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Cover Page Footnote
This article is a revised version of a paper presented at the 1989 Council for Northeast Historical Archaeology meetings in Morristown, New Jersey. The author would like to thank Dr. Mary Beaudry for the opportunity to study the faunal material from the Wilkinson Backlot Site. The help of Guy Pollard, Sterling Presley, and Dr. Bryan Gordon with the preparation and interpretation of the samples is gratefully acknowledged. Thanks to Dr. Richard Meadow who read and commented on an earlier version of this paper. Thanks also to the anonymous reviewers who made valuable suggestions.

THE POTENTIAL APPLICATIONS OF TOOTH CEMENT INCREMENT ANALYSIS IN HISTORICAL ARCHAEOLOGY

David B. Landon

The study of incremental structures in animal teeth is an analytical technique that is receiving increased attention from zooarchaeologists working in many parts of the world. The seasonal and annual cycles in the formation of tooth increments makes them ideal for determining the age of an animal when it was killed and the season of its death. This type of information can contribute significantly to interpretations of past animal husbandry practices. A sample of eight domestic animal teeth from the Wilkinson Backlot Site in downtown Boston, Massachusetts, were studied in this fashion. Microscopic examination of the increment pattern of the cement on the roots of the teeth allowed age and season of death to be estimated. The results suggest that this analytical technique has a great deal of promise for the analysis of historical faunal assemblages, particularly for determining seasonal patterns in animal slaughtering.

L'étude des structures de croissance dans les dents animales constitue une méthode d'analyse à laquelle s'intéressent de plus en plus les zooarchéologues de plusieurs parties du monde. Les cycles saisonniers et annuels qui interviennent dans la croissance dentaire en font l'outil idéal pour déterminer l'âge d'un animal au moment où il a été tué et la saison de sa mort. Ce genre de renseignements peut beaucoup contribuer à faire connaître les pratiques d'élevage du passé. Un échantillon de dent du huit animaux domestiques du Wilkinson Backlot Site *due centre-ville de Boston (Massachusetts) a fait l'objet d'une étude de cette nature. L'examen microscopique du mode de croissance du cément de la racine des dents a permis d'estimer l'âge et la saison de la mort. D'après les résultats de l'étude, cette méthode d'anlyse promet beaucoup en ce qui concerne l'analyse des assemblages fauniques historiques, surtout pour ce qui est de déterminer les pratiques saisonnières dan l'abattage des animaux.*

Introduction

The determination of the age of domestic animals at death and the season in which they were killed provides information valuable for investigating a wide range of research questions. This type of information has a variety of potential applications to the interpretation of cultural activities from historical archaeological sites including animal husbandry patterns and seasonal cycles in activities or site occupation (Bowen 1988; Monk 1981; Saxon and Higham 1969). The microscopic analysis of incremental structures within animal teeth is a valuable technique for discovering the age of the animal at its time of death and the season when it was killed, but it has not been utilized by historical archaeologists. To date, most of the archaeological studies of tooth incrementation have focused on wild animals and prehistoric populations with a major emphasis on determining seasonal site occupation (e.g., Bourque, Morris, and Spiess 1978; Gordon 1982). Increasingly, however, archaeologists are recognizing the potential contributions of this type of analysis to the interpretation of the remains of domestic animals derived from historical contexts (Coy, Jones, and Turner 1982; Stallibrass 1982).

This paper explores the potential applications of this technique to the analysis of faunal assemblages from historical sites. The research questions that animal age and seasonal slaughter information could be used to address, and the typical approaches to acquiring animal age and season of death data, are examined to demonstrate the possible contributions of tooth

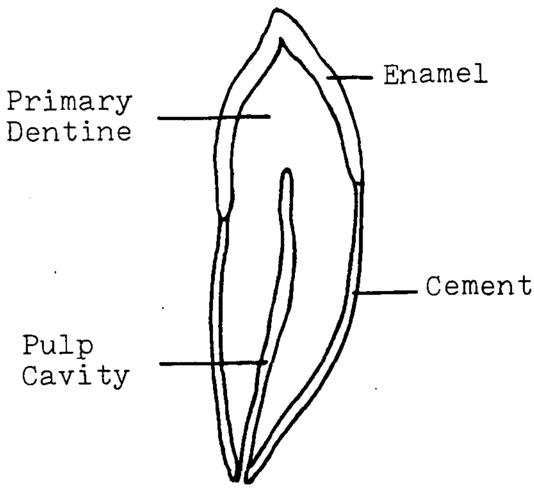

Figure 1. Schematic cross-section of an upper canine of a female pig.

