

## 9

### TOWARD A RECONSTRUCTION OF SUBSISTENCE ECONOMY IN THE UPPER PLEISTOCENE MOSAN BASIN: CEMENTUM INCREMENT EVIDENCE

Aaron J. STUTZ, Daniel E. LIEBERMAN, Arthur E. SPIESS

#### INTRODUCTION

Cementum is the bone-like tissue that surrounds the roots of teeth. In most ungulate species it grows in roughly semiannual increments, which record an individual's season of death and age at death. Since the late 1960's, archaeologists have examined cementum increments to generate seasonality and mortality profiles of prehistoric hunter-gatherer prey populations (Bourque *et al.* 1978; Burke 1992; Gordon 1988; Lieberman 1993b, 1993c; O'Brien and Miracle 1994; Pike-Tay 1991; Saxon and Higham 1968; Spiess 1976, 1978, 1979, 1990; Stutz 1993). In this chapter we report the results of cementum increment analysis of a small sample of ungulate teeth (n=7) from strata 2 and 3 at Trou Magrite. These cementum increment results complement the seasonality information that has been generated from Trou Magrite juvenile reindeer tooth eruption profiles. We discuss the cementum increment and tooth eruption data from Trou Magrite in the context of cementum increment data from three other Upper Pleistocene deposits in the Mosan Basin: a mixed Mousterian and Aurignacian stratum from Trou du Diable à Hastière-Lavaux (n=10); a mixed Aurignacian and Perigordian stratum from Trou Reuviau à Furfooz (n=2), and a sealed Mousterian living floor in le Grotte de Sclayn (n=5) (Stutz 1993). From this basis we discuss the strengths and limitations of our seasonality and mortality data. We also outline some problems for future research on Upper Pleistocene hominid subsistence economy in northwestern Europe. We conclude by offering one possible reconstruction of Mosan Basin hunter-gatherer mobility patterns and hunting strategies across the Middle-Upper Paleolithic transition.

#### MATERIALS AND METHODS: PREPARING AND INTERPRETING CEMENTUM INCREMENT SPECIMENS

Several interrelated factors, physiological, functional, and environmental in nature, underlie cementum's utility as a source of mortality and seasonality information. Cementum functions to anchor an animal's tooth roots into the gum

(periodontal ligament). This is accomplished as cementoblast cells deposit a mixture of collagen fibers and hydroxyapatite crystals around collagen bundles (Sharpey's fibers) that originate in the periodontal ligament and extend to the root (see Fig. 9.2). The cementoblasts are located along the periodontal ligament, so that they secrete cementum matrix from the gum onto the root's surface. Growth occurs in this manner--with new cementum constantly forming on the outer surface of the root--throughout the lifetime of the individual (or tooth).

Recent research indicates that diet is the factor that determines the rate of formation, density, and Sharpey's fiber orientation of newly deposited cementum (for details see Lieberman 1993a, 1994; but see also Burke 1992). Thus, ungulates that regularly alternate between winter and summer diets will grow two seasonally distinct types of cementum. The regular changes in cementum growth appear as distinct tree-ring-like increments that surround the tooth root. A ground thin section of a tooth, when viewed in the microscope in transmitted cross-polarized light, reveals cementum increments as alternating translucent and opaque bands.<sup>1</sup> This pattern of banding is most clearly seen in the area of cementum around the gum line. This region is marked by the juncture of four histological features: the alveolar bone, the enamel, the dentine, and the cementum (see Fig. 9.1). Along this portion of the tooth root, the cementum grows at a slow, roughly constant rate. As a result, seasonal increments are sharply discernible. The cementum near apical extent of the enamel is classified as "acellular cementum" because it does not exhibit the lacuna-traces of cementoblasts. This histology contrasts with that of the "cellular cementum" that pads the root apices and furcation; such cementum is very thick, irregularly banded, and dotted with cementoblast lacunae (cf. Lieberman and Meadow 1992).

Incremental structures have been documented in the cementum of most ungulate taxa, including those species included in our archaeological sample: reindeer/caribou (*Rangifer tarandus*), red deer (*Cervus elaphus*), bison (*Bison* cf. *priscus*), and ibex (*Capra ibex*) (see, e.g., Spiess 1976). Analysis of modern *Rangifer* and *C. elaphus* field specimens of known age and season of death demonstrates that populations of these species throughout North America and Europe--regardless of latitude, altitude, or microhabitat--exhibit growth of "translucent" cementum from late April-early May through late December, and of "opaque" cementum from January through April (Gordon 1988; Grue and Jensen 1979; Pike-Tay 1991; Spiess 1976, 1979). There is no comparable documentation of the timing of growth of translucent and opaque cementum in modern ibex and bison. However, ibex and those bison inhabiting cool, continental regions survive winter under stressful dietary constraints comparable to those confronted by reindeer and red deer. Because

---

<sup>1</sup> On a thick polished section viewed under reflected light, the cementum increments appear "in negative." Thus, bands that are translucent under a transmitted polarized light appear dark under a reflecting-light microscope because the light source is not reflected back through the objective lens to the viewer. For the same reasons, bands that are opaque under transmitted light appear bright under the reflected light. Throughout this chapter, unless otherwise indicated, "translucent" and "opaque" will refer to increments that appear as such on ground thin sections under a transmitting polarized light microscope. This is because the bulk of the data presented below was obtained from analysis of thin sections viewed under transmitted light.

