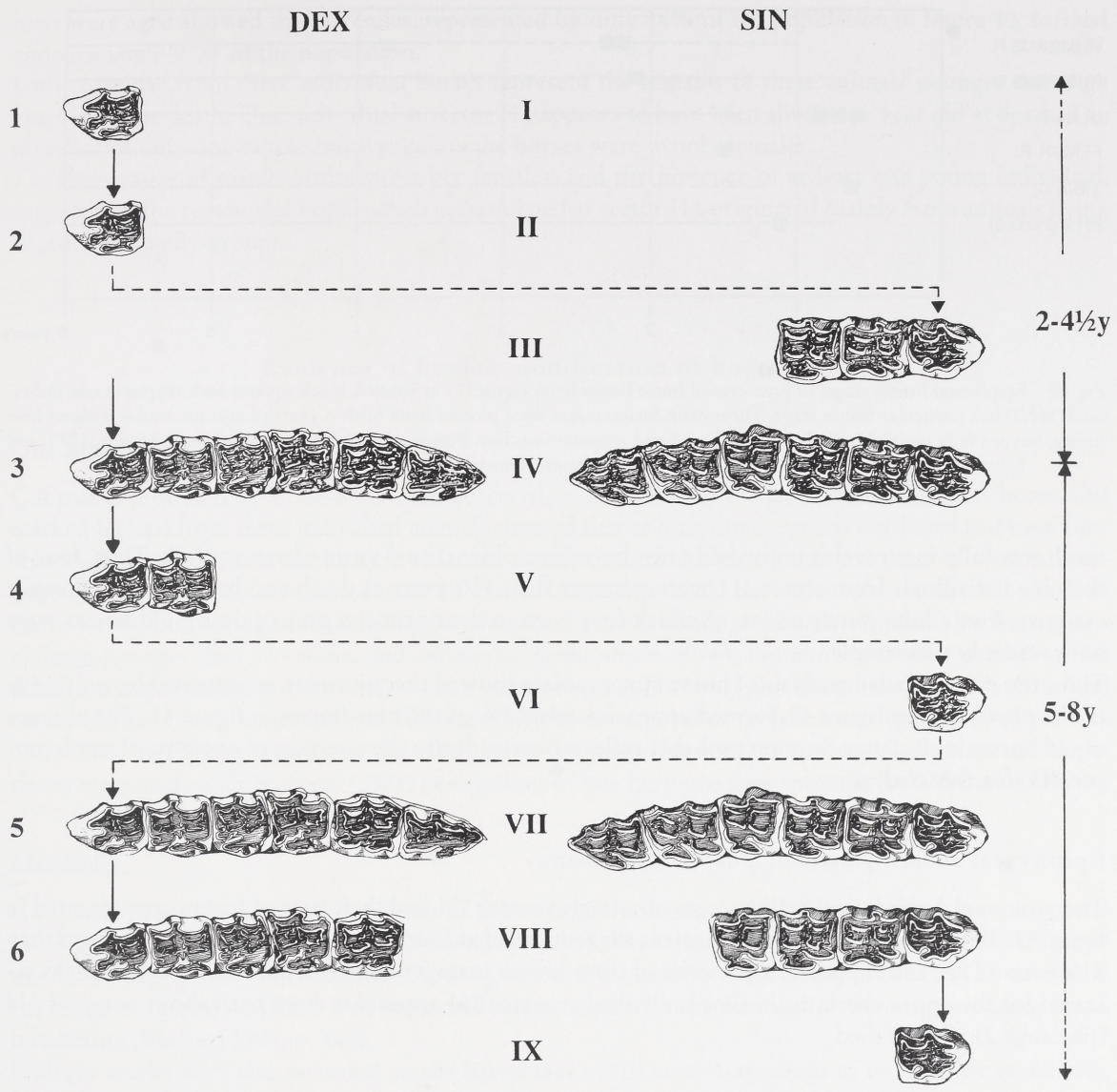


Fig. 41 An alternative method of counting numbers of individuals of horse from sector I11 using upper cheek teeth. 1-6 the minimum number of individuals (MNI) counted on six upper M3's from the right side of the body. I-IX higher minimum number of individuals established by comparing body-side, tooth morphology and tooth wear. The approximate ages of the individuals are given on the right side of the figure.

duals of differing ages could be established. The flow-chart in figure 41 shows how this higher number of individuals was assessed using isolated upper third molars and third molars in sets of upper cheek teeth belonging to individual animals, and gives their approximate ages.

The third molars of horses I-III are unworn and belong to individuals which died between 2 and 4 1/2 years of age, this being the period prior to upper M3 being in wear. Horse 4 has the first trace of wear on the M3. Wear can begin at around 3 1/2-4 years on this tooth, and horse 4 thus belongs to the older end of 2-4 1/2 year age-cohort. Horses V, VI and VII could be aged by their tooth heights and are prime adults aged between 5 and 8 years. Horse VIII was about 8-9 years old when it died. Horse IX couldn't be aged by tooth height as the roots of this tooth were missing. However, as the occlusal surface of the

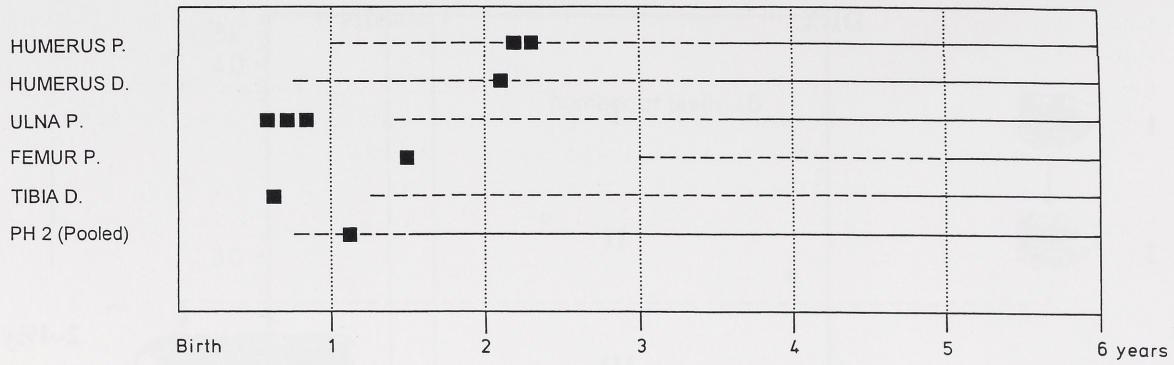


Fig. 42 Epiphyseal fusion stages of post-cranial horse bones from sector I11 at Solutré. Black squares each represent one individual (MNI) in a particular fusion stage. Three main fusion stages were plotted from birth-6 years of age: unfused = without line; fusing, but not fully ossified = discontinuous line; fused = continuous line. Fusion stages based on data given in Levine (1979) and Schmid (1972). P = proximal; D = distal. PH = phalanges, data pooled from anterior and posterior specimens.

tooth was fully in wear this individual must have been older than 4 years of age at death. Thus, four of the nine individuals from sector I11 were younger than 4 1/2 years at death and belong to the juvenile category. Five adults were present, of which four were in their prime at time of death: old horses were not present in this sample.
Thus, the more detailed analysis of horse upper molars showed that juveniles, represented by only 14% of the population in figure 40, formed approximately 44% of the nine horses in figure 41. The absence of old horses in the latter diagram probably reflects biasing due to the selection of one type of tooth (upper M3) for this analysis.

Epiphyseal fusion stages of post-cranial bone

The post cranial epiphyseal fusion stages observed at sector I11 and their time of fusion are presented in figure 42. The three unfused ulnae represent the remains of at least three animals at the site younger than 3 1/2 years of age and support the presence of three horses younger than 4 1/2 years at time of death as assessed for the upper cheek teeth. One individual at sector I11 appears to have been about one year old (phalange 2) when it died.

Sexual demography and season of death

The absence of foetal bones among the horse remains meant that there was no evidence of season of death for this species from the sector I11 site. Only one canine was recovered, suggesting that the majority of the horses recovered from the Magdalenian deposits at sector I11 were females.

Summary

Information about the age-structure and sexual demography of the horses from sector I11 was obtained from analyses of cheek teeth heights and tooth wear stages, epiphyseal fusion stages of post-cranial bone and numbers of canines.
A conventional analysis of tooth height and wear stages produced a mortality-profile dominated by prime adult horses in the age-classes 3 (5-6 years) and 4 (6-8 years). Approximately 14% of the population were juveniles and only 2% were old horses. A similar mortality structure with low numbers of juveniles and old horses and a dominance of prime adults was established for the sample of aged horse teeth from sector P16. A more detailed analysis of the I11 sample, in which teeth from individual ani-

mals were aged showed that juveniles, represented by only 14% of the population in figure 40, formed approximately 44% of the population.
Unfused ulnae from three individual horses represent the remains of three animals younger than 3 1/2 years of age at death. One individual at sector I11 appears to have been about one year old at death. The presence of only one canine tooth suggests the horses were mainly females.
The dominance of prime adults, probably females, and the presence of at least one young individual, suggest that the remains of horse which accumulated at sector I11 originated mainly from animals living together in family groups.

Evidence of human modification of horse bones

Cut marks

Cut marks produced by stone tools were observed on 24 (5.1%) of the elements identified as horse. Cut marked humeri from three individual animals showed that at least three carcasses of horse had been butchered. At sector I11, cut marks were recorded mainly around the bone joints and these are normally attributable to carcass dismemberment. In the case of horse, this would have taken place at the kill-site. Evidence for the butchering of juvenile horses comprised a cut marked, proximally unfused ulna from an individual younger than 3 1/2 years, and cut marks on the shafts of two humeri which were partly ossified distally, a stage reached at between 1 1/4-1 1/2 years of age. A few examples of cut marks on rib shafts and on the shafts of long bones indicate filleting activities or removal of surface tissue (periosteum) prior to bone smashing. The cut marks are described below and their locations are depicted in figure 43a: comparisons were made with Binfords (1981) descriptions of butchery practices amongst the Nunamiut eskimo.

Mandibles

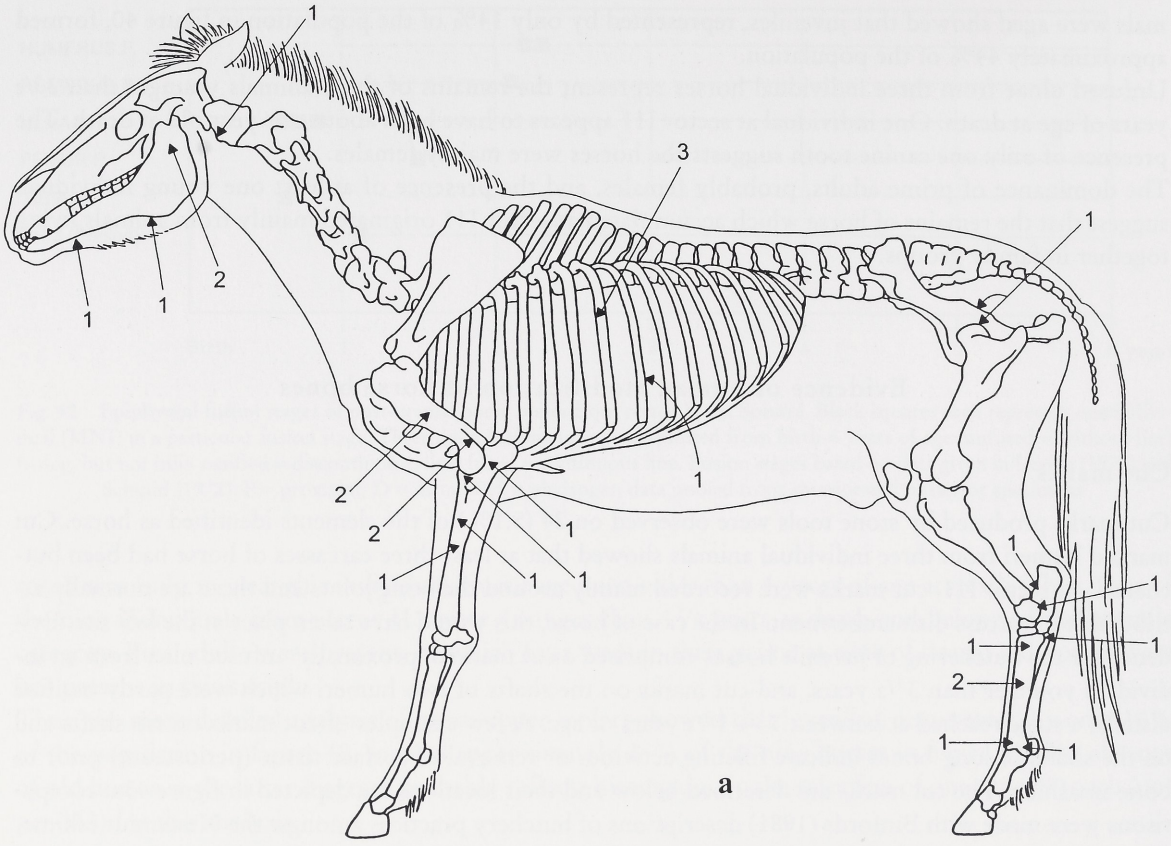
Cut marks were observed on fragments of four mandibles. Sets of oblique marks were located on the inner or medial face of a right mandible (79/306) just behind the third molar, and on the medial face of the dorsal edge of another mandible (79/649), close to the anterior edge of the lower P2. Cut marks on the inner or medial mandible side are usually associated with the removal of the tongue during initial butchering (Binford 1981, p. 109)
Oblique marks were also recorded on the lateral face of the ascending ramus of two further mandibles, located towards the basal edge on one find (79/4) and close to the anterior edge of the second specimen (79/669). The cut marks were probably produced when the masseter muscle was cleaned off the mandible, a process described by Binford (ibid.) as filleting in situ.

Cervical vertebrae

The rather fragmentary atlas (89/375) was the only element from the vertebral column with traces of cut marks. A transverse cut was located on the ventral side of the right cranial surface of the atlas. This mark compares with Binfords CV-1 (1981, fig. 4. 20) cut mark produced when severing the head from the neck of the carcass during primary butchering.

Pelvis

Only one pelvis (conjoining finds 69/272 and 69/328) showed traces of butchery. Four sets of multiple cut marks were located around the acetabulum. Two sets are on the lateral sides of the pubis and ischium bones just below the acetabulum rim, corresponding to Binfords (1981, fig. 4. 22) PS-9 and PS-10 cut



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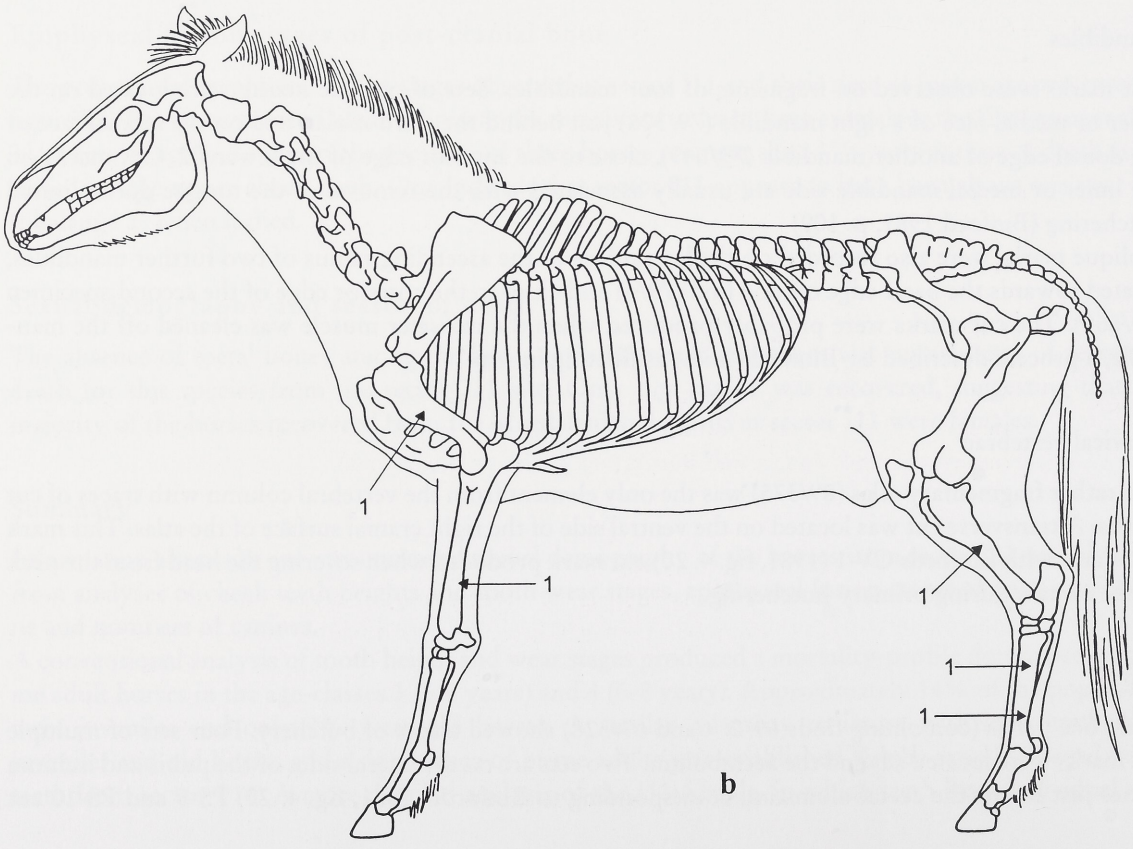


b

marks which are produced while severing the rear-leg muscles during disarticulation of the femur head from its pelvis socket. More interesting are two further sets of marks located on the inner or medial side of the pubis bone, one set at the base of the pubis bone close to the ventral edge, and a second set placed close to the end of the stump of bone left behind after the pubis bone had fractured. These marks were probably produced during evisceration of the carcass.

Ribs

Three rib fragments bore oblique or transverse cut marks on the outer or lateral surface of the bone. The ribs were too fragmentary to establish the exact location (eg. proximal part or distal part) of the cuts, but they could have been produced during the removal of the tenderloin from the rib-cage. Cuts on the inner side of the rib were observed on a fourth rib fragment (89/636): these could have originated while major organs, such as the heart and the lungs, were removed from the chest cavity. Similar cut marks were recorded by Olsen (1989) in her study of the horse remains from Solutré.

Humerus

Sets of cut marks on two distal humeri from the right side of the body (89/21 and 89/361), correspond to Binfords (1981, fig. 430 f) Hd-2 mark, this being the most common cut on the medial face of the distal end of the bone during dislocation of the humerus from the radio-cubitus. On the 89/21 specimen, the Hd-2 mark is restricted to a set of three distinct transverse cuts located on the medial face of the distal trochlea. On the 89/361 find, the Hd-2 marks consist of a set of oblique cuts located on the medial face of the distal epicondyle. This specimen also has a further set of marks higher up on the cranial face of the bone shaft. These transverse marks indicate that they were associated with dismemberment rather than filleting activities, where the marks are located in a similar position, but placed obliquely to the shaft (cf. Binford 1981, fig. 439, Hd-6) (plate 5, 4). Two humeri from one individual bore fine marks similar to those produced by stone tools on the medial and caudal shaft faces respectively (79/157 and 79/160).

Radius

Cut marks were recorded on two radii of horse. The first specimen is an almost complete right radio-cubitus (79/179: missing are parts of the proximal and distal ends and the proximal ulna). A set of marks similar to those produced by stone tools are located on the medial face of the bone towards the proximal end and lower down in the mid-shaft area of the bone.
The second specimen is a proximal radius fragment (79/343) from an articulating set of three bones (proximal radius, ulna and distal humerus) forming the »elbow joint« of a mature horse. The radius is the only bone out of this set which is cut marked. Three sets of marks were located on the dorsal face around the proximal margin of the bone corresponding to Binfords RCp-5 mark (1981, fig. 4. 32 a-c) produced during dismembering. A fourth set of oblique marks is located on the dorsal face of the shaft close to the green fracture of the shaft end (about 80 mm below the proximal end).

Ulna

One cut marked ulna was present in the assemblage of horse bones. The specimen (69/148) is from a young animal not older than 3 1/2 years of age at death (epiphyseal fusion). A single set of short cut

Fig. 43 The various stages of horse carcass butchery recorded at sector I11 at Solutré. – a Location of cut marks. Arrows with numbers indicate the approximate location and number of times cut marks were observed in these locations. – b Location of impact notches produced during marrow extraction. Arrows and numbers indicate the approximate location of impact notches and the total number of times impact notches were observed on each element. ←

marks more or less parallel to the long axis of the bone are located on the lateral face of this ulna close to the proximal articulation. The location of these marks is similar to those described by Binford (1981, fig. 4. 32 a, RCp-2) produced during dislocation of the humerus from the radio-cubitus.

Metatarsals

A single transverse cut mark is located just below the proximal edge of the bone on a right metatarsal (79/14). A similar mark at the same level and in the same direction was observed on the lateral face of a proximal fourth metatarsal (79/28), which may have belonged to the same individual. Such marks are produced during primary or secondary butchery activities, and if the two bones do belong to the same horse, the placement of the marks shows that the elements were still anatomically connected when butchered.
A single cut mark was observed on the distal end of a complete right metatarsal (79/237). The mark was placed on the dorsal side of the distal keel. Cut marks relating to dismemberment were present on the lateral (multiple marks) and medial (single cut mark) condyles of a distal metatarsus (89/136). This bone had been subsequently utilized as a »needle-core«.
Two mid-shaft fragments bore cut marks. One fragment (69/616) had two sets of oblique marks located at the proximal and the distal ends of the fragment. The second fragment (79/681) had a set of very short marks located mid-shaft. Cut marks on bone shafts probably indicate that bones were being cleaned of periosteal tissue, a technique employed so that the bone could be successfully smashed open afterwards.

Tarsals

Cut marks were observed on two major tarsal bones, a right calcaneum (89/261) and a left astragalus (89/360). A series of short oblique marks on the dorsal edge of the calcaneum just behind the arcticulation for the astragalus compares with those figured by Binford (1981, fig. 4. 27, TC-3). This mark has often been interpreted as being produced during tendon cutting. Binford (ibid) suggests that such marks could also have been produced when the carcass of an animal is hung up by its rear legs by cutting through the thin skin between the tibia shaft and the tendon at the tuber calcis and inserting a rope through the opening. Hanging of the whole carcass would probably be associated with primary butchery activities, for example to facilitate removal of the viscera. Marks comparable to these have been described not only on the bones of medium-sized mammals (Frison 1971), but also on the bones of large animals such as bison (Wheat 1979).
A set of fine, short oblique cut marks were located on the dorsal edge of the medial trochlea of a left astragalus (89/360). They correspond to Binfords TA-1 (1981, fig. 4. 27, e) and are produced during dismemberment.

Impact notches

That some bones were deliberately smashed open at the site, presumably to obtain marrow, can be seen by the presence of four specimens with impact notches and one example of a metatarsal opened longitudinally (fig. 43b).

Humerus and radius

The humerus belongs to the set of anatomically reconstructed bones forming the elbow joint of a horse and has a clear impact notch on the cranial face above the distal joint. This humerus was not cut marked, but the articulating proximal radius bore dismembering marks around the joint. Both the radius and the ulna had been deliberately fractured below the joint as an articulated unit: the set of cut marks on the

dorsal face of the radius is located just above the fracture edge and probably indicates cleaning of tissue from the bone surface to obtain a clean break at this point. The radius shaft fragment which had been utilized as a »needle-core« (79/705) also has an impact notch on the volar shaft face.

Tibia

A clear impact notch on the planter side of the tibial shaft fragment (79/339) shows that this bone had been smashed open by humans in the mid-shaft region.

Metapodials

Two fragmentary finds show that some intentional smashing of metapodials was carried out. Two impact notches were observed on one edge of a mid-shaft fragment of a metapodial bone (79/670).
Although only a single impact notch was observed mid-shaft on the second fragment, the form of the remaining piece is typical for metapodials which have been split longitudinally by controlled blows to the shaft.

Summary of horse butchery practices at Sector I11

Altogether 24 horse bones with cut marks and five horse bones with impact notches were recorded from the Magdalenian horizon at the sector I11 site. The counts represent 5.1% and 1.0% respectively of the total number of horse bones found at this site. The carcasses of at least three individuals of horse were processed, and both adult and juvenile horses had been butchered.
The locations of the cut marks show that primary butchery activities included hanging the carcass by its rear legs, probably in order to facilitate evisceration. The chest cavity had been emptied. Cut marks on the mandible show that the tongue had been removed and the masseter muscle had been cleaned off the jaw. The carcasses had been dismembered (separation of head from neck, humerus from radio-ulna, and metapodials from phalanges). Secondary butchery activities included the removal of tissues from the surfaces of a radius and two metapodia, and possibly filleting of the tenderloin.

Worked bone

Altogether four horse bones from the Magdalenian deposits at Sector I11 had been worked. These comprise a horse radius and a metatarsus which had been utilized as needle cores, as well as a rib fragment and a fragment of a maxillary or mandibulary bone which appear to have been engraved. The long bones are of interest as they show traces produced during butchering activities, such as dismembering cut marks on the lateral and medial condyles of the distal metatarsus and a single impact notch on the radius shaft, associated with evidence of deliberate working of the bone afterwards. Multiple cut marks and the remains of a groove on the dorsal face of the metatarsus show that this find was utilized as a needle-core (fig. 44a). The bone appears to have been fractured after the spall had been removed. An attempt to remove a spall of bone from the radius was, apparently, not completed (fig. 44b).
Two small fragments of bone, including a piece of maxillary or mandibulary bone and a segment of a rib from a horse, show stone tool traces which appear to have been carried out in a more deliberate manner than those attributed to butchering activities, as though these finds represent fragments of engraved pieces (fig. 44c and d). Only one large piece of engraved bone has been recorded from the I11 site. It is a fragment of the iliac blade from the pelvis of a horse, upon which a stylized depiction of a reindeer has been engraved (Combier 1987).

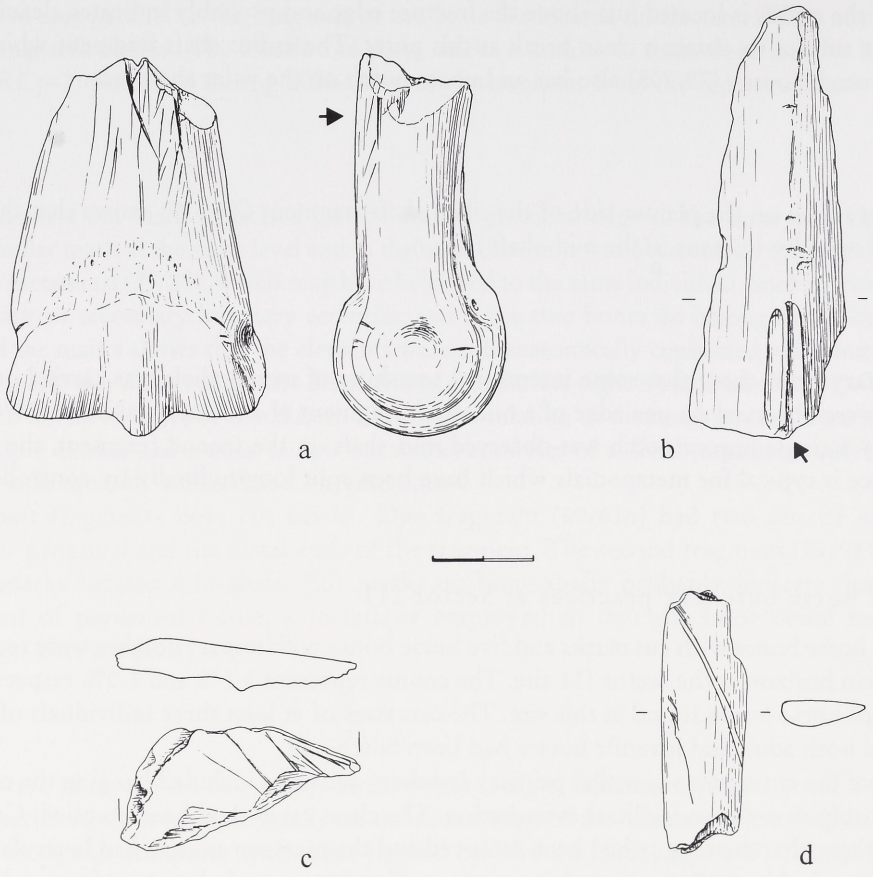


Fig. 44 Bone needle cores from sector I11 at Solutré. – a Horse metatarsus (I11 89/136). – b Horse radius shaft (I11 79/705). – c Fragment of horse cranium with ? partially preserved engraving (I11 69/312). – d Fragment of a horse rib with ?engraved lines (I11 79/170).

