APPENDIX II
CEMENTUM ANNULI SEASONALITY ANALYSIS OF *Odocoileus hemionus* TEETH FROM TEN SITES ON THE BIG SUR COAST

STEVEN A. MOFFITT

Cementum annuli analysis was completed on 44 specimens of *Odocoileus hemionus* teeth recovered from eleven sites (CA-MNT-63, -521, -759/H, -1223, -1227, -1228, -1232/H, -1233, -1235, -1277/H, and CA-SLO-267). The deposition of annuli growth and rest bands in the teeth of mammals leaves a permanent record of the season of death of the animal that can be exploited by archaeologists. Wildlife managers have long used cementum-annuli analysis to age animals under their care. Biologists studying the Alaskan fur seal (*Callorhinus ursinus*) and the northern elephant seal (*Mirounga angustirostris*) made the initial discovery that the roots of mammal teeth have structural properties that correspond with the known ages of animals (Scheffer 1950, Laws 1952).

Cementum is a calcified tissue incrementally produced at the distal margin of the tooth throughout life. Cells of the dental follicle produce cementum on the surface of dentine and enamel. As the occlusal surfaces wear down and the tooth erupts minutely to compensate for the wear, cementum is deposited on the longitudinal areas of displacement, particularly in the regions of the apex of the root and forks of the roots in multirooted teeth.

Cementum annuli analysis has been shown to be consistently more accurate in determining the age of mammals than the previously used method of tooth eruption and wear (Lockard 1972:46). Numerous studies on both wild and domesticated populations including deer (Gilbert 1966; Lockard 1972; Low and Mct.Cowan 1963; Ransom 1966), red deer (Mitchell 1969), reindeer (Reimers and Nordby 1968), moose (Sergeant and Pimlott 1959), and sheep (Saxon and Higham 1969), among others, have clearly established the correlation between the depositional banding of cementum annuli in the teeth of known age control samples with the age of the animal at the time of death. Further investigation has determined that the banding is deposited seasonally. Cementum annuli thin-sections observed under transmitted polarized light has confirmed a seasonal growth pattern consisting of alternating translucent and opaque bands. The outermost band indicates the season of death.

The biological basis for this visually distinct dual banding is not precisely understood. Alternate theories have been offered which suggest an environmental or metabolic influence (Stallibrass 1982), photoperiodicity (Pike-Tay 1991), climate (Kleinenberg 1969), latitude (Pike-Tay 1991), or the quantity and quality of food (Stallibrass 1982). Nutrition, which closely relates to environment, and hormonal changes or sexual cycles may be some of the metabolic causes of the banding (Stallibrass 1982). Recent experiments by Lieberman (1993, 1994) on the
banding effects of diet on goat annuli support a nutritional/environmental correlation. Seasonal variation of available forage may impact annuli in several ways. First, a change in band mineralization appears to occur as seasonal nutrition varies. The band may become hypomineralized as available calcium is reduced or hypermineralized when reduced nutrition restrains cementogenesis or impacts the production of Sharpey's fibres in the periodontal ligament (Lieberman 1994:528). Second, a seasonal change in available flora may require differential biomechanical forces for processing these different food items. Diets that contain material which is more difficult for the animal to chew and/or which is lower in nutrition may place greater stress upon the biological structures used to process the food. Lieberman (1993) reported that cementum may reflect the higher stress by containing an increased number of collagen fibre bundles which attach the tooth roots to the periodontal ligament, by an increased mineralization as the result of growing more slowly, or by a directional change in the mineralization of Sharpey's fibres at times when occlusal forces are increased. Clearly, environment greatly influences the deposition and banding of annuli, whether directly or indirectly. Although the biological processes behind cementum annuli deposition and banding may not be explicitly known, most researchers agree that a comparative standard must be established from a control sample of known age/known season of death animals from the same geographical/environmental area in order to successfully apply this technique to age or seasonally date the death of an unknown sample (Beasley et al. 1992; Burke and Castanet 1995; Gordon 1993; Pike-Tay 1991; Stallibrass 1982).

Zooarchaeologists have been quick to capitalize on the discovery of seasonal banding and have expanded its application to archaeological faunal remains where teeth are often numerous and well preserved (Kay 1974). Archaeological applications of cementum analysis are dependent upon the clarity and regularity of the seasonal deposition pattern. Seasonality estimates are based upon the last increment deposited on the periphery of the tooth root. A one year cycle of cementum deposition leaves two bands on the periphery of the tooth root, a narrow dark band deposited during the non-growth winter season and a wide light band deposited during the summer growth season. The season of death of the animal is determined by estimating the amount of growth that has occurred on the last formed band of the tooth root. Since the width of the bands tend to narrow slightly as the animal grows older, especially the wider light colored growth band, the seasonal calculation for the death of the animal can only be reasonably estimated to a period of about three months (Quintero 1987; Spiess 1976, 1990).