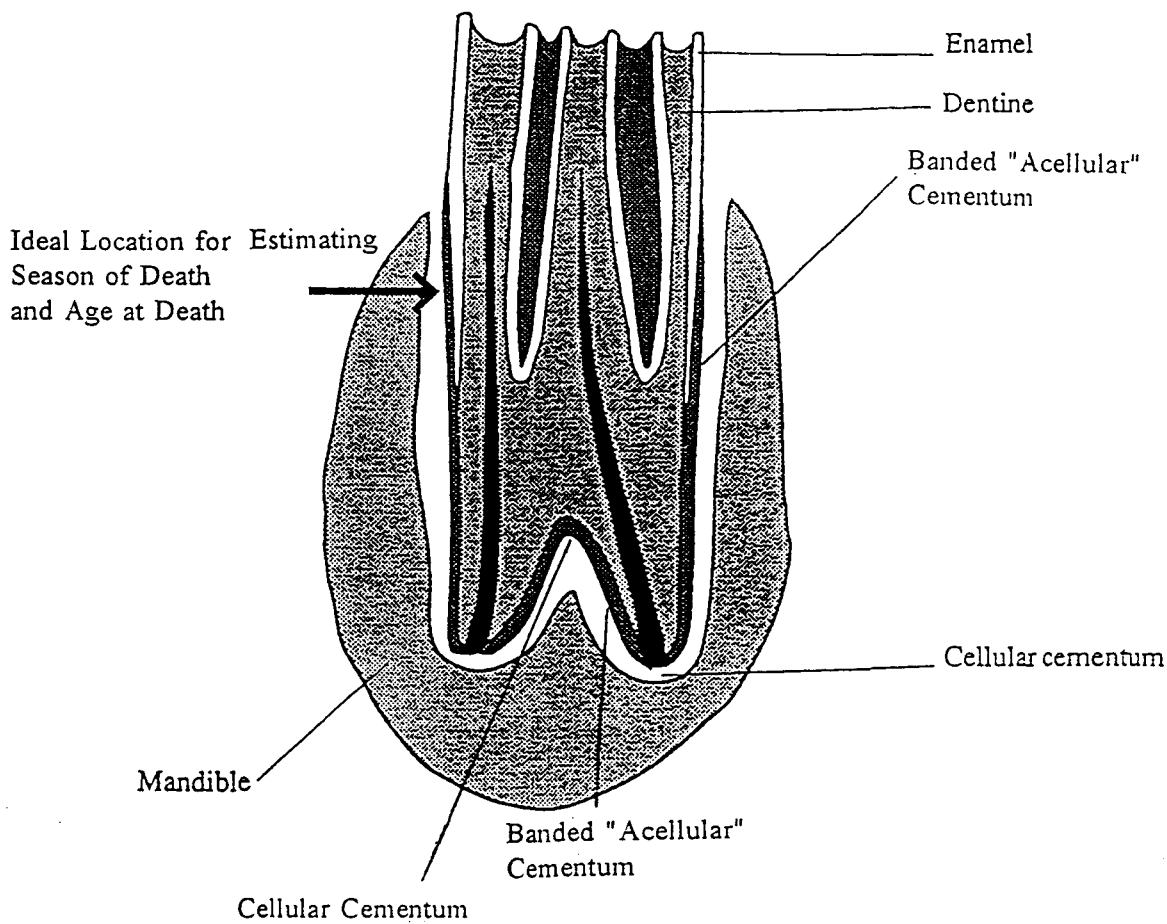


Figure 9.1 : Idealized Cross-Section Through Gazelle M<sub>1</sub>. The best region of cementum for determining the individual's age at death and season of death is around the cementum-enameldentine junction, just below the gum line (From Lieberman 1993b : 195).

we know how such winter constraints affect the process of cementogenesis, we can use data on ibex and bison seasonal nutrition cycles to predict reliably the timing of growth of opaque and translucent cementum bands in these species.<sup>2</sup>

Beginning around January and continuing as late as May, populations in each of these taxa survive on protein-poor graze and browse, and depending on the temperature and snow cover, they must often rely on physically hard, tough bark and twigs (cf. Spiess 1979:31, 254-263). The low availability of dietary protein means little material for collagen synthesis by cementoblasts and the fibroblasts that deposit Sharpey's fibers. The winter decrease in dietary minerals is not as significant as that in protein, though, so that normal amounts of calcium phosphate (hydroxyapatite) precipitate in a smaller volume of new cementum, forming denser tissue.<sup>3</sup> In transmitted light the dense winter cementum appears relatively opaque. In contrast, cementum that grows from late spring through the fall is less dense and appears relatively translucent because it corresponds to a period with higher amounts of dietary protein.

Winter forage is also typically harder than the relatively protein-rich summer-fall graze, so that the animals need to produce more force during mastication. This places more compressive strain on a tooth, and Sharpey's fibers respond to this occlusal strain by growing in a more oblique orientation, acting as an occlusal "shock absorber." Under cross polarized light this winter cementum will bend polarized light differently than adjacent, more horizontally oriented summer-fall cementum (see Fig. 9.2). All other factors being equal, any given band, regardless of season of formation, may appear as either translucent or opaque, depending on its orientation relative to the polarized light source in the microscope. However, the hypermineralized (dense) winter-early spring increments always appear relatively opaque, regardless of the orientation of polarized light. The summer-fall bands, then, can only be differentiated from winter cementum when they are in an orientation that transmits the polarized light. In summary, for the reasons given above, opaque bands in ibex and bison almost certainly formed from about January through April, give or take one month depending on the species' seasonal foraging patterns and the local climate (cf. Spiess 1979:261-2, 1990:31).

