# Bison dentition studies revisited : Resolving ambiguity between archaeological and modern control samples

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RÉSUMÉ

Les zooarchéologues emploient souvent les analyses dentaires pour en induire la saisonnalité de l'occupation des sites archéologiques et les courbes de mortalité des populations préhistoriques de bisons. Les résultats risquent d'être peu crédibles si les déterminations des classes d'âge des assemblages fauniques donnés sont fondés sur les résultats d'analyses d'autres sites archéologiques, eux-mêmes basées encore sur les résultats d'analyses d'autres sites archéologiques. On argumente ici sur la nécessité d'accroître notre information sur les échantillons de références, afin de développer une méthodologie plus fiable pour la détermination des âges et la saisonnalité pour des populations animales archéologiques.

ABSTRACT

Zooarchaeologists frequently use dental analyses to make inferences about the season of occupation of archaeological sites and about mortality profiles of prehistoric bison populations. There is a great danger that archaeologists are forming untested inferences based solely on data from archaeological material, basing their determinations for their bison age classes upon the results of possibly incorrect analyses of data from other sites, which in turn were based upon the work of even earlier analyses of zooarchaeological materials. An argument is made for the necessity of increasing our information about known-age modern control samples as a more soundly based methodology for determining the age and seasonality of archaeological faunal populations.

## Introduction : determination of age and season of death

Determination of the age of animals and their season of death are of fundamental importance for understanding the exploitation of prey animals in human adaptations (Kurtén 1953 ; Voorhies 1969). Various species can be used in widely different fashions as functions of differential availability of prey, of human hunting tactics, or of overall subsistence strategies. The differences in the modes of exploitation can be as important for our understanding of those adaptations as are which faunal taxa were chosen as prey.

This essay has two objectives. First, it will review the methodological basis for bison dentition studies and outline their inability to fully link analytical approaches with well-controlled studies

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of modern bison. Second, it will suggest methods for solidifying this theoretical link through improved comparative studies.

To begin with, it is necessary to discuss the importance and purpose of dentition studies. The determination of the age and season of death of animals recovered from archaeological sites can provide important inferences about past human behavior (Hillson 1986). The age at which animals were killed can inform about the general selection preferences of hunters (e.g., Enloe 1997) or the practices of people who keep livestock (Grant 1982). Likewise, the time of year animals were killed can provide information about the seasonal or annual cycles of hunters (e.g., Enloe and David 1997) or stockbreeders (e.g., Landon 1996 : 96-114) as well as the time of year a site was occupied.

There are many ways of archaeologically determining the age of animals (Klein and Cruz-Uribe 1983), such as through observation of skeletal element fusion (e.g., Bullock and Rackham 1982), counting rings of cementum annuli in teeth (e.g., Pike-Tay 1995), the analysis of horn or antlers (e.g., Grigson 1982) and the analysis of dental eruption and wear (Hillson 1986). Season of kill can also be determined in a number of ways, such as through the analysis of insect (e.g., Chomko and Gilbert 1991), micromammal or botanical remains in association with bone ; the presence and measurement of fetal remains (Frison et al., 1978 : 42-45 ; Whittaker 1998) ; the measurement of dental cementum annuli rings ; the study of antler growth ; and the analysis of dental eruption stages of younger animals.

Despite the multiplicity of methods of determining age or seasonality, there are serious problems with the application or interpretation of many of them (Lyman 1987). Poor preservation or questionable stratigraphic association frequently limits the usefulness of analyses based on insect, micromammal, botanical, and fetal material. Cementum annuli analysis is destructive and difficult under ideal conditions and impossible to perform under many conditions. Analysis of skeletal fusion requires the identification of multiple elements from an individual animal, which is difficult at most sites ; furthermore, epiphyseal fusion is of little help in determining the age of fully-mature animals and usually cannot be used to determine season of death. Studies of antler or horn remains are useful for only a few species of animals, and antlers and horn cores typically do not preserve well. Because of these reasons, analysis of dental eruption and wear is the most frequently-used method of determining age and season of death (Brugal et David 1993, Klein 1978, 1982 ; Klein et al. 1983 ; Reher 1970, 1978 ; Whittaker 1999).

To determine correctly the age of animals on the basis of dentition, it must be first established that all animals within that species follow the same general chronological pattern of tooth eruption and wear. In addition, to determine season of death it must be established that virtually all of the animals of that species are born within a fairly short annual period, such as a few weeks in spring, so that animals of a same generation will be at an approximately similar stages of tooth eruption and wear throughout the year. If these conditions are not satisfied, analyses based on dentition will be of dubious value.