increment analysis the interpretation of these issues. The general process of tooth increment formation is then described, followed by a short review of the existing tooth increment studies for the major domestic animals that typically dominate historical assemblages. A discussion of a sample of eight teeth analyzed from the Wilkinson Backlot Site in downtown Boston follows, including and explanation of the procedures used in the preparation of the samples for analysis. The results of the analysis are presented and interpreted within the context of present views about husbandry practices in colonial New England, with an emphasis on the patterns of seasonal slaughter of different domestic animals.

Seasonality Estimates and Age Profiles

Accurate information about the ages of different animals and their season of death has the potential to elucidate a variety of different issues. This type of information is fundamental to understanding and characterizing past husbandry practices. The "kill-off" patterns derived from age data provide insight into the way that domestic animals were managed (Payne 1973). By combining age data with data about the sexual composition of a specific taxonomic category, interpretations can be developed about the relative importance of different uses of specific species.

Faunal assemblages can provide information about the relative age of animals at the time of death through analysis of the patterns of epiphyseal fusion, tooth eruption, and tooth wear (Davis 1987: 39; Hesse and Wapnish 1985: 73–76). Tooth increment analysis has the potential to provide more accurate information about age than any of these. Epiphyseal fusion "is a sequence that ends relatively early on in the life of the animal" and the remains of immature animals do not survive in the archaeological record as well as the remains of adult animals, two factors that could skew interpretations of kill-off patterns (Payne 1973: 283). Teeth are among the most durable parts of the skeleton and survive postdepositional destruction very well. But basing age estimates on tooth eruption and wear also has some inherent problems, the greatest being that a number of different factors, such as sex and diet, can greatly influence the eruption and wear sequence (Hillson 1986: 201). On the other hand, cement increments in the teeth form throughout the entire life of the animal and can be accurate to several months for deriving age estimates.

Season-of-death data are also directly applicable to understanding herd management practices. The decisions involved in choosing when to slaughter a particular animal were influenced not only by the uses for the animal, but also by meat preservation and other concerns, such as seasonal variations in the availability of fodder and the type of distribution systems utilized for foodstuffs (Bowen 1988; Worlidge 1675). A variety of sources all seem to present a similar pattern for seasonal husbandry and meat procurement practices in colonial New England (Bowen 1988; Derven 1984; McMahon 1981). The beginning of winter was the primary time for the slaughter of cattle and swine, and some of this meat, especially the pork, was salted for consumption during the end of winter and into the spring. Wild fish and fowl were also included in the diet during the winter and through the spring. With the exception of an occasional calf or lamb being slaughtered and eaten, the summer was marked by relatively low meat intake until the slaughter of sheep began in early autumn.

Perhaps the greatest value tooth increment analysis has for historical archaeology is that it provides an analytical technique for incorporating the study of seasonality into the analysis of historical faunal assemblages. Although a seasonal agricultural cycle for rural New England has been clearly demonstrated from the historical documents, it has not been properly addressed by historical archaeologists. Seasonality is more frequently investigated by prehistorians with zooarchaeological studies of seasonal cycles typically based on the characteristics of wild animal assemblages and theoretically framed in a non-sedentary settlement pattern model (Bowen 1988: 161–162). Since historical archaeologists generally study sedentary people and faunal assemblages that are dominated by domestic animals, few attempts have been made to study seasonality even though the seasonal cycle might be an important causative factor in assemblage patterning (Bowen 1988: 162, 170). Tooth increment analysis, by providing a means of determining season of death for domestic animals, can contribute significantly to the interpretation of historical faunal assemblages.