Specific teeth in each species are favored for use in cementum analysis due to the clarity and regularity of their annuli deposition. For *Odocoileus hemionus* specimens the permanent first incisors provide the most consistent annuli for seasonality assessments (Matson 1981; Quintero 1987; Thomas and Bandy 1973). The analysis of first incisors from modern herds of *Odocoileus hemionus* revealed that 57% of the study sample produced annuli that closely matched the standardized model (Matson 1993).

While wildlife biologists established the basis for using this method on specific species in specific geographic/environmental regions, zooarchaeologists occasionnally followed suit and constructed modern comparative collections for previously investigated species in different environmental regions (Beasley et al. 1992; Burke and Castanet 1995; Lieberman 1990, 1991; Pike-Tay 1991; Quintero 1987). It is important to use a local comparative collection as the standardized model for the analysis so that generalized designations such as spring, summer, and fall can correlate on a scale with actual months. Such a collection was used for this study along with the scale derived from that collection by Quintero (1987). The set consisted of teeth from 219 wild deer killed in 1984 in Los Angeles (5), Riverside (53), San Bernardino (87), and San Diego (74) counties. It was obtained from the State of California, Department of Fish and Game, and had been compiled to facilitate their deer herd management programs (Quintero 1987). The scale used for this analysis is a slight variation of the scale compiled by Thomas and Bundy (1973) for British Columbian deer teeth and accommodates the slight differences in environmental conditions (Quintero 1987):

- **Fall/Winter**: Summer band complete, November to February.
- **Early Spring**: Arrest band distinct, March to April.
- **Late Spring/Early Summer**: Summer band, May to July.
- **Late Summer/Early Fall**: Summer band over but not complete, August to October.

It is not possible to differentiate growth related periods during the winter months, because growth does not occur after early November and the growth arrest annuli are not formed until March. The summer scale is just the opposite, and is more accurate because the rapid growth period is easily augmented into discrete seasonal or three-month increments.

**METHODS**

Each sample was assigned a laboratory number prior to processing. In general, the teeth were in good condition although only one tooth was encased in bone matrix, allowing some protection to the root periphery.
The technique used to expose the annuli on the current sample followed the method developed by Bourque et al. (1978) and used by Quintero (1987). It is a modification of a technique first reported by Erickson and Seliger (1969) when they attempted to simplify and expedite the process originally developed by Low and Cowan (1963). First, all teeth were encased in a protective resin matrix to hold them securely. Following Bourque et al. (1978) and Quintero (1987), liquid plastic casting resin (Styrene Monomer/Polyester resin) was used, embedding the teeth in incremental layers. The resin was catalyzed and poured in layers over a tooth placed in a mounting cap. Each layer was allowed to set before the addition of the next layer. After the addition of the final layer each mounting cap was placed in a vacuum chamber for 24 hours to remove any bubbles which may have formed during the casting process and to force resin into the pulp cavity. The mounting cap was removed from the vacuum chamber and allowed to dry for another 24 hours. Each cast was then removed from its mounting cap. A Felker lapidary saw with a continuous face diamond blade that was constantly lubricated with a stream of water was used to cut a longitudinal (sagittal) section of each tooth root. Longitudinal sections are preferable to transverse sections because a larger portion of the root structure is exposed. Each cast was cut to expose the lingual-lateral quarter of the root where possible, however, several of the specimens were fragments or had broken roots which provided little choice of positioning. Each exposed surface was polished twice. First, with #400 grit on a high speed rotating lapidary wet polisher and then with #600 grit on a slow speed wet polisher. The exposed surface was then affixed to a 27 x 40 mm microslide with epoxy and allowed to dry for 72 hours. A thin-section approximately 100 microns in width was cut from the section affixed to the slide by using a Hillcrest thin-sectioning saw. The slide thin-section was ground to a width of approximately 30-50 microns. The final reduction was accomplished by using a Hillcrest thin-sectioning machine.

RESULTS

Each thin-section was examined under 40 to 100 magnification using a binocular microscope under transmitted light. The analysis was conducted on June 15, 1995 at Northern Arizona University, Flagstaff, Arizona. Sixteen of the 20 teeth (80%) provided seasonal estimations of death based upon the final incremental layer deposited on the periphery of the tooth root (Table 1). The majority of specimens (13) indicated a late fall or winter death. Three of the teeth indicated a mid-summer death. These specimens had an outer annuli band that was approximately deposited, indicating a June through August death. However, the sample is small and should only be tenta-
Table AII-1 Cementum deer teeth seasonality from study sites

<table>
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<th>Site</th>
<th>Specimen</th>
<th>Component</th>
<th>Unit</th>
<th>Depth (cm)</th>
<th>Tooth</th>
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Table AII-1 Cementum deer teeth seasonality from study sites (continued)

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