## Bison dentition Studies

The archaeology of the Great Plains of North America has been at the forefront of dental analysis of the bison, compiling what is arguably the largest archaeological collection of dental eruption and wear data for any animal. Of Plains PaleoIndian sites alone, at least 38 kill events have established seasons of kill based upon analysis of bison dentition (Buehler 1997 : 177-179). This amount of work is remarkable and commendable ; unfortunately, many researchers working with Plains bison material (including the authors of this essay) have put the proverbial cart before the horse, coming to broad conclusions about the lifeways of prehistoric Plains Indians based upon analysis of bison dentition without ensuring the validity of their underlying methodological assumptions.

A comprehensive, systematic, metric schedule of eruption and wear for known age, modern bison has never been published. To date, there have been only five partial analyses of modern bison dentition, three of which were apparently made on the same comparative collection at the University of Wyoming (Frison and Reher 1970; Gifford-Gonzalez 1991; Todd et al. 1996), the other two are based upon wood rather than plains bison (Fuller 1959; Haynes 1984). The Wyoming collection is a blend of domestic ranch bison, which are presumably Plains bison, and wild bison from Yellowstone National Park (Frison and Reher 1970 : 46), which is considered by many to be at least part wood or "mountain" bison (Meagher 1973 : 13-17). The biological relationship between wood and Plains bison remain unclear (Peden and Kraay 1979), but there do appear to be differences in dentition wear rates, either because of biology or diet (Haynes 1984).

The most frequently cited dentition study in archaeological site reports is *The Glenrock Buffalo Jump* (Frison and Reher 1970 : 46-47). There are a number of problems with relying on this analysis for bison age determination in prehistoric sites. Frison and Reher presented eruption and wear schedules for prehistoric bison, but not for the modern bison samples on which their ages were based. In one paragraph Frison and Reher briefly described comparing the Glenrock mandibles to mandibles of living animals, but it is not stated how many mandibles of modern bison were studied, what variation existed between bison mandibles of the same age, how the age of the extant bison were independently verified, how much variation there was between herds of different locations, nor were there any tooth measurements presented. The data presented do not subdivide the age of animals greater than 4.5 years of age, because older age classes were not considered distinct enough. Finally, and perhaps most important for use in determining season of kill, Frison and Reher made no attempt to determine the expected eruption and wear of bison at any seasons other than y+0.5 years (six months after birth, or late October - early November).

While Fuller's (1959) study of wood bison in Canada has an advantage over the more frequently cited Glenrock article in that it presented actual data on modern bison, it is of limited use. Fuller used animals from an uncontrolled setting and could not determine their precise ages. Furthermore, wood bison may have a different wear rate than Plains bison (Haynes 1984). In addition, no metric data were presented, and no attempt was made to age animals greater than four years (for further critique of Fuller's study, see Reher and Frison 1980 : 62-64).

In a study that is almost never cited in archaeological reports, Haynes (1984) presented metric data about modern wood bison. This report has four main drawbacks : first, it presents data on wood bison rather than Plains bison; second, it has a comparatively small sample size (N=20); third, it presents measurements on only the first permanent lower molar (M1); and fourth, it presents no information about season of kill. Haynes's results conflicted with the data presented by Frison and Reher, with Haynes's dentition having a much lower rate of tooth wear than Reher and Frison predicted (Haynes 1984 : 488; Reher and Frison 1980). This difference was attributed to either biological or dietary differences between wood and Plains bison.

The most informative study of the tooth wear rate and age of contemporary bison is Gifford-Gonzalez's (1991) study of the comparative bison mandibles at the University of Wyoming. Although intended to demonstrate the applicability of crown-height quadratic age formulas to a variety of zooarchaeological assemblages, it is ironically the only example of published crown height schedules of known-age Plains bison. However, Gifford-Gonzalez's data is of limited use. By measuring standard deviation and performing T-test analyses on 117 known-age Plains bison, she revealed that M1 crown height measurements are not statistically significant measures of age ($p<.05$) until 42 months (age class 4), M2 crown heights are not statistically significant until 54 months (age class 5) and M3 crown heights are not statistically valid until sometime after 54 months, if ever (Gifford-Gonzalez 1991 : 57-58). From the data she presents, crown heights can only accurately age animals in age class 4 or 5, and then only by using the saddle heights of M1 or M2. Animals younger than age class 4 cannot be calculated because the M1 saddle is not always in wear, and animals older than age class 5 cannot be determined because no crown height data were presented.