---

2 Several sources of data suggest that bands in cementum form in response to regular seasonal shifts in diet. Controlled feeding experiments on domesticated Nubian goats (*Capra hircus*) illustrate how changes in the physical and nutritional qualities of diet affect cementum increment formation (Lieberman 1993a, 1993b, 1994). Keeping in mind the results of the feeding experiments, we can examine ecological data on annual foraging cycles (and possibly endocrine-related physiological cycles, and periodicity in mating and birth events) to infer the parameters on the rate of cementum growth, its composition, and Sharpey's fiber orientation (cf. Lieberman 1993a; 1993b, 1994; Lieberman and Meadow 1992; Spiess 1990). Finally, we can utilize analyses of cementum increments in the teeth of modern wild ungulates of known age and season of death (e.g., Burke 1992; Gordon 1988; Grue and Jensen 1979; Klevezal 1988; Lieberman 1993b, 1993c; Pike-Tay 1991; Spiess 1976, 1990); these results reveal that the timing of formation of these semiannual cementum increments corresponds to the timing of seasonal changes in diet.

3 An additional factor may catalyze the hypermineralization of winter cementum in northern-latitude ungulates: "To survive this winter period, deer must build up substantial fat reserves in late summer and fall. Lipogenesis (fat formation) is under endocrine control triggered by decreasing day length and is physiologically obligatory" (Spiess 1990:31). The diversion of dietary resources for building up fat reserves would compound the late fall and winter reduction in protein intake.

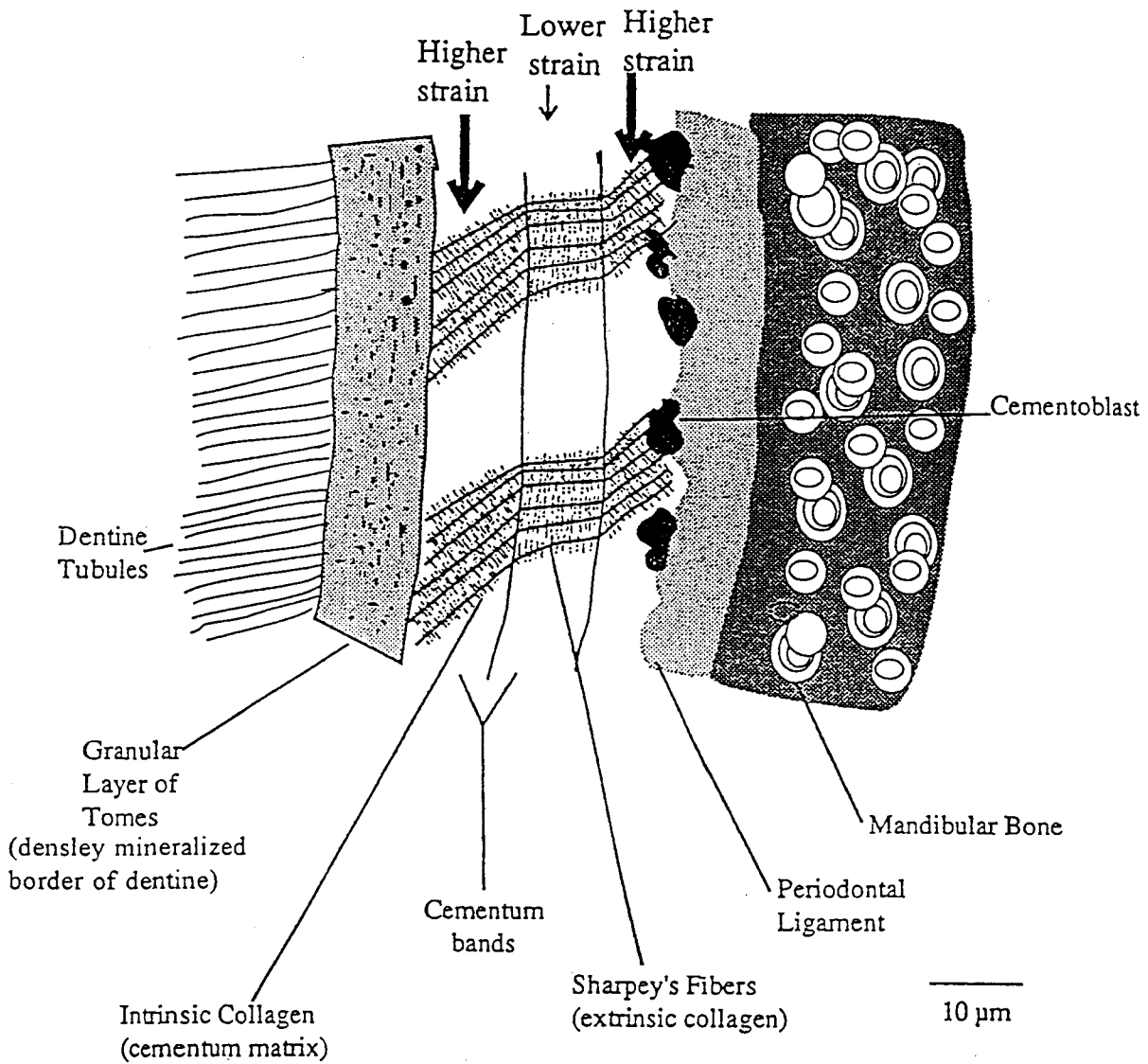


Fig. 9.2 : Schematic View of Variations in Sharpey's Fiber Orientation in Response to Changes in Occlusal Strain (From Lieberman 1993b : 175).

## *Interpreting Cementum*

These seasonal effects of diet on acellular cementum histology are basically what archaeologists exploit in estimating an animal's age at death and season of death. Since cementum begins to accrue when a tooth erupts into occlusion, age at death is calculated by counting the total number of bands, dividing the sum by the number of increments per year ( $n=2$ ), and adding the age of eruption (see Hillson 1986). Season of death is approximated by assessing the optical nature of the tooth's youngest, outermost acellular cementum band. As discussed above and this cycle characterizes only those ungulate populations occupying temperate and arctic habitats--an opaque outer increment indicates that the animal died in winter or early spring; a translucent outer band demonstrates a death in late-spring, summer, or fall. It is also possible to infer season of death more precisely. The rate of growth of cementum for a given individual may slightly vary through time, but on a population-wide level the thickness of an outer increment correlates closely with the amount of time that the band had been growing (Lieberman 1993b; Spiess 1990). Based on this statistically significant pattern, one can maintain confidently, for example, that a *Rangifer* molar with a very thick outermost translucent band (e.g.,  $>15\ \mu\text{m}$ ) died near the end of that growth phase, or, conservatively, between October and December.