Cement Increment Formation

Teeth are particularly good for incremental analysis because incremental formation can take place in most of the major components (i.e., enamel, dentine, and cement; FIG. 1). Cement increments are ideal for analysis for a number of reasons. Cement serves to anchor teeth into the mandible, forms continuously, and is not subject to as much reabsorption as some other structures, such as bone (Hillson 1986: 166). Further, since the primary area of cement formation is on the exterior of the root of the tooth, it is not subject to spatial constraints in its formation, unlike secondary dentine, which forms in the pulp cavity (Stallibrass 1982: 111). Finally, research has shown that in a wide variety of mammals the formation of cement increments is tied to an annual rhythm, highlighting the applicability of this type of analysis to age and seasonal estimates (Hillson 1986: 165).

At present there is some disagreement among researchers as to what factors cause the formation of incremental structures in cement; factors such as lactation, rutting, and nutritional stress have all been suggested (Stallibrass 1982). The underlying physiological processes leading to the cyclical deposition of tooth cement are still unknown, and a comprehensive multifactorial model for increment formation has yet to be formulated (Condon et al. 1986: 328). There is general agreement, however, that the causes are primarily related to physiological responses that result in alternating periods of rapid and slow deposition of cement that most researchers correlate with periods of summer and winter deposition, respectively (Saxon and Higham 1968; Stallibrass 1982). The changes in the rate of cement deposition result in the formation of alternating wide and narrow bands of cement. One narrow and wide band together represent one year, and since these alternating bands are formed seasonally, identification of the outermost band allows estimation of the season of death.

Cement Increments in Domestic Species

As mentioned previously, little work has been done with tooth incrementation in domestic species. The studies that have been done on sheep teeth are primarily based on analyses of wild sheep (Hemming 1969; Turner 1977), although Saxon and Higham have studied domestic sheep (1968, 1969). All four studies agree on the value of cement increment analysis for forming age estimates, but there is some disagreement on the factors causing increment formation. Hemming (1969) and Turner (1977) suggest, respectively, that the lambing season and the rut influence the formation of increments. Saxon and Higham (1968, 1969), on the other hand, found no conclusive evidence of sexual cycles as causative factors in increment formation, and argue for formation based predominantly on seasonal metabolic changes (1968, 1969). Only Saxon and Higham (1969) focus on the potential of increment analysis for interpretations of the season of death. Samples of domestic cow and pig teeth have received even less attention. In their study of sheep teeth, Saxon and Higham state that domestic cattle and pigs do appear to have increments in the cement (1968: 635). This appears to be the only account of increment analysis of pig teeth. Both modern and archaeological examples of cow teeth have been studied. Coy, Jones, and Turner (1982) examined teeth from modern cattle and also archaeological materials from the Saxon period. Their results from modern cattle teeth clearly point out the potential difficulty of using cement increment analysis to study archaeological samples. Analysis of the same tooth (M_1) from both sides of the same mandible produced different increment counts in fourteen out of seventeen cases, with the average difference being just under three (2.88) increments (Coy, Jones, and Turner 1982: 136). The increment count also failed, in most instances, to accurately correlate with the known age of the animal. Analysis of archaeological samples appeared to be somewhat more successful; there was a closer correlation between the tooth wear

stage and the increment count in the archaeological samples than in the modern samples. This must be viewed cautiously, however, since the actual ages of the animals in the archaeological samples were unknown. In addition, since only one tooth was examined from each archaeological sample, there was no chance to see the type of intertooth variation present in the modern sample. The extremely high degree of intertooth variation in the modern sample and the absence of a clear correlation between the increment count and the animal's known age raises some serious questions about the validity of making age or season-of-death estimates from archaeological samples of cattle teeth. As these researchers point out, accurate interpretation of archaeological samples of cow teeth will require a good deal more work with modern examples of known age, sex, and nutritional history. Since very little study has been done of tooth incrementation in domestic animals, it is difficult to determine the implications of Coy, Jones, and Turner's work for the study of other domestic animals. In their study of sheep teeth, Saxon and Higham (1969) sectioned and analyzed a number of different teeth from each animal but found no intertooth variation which could not be correlated with differences in the sequence of tooth eruption; in all instances, the increment count consistently matched with the known age of the animal. The differences between the results of these two studies suggest that there may be differences in the pattern of cement increment formation in different domestic animals. As a result, the potential contributions of cement increment analysis to the interpretation of historical faunal assemblages will only be realized once detailed studies of increment formation in modern domestic animals have been completed. Studies of this type by historical archaeologists would not only be of value to the interpretation of historical faunal assemblages, but clearly would also have value for researchers studying the formation of tooth increments in other animals.