A recent overview and study of bison dentition was presented in the Mill Iron site report included some metric data on modern, controlled samples (Todd et al. 1996). Much of this essay will discuss issues raised by the Mill Iron dentition report because it contains the most recent comprehensive overview of bison dentition studies. The Mill Iron site report presented data on modern comparative bison teeth via two analytical methods. The first showed the distance of the M3 metaconid from the alveolus of 78 extant bison from the University of Wyoming bison comparative collection (Todd et al. 1996 : 150). All the mandibles were stated as being from age group 2, however it was not stated how the ages of the bison were determined, or from what herds they were recovered. Ironically, the extreme variation within the data presented contradicted the notion that eruption occurs in tightly-clustered events. For example, the distance of the M3 metaconid from the alveolus varied from 16 mm below the alveolus to 4 mm above the alveolus (Todd et al. 1996 : 150).

The other analytical method presented in the Mill Iron site report discussed ectostylid-to-wear measurements for age groups 2, 3, and 4 of modern bison (Todd et al. 1996 : 157) and the data presented contradicts the idea of discrete eruption and wear patterns. There was considerable overlap between the different age classes ; for example, if ectostylid to wear of an individual's M2 is 12 mm, it could be either age class 2, 3, or 4. None of the data on modern bison dentition presented in the Mill Iron site report can be used to determine the season of kill, or determine the age of animals older than age class 4, or younger than age class 2.

Beyond these five studies, studies of the eruption and wear patterns of modern bison have been scattered and sketchy. In a review of aging methods Frison (1978 : 51-52) stated that an analysis of more than 80 modern specimens (again, presumably from the Wyoming collection) at the same age (approx. 1.7 years old, and another group 2.8 years old), had eruption schedules which "clustered very closely". Frison presented no data to clarify how tightly clustered they were, or which teeth were studied, nor were there any metric data given, nor were the expected eruption stages of these animals given. In addition, these animals came from a single herd, and thus were presumably closely-related and had the same diet, therefore they would not be ideal subjects of study of potential variation in bison dentition.

Other reports cited as a basis for determining seasonality and age profiles are Reher and Frison (1980) and Reher (1974) (e.g., Niven and Hill 1998 : 8). Reher and Frison (1980) listed general eruption and wear stages for the archaeological mandibles found at the Vore site, but not for modern bison (Reher and Frison 1980 : 64-65). Some metric data were presented for modern bison dentition, but only regarding the comparative sizes of tooth surface, intended to demonstrate change in size of bison over time (Reher and Frison 1980 : 84). These data were not intended, nor can they be used, to age animals or determine season of kill. Like Frison and Reher's (1970) earlier work, Reher's report (1974 : 115) contained no data on modern comparative bison other than one indistinct photograph of four modern mandibles aged less than six months.

## Indications of a problem

Despite such limited data about the eruption and wear of living bison, researchers have made many inferences about the season of occupation and mortality profiles of prehistoric bison (e.g., Frison 1982 ; McCartney 1990 ; Todd 1991 ; Buehler 1997 ; Whittaker 1998). Archaeologists are forming untested inferences based solely on data from archaeological material (see Frison 1978 for an oblique description of this process). This is problematic. Archaeologists have based their justifications for their bison age classes upon the results of possibly incorrect analyses from other sites, which in turn were based upon work from earlier sites, without ever anchoring their data on direct age data from modern, known-age bison. This is a self-reinforcing cycle - a mandible eruption/wear stage was assigned, correctly or incorrectly, to an actual age because it appeared older or younger than mandibles from other sites. In turn, these newly-aged mandibles became the basis from which mandibles from newer sites were aged. The process has been repeated over and over and has created a complex web of data that were not fully linked to modern control data.

Weaknesses in the methodology of bison dentition studies can be seen in the results obtained from archaeological bison dentition analyses. For example, there is as much as 5.3 mm difference in the crown height of M1s between individual prehistoric bison of age class 7 from the same site (Todd et al. 1996 : 167). This is remarkable considering the anticipated annual rate of wear for permanent molars of adult bison varies between 1.7 to 3.8 mm/year for bison (Reher and Frison 1980 ; Haynes 1984 : 488), thus variation between specimens of the same age class can be far greater than the variation expected between specimens of different ages. This is far from an isolated example, virtually every published data set of crown height measurements includes a wide variation in measurements for each age class ; it cannot be argued that these are quantitative outliers unless the expected, natural range is known from comparative studies (e.g., Gifford-Gonzalez 1991).