It is stressed that because of variations in the rate of cementogenesis, precise season of death determinations can only be made when the outermost band is either very thick or very thin. In making such determinations, we estimate the width of the outermost band relative to that of the same band (translucent or opaque) from the previous year (cf. Spiess 1990). Table 9.1 shows the seasonal relationship between "thin," "normal," and "thick" outer bands and season of death. A normal band is approximately the same width as the previous year's band; a thin band exhibits  $<50\%$  of the width of the previous year's band; and a thick increment is  $>150\%$  of the previous year's band. The width assessments represent an increment's width relative to the thickness of the same band (translucent or opaque) from the previous year. We also caution that precise determinations of season of death in subadults (3 years) display relatively high error ranges, because young animals are most likely to undergo fluctuations in growth rates from year to year (Spiess 1990).

### *Specimen Preparation and Analysis*

In order to "read" the cementum bands the researcher requires a method of obtaining a cross-section view of the tooth and a means of observing and assessing the cementum itself. Lieberman (DEL) and Stutz (AJS), on the one hand, and Spiess (AES), on the other, employed slightly different preparation and analysis techniques. The former followed the "thin section" procedure described in Lieberman *et al.* (1990), and the latter utilized "thick section" approach outlined in Bourque *et al.* (1978) and Spiess (n.d.). Both methods involve some destruction of the archaeological materials. Before each maxillary and mandibular fragment and isolated tooth was prepared for analysis, standard anatomical measurements were

Tableau 9.1 : Cementum Increments and Season of Death

Cementum Increment (appearance and Width)*	Season of Death	Approximate Months **
Thin Opaque	Winter	January-March
Normal Opaque	Winter-early Spring	January-April
Thick Opaque	Late Winter-Early Spring	February-April
Thin Translucent	Late Spring-early Summer	May-July
Normal Translucent	Summer-Fall	June-December
Thick Translucent	Fall	October-December

\* The "opaque" and "translucent" terminology refers here to thin section analysis under transmitted cross-polarized light.

\*\* See Gordon 1988; Pike-Tay 1991; Spiess 1976, 1979.

taken, and the sample was photographed from buccal, lingual, and occlusal views. In addition, the degree of crown wear was estimated for each tooth as light, medium, or heavy.

#### *The Thin Section Method.*

For all specimens prepared by Stutz and for most of those by Lieberman, the tooth was in articulation in the alveolar bone, which protects the cementum from physical diagenetic processes. This increases the likelihood that the preserved cementum includes an accurate record of season of death (Lieberman *et al.* 1990:520). When these fragments included several teeth in articulation, one tooth was chosen for analysis and removed with a hand-held Dremel high-speed rotating saw. Mandibular first molars were preferred, because they exhibit a very narrow population-wide range of eruption age values, allowing the most precise age estimations (Hillson 1986). If the fragment contained a relatively complete tooth row, the most mesial or distal tooth was usually removed in order to minimize further fragmentation.

The selected tooth was embedded in Epotek 301<sup>TM</sup> epoxy resin. Once dry, the epoxy block was cut along the mesiodistal plane with a high-speed Raytech Gem Saw<sup>TM</sup>; this cut revealed the cementum tissue around the margins and the furcation of the roots. One half of the block was polished successively on 70  $\mu\text{m}$  and 15  $\mu\text{m}$  Buehler diamond grit polishing wheels, and it was then affixed with Epotek 301<sup>TM</sup> to a glass slide. After the epoxy dried, the block was cut to a thickness of about 300  $\mu\text{m}$  using either a Buehler Isomet<sup>TM</sup> low-speed rotating saw or a Buehler Petrothin<sup>TM</sup> high-speed thin-sectioning machine. The remaining portion on the slide was ground on the Petrothin to a thickness of about 40-70  $\mu\text{m}$ . Finally, the slide was polished on the 15  $\mu\text{m}$  wheel until microscopic histological features of the tooth, including cementum, dentine tubules, and osteons in the alveolar bone, could be seen clearly. The slides often varied in their final thickness, depending on the quality of preservation of the histology.

The thin section of the tooth was then examined at magnifications of 50x, 100x, and 200x under transmitted cross-polarized light through an Olympus<sup>TM</sup> BH-2 bifocal microscope. The cementum tissue was examined along all cross-sectional margins of the roots. This "total-sample approach" emphasizes the general state of preservation of the tooth, facilitating the identification of locations where the cementum has physically and chemically deteriorated. In turn, this reduces the possibility of counting "false" bands or of overlooking bands that through diagenesis have become discontinuous along the root.

#### *The Thick Section Method.*

The fragmented tooth specimens prepared by Spiess were sectioned by utilizing fortuitous fractures or with a jeweler's saw. Tooth fragments that preserved

coronal portions of tooth roots and the lower portions of enamel were preferred for sectioning, because incremental structures appear very clear and regular in this region of the tooth, around the cementum-dentine-enamel juncture. The pieces chosen for sectioning were coated with a dilute B-76 resin dissolved in acetone (this is a museum conservation glue that inhibits penetration of the tooth by epoxy during the mounting stage). The tooth fragments were subsequently mounted in West System 105 epoxy and hardener. The appropriate longitudinal section was ground through the tooth fragment with a series of finer and finer-grit sandpapers on a Buehler grinding wheel, followed by a final polishing of the thick section. The thick sections were observed in reflected light under a binocular microscope at magnifications of 40x and 100x.