An Example from Boston

A discussion of a sample of eight teeth, all from domestic animals, excavated from the Wilkinson Backlot Site in downtown Boston, Massachusetts, provides a more specific example of the applicability and value of tooth increment analysis (FIG. 2). The site was excavated in 1983 by Mary Beaudry under the auspices of the Center for Archaeological Studies at Boston University. One of the most significant features discovered was a waterlogged pit filled with materials dating to the late 17th century (Beaudry 1984). The pit apparently was dug originally as a sawpit and was later filled with domestic refuse (Kelso and Beaudry 1990: 73). As a result of the waterlogged conditions, preservation of organic material, including faunal remains, was quite good. Six of the eight teeth examined came from this pit, and the other two came from a later deposit at the same site.

Essentially from the time of Boston's founding, market transactions of agricultural products took place. "Boston had outgrown its own food resources when the

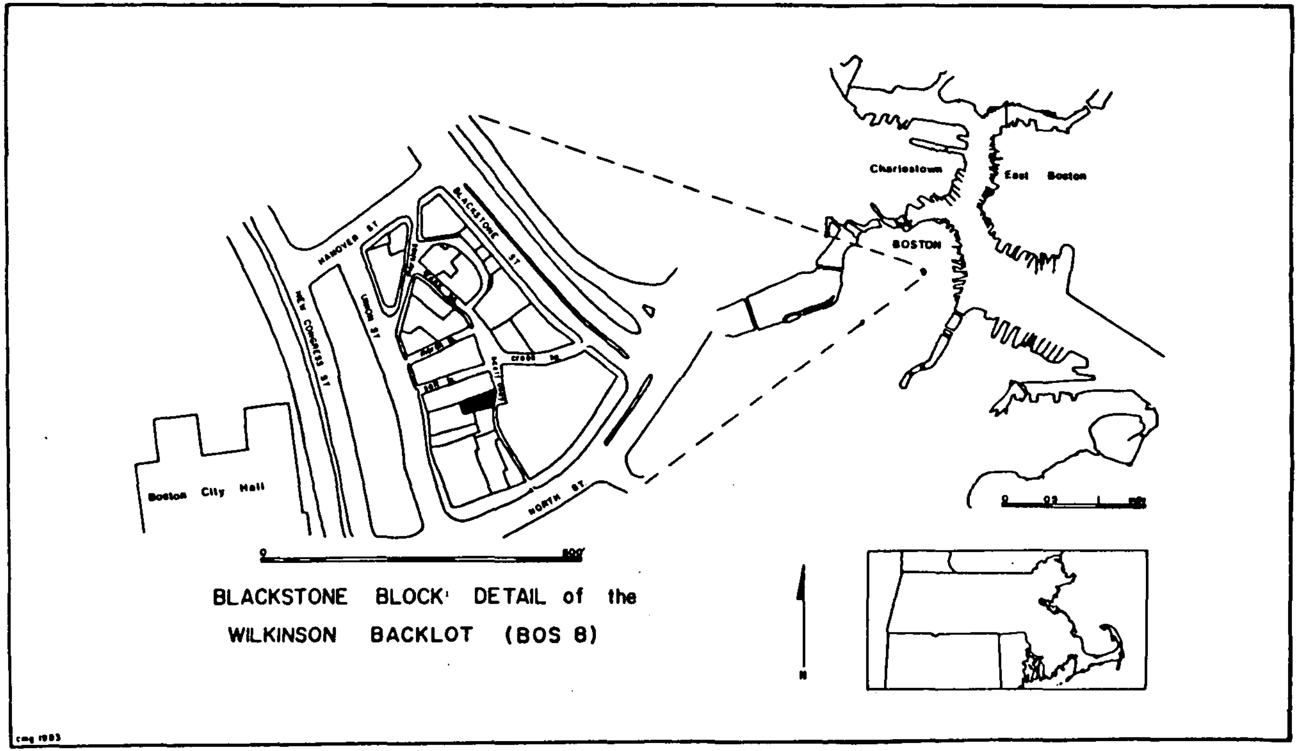

Figure 2. Location of the Wilkinson Backlot Site in downtown Boston. (Drawing by Conrad M. Goodwin.)

population reached an estimated 1,200 in 1640, a decade after its settlement" (Friedman 1973: 189). To meet the demands of the city's population for food, and at the same time provide agricultural surplus for export, required the establishment of a market structure to bring such products into the city. While it is difficult to derive a comprehensive picture of Boston's food supply, historical studies have pointed to the growth of an important market orientation and structure (Clemens 1923; McManis 1975; Russell 1976; Rutman 1963).