Carnivore modification

Details of carnivore modification of the horse bones from sector I11, percentages of gnawed bones out of the total number of finds for each element and a description of the type of damage and the degree of bone and carcass utilization following Binford (1981) and Haynes (1982) are listed below (see p. 129).
Carnivore gnawed elements represented 16.4% of the total number of horse bones present in the Magdalenian horizon at this site. Almost all the elements of horse, except the teeth, had been affected by carnivore modification ranging from minor tooth mark traces on the distal end of metapodials to total destruction of some long bone joints. Patterns of damage show that all stages of carcass utilization, from light to heavy, are represented.
The location of gnawing marks depicted in figure 45 shows that carnivores had access to horse bodies rather than their heads and necks. Only one fragment of mandibular bone bears tooth scores; gnawing marks were not recorded on any of the elements of the skull. This underrepresentation may be due to the fragmentary nature of the cranium, which was represented at the I11 site mainly by petrosum bones and pieces from the occipital and zygomatic areas. Nasal and palate bones, where carnivore gnawing is often located, were not identified although it is possible that they are present as not further identifiable cranial fragments in the »secondaire« category of material.

	%	damage type	carcass utilization
Cranium			
mandible	9.0	Light furrows on lateral face of mandible fragment	
Axial			
pelvis	50.0	Pitting and furrowing on ilium, ischium and pubis bone stumps; gnawing on cranial edges of ilium and caudal edge of ischium	Light to heavy carcass utilization
ribs	15.3	Single or multiple puncture marks just below proximal articulation	
cervical vertebra	7.6	Single puncture (?) mark on caudal articulation of one specimen	
thoracic vertebra	44.0	Single or multiple puncture marks on ventral surfaces of centrum; Puncture marks along fracture edges of processes	Typical carnivore modification
lumbar vertebra	38.8	As thoracics	
Fore-limb			
scapula	40.0	Transverse tooth scoring on lateral end. Typical gnawing pattern on distal face; furrowing and puncture marks on distal end	
humerus	62.5	Tooth scoring and furrowing on proximal head or proximal end missing; one example with crenulated proximal shaft end. Pitting, furrowing and gouging of distal joint leading to bone loss	All carcass utilization stages light through to heavy. Gnawing of distal condyles typical of scavenging.
ulna	80.0	Puncture marks and tooth scoring on olecranon; proximal edge of olecranon missing	Typical gnawing pattern.
radius	60-75	Distal end missing, chipping back at distal end of shaft; oblique tooth scores mid-shaft	Distal end commonly chewed off
carpals	5.2	Single puncture mark on articular surface	
metacarpals	55.5	Furrows and gouging leading to some bone loss distally on third metacarpals; furrows on proximal articulation; transverse tooth scoring and pitting on shaft	Typical minor damage on distal end resulting from chewing up through phalanges
Rear limb			
femur	71.4	Light tooth scoring on third trochanter on one specimen; femur head undercut. Punctures and furrows leading to bone loss on distal end; gouging on medial condyle	All carcass utilization stages present
patella	100	Tooth furrows, scoring and bone loss on inner side	
tibia	25.0	Possible tooth marks on proximal edge of shaft; proximal joint missing	Heavy carcass utilization
calcaneum	33.3	Furrowing and bone loss on distal on end of corpus	Most common form of gnawing this element
metatarsals	14.2	Lightly furrowed distally	See above metacarpals
second phalanges	21.4	Tooth scoring on distal articulation; distal end chewed away on one specimen	See above metacarpals

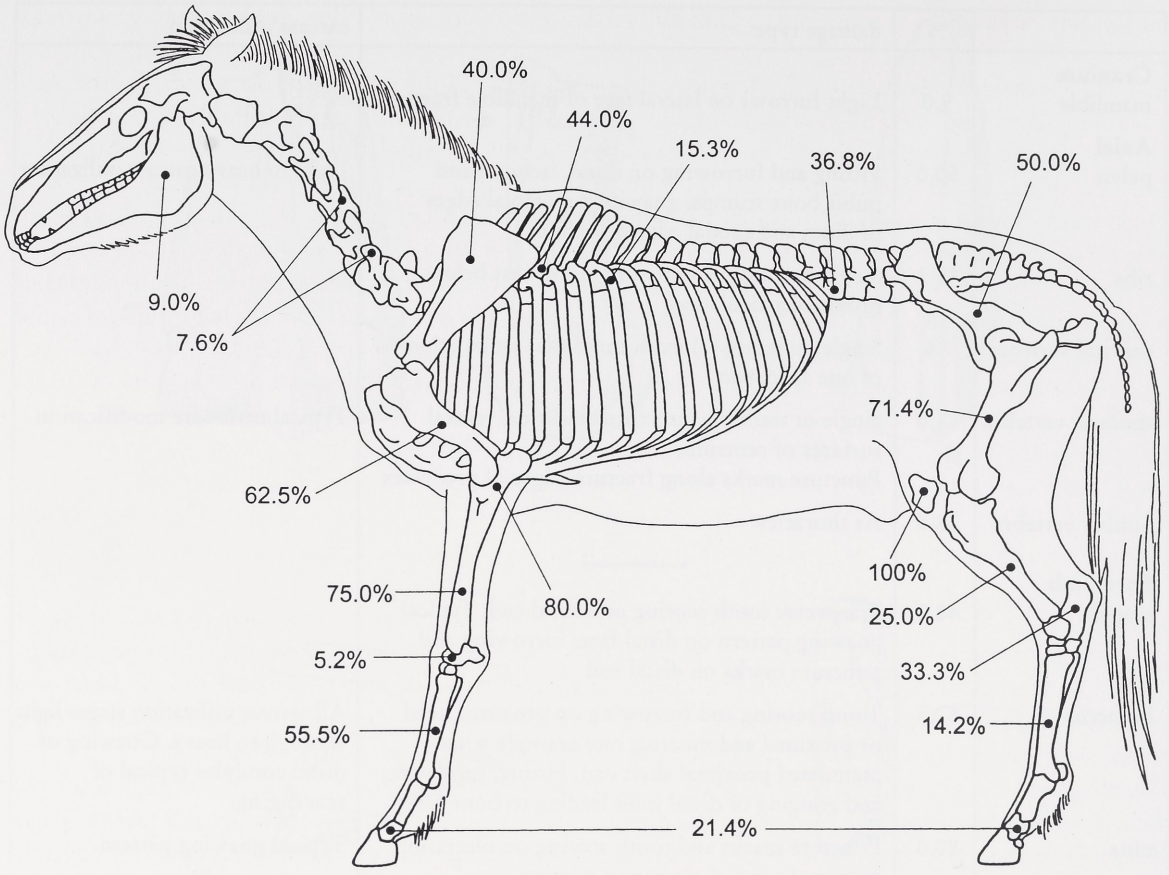


Fig. 45 Carnivore modification of the horse bones from sector I11 at Solutré expressed as a percentage of the total number of finds for each element.

Interesting is the relatively high incidence of gnawing on thoracic and lumbar vertebrae and a very low incidence (one element with a possible puncture mark) of tooth-marks on the cervical vertebrae, suggesting that carnivores had access to the rib-cage and back of some carcasses, but not always to the neck. The percentage of gnawing by element shows, as to be expected, that high-utility bones from the upper limbs of the fore-leg (humerus, radius and ulna) and the pelvis-femur area were preferentially gnawed. On the whole foot bones were less sought after, with the exception of the third metacarpal.
The form of carnivore modification indicates that wolves were the main scavengers of horse carcasses. However, tooth punctures on some bones were rather small in circumference. One puncture mark on a vertebra (79/303) measured only 4.07 mm in diameter, another example on a rib shaft measured 3.54 mm, indicating a small carnivore (juvenile wolf?) in these cases.

Bone pathologies

Four horse bones were pathological specimens. A small, elevated patch of open, porous bone located mid-shaft on the lateral side of a complete metatarsal (89/387) was probably caused by an infectious inflammation, in this case osteoperiostitis. An area of dissoluted spongiosa above the distal end of the bone

on the dorsal side and pitting on the proximal articulation surface may have also resulted from this disease.
Interesting was the presence of a short, sinous depression close to the anterior or dorsal edge of the proximal articulation of this bone. Baker and Brothwell (1980, p. 110-111; fig. 5) have described similar, non-pathological, »slits« on the articulatory surfaces of bovine third phalanges from Scottish Neolithic sites and these are the closest comparisons found so far to this feature on the specimen from Solutré.
The proximal metatarsus (79/340) has excess bone growth or exostosis around the dorsal edge of the articulation. Two tarsal bones (79/190) were fused together, a condition termed »spavin« in domesticated and draught horses, which typically affects the small bones of the distal tarsal row but can also extend onto the proximal tarsal row and the proximal metatarsus. Exostose of the bone limits movement at the hock joint and can lead to a mild degree of lameness (Baker and Brothwell 1980). Mild forms of »spavin« probably occur in wild horse populations, and Baker and Brothwell point out that Moodie (1923) illustrates a probable case of spavin in fossil three-toed horse from the American Pliocene.

Summary of the horse remains from the Magdalenian deposits at Sector I11

The remains of horse represent the bulk of the faunal material from the Magdalenian deposits at sector I11. A total of 466 remains could be identified to horse and these bones form 92.8% of the total number of bones from this site which could be identified to a species. The highest number of individuals – 6 – was counted on upper third molars from the right side of the body. However, a more detailed analysis of the upper cheek teeth showed that at least nine individuals of horse could be identified.
The effects of density-mediated bone destruction on this assemblage were minimal, as shown by the high counts for less dense post-cranial bones and relatively low counts for dense teeth. All skeletal parts of horse were recorded from this site, except the caudal vertebrae and second metatarsals. High counts of individuals were also recorded on the pelvis, humerus, third metacarpals and third metatarsals. Low counts on the ribs, sternebrae, patella and sesamoids were probably due to the fragility or porosity of these elements, or carnivore attrition.
At sector I11 high numbers of individuals were counted on high and low-utility parts of the carcass, and a comparable situation was recorded on horse bones from Sector P16. Equally comparable was the role that bone preservation played in the representation of portions of the bones, and high numbers of individuals were counted on the robust portions of the elements concerned.
A conventional analysis of cheek tooth height and wear stages produced an age-structure, or mortality profile, dominated by prime adult horses with low numbers of juvenile horses and extremely low numbers of old horses. A more detailed analysis, in which teeth attributed to individual horses were aged, showed that juveniles represented approximately 44% of the horses from this site.
Epiphyseal fusion stages of post-cranial bones showed that at least three horses were younger than 3 1/2 years of age at death, and one horse was younger than one year at death. The presence of only one canine suggests that the bulk of the horses were females.
Thus, the dominance of prime, mainly female, adults and the presence of young animals indicate that the horse remains which accumulated at the I11 site originated from animals living together in family groups.
Cut marks were recorded on 24 horse bones and impact notches on five horse bones. At least three horse carcasses had been butchered, and the remains of both juvenile and adult individuals bore traces of butchery. Two horse bones had served as raw material for a bone industry and two further horse bones had possibly been engraved.
Carnivores had modified 60 horse bones from sector I11. Patterns of damage show that all stages of carcass utilization by carnivores, from light to heavy, are represented.
Three horse bones showed traces of pathological and non-pathological alterations resulting from osteoperiostitis, abnormal bony outgrowths, non-pathological bony lesions and a case of spavin.

REINDEER

Introduction and basic data

Remains of reindeer *Rangifer tarandus* represented only 5.7% of the total number of faunal remains identifiable to a species from the Magdalenian horizon at sector I11. Basic data for this species is given in table 22.

NISP	NISP after refitting	MNE	MNI	carnivore gnawing	cut marks	impact notches	worked bone	charred bone
29	29	22	3	0	4	1	4	0

Tab. 22 Basic data for the remains of reindeer from the sector I11 site.

A total of 29 bones representing 22 elements of reindeer could be identified. A minimum of three individuals was established on lower permanent third molars from the left body side. An extremely worn upper molar probably provides evidence of a fourth individual of this species. Nevertheless, in comparison to the remains of horse, reindeer remains are highly underrepresented. Cut marks and impact notches were observed on a total of five reindeer remains. None of the remains of reindeer bore traces of gnawing by carnivores and none had been charred. Three fragments of reindeer antler and one fragment of reindeer bone had been utilized by humans as raw materials for tools.

Numbers of individuals and skeletal part representation

Counts of reindeer skeletal remains are listed in table 23, where element type, body-side, minimum number of elements (MNE) and minimum number of individuals (MNI) are given.

	left	*	right	MNE	MNI	number gnawed
Head						
antler fragments		3		0		0
mandible	0	0	1	1	1	0
maxillary teeth	1	1	0	2	2	0
mandibulary teeth	3	2	4	9	3	0
Axial						
ribs	0	2	0	1	1	0
Fore-limb						
P metacarpal	1	0	0	1	1	0
Rear-limb						
femur shaft	0	0	2	1	1	0
tibia shaft	1	0	0			
D tibia	1	0	0	1	1	0
astragalus	1	0	0	1	1	0
P metatarsus	0	0	2	2	2	0
phalange 2	1 proximal; 1 distal; 1 fragment			2	1	0
phalange 3	1 proximal			1	1	0
Totals	**29**			**22**		0

Tab. 23 Counts of reindeer remains from sector I11. – P = proximal, D = distal, * = indeterminable to body-side. All MNI's and MNE's are based on number of fragments after refitting.

The skeletal part representation of reindeer is shown in figure 46, where minimum numbers of individuals, taken from table 23, are depicted for those portions of the reindeer skeleton present at the I11 site. Reindeer remains are extremely underrepresented in this assemblage, and even when factors such as differential bone preservation and carnivore attrition are taken into consideration, it is more or less impossible to interpret the very small collection of reindeer bones from this sector.

Determination of reindeer age-mortality on certain skeletal elements

Numbers of individuals and age at death using the upper and lower cheek teeth

Three adult reindeer were counted on three left lower third molars in different stages of wear. An extremely worn upper molar, which did not belong to any of the individuals represented by the lower cheek teeth rows, probably indicates the presence of a fourth adult individual at the site.
The lower third molars were aged using Miller's age class groupings (see page 75).

Reindeer 1: the crown of the lower M3 (79/383) shows only slight traces of wear on the buccal part of the anterior cusp, placing this individual into the age-cohort two years or younger.

Reindeer 2: the crown of the lower M3 (79/118) has all three cusps in wear, but the cusps are not fused together. This individual belongs to the 3-5 year age-cohort.

Reindeer 3: the lower M3 from this animal has the same stage of wear as reindeer 2, but the cusps are in an advanced stage of fusion. This individual belongs to the 3-5 year age-cohort.

Reindeer 4: the extremely worn upper molar places this putative individual in the 10 + year age-cohort.

Epiphyseal fusion stages of postcranial bone

Two reindeer bones in different stages of epiphyseal fusion provided evidence of at least one individual younger than 14-15 months of age at death. The distal epiphysis of a tibia was fused to the diaphysis but the fusion line was still visible indicating an animal between 14-15 months of age. An unfused proximal epiphysis from a second phalange shows that one reindeer had died in its first year.

Evidence of human modification of reindeer bones

Cut marks

Cut marks were recorded on four reindeer bones representing a total of 13.7% of the elements from this species; the percentage is only slightly higher than that reckoned for cut marked horse bone. The marks were generally located in positions recorded during filleting processes.

Ribs

Two fragmentary ribs (69/612 and 69/613) were assigned to this species due to their small size. Both bore oblique cut marks on the outer rib surface and may testify to filleting processes in much the same manner as recorded for horse.

Femur

A right femur shaft (79/102) showed two sets of fine cut marks, one set of oblique marks placed towards

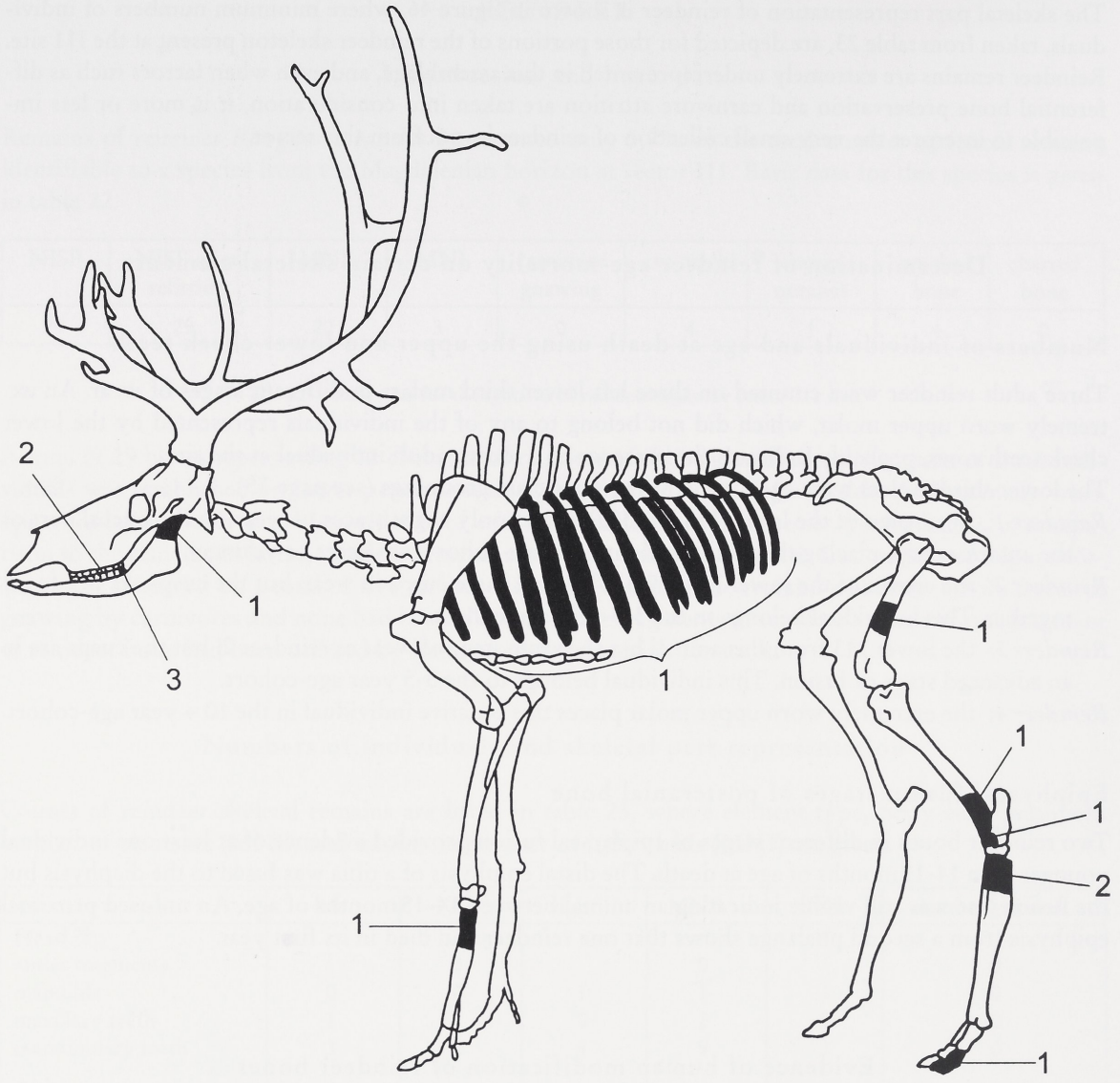


Fig. 46 Reindeer skeletal representation at sector I11 depicting the minimum number of individuals (MNI) for each element. Black areas on elements of the head, legs and on the pelvis indicate those portions of the bones which were preserved in the assemblage.

the distal end at the top of the *Fossa plantaris* and a second set mid-shaft on the cranial side of the bone. Both sets were probably produced during filleting.
Oblique cut marks were observed on a second femur shaft fragment (89/626). Two sets, one consisting of only a single mark, were located on the cranial face of the shaft just to one side of the foramen at the proximal end of the shaft and may correspond to Binfords Fp-6 mark (1981, fig. 4. 37, b).

Tibia

One set of oblique marks is located on the lateral edge of a left tibia (89/625). They probably derive from filleting activities comparable to Binfords Tp-4 and 5 marks (1981, fig. 4. 37, d).

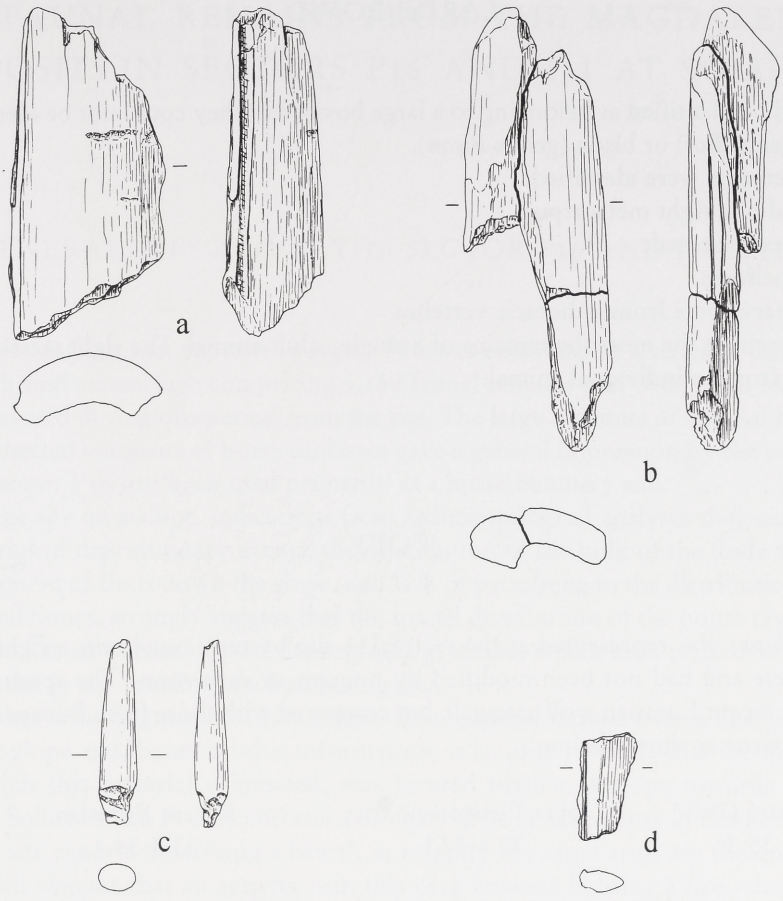


Fig. 47 Worked reindeer antler and bone from sector I11. – a (I11 69/704) and b (I11 69/613) fragments of antler beams with traces of grooves produced during working using the groove and splinter technique. – c Fragment of an antler point (I11 79/312). – d Fragment of ?reindeer bone with a groove on the outer surface of the bone (I11 89/621).

Impact notches

Only one possible impact mark was noted on the reindeer remains. The notch is located just below the proximal end of a metatarsal fragment (79/666) and has left a clear negative on the inner side of the bone on the dorsal face of the bone.

Worked antler and bone

Two larger pieces of antler represent fragments of debitage produced during the working of this material. Both finds bear traces of grooves on the outer surfaces (fig. 47 a-b). The antler industry also comprised a small point (fig. 47 c). A tiny fragment, possibly from a reindeer bone, bore the remains of a groove on the outer surface (fig. 47 d).

LARGE BOVID

Four bones could be identified as belonging to a large bovid, but they could not be identified further to either aurochs (genus *Bos*) or bison (genus *Bison*).
The following elements were identified:

distal end of a right metacarpus
right os centrotarsale
right cuneiform
fragmentary spine from a thoracic vertebra

These finds represent at the most the remains of a single, adult animal. The right tarsals could be re-articulated and are from an individual animal.

WOLF

The wolf *Canis lupus* was represented at the sector I11 site by only one bone, a right astragalus. The bone was complete and had not been modified by humans or carnivores. The specimen was slightly longer than some recent Eurasian wolf astragali, but compared with those from European sites dating to the Upper Pleistocene as shown below.

	Solutré (79/6)	Upper Pleistocene sites	Recent Eurasian
Length	35.2	33.4-37.1	33.3-34.4

Measurements given in mm. Comparative data taken from Kunst (in Nagel and Rabeder 1992)

SMALL CERVID

A fragment of a left metatarsal and a lower third incisor from a small-sized cervid (deer) were recovered. The metatarsus consists of the medial side of the proximal end and part of the shaft. The well-defined sulcus on the dorsal bone side is typical for all deer types; members of the caprid family have a less prominent sulcus. It was, however, clear that this bone did not belong to a reindeer. Reindeer foot-bones have a very characteristic morphology, including an extremely prominent medial sulcus edge at the proximal end of the metatarsus, so that the bone is asymmetrical in section. In smaller deer, such as fallow and roe deer, the edges of the sulcus extend equally and the sulcus is symmetrical in form. The morphology of the fragment from sector I11 resembled that of the smaller deer and, as far as could be ascertained from the form and size of the proximal end, compared more with roe deer metatarsals in the recent comparative collection.
The lower incisor has a broad, almost spatulate, crown not typical of the narrow-crowned teeth of reindeer recorded from the site.

THE FAUNAL REMAINS FROM THE MAGDALENIAN DEPOSITS IN SECTORS P16 AND I11 AT SOLUTRÉ

GENERALITIES ABOUT THE SECTOR P16 AND I11 SITES

A total of 95 m^2 of Magdalenian deposits in sector P16 was excavated in a series of campaigns between 1968-1974. A rich find assemblage comprising 4,159 faunal remains and over 1,100 Magdalenian lithic artefacts was recovered during this period from the site. The large amounts of bone of horse and several anatomically connected segments of horse carcasses gave a general impression by the end of the excavation period that sector P16 had been used primarily as a horse butchery site.

The location of the site on a slope, indications from sedimentological analyses that sediments accumulated during a series of depositionary events, the distribution of the bulk of the finds within a channel, evidence of movement of finds down the slope, and lack of patterning in the distribution of humanly or carnivore modified bones, strongly suggest that the spatial distribution of the bones revealed during excavation is the product of a series of post-depositional processes which took place over a long period of time, rather than the *in situ* remains of a butchering site.

Conjoin lengths between fragments of bone show that material moved over a distance of up to four metres down the slope and, based on this information, it is quite possible that the butchery site – or sites – from which this material originated, was located further upslope towards the base of the southern cliff of Solutré rock. A concentration of charred bone fragments in the northern section of the channel, and site reports describing a hearth in roughly the same area, are the only pieces of evidence which could suggest that an activity – in this case humans lighting a fire – had actually taken place at sector P16.

The sondage in sector I11 (quadrats 69, 79 and 89) was excavated in 1987 as part of a programme of sampling for sedimentological studies. Although less than two square metres in size, excavations at this site produced finds from five cultural horizons, the richest of which belonged to the Magdalenian period. The location of the site on the slope of the hill below the Roche de Solutré and the presence of long bones embedded vertically in the deposits led Combier to the conclusion that the finds in the Magdalenian horizon had probably accumulated at the site as a result of solifluction and movement of material down the slope, a conclusion that was supported by the results of a study of conjoining bones undertaken during the course of this analysis.