## MATERIALS : THE ARCHAEOLOGICAL CONTEXT

Our cementum increment analysis assemblage focuses on ungulate teeth recovered from Aurignacian strata 2 and 3 in trench C during the 1991 and 1992 field seasons at Trou Magrite (Straus *et al.* 1992, 1993a, 1993b). Radiocarbon assays date these materials to ca. 34.0-27.0 Ka (Straus *et al.* 1993b). Stratum 3 is represented by only one specimen: a bison (*Bison* sp.) maxillary molar. The stratum 2 sample is comprised of six specimens, including reindeer (*Rangifer tarandus*; n=2), ibex (*Capra ibex*; n=3), and horse (n=1; probably *Equus* cf. *germanicus* [Spiess n.d.]). The total stratum 2 "cementum assemblage" represents a minimum of three individuals (MNI=3).

The rest of the "cementum assemblage," providing a broader--although still highly limited--interpretive context for the Trou Magrite remains, includes reindeer, red deer (*Cervus elaphus*), and ibex teeth from Sclayn, Trou du Diable à Hastière-Lavaux, and Trou Reuviau à Furfooz. The Sclayn V<sub>b</sub> teeth (n=5; MNI=3) are associated with Middle Paleolithic artifacts from what may have been a discrete living floor; this material dates to the end of the last interglacial (ca. 80.0 Ka) (Otte 1990; Otte *et al.* 1988). The Sclayn I<sub>a</sub> tooth is from a late Mousterian context, dating to 38.0 Ka (Otte 1984b).

The two samples from Trou Reuviau (MNI=2) and the ten teeth from Hastière (MNI=5) were excavated by E. Dupont during the late 19th century (Dupont 1872). Although Dupont defined geological and archaeological strata during his excavations, he clearly conflated cultural layers at these two sites (Otte 1979; Sonnevile-Bordes 1961). Consequently, the samples from Reuviau are associated with either Aurignacian or Perigordian artifact assemblages (Otte 1979). No radiocarbon dates have been obtained from this site; on typological grounds the Reuviau teeth may date from 34.0 Ka-20.0 Ka. The Hastière material is from Dupont's stratum 2, which is a *mélange* of Mousterian and Aurignacian lithics. Recent excavations provide a secure radiometric date of 46.0 Ka for the Mousterian deposits at Hastière (Toussaint 1988). The Aurignacian materials are dated by

typological associations to the Arcy oscillation, an episode of climatic amelioration from 31.0 to 29.0 Ka (Otte 1984a). The teeth from Hastière may be associated with either of these two periods of occupation. Consideration of these materials from Reuviau and Hastière requires an additional qualification about context; these faunal assemblages have not been re-analyzed systematically, and consequently, carnivore activity cannot be excluded as a depositional agent at the two sites.

## RESULTS

The results of analysis are presented in Tables 9.2-9.3-9.4. Three specimens from Trou Magrite strata 2 and 3 exhibited very poorly preserved cementum, and in certain locations on the roots the cementum had been entirely removed by diagenetic processes. These specimens, for which no seasonality and mortality results were obtained, represent isolated teeth, unprotected by alveolar bone. Only one tooth yielded a reading from both Lieberman and Spiess, resulting in mutually contradictory interpretations. This contradiction is not surprising considering the relatively poor condition of preservation of the tooth (Spiess n.d.).

In all other cases--for the reindeer samples from Trou Magrite and for the other three sites--the outer cementum band was positively identifiable. In most, but not all, of these samples, the number of increments was exactly identified; for some samples, though, post-depositional degradation of the collagen in the cementum blurred originally distinct bands, allowing only an estimation of the number of bands. Overall, the results allow us to infer a "revised MNI" for each site, because teeth from potentially complementary elements (e.g., right and left mandibles) that exhibit different season of death and/or age at death in their cementum cannot be from the same individual (cf. Pike-Tay 1991). The revised MNI numbers are presented in Tables 9.2-9.3-9.4. The seasonality and mortality patterns are treated below for each separate site.

### *Trou Magrite*

With the exception of Spiess's finding on the ibex M<sup>2</sup> (TM-I6-54), the strata 2 and 3 data exhibit reindeer, ibex, and bison kills between January and April. A. Gautier has provided additional seasonality information from his assessment of tooth eruption patterns in juvenile reindeer mandibles from strata 2 and 3 (L. G. Straus, personal communication). From his stratum 2 sample (n=3) Gautier determined that one reindeer fawn was taken in early fall and two killed during winter. The stratum 3 tooth eruption assemblage (n=3) reveals one fawn killed during the fall, one yearling taken in early fall, and one fawn hunted during the winter. Thus, the cementum and tooth eruption data now available hint that fall, winter, and early spring kills predominate the Aurignacian strata at Trou Magrite. The mortality information from the cementum increment analysis reveals that four prime adults were taken during the Aurignacian occupations at Trou Magrite. Also,

Tableau 9.2 : Le Trou Magrite-Aurignacien

Revised MNI = 4

Sample	Stratum	Species	Bone	Tooth	Wear	No. of Bands	Outer Band	Est. Age at Death	Est. Season of Death
TM3 (DEL)	3	<i>Bison cf. priscus</i>	max	M1?	H	4	thin-normal opaque	2.5-3.5?	winter
TM-I6-54 (AES)	2	<i>C. ibex</i>	I. max	M2	H	7	thin "opaque"*	4.5-5	late spring-fall
TM-I6-54 (DEL)	2	<i>C. ibex</i>	I. max	M2	H	8	normal opaque	5.0?	winter-early spring
TM-G6-2 (AJS)	2	<i>R. tarandus</i>	r. max	M2	L-M	4	thick opaque	3.0-3.5	late winter-early spring
TM-I7-19 (AJS)	2	<i>R. tarandus</i>	I. mand	M2	M	10	normal opaque	6.0-6.5	winter-early spring

\* This sample was analyzed under reflected light; "Opaque" here is equivalent to translucent in all other samples.