Information on the age and season of death of domestic animals from colonial Boston might offer insight into the nature and development of the city's food supply and distribution system. Significant differences may exist between urban and rural assemblages in terms of the age and sex structure of the animals represented. Animal husbandry geared solely towards food production entails a series of choices about animal slaughtering based on ages and sexes that might differ from husbandry focused on utilization of domestic animals for nonfood uses such as important byproducts (hair or hides), transportation, or traction (e.g., Payne 1973). An urban marketing system for animal foods, such as the one in colonial Boston, might be dominated by animals husbanded primarily for food production. Faunal assemblages deposited by urban consumers might therefore have a certain degree of patterning in terms of the age and sex structure of the animals represented (Zeder 1984: 285).

The potential for a seasonal cycle in the availability of different food sources is also relevant to the examination of the relationship between food consumers and producers and the type of internal distribution mechanisms within Boston. In more rural areas of New England local exchange and seasonal slaughtering helped overcome meat preservation problems (Bowen 1988: 165). The husbandry decisions of rural producers in terms of a seasonal slaughtering might not hold for production aimed at meeting the high level of urban demand. The degree to which urban faunal assemblages in New England agree with rural seasonal husbandry and meat availability cycles would have implications for understanding the development of distribution and procurement patterns in an urban area. If, for example, urban assemblages show a similar seasonal cycle in animal slaughtering patterns, it would suggest that the typical rural practices still held for Boston and that the urban market did not sufficiently affect production to alter the seasonal slaughter pattern. On the other hand, if urban assemblages do not seem to follow this type of pattern, it might be in part the result of the high and constant demand for meat and the effective distribution systems present in a large urban area. An animal could be slaughtered at any time of the year and still be distributed and consumed before meat preservation problems (which helped influence slaughter decisions in more rural areas) became an issue (Bowen 1988: 169).

Table 1. Characteristics of the teeth sectioned

Sample #*	Species	Tooth	Tooth Wear/Age†	Measurements§	
1	*Ovis/Capra* sheep/goat	M_2	M_1: 15A, M_2: 12A, M_3: 11G/ 6-8 years	7)	65.2
				8)	44.0
				10L)	21.8
				10B)	8.4
				CH)	8.9
				15a)	32.4
				15b)	20.2
				15c)	18.8
2	*Bos taurus* cow	M_3	M_3: g/ > 24-30 months	10L)	39.0
				10B)	15.8
				CH)	44.6
3	*Sus scrofa* pig	LC**	≥ 6-12 months	CH)	21.4
4	cf. *Ovis* probable sheep	M_1	M_1: 0, dP_4: 13L/ ca. 2-6 months	B)	4.5
				CH)	14.7
				CHI)	2.15
5	*Sus scrofa* pig	I^1	≥ 11-17 months	L)	11.2
				B)	6.1
6	*Sus scrofa* pig	UC**	≥ 11-17 months	L)	12.5
				B)	7.8
7	*Sus scrofa* pig	I_3	≥ 6-12 months	L)	17.5
				B)	5.4
8	*Sus scrofa* pig	M^1	M^1: c, M^2: a/ > 12-16 months	L)	1.5
				B)	13.6

* These numbers are used consistently to refer to the same tooth.
†Tooth wear stages based on Payne (1987) for Ovis/Capra and Grant (1982) for Bos taurus and Sus scrofa. Ages are based on information in Hillson (1986). If the tooth sectioned was in a mandible or maxilla with other teeth all wear stages are given.
§ Measurements are in millimeters and are based on von den Driesch (1976). CHI is the crown height index for dP_4 (Payne 1985). Missing measurements indicate fragmentary teeth.
** Female.