Columns of samples for pollen were taken twice during excavation of the P16 site. The most significant sample, Solutré B, yielded low values of arboreal pollen dominated by pollen of pine, indicating cold climatic conditions. Low values of thermophilous taxa such as lime, hornbeam and walnut show that the climate was not extremely cold. Herbaceous pollen was found in all the samples, grasses were rare and the presence of some Chenopodia indicated open terrain at the site. It was concluded that although the pollen remains could not be used to date the site exactly, the »temperate« climatic conditions indicated in the pollen diagram, combined with the age of the bone dated by the Lyon laboratory (see below), indicated deposition of the find-assemblage during the Bölling Interstadial.

During excavation of the P16 site a bone was submitted to the C^{14}-laboratory at Lyon for dating: the find was dated to 12,580 ± 250 BP. A cut-marked horse tooth from P16 and a cut-marked horse calcaneum from sector I11 were submitted during the course of the current analysis to the Accelerator Unit in Oxford which produced older C^{14}-dates of 15,080 ± 130 BP and 14,570 ± 130 BP respectively for the new samples. The differences between these dates and the date produced by the Lyon laboratory could be due to the different methods of dating used, or indicate that deposition of finds at P16

took place over a long period of time. It is however clear, that neither the Lyon date nor the Oxford dates place deposition of bone at sector P16 into the short, temperate phase known as the Bölling Interstadial. According to a chronology of the Upper Weichselian established by Lanting and van der Pflicht (1996), the short temperate Bölling Interstadial sensu stricto begins at around 12,500 BP. A date of 12,580 BP places the bone sampled by the Lyon laboratory into Lanting and Pflicht's older Dryas I/Bölling (sensu lato). The older date produced by the Oxford laboratory suggests deposition of cut-marked horse remains in the period between the Pleniglacial and the Late Glacial Interstadial Complex.

A total of 4,159 faunal remains was seen and recorded during the present analysis of the sector P16 faunal assemblage. 4,133 of these finds were attributed to the Magdalenian fauna. These bones were well-preserved with varying stages of root-etching. The Magdalenian fauna consisted of 93 finds which were too fragmentary to be identified to a species, three bird bones, five bones from small carnivores (?) and a very worn tooth, probably from a lion. The remaining 4,031 bones could be definitely identified to a species and this assemblage is dominated by horse, but the remains of other animals, reindeer, bison, wolf, fox and wolverine, are also present. Of the 528 bones recorded from the Magdalenian deposits in sector I11, 500 finds could be identified to specific level and two finds to generic level.

The composition of both faunas with large herbivores such as horse and bison indicating a predominantly open, herbaceous environment, and reindeer indicating cold climatic conditions, is comparable to that deduced from pollen analysis.

The species present in the P16 and I11 faunas were separated into an archaeological faunal group and a non-archaeological, or »background«, faunal group, based on the presence or absence of traces of human modification of the bones such as cut-marks, hammerstone-induced impact notches or evidence of use of bone and antler as a raw material to produce tools. At P16 human modification was observed on the remains of horse, reindeer, bison and possibly wolf. At I11, human modification was only observed on the bones of horse and reindeer. In the following section, aspects of the remains of the three main species, horse, reindeer and bison are compared.

A COMPARISON OF THE REMAINS OF THE THREE MAIN SPECIES – HORSE, REINDEER AND BISON – AT THE SECTOR P16 AND I11 SITES

Numbers of finds and numbers of individuals

Horse dominates the fauna from the Magdalenian deposits at P16 with a total of 3,577 finds or 88.7% of the total number of bones identified to a species. The remains represent some 2,672 skeletal elements from this species. A minimum of 45 individuals of horse was recorded on the acetabular portion of the pelvis. A much lower quantity of finds was identified as reindeer remains. 271 finds were identified to this species, comprising 216 elements and representing 6.6% of the total number of finds identifiable to a species. A minimum of nine individuals of reindeer, counted on nine left astragali, was recorded at P16. Large bovids, identified by morphological criteria as bison, were represented by only 142 finds, comprising 119 elements and 3.5% of the total number of finds identifiable to a species. A minimum of five individuals of bison was counted on five left metacarpals, but a more detailed analysis of the bison remains, using the minimum number of individuals as a basis, but also including counts of individual animals identified by tooth wear and eruption stages and post-epiphyseal fusion stages of bones, produced a total of at least seven individuals of bison at the site.

Horse is also the dominant species at sector I11, representing 92.8% of the total number of remains attributable to a species at this site. A minimum of six individuals was counted using conventional

methods, but a more detailed analysis of upper cheek teeth of this species produced a higher minimum number of nine individuals. Reindeer bones and teeth formed only 5.7% of the remains identifiable to a species. Out of a total of 29 remains, three individuals were counted on lower cheek teeth. A total of four bones of large bovid, probably bison, was also recovered from the I11 site.
In general, reindeer and bison are characterized at both sites by low numbers of identifiable remains, but relatively high numbers of individuals, whereas horse is characterized by high numbers of remains and high numbers of individuals.

Skeletal representation

All skeletal parts of horse are present at the sector P16 site, even if some elements are only represented by one bone or one individual. The large number of skeletal parts, high numbers of individuals recorded on many skeletal parts and approximately equal amounts of bones from the left and from the right sides of the body indicate that intact carcasses of horses were deposited at the site or close to it. The presence of numerous less dense post-cranial bones among the horse remains at sector P16 indicates that the effects of density-mediated bone destruction on this assemblage were minimal. The extremely low numbers of ribs and some axial elements are certainly related to some extent to the fragility of these elements, but not entirely. The possibility that the differential preservation of parts of the back of the horse, as well as variations between ratings for leg bones (humerus, radius, femur and tibia) and their skeletal neighbours (scapula, pelvis and metapodials), could reflect transportation of these skeletal parts away from the site by humans, for example, cannot be excluded.
The frequencies of portions of bones such as the scapula, humerus, pelvis and femur, show positive correlations with intrabone variations in density recorded for these elements in other large-medium sized ungulates. Negative correlations were observed for the shafts and ends of radii, tibiae, metacarpals and metatarsals. The low counts for the shafts of these bones may be related to the initial fracture of these elements by humans, resulting in a reduction or loss of bone prior to post-depositional destruction. Low numbers of some portions of the mandible, including the robust mandible symphysis, and the differential preservation observed between anterior and posterior mandibulary cheek teeth may have resulted from humans smashing horse jaws into smaller pieces in order to obtain marrow. Some carcass portions of horse were recovered in anatomical connection.
On the whole, horse skeletal part representation from the sector I11 site is comparable to that observed at the P16 site. The horse remains are well-preserved and had hardly been affected by differential post-depositional destruction. All parts of the skeleton are represented except the caudal vertebrae and second metatarsals. High numbers of individuals were recorded on high-utility and on low-utility parts of the carcasses, and on robust portions of the bones.
In comparison to horse, remains of reindeer and bison were rare at both sites and, considering the relatively high minimum numbers of individuals of reindeer and bison, underrepresented. At sector P16, reindeer and bison have skeletal representations which are very similar to each other, which is unusual considering that we are dealing here with two species of very different body-size. The presence of elements from the head, some first cervical vertebrae, pelves and portions of limb and foot bones are characteristic for both species, as are the absence or extremely low numbers of other axial elements. There are no apparent differences between counts of individuals assessed on high-utility and on low-utility elements. As expected, high-density portions of elements are better preserved than low density ones. However, skeletal representation alone gives little indication as to whether these elements represent the remains of intensively processed, whole carcasses of reindeer and bison hunted and killed close to the sector P16 site, or portions of carcasses of animals hunted elsewhere which had been transported back to the site.

Age structure, population demography and season of death

The age structure, or the approximate age of horses at death, was assessed on dental attrition. 232 deciduous and permanent cheek teeth were placed in age-classes according to their degree of attrition. The results showed that the bulk of the teeth (76%) are from animals that died in their prime, sexually reproductive years. Juvenile horses represented only 15% and old or senile animals 13% of the population from P16. Similar results were obtained from analyses of the attritional stages of horse incisors. An analysis of bone epiphyseal fusion stages showed that some horses could have been as young as nine months of age when they died.

Extremely low numbers of canine teeth were recovered from the site, probably reflecting a dominance of females among the horses that died here. The composition of the horse population, with a few juveniles and old animals, a dominance of adult horses in their reproductive years, the presence of young foals and pregnant females, and a dominance of females, suggests that mainly horses living in family groups died here. Stages in the development of bones from two horse foetuses indicate that two of the mares died between February and March, about $2^1/_2$ months before they were due to give birth. Cementum analyses of teeth from Magdalenian deposits (sector J10) indicate that horses died in spring/early summer, summer and winter. It was concluded that horses died at Solutré from spring to autumn with the greatest concentration of deaths during the summer months (fig. 48).

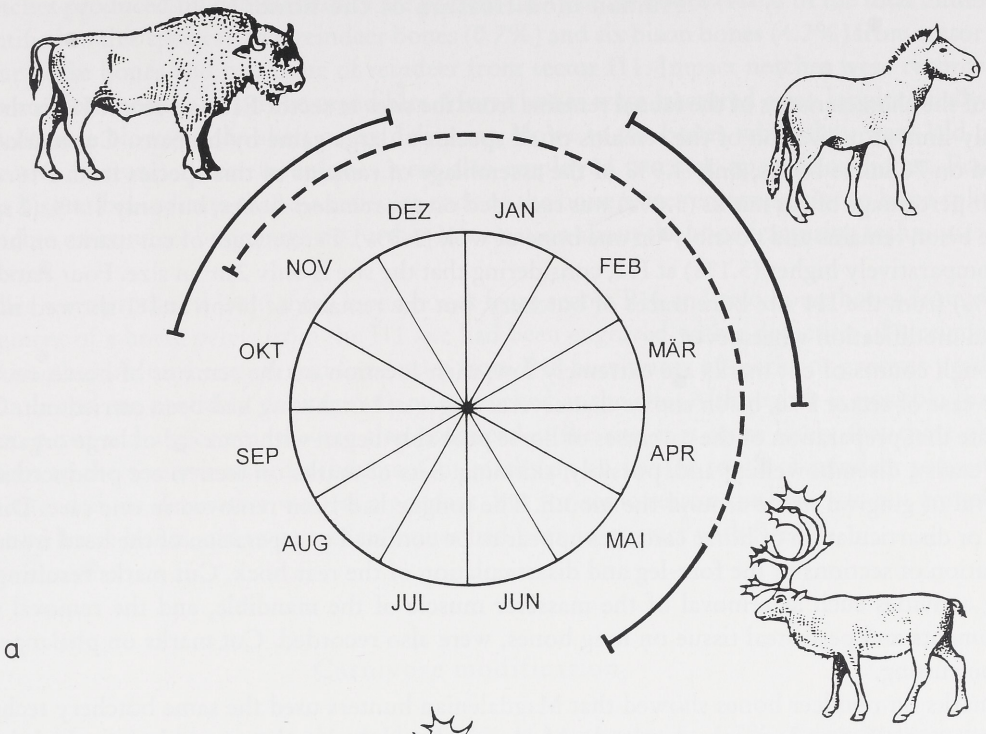
The age-structure of the horse population from sector I11 was also dominated by prime adult individuals. Juvenile horses represented 14% or 44% of the population, depending on whether the results of a conventional method of cheek tooth ageing using tooth heights and wear stages or the detailed analysis of ageing the teeth of individual animals were considered. Old or senile horses were extremely rare, representing only 2% of the population at the I11 site.

According to tooth eruption and wear patterns, young, adult and old individuals of reindeer were present at both sites, but a dominance of teeth from sub-adult and adult reindeer suggests that these animals were the preferred prey of the Magdalenian hunters.

Of particular interest for the demographic patterns and season of death of reindeer were seven pedicles from individuals which had just shed their antler and an antler frontlet from an individual which was just about to shed its antler, recovered at sector P16. The finds are from young reindeer of either sex which shed their antler in May. Reindeer are strongly social animals and maintain certain groupings known as bands. The eight juveniles at P16 were probably members of a juvenile band, common in the spring and autumn, which may have been killed together in a single hunting episode. If this was the case, the presence of pedicles and antlers from all eight carcasses suggests that these reindeer were killed at the site itself. According to the results of an analysis of reindeer tooth cementum, some reindeer also died during the winter months (December-March) and others in the spring (April-May) (fig. 48).

By using a combination of tooth eruption and wear patterns, stages of epiphyseal fusion and sexual dimorphism, the minimum number of individuals of bison at the sector P16 site could be increased from five to seven. The bison population at P16 consisted of a single adult male, two adult females, a subadult female, two juveniles, one of which was a female, and a calf of unknown sex. If these animals died during a single incidence, then the age and sex structure of the bison »herd« from P16 with its dominance of females, presence of a calf and juveniles/subadults is comparable to that observed in cow-calf groups. The time of death established for the calf and for the juveniles indicates that these young bison could have died together during a single hunting episode in autumn/winter (fig. 48). Only the remains of a single adult bovid were recovered from the I11 site.

Fig. 48 a The season of death of horse, reindeer and bison established during the current analysis. – b Compilation of a and extended by the results of incremental analyses of horse and reindeer teeth produced during earlier analyses of the faunas. Incremental analysis of horse teeth undertaken by M. Beasley (published in Olsen 1989) and incremental analysis of reindeer teeth undertaken by B. Gordon (1988). →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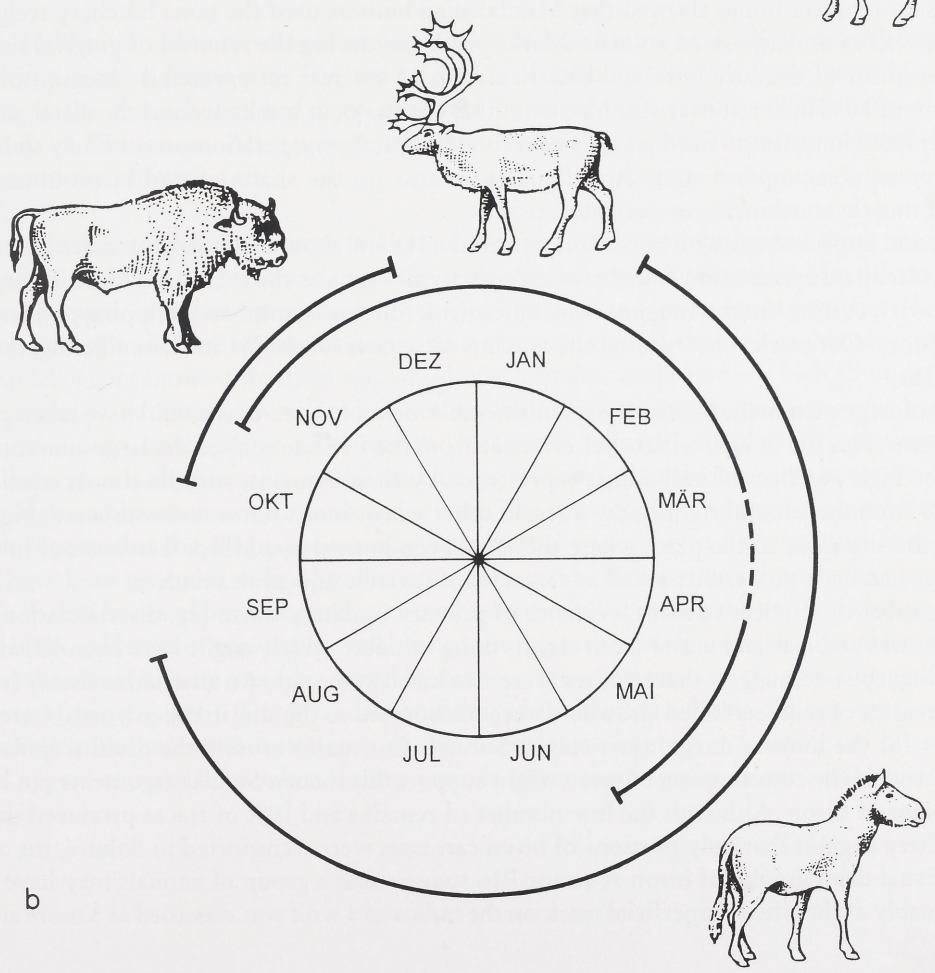
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Human modification of the bones

One of the characteristics of the faunal remains from the sites in sector P16 and sector I11 is the evidence of only limited utilization of the remains of all species of large game by humans. Cut marks were observed on 70 horse bones, only 1.9% of the assemblage of remains of this species from P16. A slightly higher percentage of cut marks (3.6%) was recorded on ten reindeer bones, but only 1.4% (2 specimens) of the bison remains and possibly on one bone of wolf (3.3%). Percentages of cut marks on horse bones are comparatively higher (5.1%) at I11, considering that the site is only 2 m^2 in size. Four reindeer bones (13.7%) from the I11 site bore traces of butchery, but the remains of bison at I11 showed no traces of human modification whatsoever.

Although counts of cut marks are extremely low, their location on the remains of horse, reindeer and, in the case of sector P16, bison shows that several stages of butchering had been carried out. Cut marks indicate that preparation of the carcasses of horse probably began with removal of large organs from the chest cavity, disembowelling and, possibly, skinning. Sets of marks on teeth were produced during the removal of gingival tissue around the mouth. The tongue had been removed in one case. Dismemberment or disarticulation of horse carcasses appear to be confined to separation of the head from the neck, separation of sections of the fore-leg and disarticulation of the rear hock. Cut marks resulting from filleting activities such as removal of the masseter muscle of the mandible, and the removal of muscle attachments and periosteal tissue on long bones, were also recorded. Cut marks on phalanges attest to tendon cutting.

Cut marks on reindeer bones showed that Magdalenian hunters used the same butchery techniques on medium as well as on large-sized animals. Marks produced during the removal of gingival tissue, separation of sections of the fore limb and disarticulation of the rear foot were all observed on reindeer remains from P16. Three reindeer scapulae from this site have cut marks around the distal articulation, often interpreted in medium-sized animals as secondary butchery operations, most likely to have taken place at human consumption sites. Superficial cut marks on the shafts of two bison bones attest to removal of muscle attachments or periosteal tissue.

Cut marks and impact notches on horse bones from the I11 site show that horse carcasses may have been hung up to facilitate evisceration and also attest to activities such as the extraction of major organs from the chest cavity, cutting out the tongue, dismemberment, filleting of meat and stripping periosteal tissues from the bones. Cut marks observed on the remains of reindeer from I11 indicate filleting, but not dismemberment.

In the case of large mammals, such as horses, dismemberment of the carcass would have taken place close to the kill-site. This fits in well with other evidence from the P16 site such as the large amounts of horse remains, the high numbers of individuals represented by these remains, and the almost equal numbers of elements from the left and right body-sides: in other words intact horse carcasses were originally deposited at the site close to the place where they had been hunted and killed. Carcasses of juvenile and adult horses had been processed as well as carcasses of juvenile and adult reindeer.

The low number of reindeer remains, evidence of primary butchery traces (eg. disarticulation) on reindeer bones, and pedicles and antler from eight young reindeer which might have been killed during a single hunting episode, suggest that reindeer were also killed at the site. 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. Cut marks around the distal scapulae of reindeer, indicative of the consumption of meat, might support this theory. Similar arguments can be applied to the remains of bison. Although the low number of remains and lack of traces produced during primary butchery suggest that only portions of bison carcasses were transported to Solutré, the age-structure and sexual demography of bison at sector P16 suggest that a group of animals may have been killed, presumably at the site. A superficial mark on the radius of a wolf was classified as a more ambiguous cut mark.

Impact notches produced by hammerstones are present on 44 horse bones (1.2% of the total number of bones identified to this species), two reindeer bones (0.7%) and six bison bones (4.2%) from sector P16, and on four horse bones and one bone of reindeer from sector I11. Impact notches were recorded on horse limb and foot bones and on the mandibles. Horse bones were fractured open longitudinally by a series of deliberate blows to the shaft or by delivering blows to the bones while they were laid on an anvil (reflective fracture). These techniques were also employed to crack open bison bones. Fracture planes on a bison tibia indicate that the articular ends of the bone were removed prior to bone splitting. Impact notches on reindeer bones give no further information about the bone fracturing techniques used on this species.
Bone needles were produced from three horse bones from sector P16 and two horse bones from sector I11. A fragment of a horse pelvis from the I11 site had been engraved with a depiction of a reindeer. A very small number of fragments of reindeer antler from P16 bear traces of marks or grooves produced by stone tools and are probably debitage of antler worked at the site. Although it is possible that the antler bâton percé and antler points were also produced at the site, it is more likely that these objects were brought to the site as finished products. Cut marks on an incisor tooth of reindeer suggest this tooth was intended for decorative wear as a pendant, but for some reason the task was not completed. A total of two horse bones and two reindeer bones had been in contact with fire.

Carnivore modification

Carnivore modification of bone was observed on 7.3% of horse remains, 6.7% of reindeer remains and 14.0% of bison remains from sector P16 and on 16.4% of the horse remains from sector I11. Practically all parts of the horse bones had been modified by carnivores, which preferentially chewed the articular ends of limb bones. All stages of carcass utilization by carnivores were recorded, from light utilisation to heavy utilization.

Cut marks, hammerstone-induced impact notches and worked bones, antler and teeth show that not only horse, but also reindeer, bison and, possibly, wolf remains were processed by Magdalenian hunters. Horses were hunted, killed and processed at the site. Reindeer and bison could have been killed at the site, or transported to Solutré as carcass parts. With the exception of the wolves, Magdalenian hunters appeared to have concentrated on three species – horse, reindeer and bison – which all undertake some form of seasonal wanderings. The valley below the rock of Solutré appears to have served as a regular migration route between the Saône valley and the Mâconnais hills for several species of game.
Based on the evidence of seasonality established during this analysis, reindeer were hunted between December to May and bison during autumn and winter. The presence of 3 young bison and the season of their death suggest that the Magdalenians may have hunted young bison on a seasonal basis. Reindeer appear to have been procured over a broader seasonal period, during which time distinct social groups were taken. Foetal bones of horse show that two mares were killed during the period February to March (fig. 48a). If the evidence of seasonality established during earlier analyses is also considered, it would appear that the site at Solutré was frequented by humans at several times of the year during the Magdalenian phase of use (fig. 48b). The physical 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 taken during periods when their condition varied substantially from poorest to best.

HORSE HUNTING TACTICS AT SOLUTRÉ

Turning now to the horse remains, the following list summarizes the main criteria established during the current analysis which characterize the assemblage of horse bones from the kill and butchery site of Solutré during the Magdalenian period. In general, the results of this analysis confirm those of previous analyses of the Magdalenian faunas from Solutré (Berke 1989; Levine 1979, 1983 and Olsen 1989, 1995):

mainly horses living in family groups were hunted
large numbers of individuals were killed
mainly adults, but also some juveniles, were killed and butchered
low numbers of cut-marked bones
low numbers of bones broken open to obtain marrow
large number of bones left at the site, sometimes in anatomical connection
extremely low numbers of bones used as a raw material for a bone industry
extremely low numbers of charred bones
relatively high percentages of carnivore gnawed bones

The most unusual aspect of this site is the discrepancy between the large number of horses that apparently died here, and the low number of horse remains bearing traces of having been butchered by the hunters. The low numbers of cut and other butchery marks are, in my opinion, not wholly related to bone preservation. Could the lack of cut marks be due to the expertise of Magdalenian butchers whose methods of carcass processing left few traces behind? 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 figure of a de-fleshed head of a horse from the Magdalenien site of Mas d'Azil in France (Piette 1907). Olsen (1989 p. 309), however, argued that it did not seem reasonable to explain low numbers of cut marks on horse bones by either »extraordinarily careful butchering« or »an ignorance of butchering methods« since butchery marks were present on the bones of other species at Solutré.
Is the minimal processing of horse carcasses linked to the way in which horses were hunted? In her paper Olsen (1989) considered five basic hunting hypotheses to explain how the site at Solutré formed. The first hypothesis returned to the »jump« theory where horses were chased up the slope of the rock and either run off the western end of the cuesta or off the southern edge of the rock directly above the site. In the second hypothesis, the possibility that the large amounts of horse bones accumulated after a series of repeated natural catastrophes was considered. In this hypothesis, the lithic artefacts and other cultural remains were either unrelated to the faunal remains or were deposited as humans scavenged from carcasses of horses at the site. That Solutré represented a base camp to which horse remains were transported from a kill-site at another location was the third hypothesis, and the killing of small numbers or single horses as they wandered close to the site was proposed as hypothesis four. In hypothesis five, horses were killed as they passed through the valley below Solutré rock in bands of around 6-12 individuals. These bands were intercepted by the hunters in the valley and driven up the slope towards the southern face of the rock, where they were corralled and killed. In a paper published in 1995, Olsen described hunters at Solutré utilizing a natural indentation in the southern face of the rock as a corral by enclosing the entrance with simple structures in a manner similar to that apparently used at bison kill sites in North America such as Wardell (Frison 1973), Boarding School (Kehoe 1967), Gull Lake (Kehoe 1973) and Garnsey (Speth and Parry 1978). Olsen (1989) concluded that all the indices – vast numbers of horses, articulated units of horse bones, scarcity of butchery marks, low numbers of spiral fractures (as a possible result of marrow extraction) and lack of evidence of transportation of meat-bearing bones away from the site (see page 139) – pointed to the killing of many horses in a single episode and an underexploitation of horse carcasses. She concluded that the best explanation for this »long tradition of wastage« (ibid. p. 324) was the relative ease associated with driving horses into a corral and then killing them, as proposed in hunting hypothesis five: a hypothesis which is also in keeping with wild horse behaviour, and is supported by the topography of

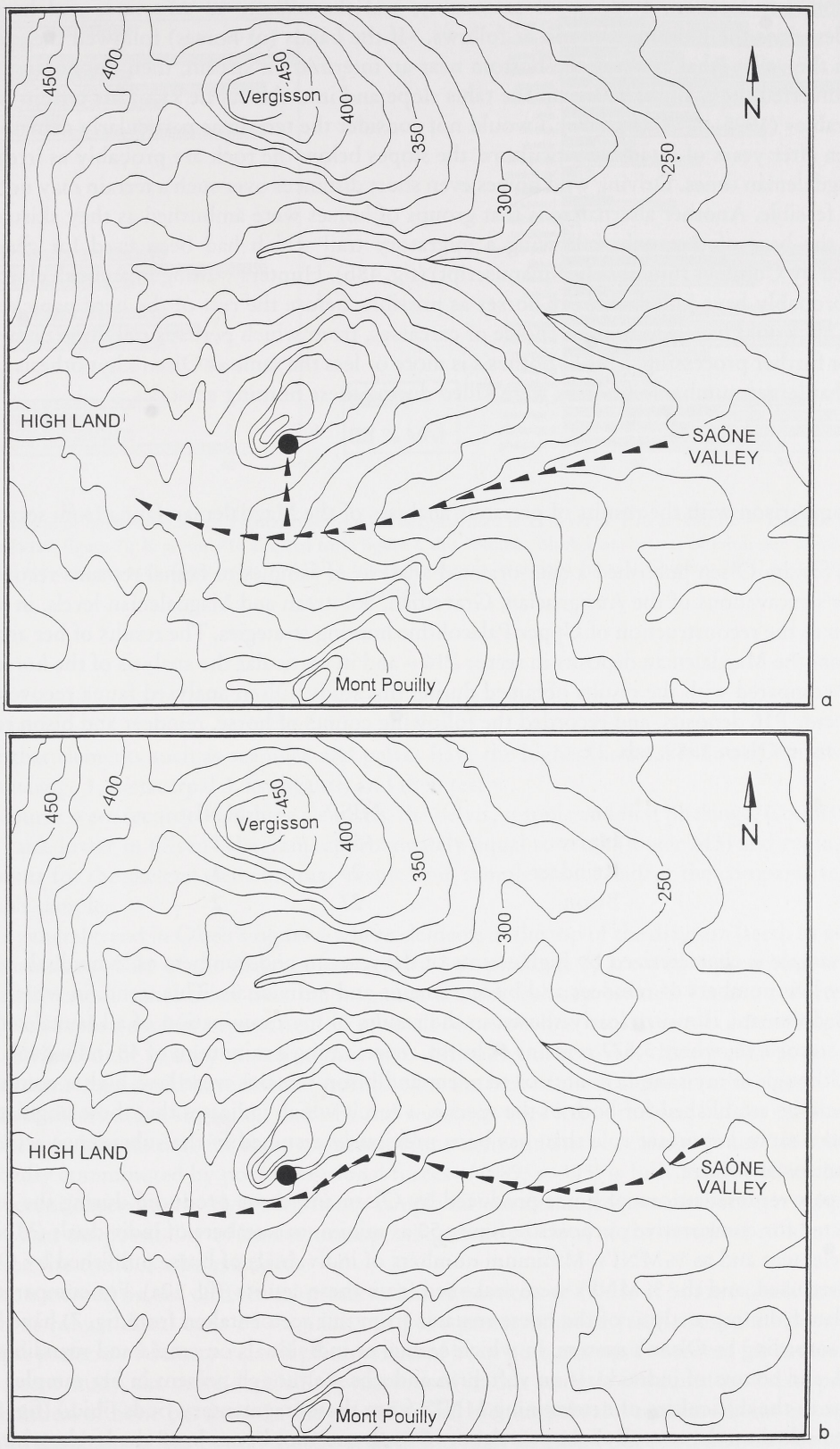


Fig. 49 Magdalenian horse hunting tactics a) Olsen's (1989, fig. 2) suggestion where horses were intercepted in the valley below Solutré rock, driven up to the bottom of the southern cliff face, corralled and killed there. b) Combier's proposal (unpublished manuscript, fig. 10) where horses were ambushed as they followed a migratory trail around the base of Solutré rock.

the region, site location, evidence of seasonality, and the scarcity of structures and hearths (ibid.). Olsen describes the hunting scenario as follows. »If the bands (of horses) followed the easiest course through the valley, that is along the bottom near an intermittant stream, then the hunters could have simply diverted them about 200 m up the talus slope and into the cul de sac. This terrain is easily manoeuverable« (1995, p. 73) (fig. 49a). I would not consider the terrain as particularly maneuverable. Today, even after years of intensive viticulture, the slopes below the rock are probably as irregular as during Magdalenian times. Driving wild horses even short distances over such a terrain may not always have been feasible. Another alternative is that groups of horses were ambushed as they skirted single file around the base of the rock, following a migratory trail which had been used for generations, as suggested by Combier (unpublished manuscript) (fig. 48b). 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 would have produced a choice of carcasses, from which perhaps only one or two were selected for further processing. This hypothesis is more or less the same as Olsen's hypothesis four, but assumes that larger numbers of horses were killed during these hunting episodes.