Table 9.3 : Le Trou du Diable a Hastière (IRSNB # 3868) - mixed Mousterian and Aurignacian

Revised MNI = 8

Sample		Stratum	Species	Bone	Tooth	Wear	No. of Bands	Outer Band	Est. Age at Death	Est. Season of Death
HAS 1	(AJS)	2	<i>R. Tarandus</i>	r. mand	P4	M-H	8-12	normal-thick opaque	6.0-9.0	late winter-early spring
HAS 2	(AJS)	2	<i>R. Tarandus</i>	r. mand	M1	L-M	3	normal translucent	2.0-2.5	summer-fall
HAS 3	(AJS)	2	<i>R. Tarandus</i>	I. max	P4	M	12	normal opaque	8.0-9.0	winter-early spring
HAS 4	(AJS)	2	<i>R. Tarandus</i>	I. mand	P2	M	12	thick opaque	8.0-9.0	late winter-early spring
HAS 5	(AJS)	2	<i>R. Tarandus</i>	r. mand	P3	M	13	normal-thick translucent	8.5-9.5	late summer-fall
HAS 6	(AJS)	2	<i>R. Tarandus</i>	I. mand	P3	M	20-24	normal opaque	12.0-15.0	winter-early spring
HAS 7	(AJS)	2	<i>R. Tarandus</i>	I. mand	M2	L	6	normal-thick opaque	4.5	late winter-early spring
HAS 8	(AJS)	2	<i>C. ibex</i>	r. mand	M1	L	7	thick translucent	4.0-4.5	fall
HAS 9	(AJS)	2	<i>C. ibex</i>	I. mand	M1	H	16	normal opaque	8.5-9.0	winter-early spring
HAS 10	(AJS)	2	<i>R. Tarandus</i>	I. mand	P2	L	5	normal-thin translucent	4.5-5.5	late spring-summer

Table 9.4 : Le Trou Reuveau (IRSNB # 2668) - mixed Aurignacian and Perigordian

Revised MNI = 2

Sample	Stratum	Species	Bone	Tooth	Wear	No. of Bands	Outer Band	Est. Age at Death	Est. Season of Death
TR1	(AJS) n/a	<i>R. tarandus</i>	I. mand	P4	L-M	2	normal opaque	0.5-1.0	winter-early spring
TR2	(AJS) n/a	<i>R. tarandus</i>	I. mand	M1	L-M	5	normal translucent	3.0-3.5	summer-fall

La Grotte de Sclayn-Mousterian

Revised MNI = 6

Sample	Stratum	Species	Bone	Tooth	Wear	No. of Bands	Outer Band	Est-Age at Death	Est. Season of Death
SC-D15-5Vb	(AJS) Vb	<i>R. tarandus</i>	r. mand	M3	L-M	9	normal translucent	6.0-7.5	summer-fall
SC-82-337	(AJS) Vb	<i>R. tarandus</i>	r. mand	M1	M	6	normal opaque	3.5-4.0	winter-early spring
SC-83-81VB	(AJS) Vb	<i>R. tarandus</i>	I. mand	P4	L	4	thin-normal opaque	1.5-2.0	winter
SC-83-90Vb	(AJS) Vb	<i>C. elaphus</i>	r. mand	P3	L	4	normal opaque	2.0-2.5	winter-early spring
E19167	(AJS) Vb	<i>C. elaphus</i>	r. max	P3	L	3	normal-thick translucent	1.5	late summer-fall
SC-82-246C1a	(AJS) Vb	<i>R. tarandus</i>	r. max	M1	L	8	normal opaque	4.5-5.5	winter-early spring

Gautier has identified an additional minimum of 8 additional prime reindeer from stratum 2 (L. G. Straus, personal communication). The six tooth eruption samples reflect that juvenile animals were also hunted, but the available sample indicates a prime-dominated mortality profile.

*Trou du Diable-à-Hastière-Lavaux*

In contrast to the Trou Magrite results, the samples from the mixed Mousterian and Aurignacian deposits at Hastière indicate clear evidence of summer kills (see Table 3: HAS10 and possibly HAS2). However, the prevailing pattern remains one of fall, winter, and early spring kills (October-April), with two specimens (revised MNI=2) providing strong evidence for fall kills and six teeth (revised MNI=5) suggesting winter-early spring hunting. The mortality profile reveals a bias toward old individuals; four of the reindeer and one of the ibex taken were eight years or older at death, and an additional reindeer may have been as old as nine years. HAS2 represents the only sub-adult in the assemblage.

*Trou Reuviau-à-Furfooz*

Not enough data from the Aurignacian-Perigordian deposits at this site are available to suggest any apparent seasonality and mortality patterns.

*Le Grotte de Sclayn V<sub>b</sub>*

The Mousterian data from Sclayn V<sub>b</sub> reveal a pattern that is consistent with the focus on fall-winter kills evident from the cementum and tooth eruption data for Trou Magrite and Hastière. Three individuals (revised MNI=3) from Sclayn V<sub>b</sub> were taken between January and April. The other two specimens (a reindeer mandibular molar and a red deer maxillary deciduous premolar) could have been taken at any time between May and December. If the Mousterian foragers at Sclayn followed the same fall-early spring seasonality pattern that we have suggested for the other sites, then these latter two specimens would have been hunted during the fall. However, the data from Sclayn does not preclude the alternative interpretation that about half of the specimens represent winter-early spring kills and the other half show summer kills. The mortality profile reveals three juveniles, one prime adult, and one old prime adult.