Thin-Sectioning Procedures

Examination of the tooth increments is based on microscopic analysis of the cement. A variety of different procedures can be used for preparation of samples; the method used influences the appearance of the increments (see Hillson 1986: 167–175 for a discussion of procedures). Polarized transmitted light observation of unstained thin sections was used for the samples reported in this paper. As a result age and seasonality estimates are based on observation and counting of alternating wide translucent increments (interpreted as summer deposition) and narrower opaque increments (interpreted as winter deposition).

The sample of eight teeth consisted of one cow tooth (*Bos taurus*), two

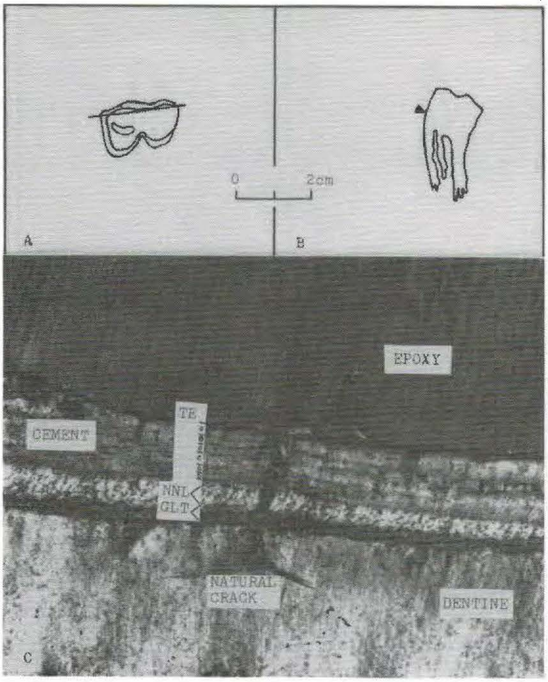

Figure 3. *Ovis/Capra,* M_2 (sample 1): a) occlusal view of tooth showing location of section cut; b) sketch of thin section showing location of photograph; c) photograph of cement increments at 75X, f16, 1sec. [GLT– Granular layer of Tomes. NNL– neonatal line. TE– tooth edge. –= opaque increment. o= translucent increment.]

sheep/ goat teeth (*Ovis/ Capra*), and five pig teeth (*Sus scrofa*) (TAB. 1). The procedures used to prepare the sections for analysis were designed to produce a high quality thin section of approximately 35 microns in thickness to allow examination using a polarized transmitted light. Specimens were labelled with India ink on both sides of the enamel, placed in a small flat plastic box, and all were completely covered with epoxy. They were then placed in a vacuum chamber and evacuated at 25–30 in of mercury for about 20 minutes. The molds were allowed to cure for approximately 24 hours and were monitored to avoid heat buildup during the time that the epoxy was setting.

Once the epoxy had cured, the block of epoxy containing the specimens was segmented into blocks containing individual teeth using a high-speed Raytech Jem Saw with a diamond wafering blade. Each tooth was then sectioned in such a manner that the cementum was 90° to the face of the sectioned specimen (FIGS. 3a, 4a, 5a). The face of the block to be mounted to produce the specimen was first flattened on a 100 micron grinding wheel and then polished by hand on a Beuhler Handimet stripgrinder. The polished surface was then cleaned and mounted with epoxy on a glass microscope slide labelled with the site designation and the specimen number.