Comparison with the results of previous analyses of the Magdalenian fauna from sector P16

In 1989, Sandra Olsen published a data-oriented analysis of samples of faunal remains recovered during Combier's excavations of the Aurignacian, Gravettian, Solutrean and Magdalenian levels, in a theoretical approach to the reconstruction of Upper Palaeolithic hunting strategies. The results of her analysis of the fauna from the Magdalenian deposits in sector P16 – and in particular the analysis of the horse remains –, are now compared with the results obtained during this study. Olsen analysed fauna recovered in 12 m^2 of the sector P16 deposits, and recorded the following counts of horse, reindeer and bison remains (data taken from Olsen 1989, tab. 2):

	NISP	MNI
Horse	658	11
Reindeer	25	3
Bison	27	2

Olsen's sample is characterized by high counts of the remains and numbers of individuals of horse and relatively low numbers of reindeer and bison remains and individuals. This trend, in which remains of horse predominate, is more clearly shown in the results of my examination of all faunal remains excavated at sector P16, where 3,577 remains of horse, representing a minimum of 45 individuals were identified. Although in my sample counts of reindeer and bison remains were low, higher counts of individuals could be established for both of the species, a result which indicates that these ungulates may have played a more important role than has been previously assumed in the subsistence activities of the Magdalenians at Solutré.

Skeletal part representations of horse produced by Olsen and those produced during the recent study are depicted for comparative purposes in figure 50 as minimum numbers of individuals (MNI) for each skeletal element and as %MNI's. Minimum numbers of individuals of horse published by Olsen (1989, fig. 8) were used, and the %MNI's were reckoned from these counts (fig. 50a). For comparative purposes the data from my analysis of the horse remains from this sector (taken from fig. 7) have been re-organised according to Olsen's system, in which counts of individuals on crania and mandibles were not depicted, and counts of individuals on vertebrae and ribs – although present in her samples – were not given due to the difficulties of determining MNI's from these fragmentary finds (ibid.) (fig. 50b).

Olsen remarked on the overall slight prevalence of teeth and foot bones in all the levels, which she attributed mainly to their durability when compared to other skeletal elements. The new analysis has, how-

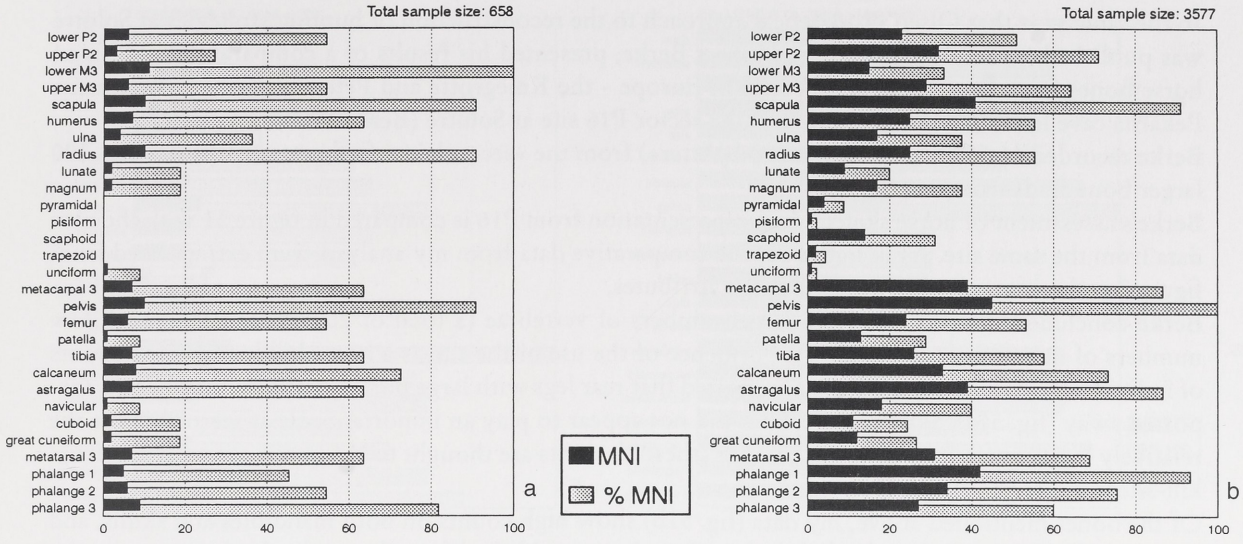


Fig. 50 Comparison of horse skeletal representations from the Magdalenian level in sector P16 at Solutré. – a: sector P16 adapted from Olsen (1989, figure 8); b: sector P16 adapted from figure 7, this volume. Black bars: counts of minimum numbers of individuals (MNI) for each element. Grey bars: % MNI's for each element, reckoned from the highest MNI (= 100%) of each sample.

ever, shown that elements such as scapulae and pelves have the highest counts, followed by lower limb bones (eg. phalange 1, metacarpal 3, astragalus) and then teeth.

High MNI counts were recorded on three elements, the pelvis, scapula and first phalange. Counts for these elements rank lower in Olsen's diagram, approximately equal to teeth (lower M3) and radius. Differences in counts for the skeletal elements may result from sample choice and/or the comparatively small size of Olsen's sample.

Otherwise, a general trend in Olsen's figure – where elements at the top of the diagram (teeth to magnum) and those towards the base of the diagram (metacarpal 3 to phalange 3) are well-represented, and small bones, especially carpal bones other than the magnum, are less well-represented – is also reflected in the new data. Olsen reported a low representation of small bones such as carpals in all of her samples from Solutré and attributed the paucity of such elements to difficulties of recovery during excavation. I would consider that carnivores could have been responsible for the lack of these elements at the site.

Olsen's general observations suggested that ribs and vertebrae were left at the site, but for the reasons given above she provides no data for these elements. Her statement that ». . . these bones (ribs and vertebrae) were badly comminuted by postdepositional forces« (1989, p. 305) is fully supported in the case of ribs, by the recent observations. However, in my sample differences in frequencies between types of vertebrae meant that the possibility of hunters transporting some portions of the vertebral column of horse away from the site could not be excluded.

Olsen also commented on the differential preservation of portions of bones at Solutré (such as the good preservation of robust distal ends of scapulae and poor preservation of fragile scapula blades) and although similar patterns of density-related preservation of bone portions were observed for some elements during the recent study, the more detailed approach used in this analysis produced new data pertaining to the preservation of bone portions. In the case of tibias, metacarpals and metatarsals for example, low frequencies of the shafts of the bones, usually regarded as high-density bone portions, may be related to the initial fracture of these bones by the hunters to extract marrow.

In the same year that Olsen's theoretical approach to the reconstruction of hunting strategies at Solutré was published, a German researcher, Hubert Berke, presented his results of a comparative analysis of horse bones from four Magdalenian sites in Europe - the Kniegrotte and Petersfels caves in Germany, Pekárna cave in the Czech Republic and the sector P16 site at Solutré (Berke 1989).
Berke recorded 16,500 bone fragments (»Splitter«) from the »secondaire« find category as well as 3,190 larger bone finds from sector P16.
Berke's assessment of horse skeletal part representation from P16 is compared in figure 51 with the new data from the same site. As in figure 50, the comparative data from my analysis were extrapolated from figure 7 and re-organised to match Berke's attributes.
Berke concluded that the relatively large numbers of vertebrae (a total of 200 finds), along with low numbers of mandibles and skulls were evidence of the use of the site as a horse kill locale. Low counts of individuals on femurs and patellae suggested that rear legs with large portions of meat had been transported away (fig. 51a). Skinning activities did not appear to play an important role at sector P16, as the relatively high counts for phalanges showed (these elements are thought to have been carried away from kill-sites attached to the skins).
Of the bones mentioned above, my data (fig. 51b) show high counts on both mandibles and skulls, and the count for the femur is only slightly less than those established for other major leg bones at the site (tibia, humerus and radio-ulna). Only the relatively low count for the patella is comparable to Berke's data, and probably reflects the lower survival chances of this porous bone, rather than transportation from the site as part of the economic decisions of the Magdalenian hunters. Relatively high numbers of individuals are depicted for the phalanges in both samples but in my diagram, the counts are inverse to those produced on these elements by Berke.
The differences in data depicted in figure 51 are probably not due to sample size. Assuming that the individual counts depicted in Berke's diagram are based on the larger bone finds, then there is little difference between the 3,190 finds that Berke recorded and the 3,477 finds recorded in the recent analysis. This fact makes the large numbers of individuals counted in my sample – generally twice the numbers that Berke published for each element – somewhat surprising.

Olsen noted that despite heavy root-etching, a few cutmarks could be observed on the surfaces of three horse bones from sector P16 attesting to dismemberment and tendon removal, and on one mandible of reindeer. Although the analysis of the total number of faunal remains from sector P16, produced a larger number of bones with butchery traces, I would agree with Olsen's conclusion that the relative scarcity of butchery marks (cut marks), particularly on the equid remains, cannot be explained by poor bone preservation alone. In my opinion, this phenomena is probably related to the methods used to kill the horses which produced a glut of carcasses from which perhaps only one or two were chosen for further processing.
My observations show that not only dismemberment and tendon removal took place, but also filleting, the removal of gingival and periosteal tissues and, possibly, skinning.
Berke (1989) observed butchery marks (cut marks and impact notches) on 113 or 3.5% of the horse bones from sector P16 that he analysed. I observed a total of 114 horse bones with cut marks and impact notches, and this number is comparable to his total. The locations of butchery marks depicted by Berke (1989, fig. 5) are also comparable to those that I recorded. Berke also noted evidence of the use of an anvil to support bones during fracturation (reflective percussion), and several horse bones found during the recent analysis had been fractured using this method. Olsen recorded spiral fractures on a total of 16 horse bones from her Solutrean and Magdalenian samples, but she did not describe bones with hammerstone-induced impact notches in detail.
Olsen interpreted bone artifact debitage, needles ornaments and mobiliary art at Solutré as evidence that hunters conducted a variety of activities at the site other than hunting and butchering. For Berke, the low number of bone artifacts at Solutré is typical of kill-sites, and he suggests that the hunters were probably removing large amounts of raw material – metatarsals attached to the rear legs – away from the

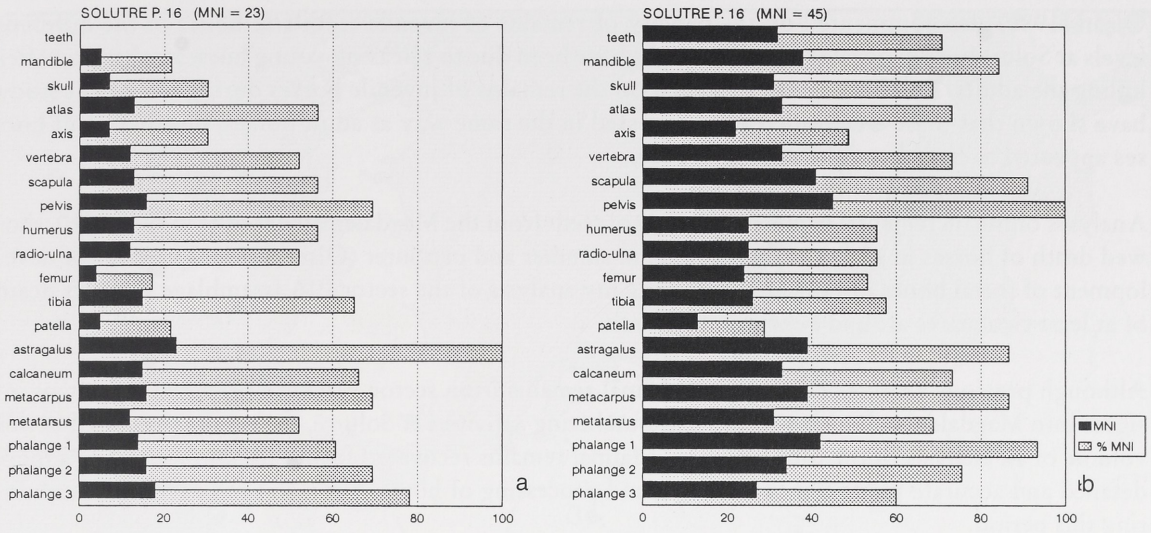


Fig. 51 Comparison of horse skeletal representation produced during two separate analyses of faunal remains from sector P16 at Solutré. – a: results of Berke's analysis of a sample of horse bone from sector P16. – b: results from the current analysis adapted from figure 7. Black bars: counts of minimum numbers of individuals (MNI) for each element. Grey bars: % MNI's for each element, reckoned from the highest MNI of each sample.

site. Needle-cores at sectors P16 and I11 do indicate the manufacture of these objects at the site and the engraving of a reindeer on the iliac bone of the pelvis of a horse suggests that the hunters did have time to indulge in such pastimes between their hunting and butchering activities. Other finds, such as the antler bâton-percé, may have been brought to the site as finished products.

Levine (1979, 1983) examined horse teeth from Solutré including a sample from the Magdalenian level in sector P16. Her sample of 364 ageable teeth from P16 was larger than the one sampled recently, but despite this similar results were produced from both studies. Levine also noted a rather low proportion of teeth from horses aged between 0-3 years. After adjustment to compensate for what she interpreted as the differential preservation of less sturdy deciduous teeth, percentages of teeth in her sample in the juvenile age-group (0-4 years) fluctuated between 10% and 6%, slightly lower than the percentage for this group in my sample. Teeth aged to twelve years, which are from horses at the beginning of their old age range, formed 3-4% of her sample; horses older than 12 years gradually diminished to less than 1%. Levine noted a rather high, but relatively unimportant representation of teeth from 3-4 year old horses, which is not present in my sample, and a proportional increase of teeth from 4-9 years (Levine 1979; 1983, fig. 4. 20).

As in my analysis, the highest percentages were recorded for teeth from prime adult horses. Teeth from horses aged to about nine years attained, after adjustment, percentages of up to 12% in Levine's analysis, but the extremely high percentages for horses dying between 6-10 years as depicted in my graph, are missing in Levine's. The differences in the results of the two analyses could be due to sampling. For example, only those cheek teeth which could be definitely identified to element and position in the jaw were included in my sample and of these the permanent teeth were aged using crown-heights; the less accurate wear-stages were only applied to the deciduous teeth. Levine also explains the low proportion of juveniles, the higher number of 3-4 year olds and the increasing proportion of 4-9 year olds in her sample, as resulting from a number of factors, including chance sampling bias. The fact that the same basic trends – low numbers of juvenile and old horses and a dominance of prime adult horses – appeared in the population structures produced by both studies, shows that sampling did not bias the different analyses too much.

Olsen (1989) also commented on the paucity of remains of juvenile teeth and bones in the different levels at Solutré and suggested that this might have been due to releasing young horses unharmed after killing the adults. Butchery traces observed on the remains of juvenile horses during the recent study have shown that these were killed and processed in the same way as adult horses, but that adult horses appeared to have been the preferred prey.

Analyses of the incremental bands of a sample of teeth from the Magdalenian deposits in sector J10, showed death of horses in spring/early summer, in summer and in winter (Olsen 1989). The stage of development of foetal bones of horse found during my analysis of the sector P16 assemblage suggests death of at least two mares around February to March.

Although previous analyses of samples of faunal remains from sector P16 have provided important insights into Magdalenian hunting tactics and butchering activities at Solutré, the results presented in this volume of an analysis of the total number of faunal remains recovered from this sector, provide a more detailed and accurate picture of the hunting and processing of horse, bison and reindeer at Solutré during this period.
The next step is to use this data as the basis for comparative analyses with faunas from other Magdalenian sites. In the following section, the data about horses collected during the analysis of the sector P16 finds will be compared with data from three other Magdalenian sites where the horse appears to have also played an important role in the subsistence activities of the site occupants.

A COMPARISON OF HORSE REMAINS FROM MAGDALENIAN SITES IN EUROPE

Faunas dating to the Magdalenian period which are dominated by horse, or where horse is the most common species in an otherwise diverse fauna have been described from a number of sites in Europe (fig. 52). Three sites, Grand Canton at Marolles in France (Bémilli 1994; Bridault and Bémilli 1999), Andernach-Martinsberg (Street 1993) in the Central Rhineland of Germany and Hauterive-Champréveyres in Switzerland (Morel and Müller 1997) have been recently analysed in detail. In the following section data from these sites are described and, finally, compared with the results of the analysis of horse remains from sector P16 at Solutré presented in this volume.

Grand Canton, Marolles (Seine et Marne, France)

The site of Grand Canton at Marolles with its horse dominated fauna, has modified the image that the Magdalenians in the Paris Basin were solely reindeer hunters (Bémilli 1994). Marolles is an open site located on an interfluve – a ridge or area of land dividing two river valleys – some three kilometres away from the confluence of the Seine and the Yonne rivers, only a few kilometres away from the major Magdalenian site at Pincevent. The site was discovered during motorway construction, and was investigated in a series of rescue excavations between 1990-91 (Alix et al. 1992; Alix et al. 1993; Rieu et al. 1990). The evidence recovered so far suggests repeated occupation of the site around 12,000 BP, during the Dryas II period. The Magdalenian industry is made up to 98% of flint from secondary deposits of alluvial origin. The total of 434 tools is dominated by burins, followed by scrapers, backed blades, points and becs. The remains of nine hearths were also revealed.
First analyses of the faunal remains were carried out by Averbouh for site sector 1 (in Alix et al. 1993) and Bridault (1993) for sector 2 of the site. The following information is taken mainly from Bémilli's



Fig. 52 Map depicting Magdalenian sites described in the text. – 1 Solutré. – 2 Grand Canton, Marolles. – 3 Andernach-Martinsberg. – 4 Hauterive-Champréveyres.

(1994) analysis of the fauna from sector 2, sample A, details of which are also published (Bridault and Bémilli 1999). The fauna from this sector of the site is dominated by horse. From a NISP of 3,269 remains of horse a MNI of 74 has been reckoned, but the total number of horse individuals for the whole site could be as high as 150. Low quantities of reindeer (MNI 4), bovid (MNI 1), canid, probably wolf (MNI 1) and mammoth (MNI 1) have also been recovered.

Practically all parts of the horse skeleton are present at the site, but in varying proportions. Tibiae, first phalanges, tarsals and calcanei have high counts, followed by low counts for atlas vertebrae, cervical and other vertebrae, ribs and small bones (fig. 53). Bémilli states that these patterns could have been produced by either human selection of certain body parts during butchery or the differential preservation of bone. Due to the lack of bone density data for horse remains during the early 1990's, she refrained from a definite interpretation of these patterns of skeletal representation.

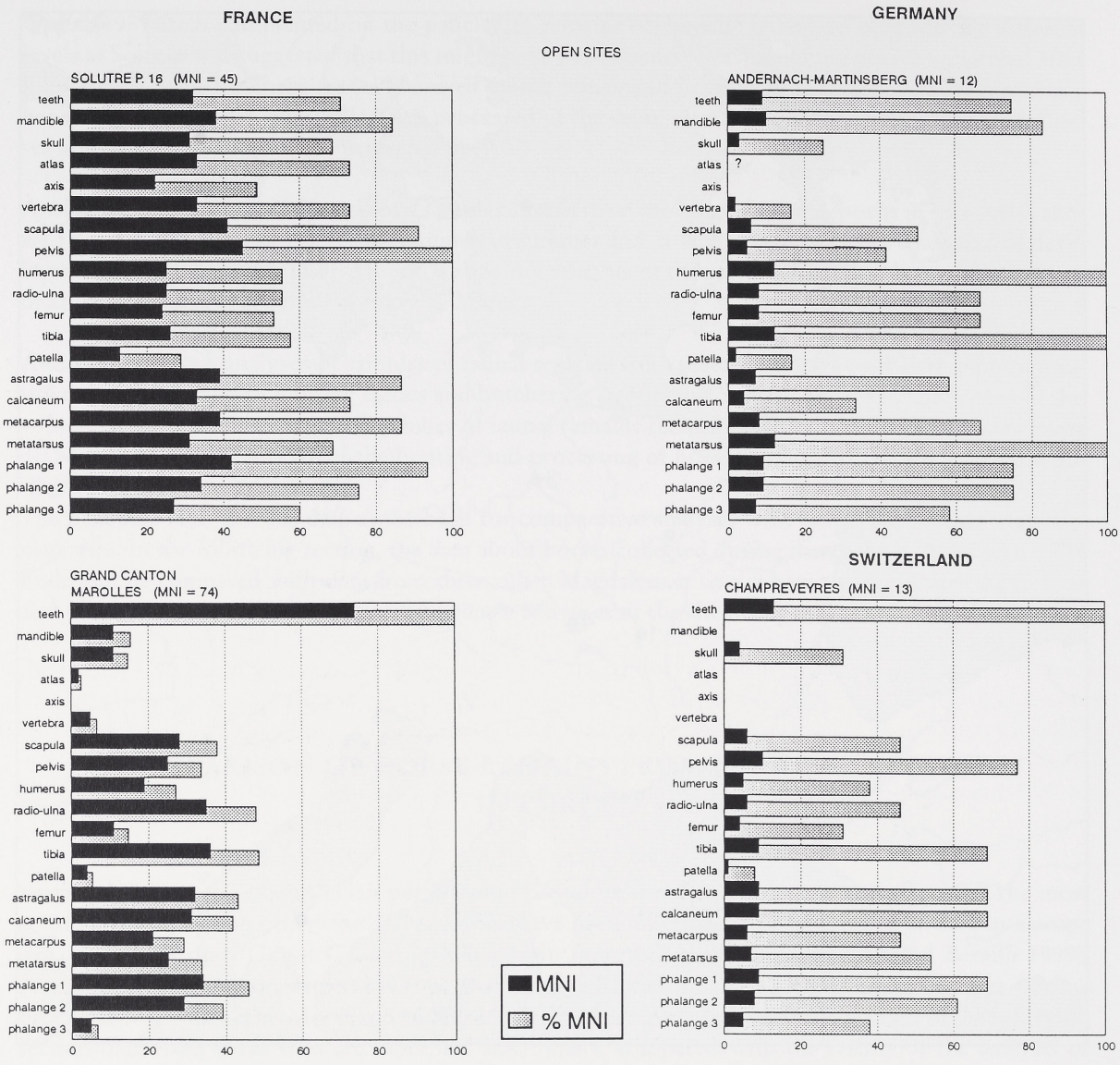


Fig. 53 Comparison of horse skeletal part representations from selected Magdalenian sites in Europe. Data for Solutré P16 taken from figure 7, this volume; Grand Canton, Marolles after Bémilli 1994, fig. 15, column NMI f; Champréveyres after Morel and Müller 1997, fig. 20, column NMI; Andernach-Martinsberg after Street 1993, fig. 60 (highest MNI).

The age-structure of the horse population has an important peak at about 6-10 years, in other words is characterized mainly by »young adults« (fig. 54), and Bémilli concluded that if hunters had been taking family groups, larger numbers of individuals in the age classes »young« and »sub adult« would be expected than this age-profile shows. There were probably less than 4 males in the population (based on numbers of canines). There was no information about the season of death of the horses.

Cut-marks were not observed on the poorly-preserved bone surfaces, but many bones had been marrow-fractured. Bémilli concluded that horses were probably hunted in small groups close to the site, to which practically all parts of the carcass were transported.

Andernach-Martinsberg (Central Rhineland, Germany)

Along with the site of Gönnersdorf, the site at Andernach-Martinsberg represents a major open settlement dating to the Magdalenian period in the Neuwied Basin of Germany. Located close to the northern entrance of the Neuwied Basin, the Andernach-Martinsberg site was discovered as early as 1883 (Schaaffhausen 1888), but systematically excavated later between 1979-1983 (Bosinski and Hahn 1972; Veil 1982). A series of six AMS dates from Andernach and three AMS dates from Gönnersdorf date the Magdalenian at these two sites to 12,982 ± 58 BP (mean) (13,365 ± 155 cal BC) and 12,809 ± 57 BP (mean) (13,195 ± 155 cal BC) respectively (Street, Baales and Jöris 1999). Thus the Magdalenian settlement of both sites definitely took place before the beginning of the Late Glacial Interstadial Complex, and not at the end of the Bölling Interstadial, as suggested by previous researchers (Bolus et al. 1988).

Four major concentrations of finds were uncovered at Andernach. Two of the concentrations are interpreted as stable, paved dwelling structures and contained slabs of slate, quartz and quartzite, along with animal bones, lithic, bone, ivory and antler artefacts, objects of personal adornment, and many objects of art, including engraved schist plaques (Street 1997). A third concentration of finds was located around a large fissure running through the site, which was probably open at the time of occupation. The fourth concentration was excavated more recently (Bergmann 1999; Holzkämper 1999).

The lithic assemblage contains all forms typical of Upper Magdalenian inventories. Different raw material groups are associated with different concentrations (e.g.: Tertiary quartzite in concentrations I and II), as are dominances of certain tool forms (e.g.: scrapers outnumber burins in concentrations I and III).

The site has produced a rich faunal assemblage including numerous remains of larger and smaller mammals, birds and fish. The following description is based on the results of an analysis of the Andernach fauna undertaken by Street (1993; 1997).

Horse dominates the hunted fauna in terms of its importance in the subsistence strategies of the Magdalenians and a total of 2,201 finds at Andernach could be identified as horse. A minimum of twelve individuals of horses are represented. Street has postulated that the underrepresentation of horse vertebrae at Andernach could be due to human destruction of these elements, since all identified fragments of these elements appear to have been pulverised, but that equally low counts for proximal ribs may indicate that proximal ribs and vertebrae were left at the kill-site. Horse skeletal part representation is otherwise characterized by the presence of practically all body parts in varying proportions, and by relatively high percentages of mandibles, humeri, tibiae and metatarsals (fig. 53).