Bison fetal material analysis should be a way of independently verifying seasonality results obtained by dentition analysis. However, the three studies which have used fetal remains to determine season of death (Wilson 1974 : 145-152 ; Frison et al. 1978 : 42-45 ; Whittaker 1998) have all obtained different seasons of death than those indicated by dentition studies. While these discrepancies may simply be a reflection of the expected size variation of fetal individuals (Rutberg 1984 : 418 ; Meagher 1973 : 38-39, 148), or the small number of comparative fetal specimens (again, from the Wyoming collection), it is another indication that something is amiss in the archaeologist's understandings of seasonality.

As another example of how bison dentition studies have created a largely unchecked, self-reinforcing paradigm is the common perception among archaeologists that bison teeth wear out around 13-15 years of age (e.g., Todd et al. 1996 : 162 ; Reher 1974 : 119-122). To the contrary, there are numerous historic and modern accounts of both wild and domestic bison living well past the age of 20, which would be an impossibility if their molars were worn out (e.g., Garreston 1938 ; Dary 1974 : 42-43 ; Berger and Cunningham 1994 : 132-135). Judging from age-weight charts (Berger and Cunningham 1994 : 132-133) wild bison do not go into serious physical decline until after 21 or 22 years of age. It is perhaps not surprising that dental wear studies consistently underestimate the potential age of bison, since there has never been a single published study of dentition wear of comparative specimens older than 54 months of age (Gifford-Gonzalez 1991). It would be fatuous to argue that prehistoric bison teeth wore out more quickly than modern ones when the determination of the age of prehistoric bison is supposedly based on modern wear rates.

Because bison dentition studies are anchored to such little comparative data, researchers have been able to assign very precise ages to very old animals without risk of their conclusions ever being refuted by control data. For example, Todd et al. (1996) were able to calculate ages of 12.0-12.1 and 13.0-13.1 years for mandibles at the Mill Iron site, a feat that would be impossible for any other animal. Even reindeer, which actually have dentition studies strongly supported by modern control data, are very difficult to assign ages by means of wear stages more precisely than within a few years once they have reached maturity (Spiess 1979). Just because the season of death of younger specimens at Mill Iron may have been determined, it does not necessarily follow that older specimens were killed at the same time.

## Discussion and Conclusions

It is not the intention of this essay to give an overly negative assessment of the current situation ; to the contrary, many of the methods used by archaeologists studying bison dentition are quite innovative and useful. For example, the regular publication of wear codes, drawings, and multiple measurement points provide a body of comparative data that is unparalleled in any other area of zooarchaeological analysis. For example, Todd et al. (1996) provide an excellent example of what the future of dentition studies should be, not just for bison, but for all mammals. Even if it turns out that current age or seasonality assignments based upon dentition are incorrect, reanalysis of sites will be a comparatively easy task because of the methodological rigor of Plains archaeologists.

The present task, however, is to link this data more completely with modern control data. Researchers need to start systematically gathering data on existing collections of modern bison specimens with determined age or season of death (i.e., in addition to the comparative collections at Wyoming). Crown height measurements would be most useful, although this often necessitates damaging mandibles to access roots. A systematic collection of wear stage data and ectostylid-to-wear information can be performed without damaging mandibles and would greatly amend the current paucity of information. It is important to segregate the data properly along multiple lines, e.g., not just separating left from right, but also according to recovery context.

Biology and diet are likely to be the primary factors influencing dental wear. Therefore, since there are at least two different sub-breeds of the North American bison (wood and Plains) and at least three general dietary scenarios (wild grassland, wild forest with some grass, and fodder), the bison should be divided into at least six categories for analysis. This data should be checked for internal consistency of aging and seasonality within each category, and for similarities between categories. If all six bison categories have similar eruption and wear patterns, it would be plausible to use this data to evaluate the age and season of death of bison from archaeological sites. If there are significant differences between the categories, the next step will be to determine if these differences are due to biology, diet, or both. If it is determined that the differences appear to be dietary rather than biological, it may still be possible to use this data for archaeology, provided there is adequate paleoenvironmental reconstruction for the region around each site.

The above are just some preliminary suggestions for improving bison dentition studies. Perhaps other researchers will have other, even better, recommendations. The point of this essay has been to get archaeologists to seriously question the methodologies currently in use. Although highly unlikely, in the end it may turn out that there is no predictable way of determining the age or season of death of bison on the basis of dentition. Even if so, this would be valuable information and infinitely preferable to the current situation, where we baselessly assume we know how to determine the age and season of kill of bison.

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