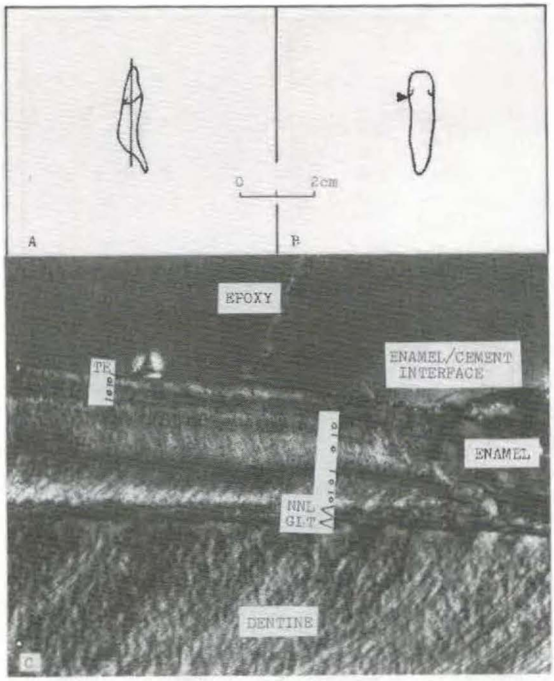

Figure 4. *Sus scrofa*, I3 (sample 7): a) lingual view of tooth showing location of section cut; b) sketch of thin section showing location of photograph; c) photograph of cement increments at 75X, f16, 1sec. [GLT– Granular layer of Tomes. NNL– neonatal line. TE– tooth edge. –= opaque increment. o= translucent increment.]

Once the mounted specimens had cured, they were resectioned to approximately 750 microns on a Beuhler Petrothin machine, and then ground down to about 130 microns using the same instrument. At this point, further grinding was done slowly by hand using a glass lapping plate and 1000 grit silicon carbide. During this process the samples were checked frequently with a polarized transmitted light microscope to ascertain if any increments were visible. When increments became visible the thinning was stopped, the slide was cleaned, and a cover slip was affixed.

Observation of the sections produced was carried out using a Vickers M70a Polarizing Microscope. To start, the entire band of cement around the edge of the root was scanned to view the entire pattern of incrementation. An effort was made to identify potential problems that could affect interpretation, such as areas where cement had been reabsorbed, areas of tooth mineralization, and the possible presence of hidden, split, or accessory increments. Places where the increments were particularly clear were marked on the slide, and the best spot was then chosen and photographed (FIGS. 3, 4, 5). To the extent that it was feasible, the interpretation and the photographs are of cement areas near the enamel/cement interface (FIGS. 3, 4, 5).

Table 2. Summary of opaque and translucent increment counts, age estimates, and season of death estimates.

Sample #	Species	Increment Pattern*	Age†	C§	Last Increment	Season of Death**	C§
1	*Ovis/Capra*	OTOTOTOTOTOT	$6^1/_2$ yrs.	4	Full T	Autumn	4
2	*Bos taurus*	OTOT	2+ yrs.	2	? T	Summer	1-
3	*Sus scrofa*						
4	cf. *Ovis*	T	several mo.	5	$^1/_4$T	Early Summer	4+
5	*Sus scrofa*	OTOTOTOTOTOTOTO	$7^2/_3$yrs.	3+	$^1/_4$O	Early Winter	2
6	*Sus scrofa*	OTOTOTOTOTOTOTO	$7^3/_4$ yrs.	2+	$^3/_4$O	Late Winter	3
7	*Sus scrofa*	TOTOTOTOTOT	$5^1/_2$yrs.	3	Full T	Autumn	4
8	*Sus scrofa*	OTOTOTOTOTOTOTOT	$8^1/_2$yrs.	2	Full T	Autumn	1

* T = translucent increment, O= opaque increment.
† Assumes a spring birth. No years were added to any of the increment counts to derive age. For cow and pig, increment ages should be considered relative until modern samples of known ages are studied.
§ Degree of confidence, subjectively scaled from 1 to 5, 5 being the greatest amount of confidence.
** Based on the wide translucent increment representing summer and the narrow opaque increment representing winter.

Results of Analysis

In terms of the implications of the age and seasonality data for interpreting husbandry practices, the extremely small sample size (which is compounded by the fact that three different species are being examined) makes it difficult to support any generalizations, and the results for cow and pig (TAB. 2) must be considered tentative until modern comparative material with animals of known ages has been further examined. Also, one of the slides (sample 3) did not survive the section preparation process very well, and became mostly separated from the slide during final thinning. Finally, the similarities between two of the pig teeth (samples 5 and 6) suggest that they might be from the same animal.

These problems aside, some interesting information can be gleaned from this study. The pig teeth all show a remarkably large number of increments compared to the amount of tooth wear, suggesting that sexual or other cycles might influence the formation of increments in pig teeth. The successful identification of increments in pig teeth does, however, show quite strongly the potential applicability of this technique and the need for future analyses of this type. As with cattle, large comparative samples of modern pig teeth need to be studied to provide a framework for interpreting archaeological samples. The fact that three of the pig teeth analyzed (two incisors and a canine) are teeth that are not commonly used in ageing by tooth wear also shows the value of incrementation studies for adding to the overall analysis of age patterns represented in a faunal assemblage.