At Andernach the horse age-profile is characterized by low numbers of juveniles and senile horses. There is a high peak in the number of animals aged to between 6-10 years, a smaller peak at 11-15 years, and a notable underrepresentation of 4-6 year olds (Street pers. comm. 1999).

The stage of development of horse foetal bones indicates death of some mares during winter.

Street (1993) describes the evidence of horse carcass processing at Andernach in detail in his dissertation, and the following is a brief summary of these descriptions. Poor bone surface preservation at Andernach meant that only a few cut-marks were preserved. Even so, cut mark evidence combined with the location of impact notches and patterns of the fracture of horse bones shows horse butchery at Andernach was very standardized. Cut marks were found on maxillary cheek teeth, possibly resulting from cutting through the lips or cutting too deeply during skinning. Cut marks on the most proximal part of the humerus, and on the distal humerus and proximal radius attest to the disarticulation of the scapula from the humerus and the humerus from the radius at the joints. Femur and tibia were disarticulated at the knee joint.

No cut marks were preserved on the metapodials, but phalanges – which due to their small size were often incorporated into pits and thus better preserved – did bear traces of cutting. These marks have been interpreted as either resulting from cutting the bones out of the soft tissues of the foot, or disarticulating the phalanges from one another, or cutting sinews and tendons from the phalanges. A cutmark across a proximal sesamoid was produced when the first phalange was removed from the metapodium. Cut marks on the third phalanges may have been produced when horn sheaths were removed. Cut marks produced during filleting activies were only observed on femur shafts.

Impact notches and/or patterns of bone fracture show intensive reduction of horse bone during the further stages of butchery. The ascending ramus of the mandible was fractured off and the lower border opened by blows to both the lateral and medial faces. Humerus and radio-cubitus show repetitive fracture patterns: very obvious is the almost complete absence of the proximal and distal humeri, whereby larger numbers of epiphyses from the radii had survived. The humerus was opened by blows to the lateral and caudal faces. Blows were often placed laterally to remove the distal epiphysis and caudally to remove the proximal epiphysis. Blows to the flat volar face were used more often than blows to the convex dorsal face to open the radius shaft. Several blows along the shaft were often employed to split the radius open.
Fracture patterns on the pelvis show that the ilium and the ischium were regularly removed by bone-smashing. Femur and tibia epiphyses are, on the whole, rare, but large numbers of distal tibia fragments from the right body-side as opposed to only two fragments from the left body-side, are an exception to this. Whether this preservation reflects differentiated treatment of the carcass by body-side is unclear. The tibia was more commonly fractured by blows to the flatter dorsal face; the femur shows a less standardized pattern of fracturation, probably due to its round cross-section.
Metapodials were fractured by blows to the dorsal and volar/plantar faces. These blows were often reflected causing the bone to split through the proximal end, leaving a detached distal end which automatically broke off. This method of fracturation also provides a suitable bone fragment (the distal end and part of the shaft) for use as a needle-core or a retouching tool. The use of an anvil as a support is attested by opposed, reflected impact notches on radius, tibia and metapodial shafts.
Fracture of first phalanges seems to have been standard practice at this site, and the number of intact first phalanges is very small.

Hauterive-Champréveyres (western Switzerland)

The late Magdalenian open site of Hauterive-Champréveyres is located on the northwestern edge of Lake Neuchâtel at the foot of the Jura mountains. Excavations between 1984 and 1986 were undertaken in advance of motorway construction and a total of about 250 m^2 of this site have been investigated. The following description of the site and its fauna is taken from Morel and Müller (1997).
The main Magdalenian horizon has been radiocarbon dated (AMS) to about 13,000 BP. Situated at about 427 asl., the site was originally located near to a part of Lake Neuchâtel which at that time was separated from the rest of the lake by a gravel bar. The late Magdalenian site of Neuchâtel-Monruz lies only one kilometre away to the south-west. Refitting blades from these sites show that site occupation was contemporary, and the two localities may have formed part of a series of camps located at strategic points for hunting along the edge of the lake. Certainly, the absence of habitation structures, poor lithic assemblage (5500 flints > 1 cm), flat, infrequently-used hearths and the spatial distribution of the archaeological material suggest that the site was either occupied only once, or on several, brief occasions. The predominance of backed bladelets in the lithic inventory, and microwear traces produced during meat and hide processing, suggest that Champréveyres was also used as a camp where game was butchered during this occupation(s) (Morel and Müller 1997).
About 16,500 bone finds were recovered during excavation and a further 120,000 unidentifiable fragments were recovered during sieving. All of the faunal remains are highly fragmented due to marrow fracturing and subsequent post-depositional deformation of the archaeological horizon. In addition to this, most of the bones are poorly-preserved, as, for example, the dominance of teeth in the assemblage of horse remains clearly shows (fig. 53).
Morel and Müller identified twenty species including ten mammals, five birds and five fish. Horse is the most common species (MNI 13 and not more than 21), followed by arctic hare (MNI 20), marmot (MNI 16), reindeer (MNI 7), ibex (MNI 3), lynx (MNI 3), arctic fox (MNI 2), and ?bison (MNI 1).
Intact or only partially dismembered horse carcasses appear to have been brought to the site. There is no evidence that horse skeletal parts were transported away from the site. A total of 2,956 remains were

definitely identified to horse and a further 1,916 were attributed to this species based on their size. The assemblage of horse remains is dominated by a total of 2,235 teeth, a direct result of the poor state of bone preservation at this site. Mandibles are, with a total of 248 finds, relatively well represented, as are tibiae (167 finds), crania (106), metapodials (114) and first phalanges (101). Axial elements such as vertebrae are extremely underrepresented (192 finds). Ribs, with a total of 116 finds, appear to be relatively well-represented, but of these pieces, only 23 could be certainly identified to horse (Morel and Müller 1997, fig. 16: fig. 52 this report).

The age-structure of the Champréveyres horses is characterized by a very high peak of young horses, especially those aged between 2-3 years, absence of horses aged between 4 and 5 years, lower peak of adults between 6 and 10 years of age and absence of horses aged over 11 years and over (Morel and Müller 1977, fig. 45). This distinctive age-structure may be due to the more detailed way in which the ages were assessed. At Champréveyres it was possible to reconstruct the dentitions of individual horses and to age these individuals using incisor wear patterns described by Habermehl (1966), and/or cheek-tooth heights following Levine's method (1983) (the authors state that a conventional plotting of tooth crown-heights, without sorting to individuals, produced the adult-dominated age-profile so typical of horse-populations found at other Magdalenian sites). The age-structure appears to indicate selective hunting, particularly for young horses, on the part of the Magdalenian hunters (fig. 53). The age of some of the young horses shows that they probably died in spring and in autumn. Attempts to assess the sexual demography of the horses was not undertaken due to the difficulties associated with this type of analysis, but the presence of young foals does suggest that family groups were hunted some of the time.

A total of 485 or 10% of the horse bones bore traces of cut marks (Morel and Müller 1997, fig. 70). Although some wear traces on lithic artefacts were produced during skinning activities, cut marks indicating skinning were not observed on the bones. Only a small number of cut marks were located in places indicating disarticulation. The bulk of the cut marks was located on the shafts of long bones – especially scapula, humerus, radius, femur and tibia – on mandibles and, more rarely, on metapodials and phalanges. They indicate intensive filleting activities and, to a lesser extent, possibly the removal of tendons.

Impact notches were not observed on the mandibles, but two notches were present on scapula blades. Notches on long bones were systematically placed relating to the form of the bone shaft. Thus, impact notches on humeri were mainly placed on the flatter medial face of the bone shaft, on the flatter palmar face of the radius and on the flatter caudal face of the tibia. Radii were often spilt open by a series of blows along the shaft; distal ends were often removed by blows to the lateral and medial sides. Both ends of the tibia were removed and, along with distal radial epiphyses, were smashed into small fragments. Only six notches were observed on the femur, mainly on the lateral and caudal sides towards the distal end of the bone. Metapodials appear to have been opened mainly by blows to the proximal (metacarpals and metatarsals) articulation surfaces and distal articulation surfaces (metacarpal). Blows to the shaft are rare on metapodials. First phalanges were spilt open longitudinally by blows to the proximal or dorsal surfaces. Third phalanges appear to have been treated in the same manner, but second phalanges were almost always intact.

A comparison of the data from the sites

During the Magdalenian period, several sites in Europe were characterized by faunas where horse was the dominant species or the most common species in an otherwise diverse fauna. The sites described here had different functions. Solutré appears to have been used solely as a kill and butchery site, Hauterive-Champréveyres as a site where horse remains were mainly butchered. Andernach-Martinsberg and Marolles functioned as settlement sites. Hearths were revealed at Marolles, but no structures. Stable, circular habitation structures were found at Andernach. These were probably permanently in place, and probably inhabited on repeated occasions over a number of years.

The Magdalenian lithic inventories recovered at these sites are dominated by a range of tool types or a

particular tool eg. backed blades, burins and borers at Solutré, burins, scrapers, backed blades, points and »becs« at Marolles, backed blades at Hauterive-Champréveyres. Detailed analyses of the spatial organization of lithic artefacts at Andernach have shown that particular tool types (as well as raw material types) are associated with different structures at the sites.

Although the faunas recorded from the sites considered here are diverse ones with numerous species present, horse dominates in terms numbers of identified specimens (NISP), minimum number of individuals (MNI) and/or in terms of its importance in the subsistence strategies of the occupants of the sites.

The highest number of horses was recorded at Marolles, where a minimum of 74 individuals was identified from 3,269 remains identified to this species from sector 1, sample A of the site. The total number of horses from the whole site could be as high as 150. This exceptionally high number seems to be unique for the Marolles site, and in general, numbers of individuals ranged between 12 at Andernach and 45 at Solutré (tab. 24).

Generally, all parts of the horse skeleton were present at the sites, but in varying proportions and sometimes only represented by one find (fig. 53). The dominance of teeth in the horse bone assemblage from Hauterive-Champréveyres is likely to be linked to the poor bone preservation recorded at this site, rather than selection of body parts by the Magdalenian hunters. Very low numbers of vertebrae and ribs, noted for example at Solutré, Marolles, Andernach and Hauterive-Champréveyres could also be related to bone preservation or, as at Solutré where some vertebrae appear to be better-preserved than others, the result of transportation of carcass parts away from the site by the Magdalenians. Similar alternative interpretations – bone preservation or human selection of certain carcass parts during butchery – were proposed to explain the low numbers of axial elements at Marolles. At Andernach low numbers of vertebrae were attributed either to the human destruction of these parts, as many vertebral fragments appear to have been pulverised or, when the equally low numbers of proximal ribs are considered, that proximal ribs and vertebrae were the parts left behind at the kill-site.

On the whole, horse age-profiles (resulting from analyses of eruption and wear stages of horse incisors and/or cheek teeth undertaken at some of the sites) showed that practically all age-groups are present and that the age-structures tended to be dominated mainly by adult animals, often those in their prime years. In figure 54, four age-profiles are depicted and even though slightly different methods of representation were employed – aged teeth expressed as a percentage of the total number of teeth sampled and placed in age-classes for Solutré P16; number of teeth and age in years for Grand Canton at Marolles; number and age in years for Hauterive-Champréveyres – the profiles can still be used for comparative purposes. The adult-dominated type of age-structure was identified at Solutré, where teeth from adults in their prime years formed 76% of the sample. At Marolles the age-structure was characterized by a high peak of young adults between 6-10 years of age. A peak between 6-10 years, a smaller peak between 11-15 years, and low numbers of juvenile and senile animals were recorded at Andernach. The underrepresentation of horses between 4 and 6 years of age at Andernach is rather unusual. The distinctive age-structure of the Hauterive-Champréveyres horses with very high numbers of young individuals, especially 2-3 year olds, absence of horses aged between 4 and 5 years, low numbers of 6-10 year olds and absence of senile horses may be due to the detailed method of age-analysis, where dentitions of individual animals were first reconstructed and then aged. A conventional analysis, in which crown-heights were measured and plotted as a sample without attribution to a particular individual was also undertaken at Champréveyres for comparative purposes, and produced the adult-dominated age-profile recorded at many of the other sites.

Whether adult-dominated age-profiles are simply a result of the method used, will have to be tested at sites which have produced large amounts of horse teeth. At the moment, all we can say is that adult-dominated age-profiles appear to be the ones most commonly found at Magdalenian sites. The presence of large numbers of adults, low numbers of canines indicating that the horses were mainly mares, presence of foetal bones and the presence of young foals all suggest that family groups were hunted at least some of the time at the sites considered here.

Site	NISP	MNI
Grand Canton, Marolles (sector 1, sample A)	3,269	74
Solutré (sector P16)	3,577	45
Hauterive-Champréveyres	2,956	13-21
Andernach-Martinsberg	2,201	12

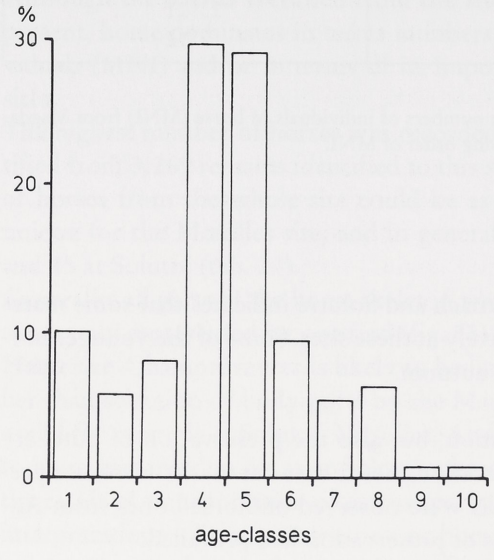
Tab. 24 Numbers of specimens identified to horse (NISP) and minimum numbers of individuals of horse (MNI) from Magdalenian sites in Europe, listed in decreasing order of MNI.

The stage of development of horse foetal bones from Andernach and Solutré indicates that some mares died in the winter and between February and March respectively at these sites. Some of the younger horses from Hauterive-Champréveyres died during spring and autumn.

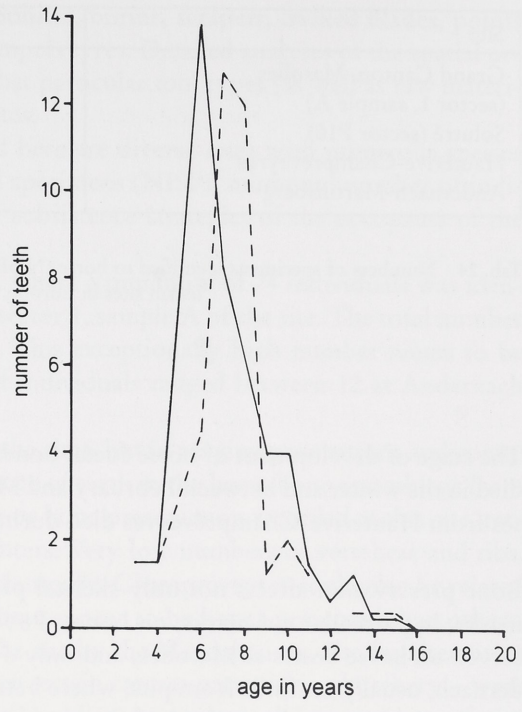
Bone preservation affects not only skeletal part representation, but also the preservation of butchery marks, in particular cut marks, on bones. Poor bone preservation meant that cut marks were not preserved on horse bones at Marolles, and only a few cut marks were observed on horse bones from Andernach, usually on finds from pits, where better conditions of preservation had prevailed.
Despite the low numbers of cut marks observed at some sites, several stages of carcass processing from skinning (Andernach and Solutré), removal of gingival tissue (Solutré and Andernach), evisceration (Solutré), carcass dismemberment and disarticulation (Andernach and Solutré) filleting (Solutré, Andernach), and tendon and sinew removal (Solutré and possibly at Andernach and Hauterive-Champréveyres) had been carried out. The carcass may have been hung at Solutré (sector I11).
Minor differences were noted in the proportions of certain types of cut marks from site to site. At the kill-site at Solutré, the bulk of the cut marks had been produced during dismemberment or disarticulation of the horse carcass rather than during other activities. The same was observed at the settlement site at Andernach, where the majority of the cut marks were located at major joints of the carcass and were produced during disarticulation; only a small number of cut marks was indicative of filleting activities. Exactly the opposite was the case at Hauterive-Champréveyres, where mainly filleting marks were observed and only a few disarticulation marks.
Cut marks on third phalanges were observed at Andernach, and were probably produced during removal of the hoof.

Horse bones were smashed open to obtain marrow at the majority of the sites described here. The systematic fracturing of horse bones to obtain marrow was logically related to their form. Thus, impact notches were more commonly found on the flatter faces of shafts of bones such as the tibia and the radius, rather than on the rounded shaft of the femur. Straight-sided bones such as the radius and the metapodials were often split open longitudinally by a series of blows to the shaft as recorded at Andernach, Solutré and Hauterive-Champréveyres. The use of anvils as supports during bone-smashing is shown by the presence of opposing, reflected notches on bones from Solutré and Andernach. At Hauterive-Champréveyres third phalanges were also systematically opened. The intensive crushing of cancellous bone for extracting juice and fat has been observed at Andernach.

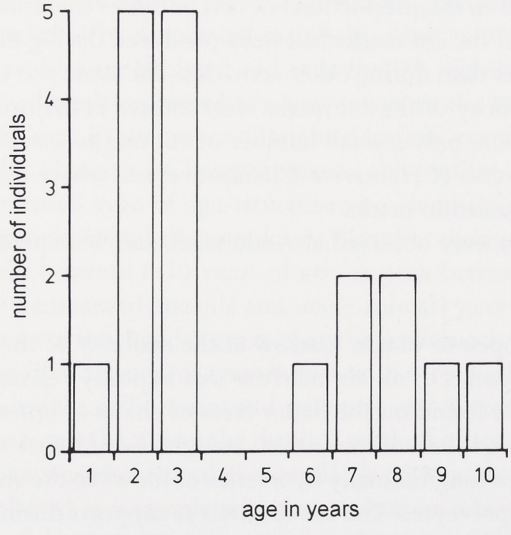
Horse bones, particularly the fractured off distal ends of metapodia, utilized as cores for the production of bone needles have been recorded from Solutré and Andernach. At Solutré (sector I11), a depiction of a reindeer had been engraved on the iliac bone of the pelvis of a horse.



SOLUTRÉ P. 16



GRAND CANTON, MAROLLES



HAUTERIVE-CHAMPRÉVEYRES

Fig. 54 Comparison of horse age-structures from selected Magdalenian sites in Europe. Data for Solutré P16 taken from figure 11, this volume; Grand Canton, Marolles after Bémilli 1994, fig. 23, black lines = upper teeth, broken lines = lower teeth; Hauterive-Champréveyres after Morel and Müller 1997, fig. 45.

The simple answer to this question is, no. Horse dominated faunas or faunas where horse is the most common species present, and evidence for the human exploitation of horse carcasses have been revealed at several Lower and Middle Palaeolithic sites in Europe. In level G at La Caune d'Arago in the south-west of France, dated to about 420,000 or 450,000 BP (Bellai 1995; Moigne and Barsky 1999) or according to some authors beginning of Saale (Desclaux 1992), horse is the resource most commonly exploited by the human occupants of the cave, representing 60% of a total of 70,000 finds from this level. 74 individuals have been identified. Cut marks, indicating skinning, disarticulation and filleting activities, were recorded and many horse bones had been fractured, presumably to obtain marrow (Bellai ibid.).
Wooden spears, recently discovered during investigation of Lower Palaeolithic sites in the brown-coal lignite mine at Schöningen near Hannover, provide undisputable evidence that humans already possessed a technology capable of producing sophisticated, long-distance, hunting weaponry at around 400,000 BP. The remains of more than 15 individuals of horse (counted on horse skulls) were associated with the spears. Many of the bones bear traces of cut marks and fracturing to extract marrow. The evidence from Schöningen suggests that herds of horses were systematically hunted using long-distance weapons and processed afterwards at the site (Thieme 1997, 1999).
Another method of obtaining horse meat has been interpreted from remains found at the karstic aven of Igue des Rameaux in France (Bas Quercy). Horse is represented by skulls (about 12), mandibles, isolated teeth, intact long bones – some in anatomical connection – and some vertebrae. The presence of canine teeth in the skulls and mandibles of the horses, and tooth eruption and wear stages suggests that a group of juvenile and young adult (males?) fell into the aven which served as a natural trap and died there. A small number of lithic artefacts, comparable to local Lower Palaeolithic or early Middle Palaeolithic inventories, were associated with this fauna; however, there are no traces of human modification on the horse bones. It has been suggested that humans regularly controlled avens in this region, knowing that animals would fall into them from time to time. The remains from Igue des Rameaux have been interpreted as evidence of controlled and active scavenging as part of the subsistence strategies of Lower Palaolithic humans (Rouzaud et al. 1990; Brugal and Jaubert 1991).
The Kulna cave is located on the northern edge of the Moravian Karst (Valoch et al. 1969). All of the deposits at this site are rich in faunal and archaeological finds, the most important layer is level 11, which was deposited during Stage 5 of the oxygen isotope stages (Svoboda et al. 1996) from which many remains of horse (MNI 35) have been recovered. Teeth are the most common elements in the assemblage of horse bone; post-cranial bones are underrepresented. Numerous shaft fragments and teeth lacking roots, attest to the systematic fracturing of both long bones and mandibles to obtain marrow. Many bones with cut marks have been observed. The ages of the horses range from very young to relatively old (Musil 1969, 1990). Horse metapodials from this site bear traces on their surfaces consistent with their use as retouchers (Valoch 1968/69; own observations, April, 1999).
Horses are also common elements of the fauna from the Middle Palaeolithic site of Ille-et-Vilaine at Mont Dol near the coast of Brittany. Faunal remains and Mousterian artefacts were recovered from a series of flow deposits stratified above the Eemian Interglacial beach and probably dating to the first cold phase following the climatic optimum of the Eemian. Horse (MNI 54) and mammoth (MNI 34) (Simonet and Monnier 1991, tab. 1) are the most common species in this diverse fauna, both in terms of numbers of finds identifiable to a species and minimum numbers of individuals. Cut marks indicating dismemberment were observed on only two horse bones – the pelvis and the rear hock. Cut marks indicating filleting were found on a vertebra, and on the shafts of metapodials. A fragment from the skull has been charred. In contrast to this, many horse bones had been systematically fractured (Langouet and Morzadec-Kerfourn 1995; Simonet and Monnier 1991).
It has been suggested that the site at Mont Dol may have functioned in much the same way as the neighbouring site at La Cotte de St. Brelade (Simonet and Monnier 1991). The ravines at La Cotte were used

as a natural pitfall for large quantities of rhinos and mammoths, as part of a Middle Palaeolithic subsistence strategy combining wide-ranging hunting of many different species with occasional large game kills in the ravines at the site (Callow and Cornford 1986). However, the early date of Mont Dol's discovery, and the subsequent destruction of the site make this suggestion difficult to verify.
The Middle Palaeolithic site at Zwolen is located about 120km south-south-east of Warsaw, on the southern slope of the Zwolénka Valley. The faunal remains and lithic artefacts are stratified in alluvial and niveo-eolian sediments which accumulated in a series of depositional cycles dating to between 80,000 and 74,000 kyr (Thermoluminescence dating) (pers. comm. A. Gautier, 1999).
Horse is the most common species among finds found up to the end of 1985, and over 30 individuals are present. Cut marks are rare, although wear traces on stone tools show that the cutting of wet hides and bone scraping was carried out at the site. Information relating to impact notches has not been published so far. Zwolen has been described as a multiple kill site, where mainly horses were driven to their death and butchered afterwards at the site (Gautier 1989, Schild and Sulgostowska 1988).
Other Middle Palaeolithic sites at which horses are common in the faunas are Grotte du Docteur (Ulrix-Closset 1975) and Grotte de Ramioul (Vandebosch 1921) in Belgium; in France, Genay (Patou 1988), Combe Grenal (layer 14) (Chase 1986), Ioton in Languedoc, Champ-Grand and Baume-Vallée in the Massif Central region (Brugal and Jaubert 1996); and layer 5 at Achenheim in Alsace (Wernert 1957). In Germany, horses are also the most common species in Middle Palaeolithic deposits at the cave of Bocksteinschmiede, IIIa (Wetzel and Bosinski 1969) and in layer III at the Vogelherd (Lehmann 1954). At the latter site, relatively numerous horse remains were also found in the Upper Palaeolithic levels belonging to the »Aurignac« and Magdalenian phases.

The long history of excavation and investigation at Solutré has shown that this site was occupied during the Mousterian, Aurignacian, Gravettian, Solutrean and Magdalenian periods. The dominance of horses in the faunas from these levels was recognised during the earliest investigations at this site, and the way in which horses in particular were hunted and processed at Solutré formed the focal point of several archaeozoological analyses undertaken by Hubert Berke, Marsha Levine, Sandra Olsen and Marie-Luise Tretschocks in the 1970's and 1980's.
In this report, data collected during an examination of faunal remains from Magdalenian deposits in sectors I11 and P16 at Solutré are presented. Focussing on skeletal part representation, age-structures, sexual demography, season of death and traces of bone modification in the form of cut marks, impact notches and carnivore gnawing, the faunal assemblages from these sites were analysed. The Magdalenians hunted mainly horses at Solutré, but also 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 are the low numbers of humanly modified bones and the relatively high numbers of bones gnawed by carnivores. However, the most important aspect of Solutré is the evidence that the locality mainly functioned during the Middle Palaeolithic and Upper Palaeolithic periods as a horse hunting site. As Olsen (1989) states, the evidence from the cultural levels Solutré demonstrates a continuity of the organized hunting of horses and horse carcass processing, stemming from considerable understanding of horse behaviour, regular patterns of horse migration throughout these periods and a social organization capable of conducting a communal hunt.
Recent evidence now demonstrates that herds of horses were systematically hunted as early as 400,000 BP at Schöningen, and that at around 420,000 or 450,000 BP, horse carcasses at La Caune d'Arago were prepared using butchery techniques similar to those employed by the Magdalenians at Solutré. The continuity observed in levels dating from the end of the Middle Palaeolithic throughout the Upper Palaeolithic at Solutré, can now be traced back into the Lower Palaeolithic period.