## DISCUSSION

The cementum increment data from the Mosan Basin, along with complementary tooth eruption information, clarify an important, but very general point. The simple presence of winter kills implies that during the Upper Pleistocene, in all but the most extreme arctic climatic oscillations, the Meuse River drainage and its adjoining tributary valleys provided adequate cold-season resources and shelter to support small groups of hominid foragers. The spectrum of faunal species present in

Middle and early Upper Paleolithic deposits in Mosan Basin caves indicates clearly that a variety of winter microhabitats survived along the river valley ecotone. Ibex would have inhabited the steep, rocky cliffs that frequently line valley margins in southern Belgium, and red deer and other cervid species would have occupied floodplain gallery forests and sheltered forest patches on talus slopes (cf. Spiess 1979). In addition, the Mosan Basin foragers appear to have taken advantage of caves with south-facing mouths, which provide maximum winter solar radiation exposure for the inhabitants (cf. White 1985).

For addressing more specific issues of hominid subsistence economy, the data we have presented do suggest new hypotheses, although they are not statistically sufficient to test them. For instance, the seasonality data presented in this chapter are consistent with the hypothesis that from the last interglacial to the early Upper Paleolithic (ca. 80.0-20.0 Ka), caves in the Mosan Basin were mainly occupied during the fall and winter seasons (October-April), and more specifically, most activity occurred during the winter and early spring. Yet, our data do make it evident that Upper Pleistocene hominids hunted in the Mosan Basin during the summer at least occasionally. The low frequency of summer kills apparent in our preliminary analysis, then, raises the unanswered question of where these hunter-gatherers settled from May through September. We will mention three possibilities. First, hunter-gatherer groups may have occupied open air sites within the Mosan Basin during the summer as part of a year-round occupation of the river valleys. Second, these groups may have moved seasonally out of the valleys to hunt reindeer, horse, and other gregarious species that would have migrated to upland or open regions, such as the plains toward the Atlantic to the west and northwest (it should be kept in mind, though, that settlement patterns probably varied through time and that the Mosan Basin may not have been occupied continuously from the Last Interglacial through the early Upper Paleolithic). Third, it is conceivable that summer kills were originally present at the Mosan Basin cave sites but have not yet been uncovered or by fluke have not survived. The mortality profiles we have presented, like the seasonality information, may also reflect a statistical peculiarity caused by our small sample size. In general, cementum increment analysis provides accurate seasonality and mortality profiles, and we hope that future research will yield robust representative samples.

## CONCLUSION

In looking toward future investigations, we propose that the cementum increment data presented above may reflect two evolutionarily important trends:

- (1) Middle Paleolithic and early Upper Paleolithic hominids occupied the Mosan Basin primarily during fall and winter.
- (2) By the early Upper Paleolithic, hominid foragers in the Mosan Basin

(for example, those occupying Trou Magrite in stratum 2 times) regularly procured prime adult herbivore prey. In contrast, their Mousterian antecedents (including those occupying Hastière and Sclayn 5<sub>b</sub>) focused on juvenile and/or elderly prey.

If future research demonstrates that the second hypothesis is correct, then it would suggest an increase in foraging efficiency across the Middle-Upper Paleolithic transition. In turn, such a temporal development would imply some important behavioral and/or technological adaptation. In particular, the Mosan Basin mortality profiles *might* reflect a temporal development similar to that which Stiner (1990) identifies in the Upper Pleistocene of west-central Italy (see also Stiner and Kuhn 1992). She presents evidence to suggest that the old-dominated mortality profiles of early Mousterian faunal assemblages from Italian sites represent a significant amount of scavenging behavior, while late Mousterian and Upper Paleolithic prime-dominated profiles reveal increasing frequencies of the ambush hunting. If our first hypothesis also proves to be correct, then we might explore possible factors of seasonal weather patterns, spatial and temporal food resource distribution, population density, and regional social networks; one or more of these variables may help reveal how a change in foraging efficiency occurred while a significant temporal continuity in seasonal mobility patterns was maintained.

#### ACKNOWLEDGMENTS

We thank L. G. Straus and M. Otte for providing the tooth samples for analysis and for their encouragement and thoughtful feedback. We are also grateful to M. Germonpré and A. Gautier for their assistance in Belgium, and to O. Bar-Yosef for advice and encouragement. R. H. Meadow kindly made the wear estimates for the *Rangifer* specimens from Trou Magrite and the samples from Sclayn, Reuviau, and Hastière. J. D. Speth provided thoughtful feedback on drafts of this paper. A. M. Burke gave additional clarifying comments. This research was partially funded by the American School of Prehistoric Research (Peabody Museum, Harvard University), the Harvard University Department of Anthropology, and the National Science Foundation.

## REFERENCES

- BOURQUE B. J., MORRIS K. and SPIESS A., 1978,  
Determining the season of death of mammal teeth from archeological sites: a new sectioning technique. *Science* 199(3):530-1.
- BURKE A. M., 1992,  
*Prey Movements and Settlement Patterns During the Upper Palaeolithic of Southwestern France*. PhD dissertation, New York University. University Microfilms International, Ann Arbor.
- DUPONT E., 1872,  
*L'Homme Pendant les Ages de la Pierre dans les Environs de Dinant-Sur-Meuse*. Librairie de la Cour et de S. A. R. le Comte de Flandre.
- GORDON B., 1998,  
*Of Men and Reindeer Herds in French Magdalenian Prehistory*. BAR International Series 390.
- GRUE H. and JENSEN B., 1979,  
Review of the formation of incremental lines in tooth cementum of terrestrial mammals. *Danish Review of Game Biology* 11:1-48.
- HILLSON S., 1986,  
*Teeth*. Cambridge University Press, Cambridge.
- KLEVEZAL G., 1988,  
*Recording Structures of Mammals in Zoological Investigations*. Nauka, Moscow.
- LIEBERMAN D. E., 1993a,  
Life history variables preserved in dental cementum microstructure. *Science* 261:1162-4.