The sample seems to be most informative in terms of the season of

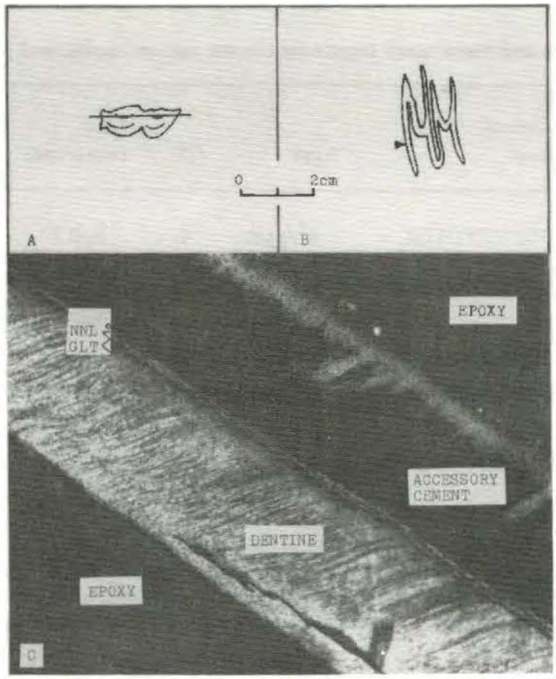

Figure 4. *Sus scrofa*, I3 (sample 7): a) lingual view of tooth showing location of section cut; b) sketch of thin section showing location of photograph; c) photograph of cement increments at 75X, f16, 1sec. [GLT– Granular layer of Tomes. NNL– neonatal line. TE– tooth edge. –= opaque increment. o= translucent increment.]

death information provided. As discussed earlier, historical accounts suggest that butchery during the colonial period in rural New England followed a seasonal cycle, with cattle and swine slaughtered from September to February and some juvenile cattle slaughtered in the summer, with sheep being most commonly slaughtered from August to November. If the seasonal interpretations derived from the sample are taken at face value, they would show a sheep or goat being slaughtered in autumn, a lamb or kid in early summer, a young cow slaughtered in summer, and pigs slaughtered in autumn through late winter. This seems to fit the overall pattern suggested by historical accounts well. If this interpretation is correct, it suggests that, at least in some areas of colonial Boston, animals were being butchered in accordance with a rural seasonal cycle. Although the small sample size and the problems with analysis that have been mentioned make this a tentative interpretation at best, it points out quite clearly the potential applications of cement increment analysis.

Conclusions

The analysis of cement increments in the teeth of domestic animals is an analytical technique that should be utilized by historical archaeologists for a number of different reasons. The potential accuracy of this technique for

determining age at death could lead to more detailed interpretations of slaughtering patterns, a fundamental component of the study of colonial husbandry practices. Perhaps more important, cement increment analysis allows for a direct determination of the season of death of domestic animals, providing the information necessary to begin to more explicitly address the issue of seasonality as a causative factor in the patterning of historical faunal assemblages. As the example from Boston demonstrates, specific age and season of death information can contribute to the study of complex research questions such as the relationship between a city and its hinterland, urban food distribution systems, and seasonal cycles in food availability. Although the conclusions about seasonal slaughtering in Boston derived from this sample analysis remain tentative, they show that this is clearly an issue meriting further investigation. The difficulties present in analyzing and understanding the cement increment patterns in the teeth of domestic animals make it all too obvious that the potential contributions of cement increment analysis to the explication of historical faunal assemblages will only be fully realized when more detailed studies of increment formation have been completed to provide a framework for interpreting archaeological samples.

Acknowledgments

This article is a revised version of a paper presented at the 1989 Council for Northeast Historical Archaeology meetings in Morristown, New Jersey. The author would like to thank Dr. Mary Beaudry for the opportunity to study the faunal material from the Wilkinson Backlot Site. The help of Guy Pollard, Sterling Presley, and Dr. Bryan Gordon with the preparation and interpretation of the samples is gratefully acknowledged. Thanks to Dr. Richard Meadow who read and commented on an earlier version of this paper. Thanks also to the anonymous reviewers who made valuable suggestions.

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