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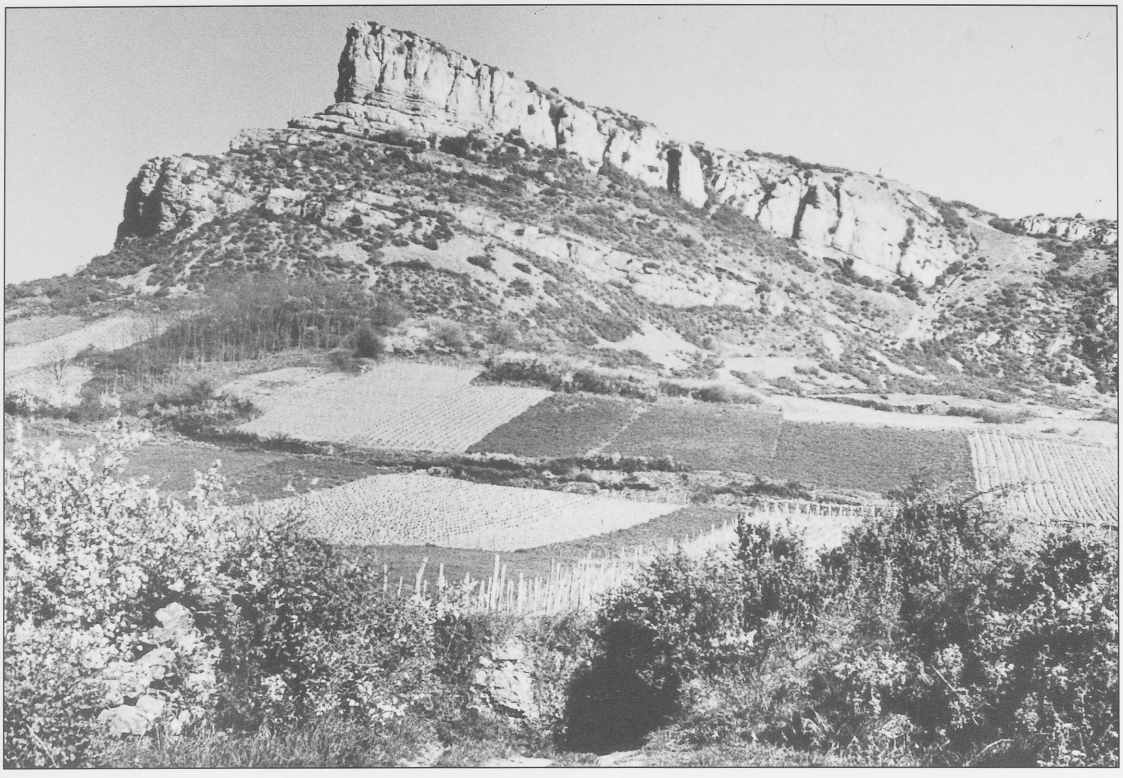
PLATES 1-20

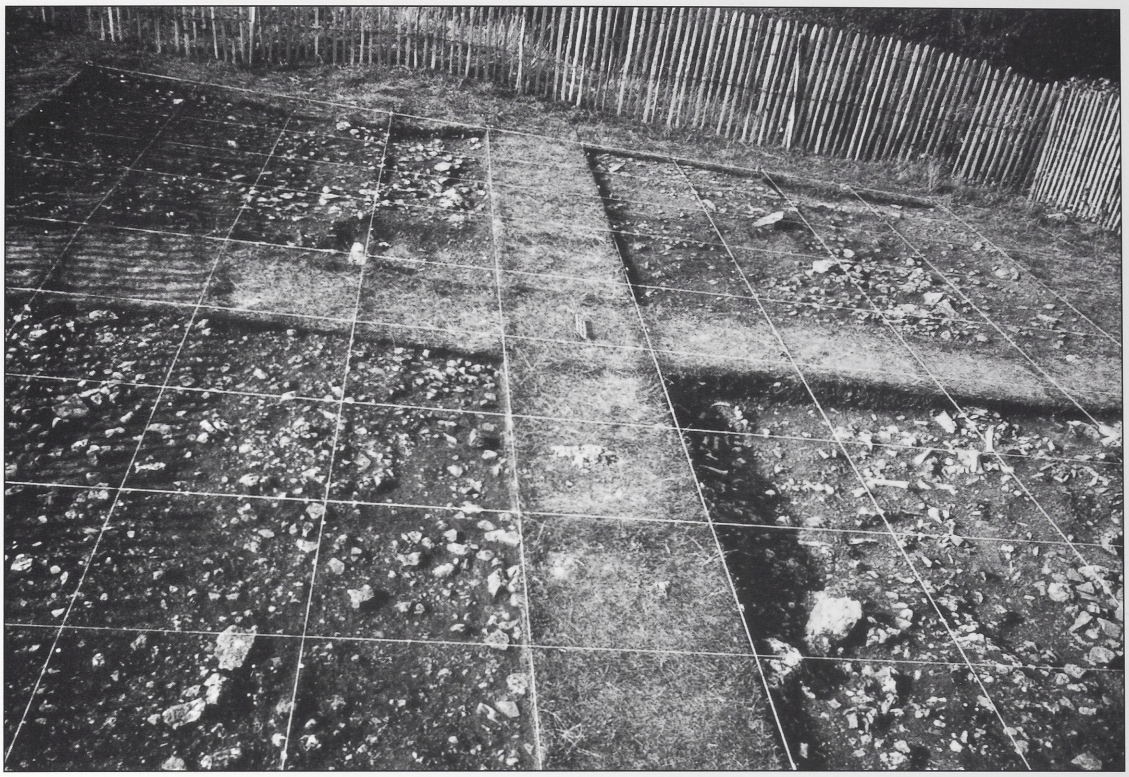


1



2

1 View of the southern cliff of the »Roche de Solutré«. – 2 Aerial view of the »Roche de Solutré« taken from the west and looking towards the Saône Valley. The white arrow marks the site of the excavations, enclosed today by a security fence. On the right edge of the photograph is the village of Solutré.

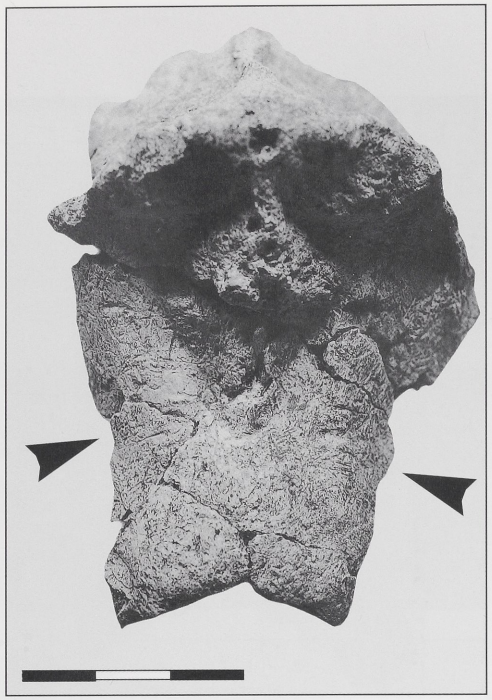


1



2

1 View of the sector P16 site during excavation. The baulks are still in place; the first 5-10 cms. of soil have been removed. –
2 View of the main concentration of bone in the channel. Note the orientation of long bones (bottom right) from NW-SE in the channel.



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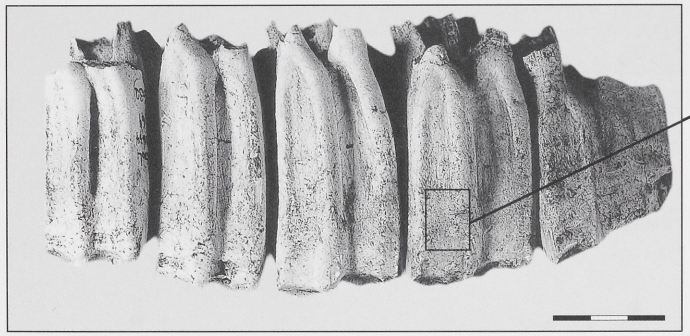
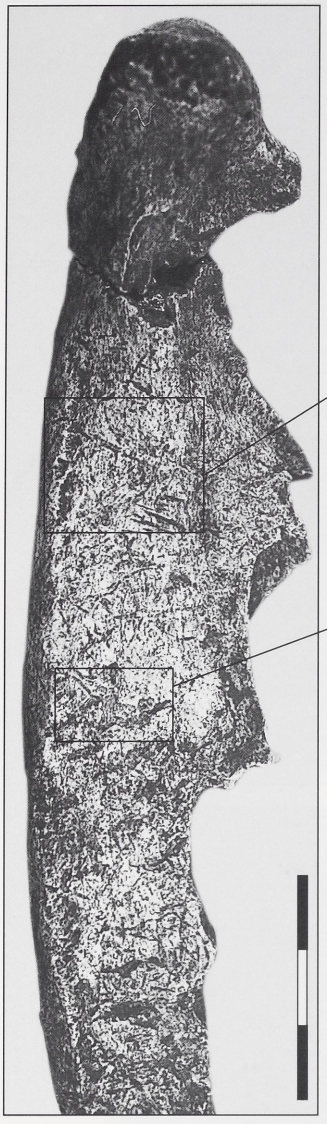


4



5

Cut marks on horse bones from sector P16. – 1 Cross the occiput of a crania. – 2-3 On the inner side of the symphysis of a mandible and close-up of cut marks. – 4-5 Cut marks across the outer (buccal) surfaces of an upper cheek tooth row (P2-M2) and detail of cuts on the P3. – All scales = 3 cms.



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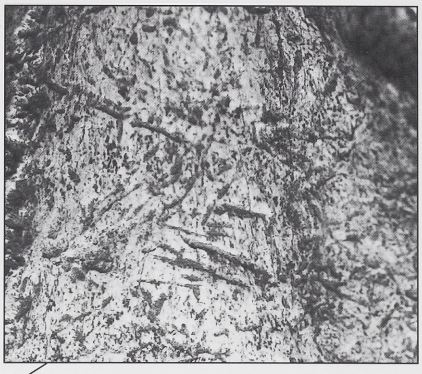

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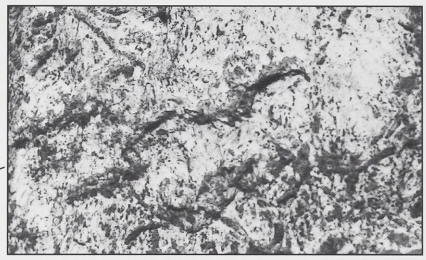



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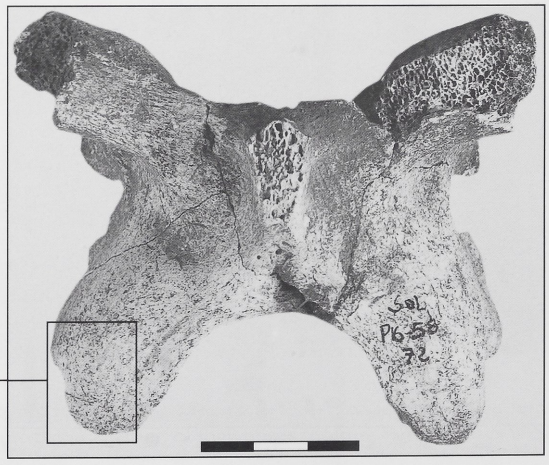
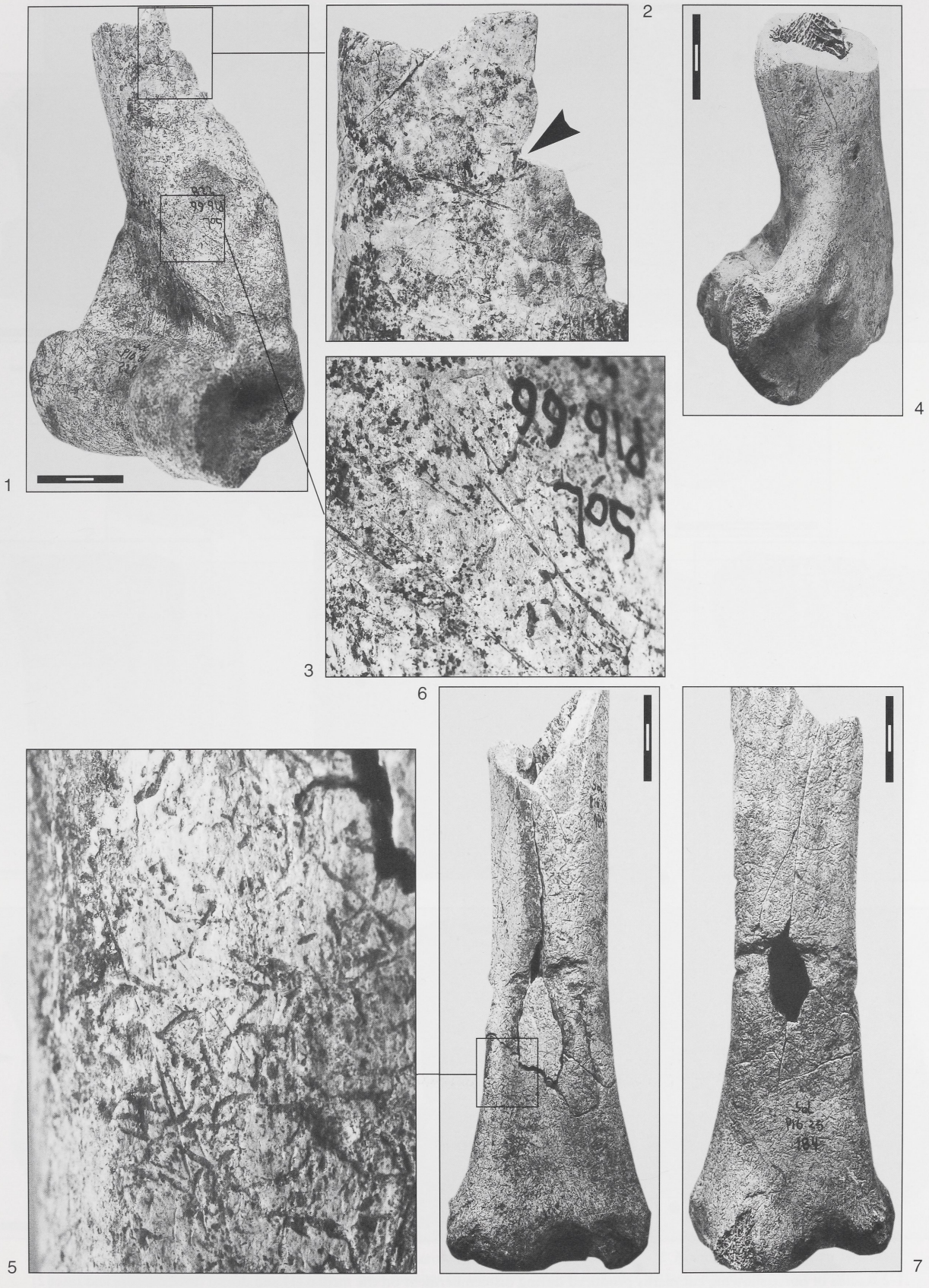
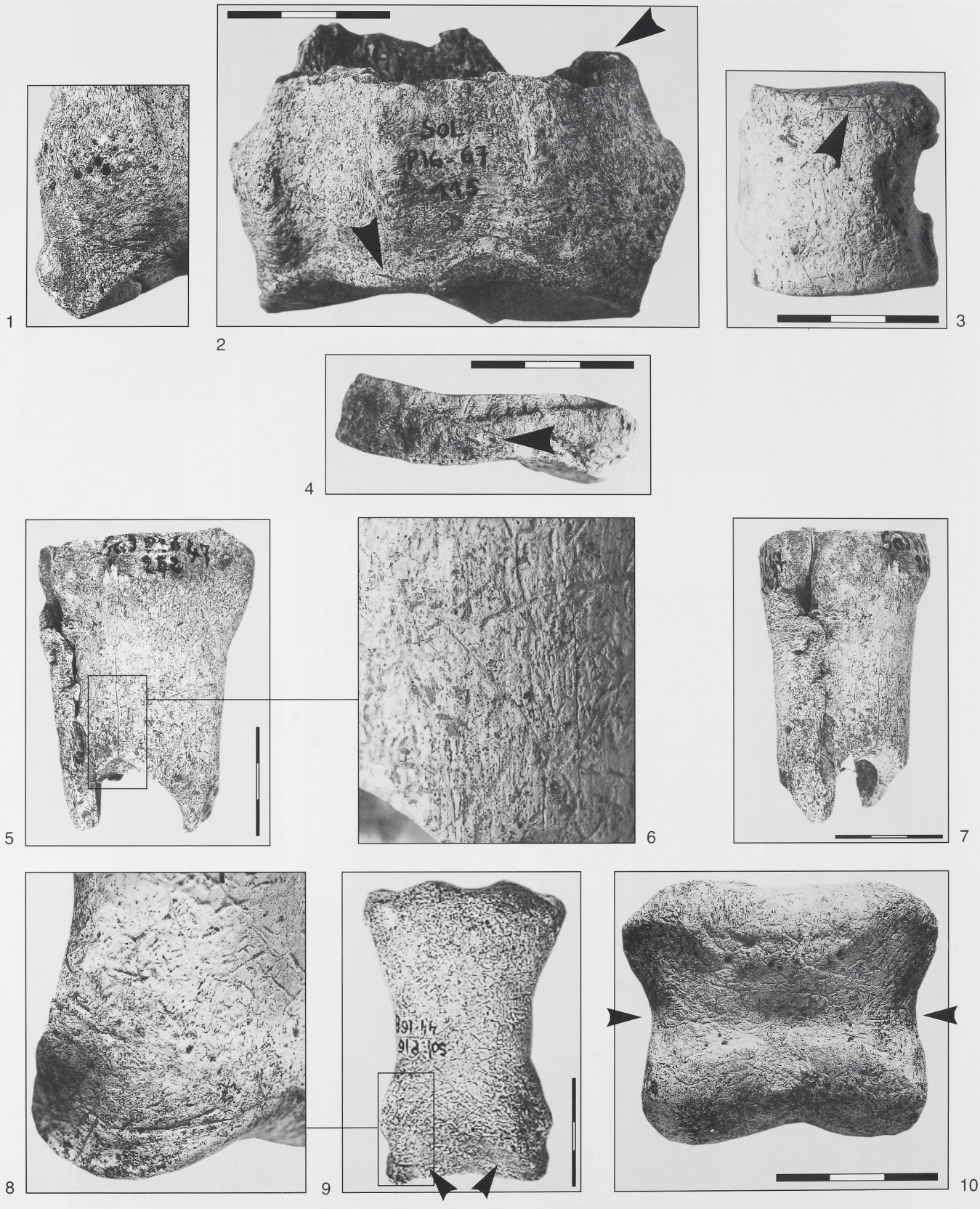


7

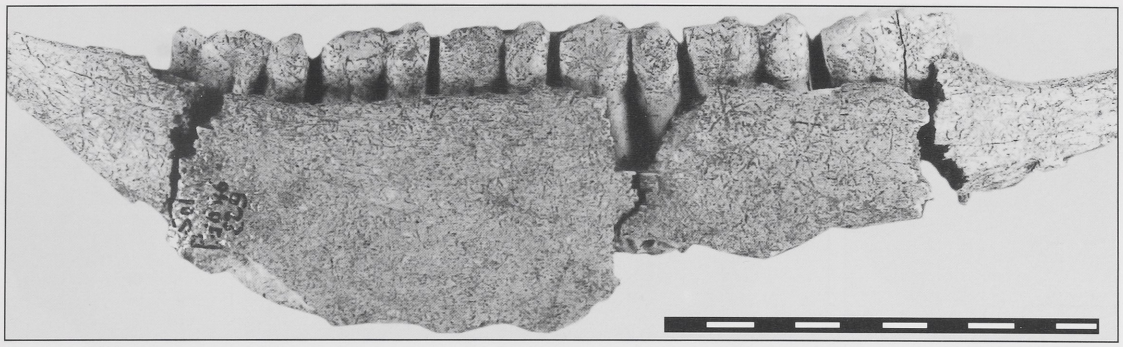
Cut marks on horse bones from sector P16 – 1-3 Cut marks (above) and carnivore tooth scores (below) on the outer (lateral) face of an ascending ramus of a mandible. Comparison of V-shaped, more sharply-defined cut marks produced during removal of the masseter muscle (2) with the undulating, U-shaped tooth scores (3). – 4-5 Cut marks in the same location on a second mandible. – 6-7 Cut marks on the ventral surface of the right cranial process of an atlas, produced during separation of the head and neck. – All scales = 3 cms.



Cut marks and carnivore gnawing on the bones of horse from sectors P16 and I11. – 1-3 Distal humerus of horse with traces of carnivore tooth notching of the edge of the bone (above and inset 2) and cut marks on the cranial face above the joint produced during dismemberment (below and inset 3). – 4 Cut marks on the shaft of a humerus from sector I11. – 5-7 Distal tibia of horse with oblique cut marks on the latero-dorsal face of the shaft above the distal joint (inset 5) and tooth furrows produced by carnivores on the dorsal and plantar surfaces of the shaft of the bone (6 and 7). The opening on the plantar face (7) was probably produced by the pressure of the carnivore's teeth. – All scales = 3 cms.



1-2 Radius of horse showing cut marks produced during dismemberment on the medial (1) and dorsal (lower arrow and inset 2) faces of the distal joint. The bone has also been chewed by carnivores, producing the typical »crenulated« end of the shaft (upper arrow). – 3 Left scaphoid of horse; the arrow points to cut marks produced during seaparation of the radius from the carpals. – 4 Oblique cut marks on the dorsal face of a tarsal bone (os tarsi 3 or great cuneiform) produced during dismemberment. – 5-7 Right metatarsal 3 of horse with oblique cut marks (inset 6) on the shaft probably produced during stripping of the periosteal tissues. The second metatarsal is fused by bony outgrowths (exostose) to the third metatarsal (7). – 8-9 Sets of cut marks (inset 8) around the distal end of first phalange produced either during skinning or dismemberment. – 10 Cut marks on the plantar face of a second phalange produced during tendon cutting. – All scales = 3 cms.



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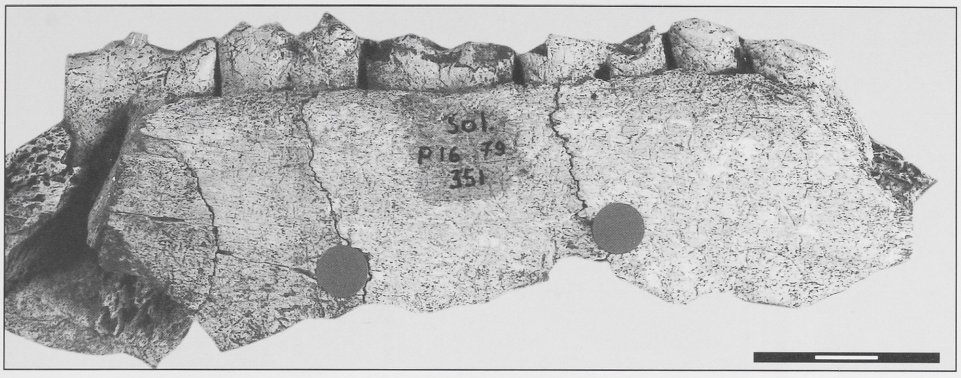

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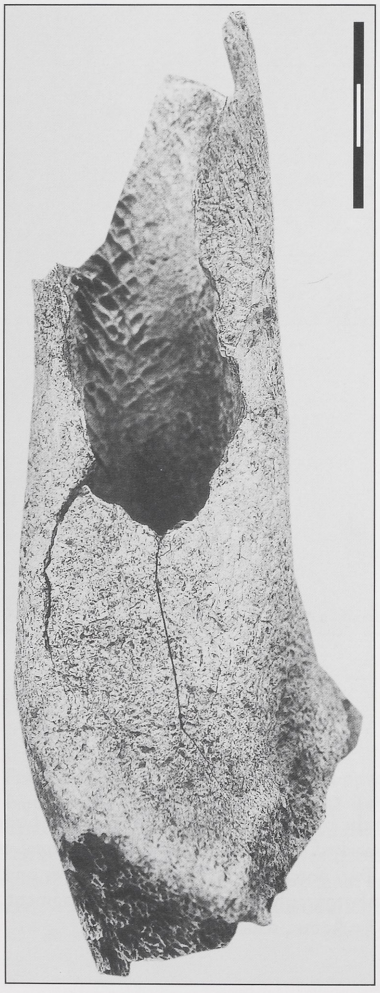

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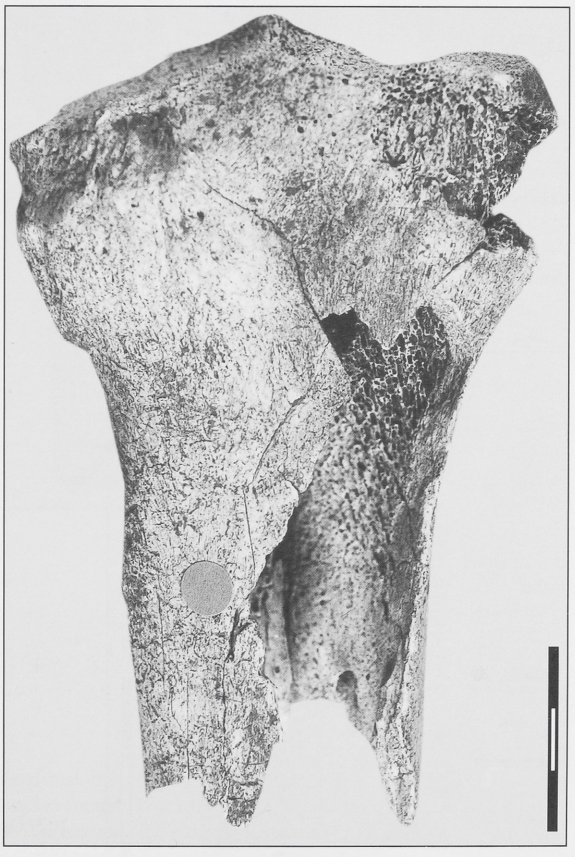

4

1 Mandible of horse showing state of preservation after removal of basal edge durig marrow extraction. Scale = 10 cms. – 2 Mandible of horse with two impact notches (marked by circles) on outer surface of the jaw placed approximately at the tips of the roots of the teeth. The teeth are heavily worn down, indicating an old individual of horse. – 3 Multiple notches on the shaft of a humerus of horse producing a »channeled« breakage pattern. – 4 Proximal end of a radius of horse, showing one of two impact notches (circle) which have opened a »window« into the marrow cavity. – All other scales = 3 cms.



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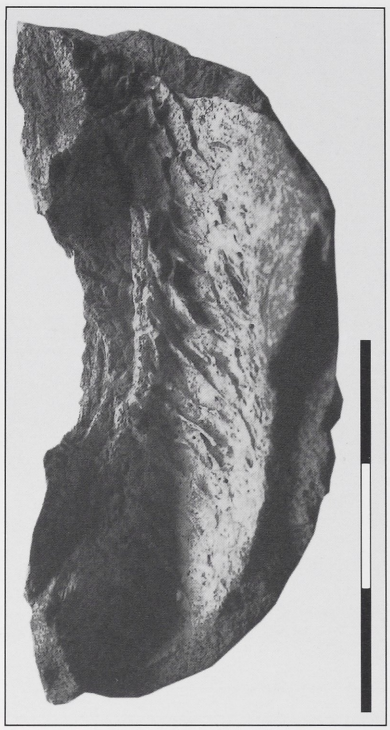

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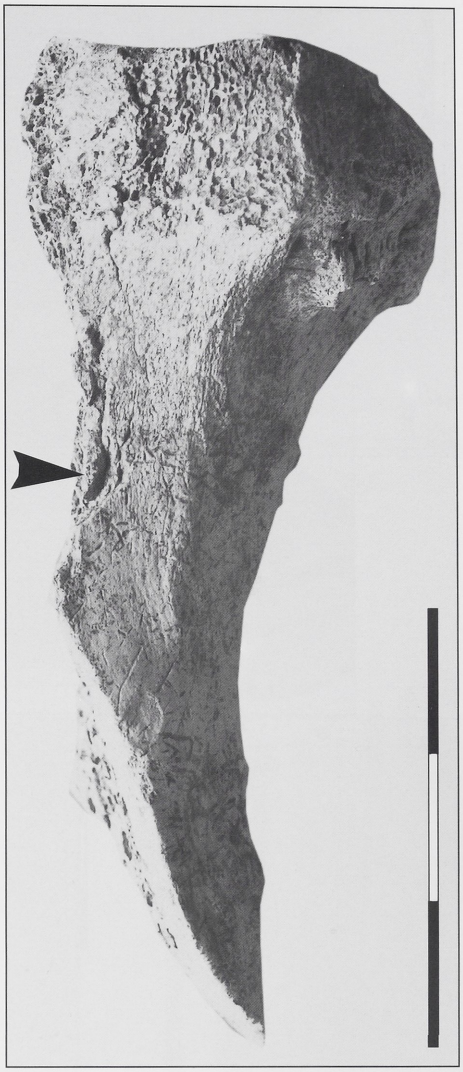

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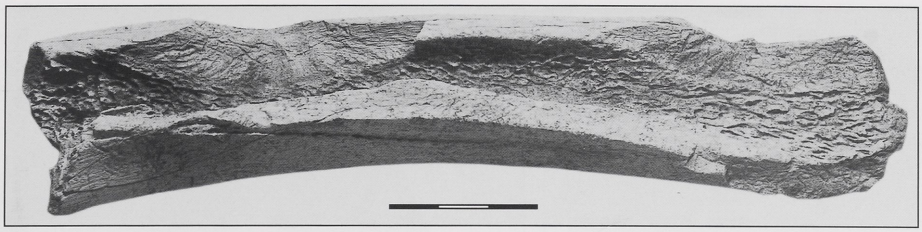
1. 2 Deep impact notch on the outer (1) and inner (2) shaft of a humerus. – 3 Incipient notch (marked by arrow) close to the proximal end of the shaft of a tibia. – 4 Two notches with overlapping flakes on the inner side (right side of photograph) of a femur shaft fragment. – Scales for 1-3 = 5 cms., scale for 4 = 3 cms.