- LIEBERMAN D. E., 1993b,  
*Mobility and Strain: The Biology of Cementogenesis and its Application to the Evolution of Hunter-gatherer Seasonal Mobility during the Late Quaternary in the Southern Levant*. PhD dissertation, Harvard University. University Microfilms International, Ann Arbor.
- LIEBERMAN D. E., 1993c,  
The rise and fall of seasonal mobility among hunter-gatherers: the case of the southern Levant. *Current Anthropology* 34(5):599-631.
- LIEBERMAN D. E., 1994,  
The biological basis for seasonal increments in dental cementum and their application to archaeological research. *Journal of Archaeological Science* 21:525-539.
- LIEBERMAN D. E., DEACON T. and MEADOW R. H., 1990,  
Computer image enhancement and analysis of cementum increments as applied to teeth of *Gazella gazella*. *Journal of Archaeological Science* 17:519-533.
- LIEBERMAN D. E. and MEADOW R. H., 1992,  
The biology of cementum increments (an archaeological perspective). *Mammal Review* 22:57-77.
- O'BRIEN C. and MIRACLE P., 1994,  
Hominid Prey Acquisition in the Balkan Late Pleistocene. Paper presented at the 59th Annual Meeting for the Society for American Archaeology, Anaheim, California.
- OTTE M., 1979,  
*Le Paléolithique supérieur ancien en Belgique*. Monographies d'Archéologie Nationale 5.
- OTTE M., 1984a,  
Paléolithique supérieur en Belgique. In *Peuples Chasseurs de la Belgique Préhistorique dans leur Cadre Naturel*, edited by D. Cahen and P. Haesaerts. Institut royal des Sciences naturelles de Belgique, Brussels. pp. 157-179.

- OTTE M., 1984b,  
Sol d'occupation du Paléolithique Moyen aux grottes de Sclayn (Belgique).  
*L'Anthropologie* 88(1):115-7.
- OTTE M., 1990,  
L'Occupation moustérienne de Sclayn (Belgique). *EAZ Ethnogr.-Archäol. Z.*  
31:78-101.
- OTTE M., EVRARD J.-M., and MATHIS A., 1988,  
Interprétation d'un habitat au Paléolithique moyen: la grotte de Sclayn,  
Belgique. In *Upper Pleistocene Prehistory of Western Eurasia*, edited by H.  
Dibble and A. Montet-White. The University Museum, Philadelphia. pp. 95-  
124.
- PIKE-TAY A., 1991,  
*Red Deer Hunting in the Upper Paleolithic of South-West France: A Study in  
Seasonality*. BAR International Series 569.
- SAXON A. and HIGHAM C., 1968,  
A new research method for economic prehistorians. *American Antiquity*  
34(3):303-11.
- SONNEVILLE-BORDES D. de, 1961,  
Le Paléolithique supérieur en Belgique. *L'Anthropologie* 65(5-6):421-443.
- SPIESS A. E., 1976,  
Determining season of death of archaeological fauna by analysis of teeth.  
*Arctic* 29:53-5.
- SPIESS A. E., 1978,  
Zooarchaeological evidence bearing on the Nain area Middle Dorset  
Subsistence Settlement Cycle. *Arctic Anthropology* 15(2):48-60.
- SPIESS A. E., 1979,  
*Reindeer and Caribou Hunters: An Archaeological Study*. Academic Press,  
New York.

- SPIESS A. E., 1990,  
Deer tooth sectioning, eruption, and seasonality of deer hunting in prehistoric  
Maine. *Man in the Northeast* 39:29-44.
- SPIESS A. E., n.d.,  
Notes on preservation and annual layers: five teeth from le Trou Magrite.  
Unpublished manuscript.
- STINER M. C., 1990,  
The use of mortality patterns in archaeological studies of hominid predatory  
adaptations. *Journal of Anthropological Archaeology* 9:305-351.
- STINER M. C. and KUHN S. L., 1992,  
Subsistence, technology, and adaptive variation in Middle Paleolithic Italy.  
*American Anthropologist* 94:306-339.
- STRAUS L. G., OTTE M., LÉOTARD J.-M., GAUTIER A. and HAESAERTS P., 1992,  
Middle and Upper Paleolithic excavations in southern Belgium: a *preliminary*  
report. *Old World Archaeology Newsletter* 15(2):10-18.
- STRAUS L. G., OTTE M., GAUTIER A., HAESAERTS P., MARTINEZ A., NEWMAN  
M. and SCHUTZ C., 1993a,  
1992 Paleolithic excavations in Belgium by the Universities of New Mexico  
and Liège. *Old World Archaeology Newsletter* 16(2):1-11.
- STRAUS L. G., OTTE M., CORDY J.-M., LÉOTARD J.-M., NOIRET P., GAUTIER A.,  
HAESAERTS P., and LACROIX Ph., 1993b,  
Paleolithic & Mesolithic research in Belgium, 1993: le Trou Magrite,  
Huccorgne, and l'Abri du Pape. *Old World Archaeology Newsletter* 17(1):17-  
24.
- STUTZ A. J., 1993,  
*Settlement Patterns in Late Glacial Northwestern Europe: the Example from  
the Lesse Valley Magdalenian.* Unpublished BA thesis. Harvard University,  
Cambridge.

TOUSSAINT M., 1988,

Fouilles 1978-1981 au Trou du Diable à Hastière-Lavaux, province de Namur, Belgique. *Helinium* 28(1):35-43.

WHITE R., 1985,

*Upper Paleolithic Land-use in the Perigord: a Topographic Approach to Subsistence and Settlement*. BAR International Series 253.