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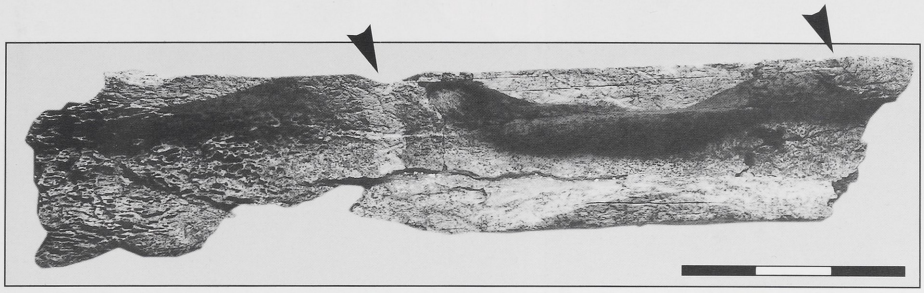

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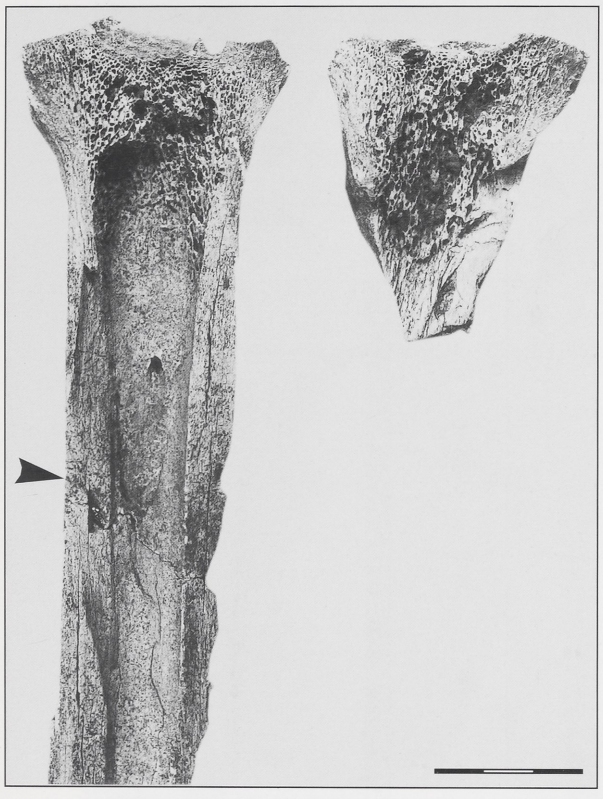

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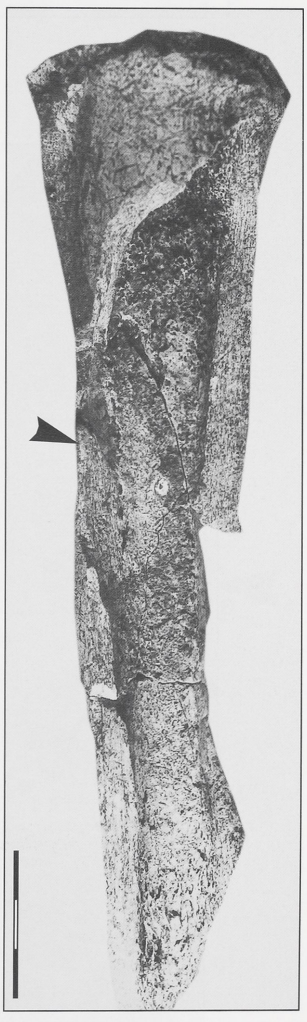

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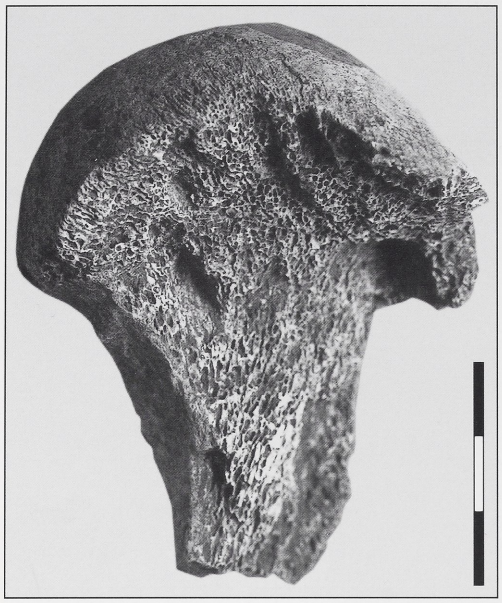
1 Fragment of a radius shaft with two impact notches with well-defined, broad arcuate flakes typical of hammerstone fracture (top edge). – 2 Two sets of opposing notches (arrows) on the shaft of a third metatarsus indicating the use of an anvil (reflective percussion). – 3 Proximal end of a third metatarsal cleaved in two when the bone was fractured longitudinally. – 4 Conjoined fragments of a third metacarpus cleaved through the proximal end. The location of an impact notch is indicated by the circle. – 5 Shaft of a third metatarsus after marrow extraction. The proximal end is intact in this specimen. All scales = 3 cms.



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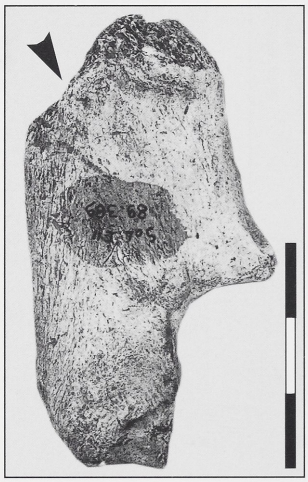

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Carnivore modification of horse bones. – 1 Tooth furrows in the spongiosa of a proximal femur. Scale = 3 cms. – 2 Tooth furrow and loss of bone on the distal end of a humerus (sector I11). Scale = 3 cms. – 3 Typical modification of the tuber calcis of a calcaneum. Scale = 5 cms. – 4 Tooth puncture (arrow below) on the body (corpus) of a vertebra and tooth notching on the stump of the vertebral process (arrows above) (sector I11). Scale = 3 cms. – 5-6 Typical carnivore modification of the proximal end of the ulna including tooth notching (5) and tooth notching and puncturing(6). Scale = 5 cms.



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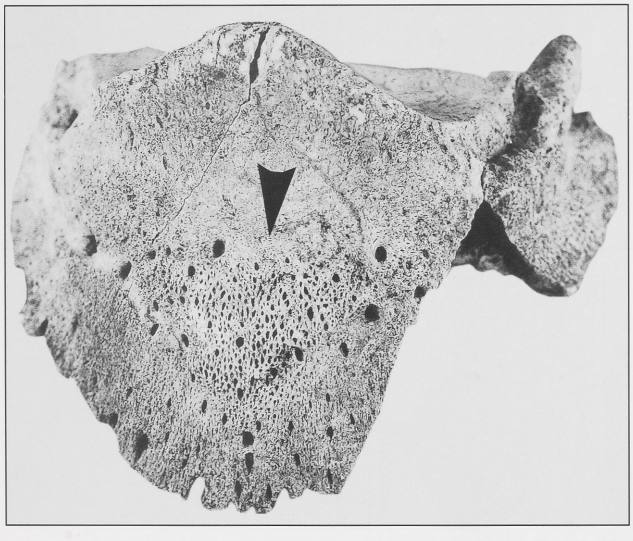

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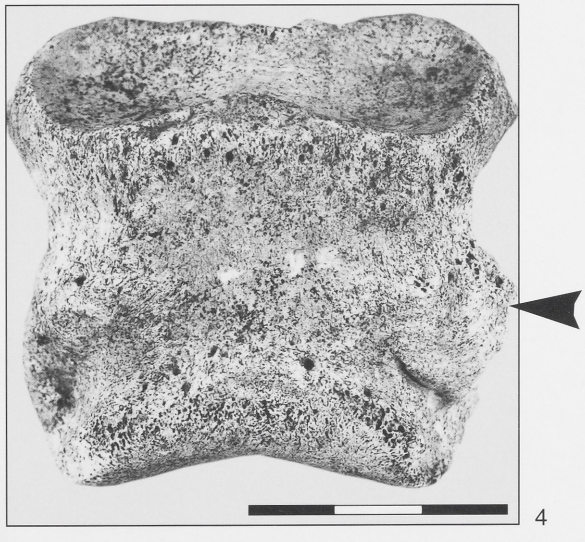


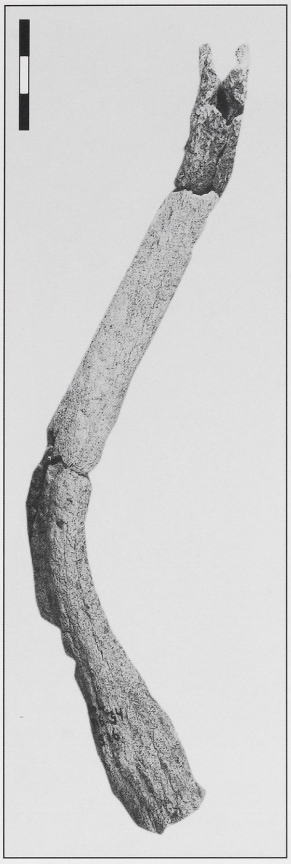
4

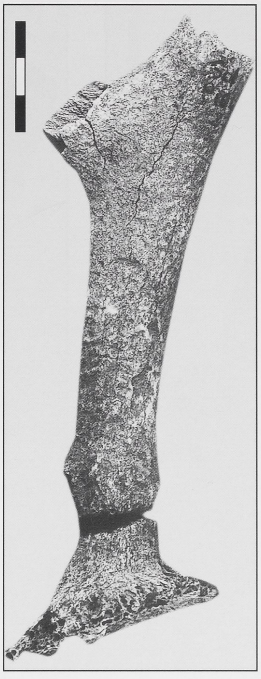
Pathological horse bones. – 1 Upper third molar with abnormal wear (arrow). – 2 Abnormal opening in the centre of a tarsal bone (Os tarsale 3). – 3 Localised lesion on a third phalange, possibly caused by osteoperiostitis. – 4 Abnormal outgrowth (exostose) on the periarticular region of a second phalange. – All scales = 3 cms.

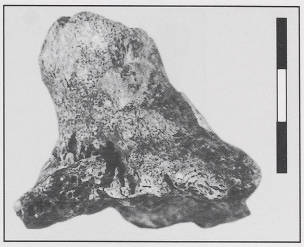


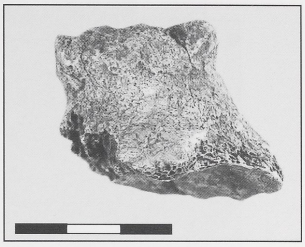
1.-2 Localised lesions (inset 2) possibly caused by osteoperiostitis on the lateral sides of a left and right pelvis of an individual horse. – Scale = 10cms.



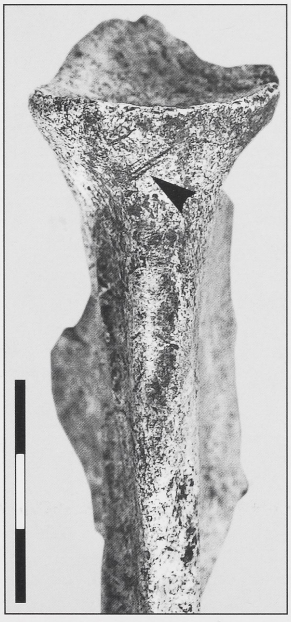


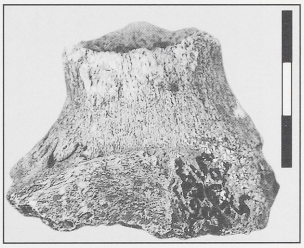


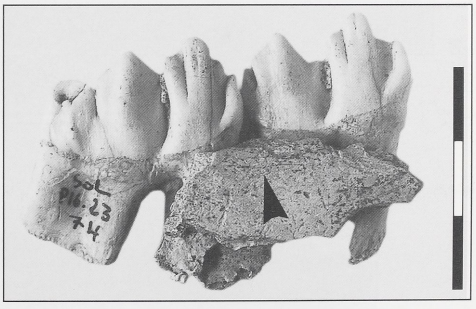












1 Shed antler of reindeer. – 2. 3 Reindeer antler frontlets. Note the presence of a resorption line towards the base of the specimen figured in 3. – 4-7 Examples of pedicles from young reindeer. – 8 Cut marks (arrow) towards the distal end of a scapula of reindeer. – 9 Cut marks (arrow) on the lingual surface of a mandible of reindeer, between lower M2 and M3. – All scales = 3 cms.



1 Scalloping of the distal edge of a scapula of reindeer by carnivores. – 2 Carnivore tooth notches and loss of bone in the region of the coracoid process. – 3 Tooth notches on the shaft of a femur. – 4 Multiple tooth punctures on the calcaneum of a reindeer. – 5 Carnivore gnawing traces on the tuber calcis of a calcaneum of reindeer. – 6 Mandible of a wolverine . – 7 Femur of wolverine with tooth notch towards head of femur. – All scales = 3 cms.



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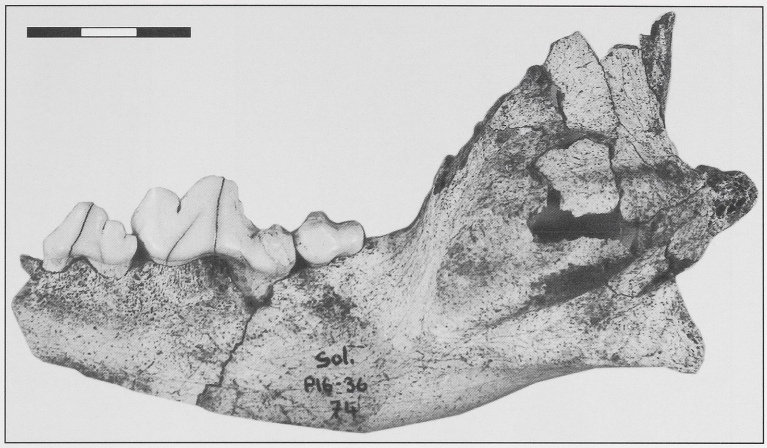

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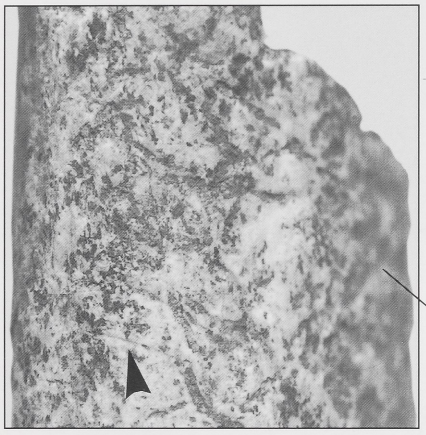

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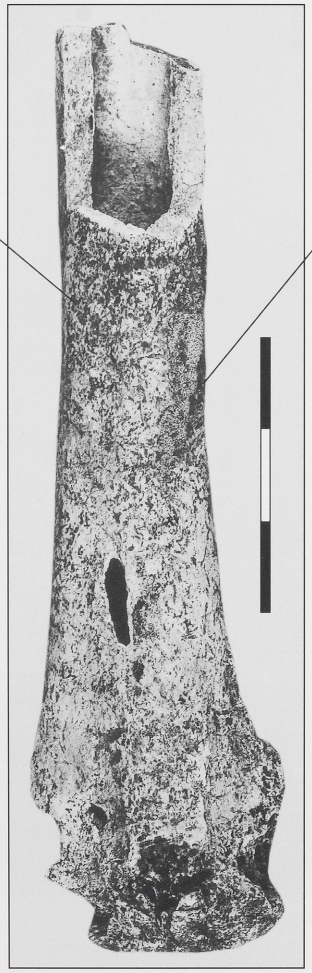

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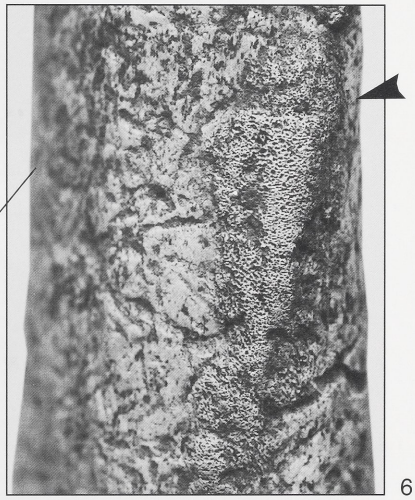

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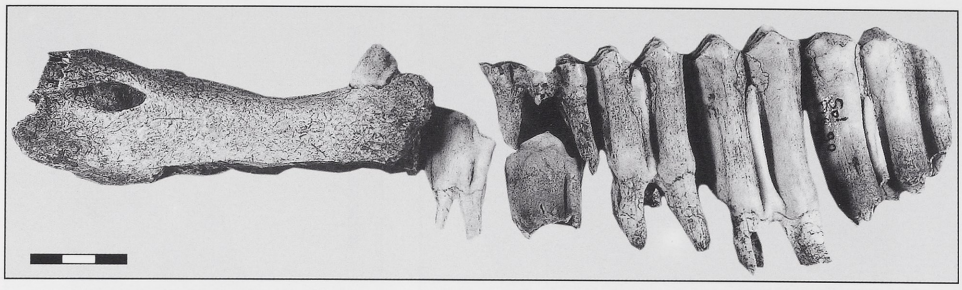
1. 2 Right and left mandibles of an adult wolf. – 3 Distal end of a radius of a wolf with ?cut marks (inset 4), traces of carnivore gnawing (inset 5) and localised lesion (inset 6). – All scales = 3 cms.



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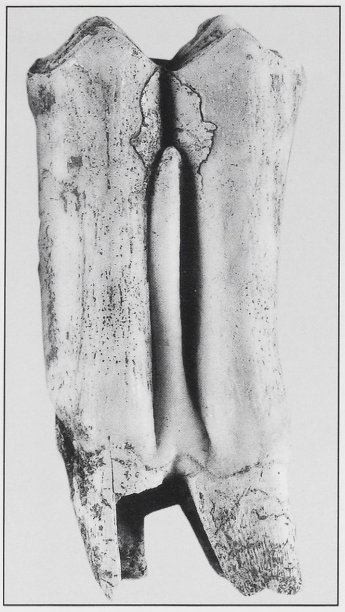
1 Left lower mandible of bison with P2, dp4, M1-3. P3 and 4 unerupted in their crypts. Permanent cheek teeth of bison. – 2 Upper M1, buccal view. – 3 Upper M1, buccal view. – 4 Upper M2, lingual view. – 5 Upper M1, lingual view. – All scales = 3 cms.



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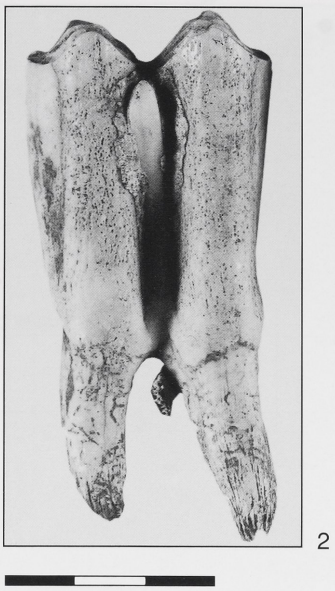

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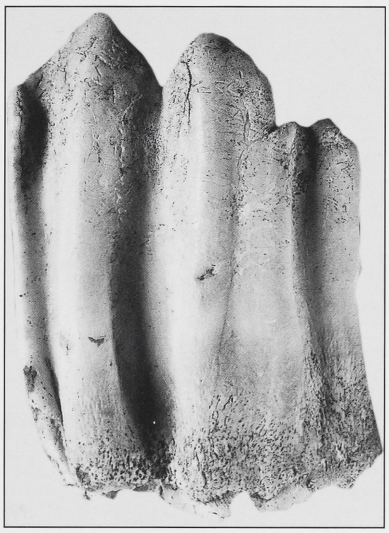

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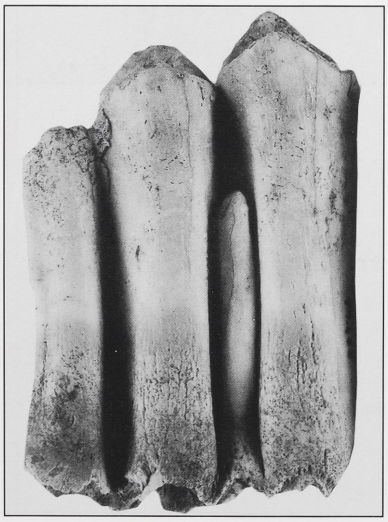

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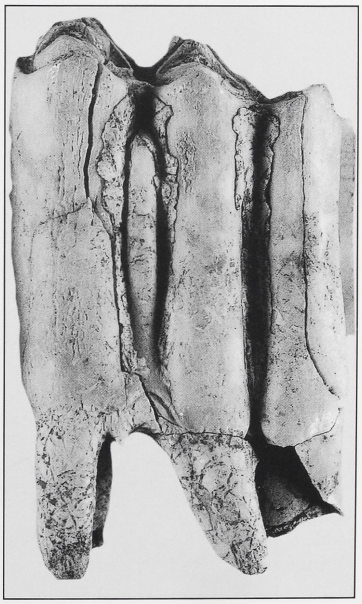
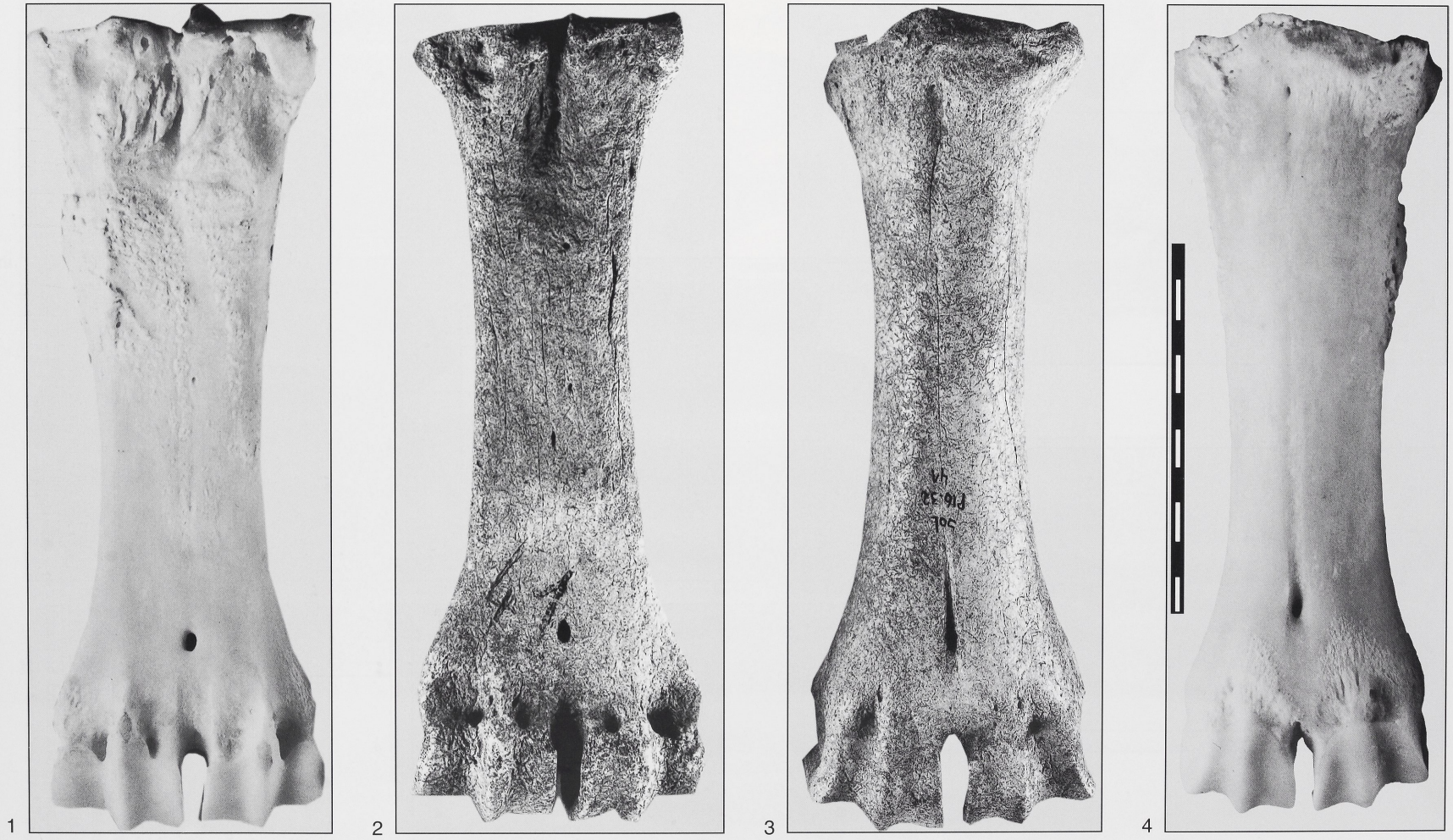


6

1. 2 Lower M2 and M1 of an individual bison, buccal views. – 3-6 Lower M3's, 3 and 4: lingual views, 5 and 6: buccal views. – All scales = 3 cms.



Metacarpals of bison from sector P16 compared with those of recent European bison (Bison bonasus). – 1 Recent bison. – 2 Specimen from P16. Plantar views. – 3 Specimen from P16. 4 Recent bison. Dorsal views. – Scale = 10 cms.



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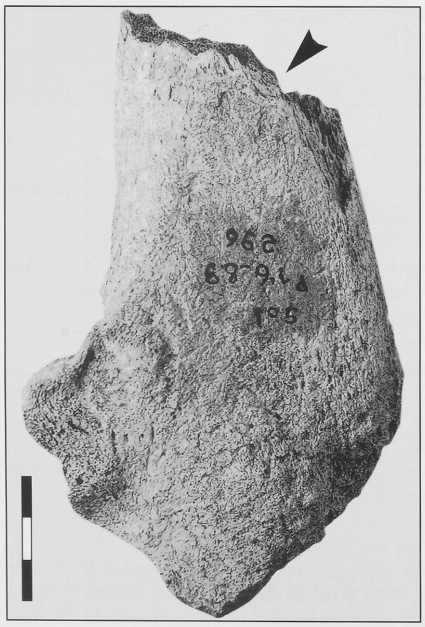

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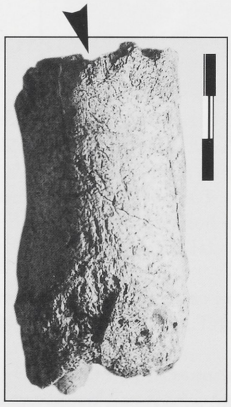

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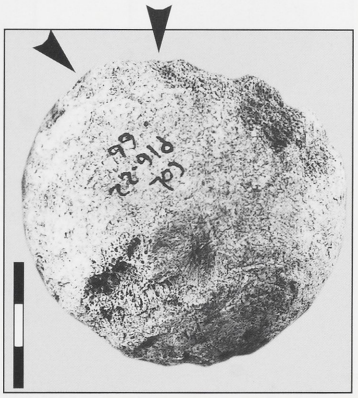

5

Carnivore modification of bison bones. – 1 Humerus showing tooth furrowing on distal end (lower arrow) and crenulation of proximal end of shaft (upper arrow). – 2 Three bone »cylinders«. All the specimens are femurs of bison with typical modification produced when carnivores gnaw away both the proximal and distal ends of the bones. – 3 Calcaneum of bison showing typical gnawing traces on tuber calcis. – 4 Gnawing traces on a second phalange of bison. – 5 Tooth scoring and gouging on the proximal head of a femur. – All scales = 3 cms.



Examples of the bone and antler industry from sector P16. – 1-2 Metacarpal of horse used as a needle-core, lateral view (1), dorsal view (2). – 3 Bâton-percé made of reindeer antler. – Scale = 10cms.

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The distribution of faunal remains at sector P16.

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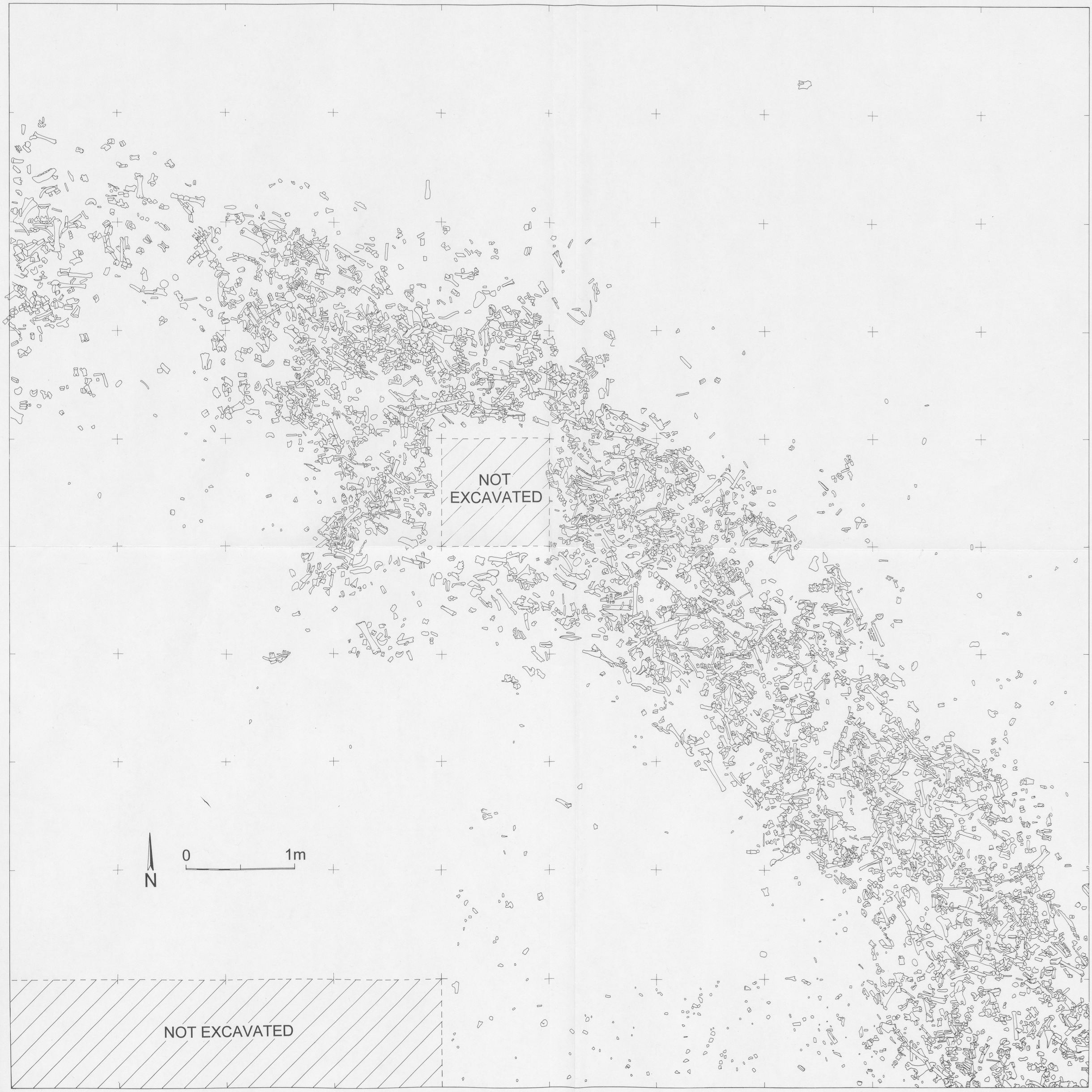

Topography of the sector P16 site. The numbers 1-4 refer to sections projected across the site to record the form of the channel feature. The »edges« of the channel were reconstructed from the distribution of finds plotted in folding illustration 1.

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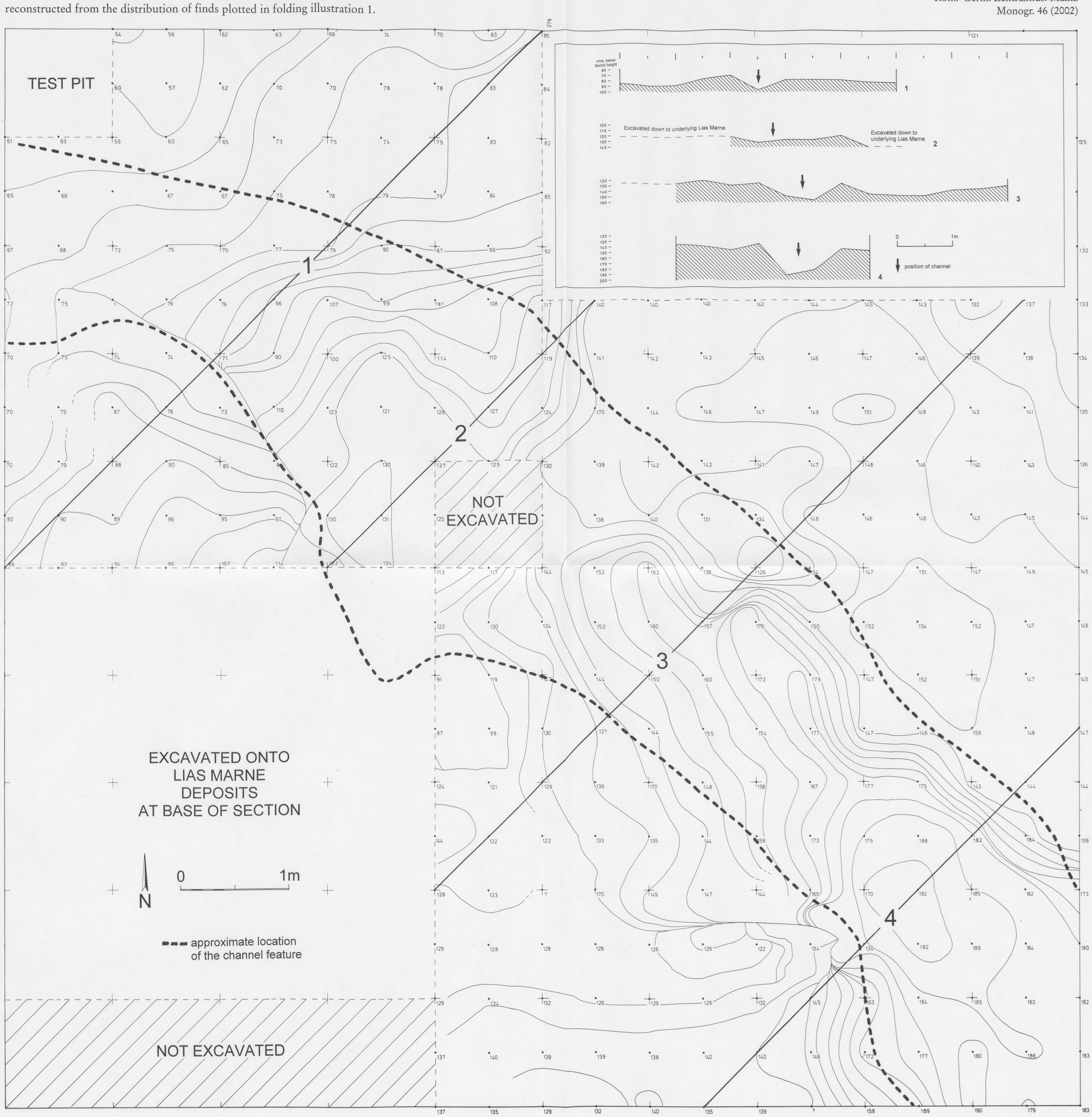

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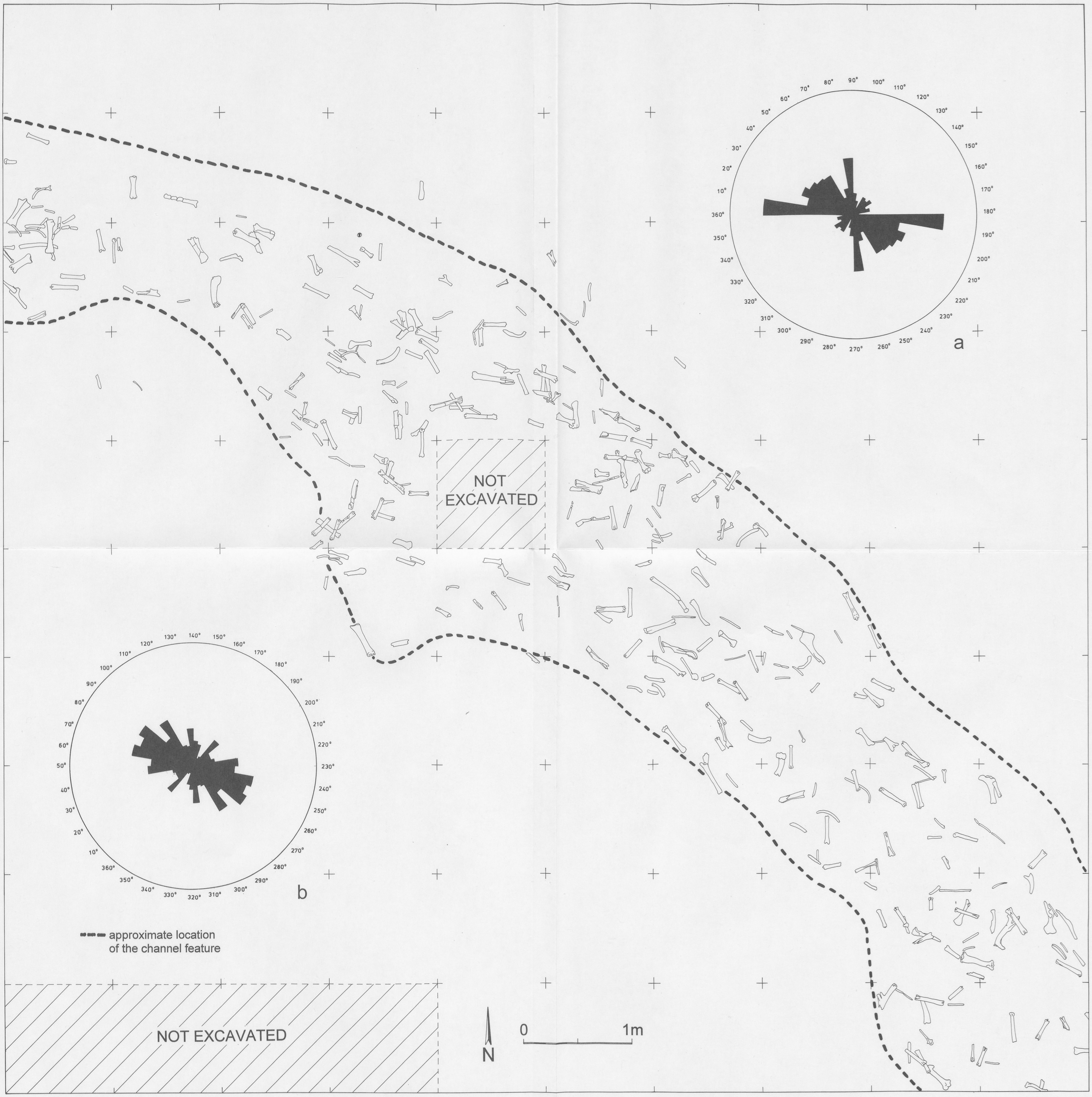
Plot of long bones recovered in the channel and rose diagrams recording their orientation. – a) Bone orientation in relation to the compass azimuth (north). – b) Bone orientation in relation to the long axis of the channel (NW-SE) (see tab. 2 for observed frequencies of bone specimens).



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Plot of mechanically and anatomically conjoined faunal remains in sector P16.



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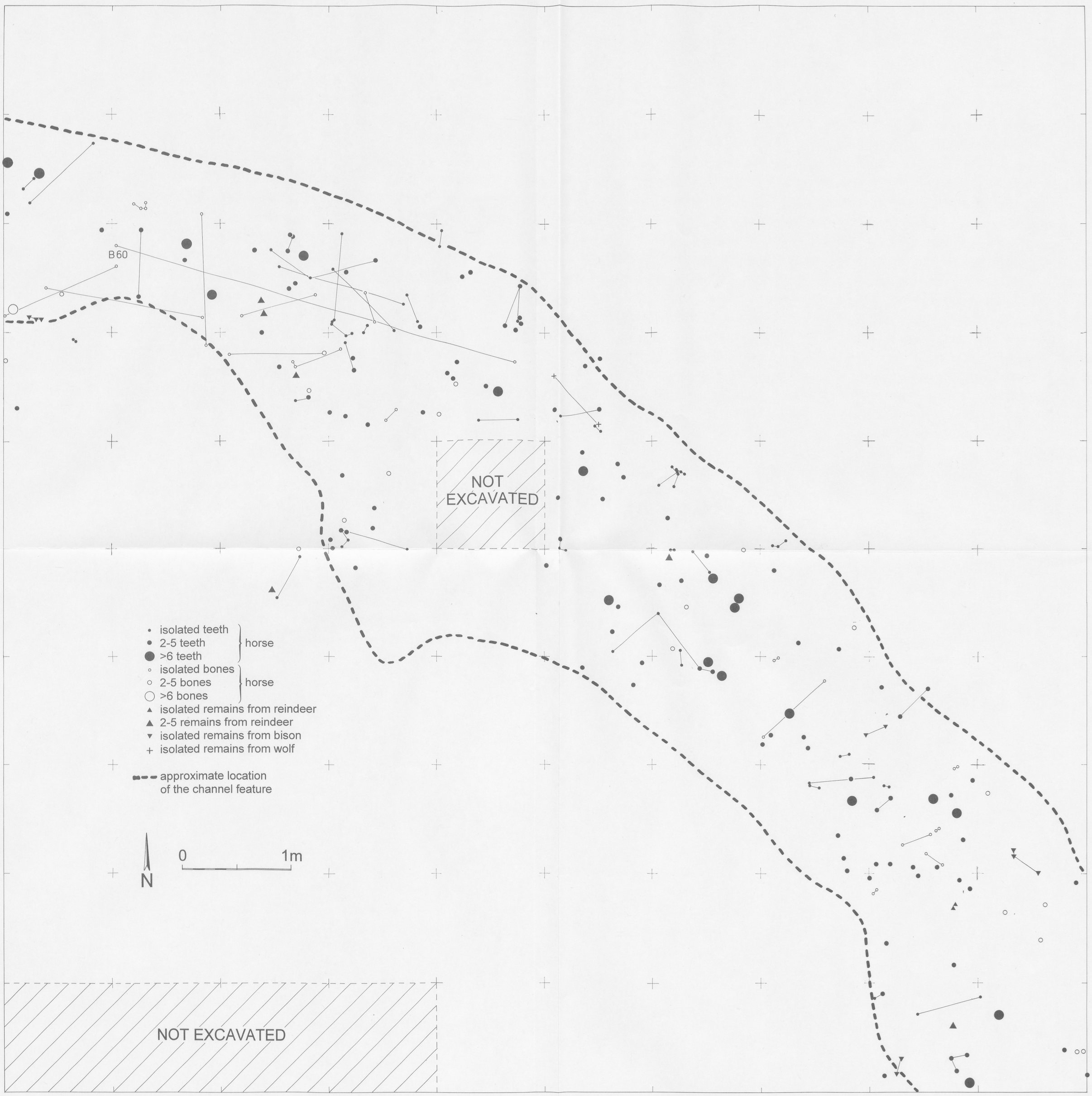
Plot of elements of individual animals in sector P16.



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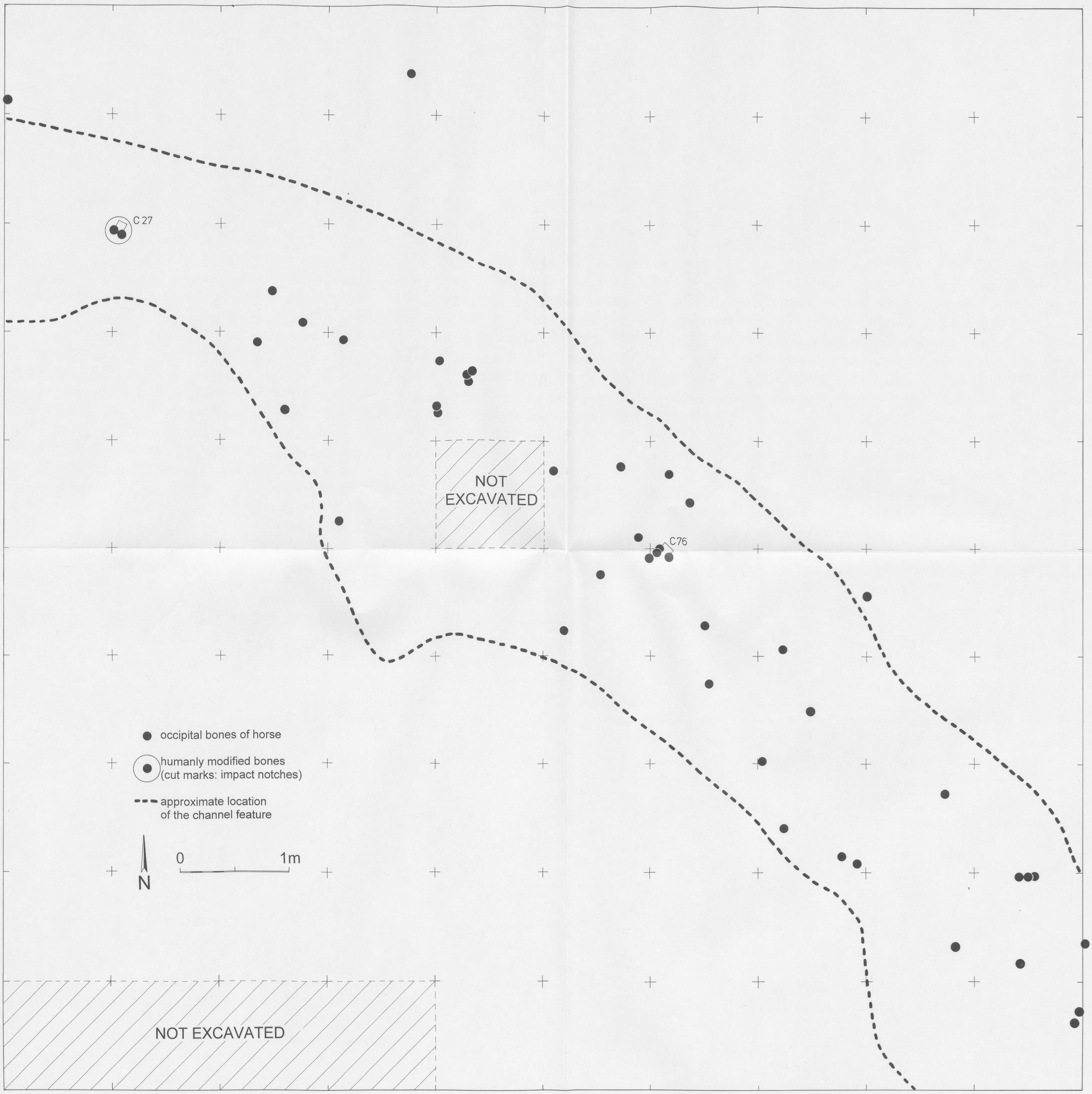
Distribution of the occipital bones of horse crania in sector P16.



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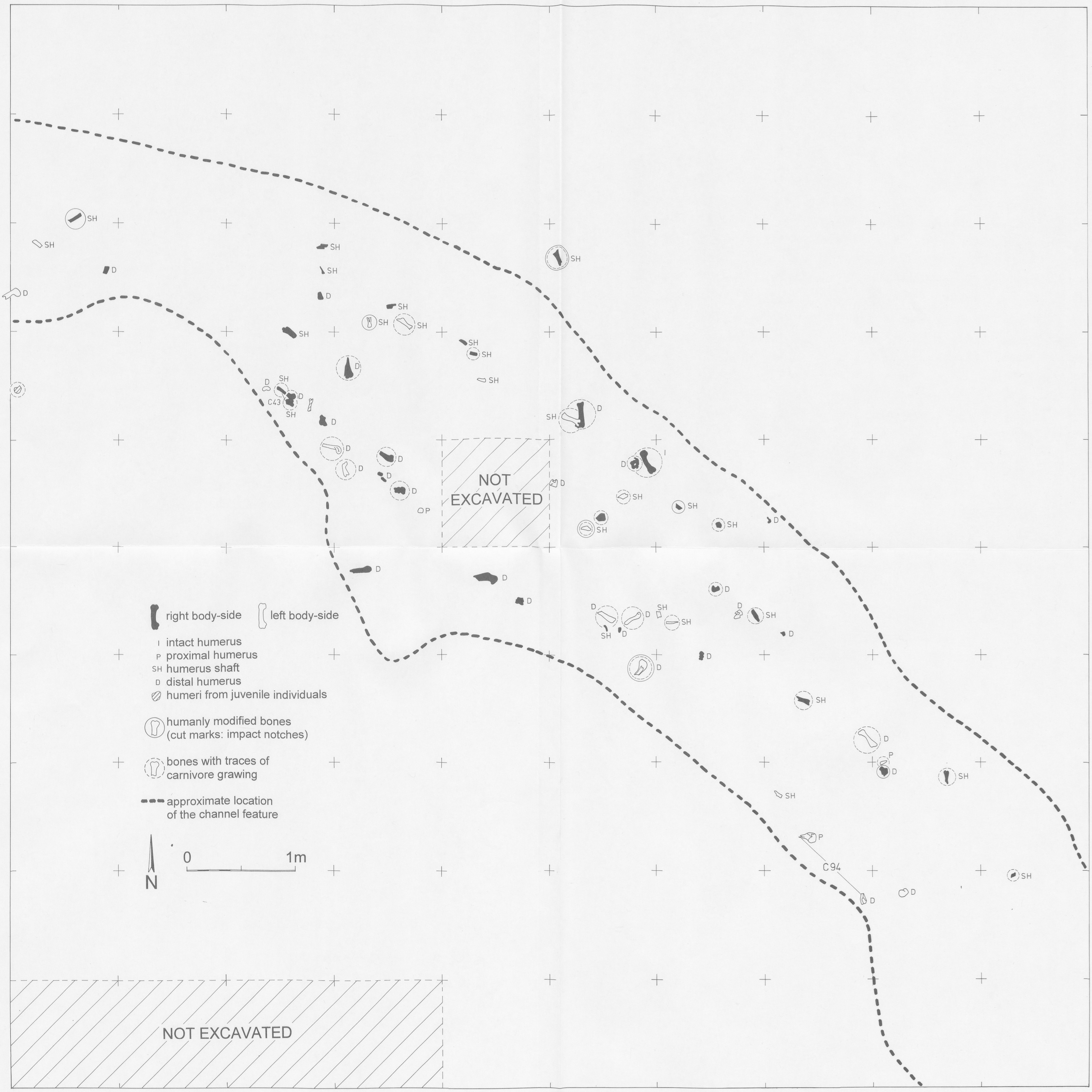
Distribution of horse humeri in sector P16.



Distribution of horse radii in sector P16.

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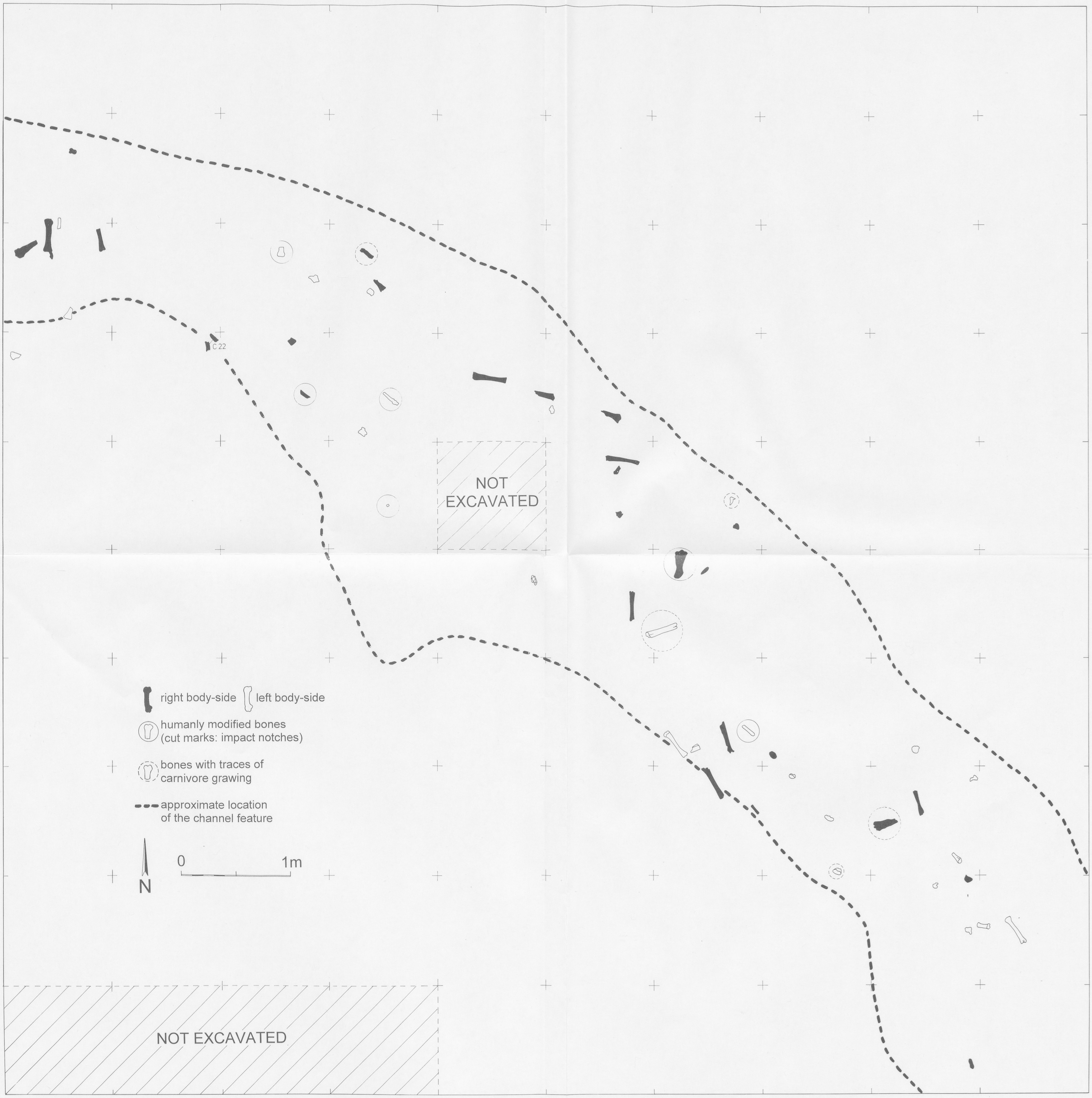

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Distribution of bison remains in sector P16.

