Mastodon butchery by North American Paleo-Indians

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It has often been argued that North American Paleo-Indians hunted both mammoths and mastodons[1–3]. However, while numerous archaeological sites involving mammoths (genus *Mammuthus*) are recognized[3,4], very few sites demonstrate direct human association with mastodons[5–8]. I report here a taphonomic analysis of several late Pleistocene mastodon (*Mammut americanum*) skeletons excavated in southern Michigan which provides compelling evidence of mastodon butchery. Butchery practices involved the production and use of tools fashioned from bones of the animal being butchered. Evidence for butchery and bone tool use includes: patterns of bone distribution and disarticulation recorded from a primary depositional context, disarticulation marks and cutmarks on bones, green bone fracturing, use wear and impact features on bone fragments, and burned bone. Moreover, determinations of the season of death of butchered mastodons[9] suggest that butchery was associated with hunting and killing, not simply scavenging of natural deaths. These findings provide new evidence of a well developed 'bone technology'[10–13] used by Paleo-Indians in eastern North America. They also add to our perception of Paleo-Indian subsistence activities and their possible role in the late Pleistocene extinction of mastodons.

The principal specimen discussed here is a partial mastodon skeleton (University of Michigan (UM) specimen 57705) excavated from a deeply stratified peat sequence near Pleasant Lake, in Washtenaw County, Michigan. Wood fragments removed from the pulp cavities of both tusks were dated at 10,395 ± 100 yr BP, and wood located stratigraphically below the skeleton was dated at 12,845 ± 165 BP using Beta-1388 and Beta-1389 (Beta Analytic Inc.). The former date is more closely associated, suggesting an age for the skeleton near the end of Paleo-Indian occupation of southern Michigan[14]. Much of the evidence for butchery at the Pleasant Lake site has been replicated by other recently excavated specimens (UM 57856 and 58028) and by specimens in older museum collections (UM 14404, 37811 and 57022). Specimens representing natural deaths have also been excavated (UM 57648 and 61246) and studied in existing collections (UM 23498 and 59936). Geological and floral evidence, as well as radiocarbon dating, suggests that all these sites are about the same age as the Pleasant Lake site.

The pattern of bone distribution at the Pleasant Lake site consists of fully articulated skeletal units displaced from one another and surrounded by isolated bones and bone fragments (Fig. 1). Direct evidence of butchery as the cause for this pattern is provided by matching marks on pairs of bones that were articulated in life but found disarticulated at the site. The conarticular surfaces of the atlas and axis vertebrae (Fig. 2) have three such pairs of marks; each mark superimposes on its counterpart as the vertebrae are rearticulated. Particularly notable are the size and character (examined by scanning electron microscopy, SEM[15]) of the highly polished, striated pair of marks C-C′ in Fig. 2. Microscopic features indicate that these marks were made by driving a relatively smooth, wedge-shaped object, probably made of bone, between the conarticular surfaces of the intact joint. Identical pairs of marks occur at other joints, notably the left knee. I have replicated all features of these marks through experiments with fresh bone and have confirmed the effectiveness of bone wedges in producing disarticulation.

Additional evidence of butchery includes a variety of cutmarks documented by SEM analysis of microstructural features[15]. These marks, made by stone and/or bone tools, can be distinguished from gnaw marks of non-human predators and scavengers, and from possible excavator's marks, on the basis of criteria developed elsewhere[16–18].

Certain bone fragments were apparently used as expedient tools[10]. Glassy polish, interpreted as use wear, is developed along formerly sharp edges of fragments that are appropriate in size and shape for cutting or scraping soft tissues. Polish is absent from comparable surfaces of other fragments. I have replicated this polish using fresh bone, and it can be distinguished from polish of non-human origin through SEM analysis[15]. Most examples of polish occur on fragments of bones that have little cancellous, marrow-bearing tissue. Their structure and anatomy make them unlikely candidates for accidental breakage or for breakage associated with marrow removal, but they are ideal for tool production. All breakage appears to have occurred while the bones were fresh, and it is accompanied by features such as local crushing at points of impact, bulbs of percussion, removal of multiple flakes from the margins of larger fragments, and broad impact depressions surrounded by sets of concentric fractures. Previous work suggests that these patterns, particularly when developed on large proboscidean bones, are indicative of the manufacture of expedient bone tools[10–13].

Evidence of burning is present on some bones. Its distribution indicates that burning occurred while much of the bone surface was still covered by soft tissue, and its microscopic features indicate attainment of surface temperatures of 440–650 °C, higher than temperatures available in most natural fires[15,19].

Analysis of incremental lamination within tusks and molars provides important life history information and also a basis for determining season of death[20]. Natural deaths analysed thus far occurred near the end of winter or the very beginning of spring,

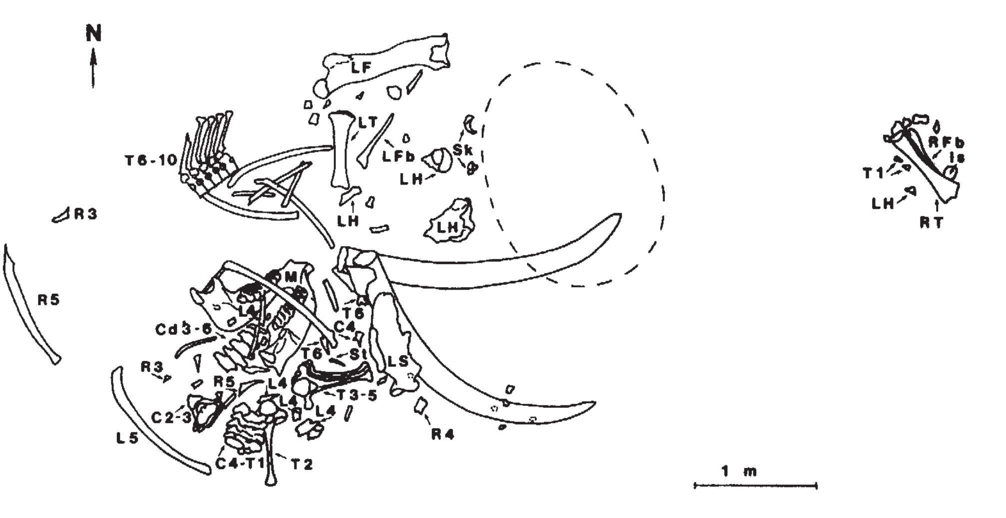

Fig. 1 Map of *in situ* bone distribution at Pleasant Lake mastodon site (UM 57705); identifications given for articulated units and representative fragments only. The dashed line demarcates the area from which the atlas vertebra and several other elements were displaced immediately before recognition of the skeleton. All other elements were undisturbed. The axis vertebra was discovered in articulation with the third cervical vertebra. C, cervical vertebra; Cd, caudal vertebra; L, left rib; LF, left femur; LFb, left fibula; LH, left humerus; LS, left scapula; ls, limestone cobble; LT, left tibia; M, mandible; R, right rib; RFb, right fibula; RT, right tibia; Sk, skull fragments; St, left stylohyoid; T, thoracid vertebra; integer suffixes indicate position in anatomical series.

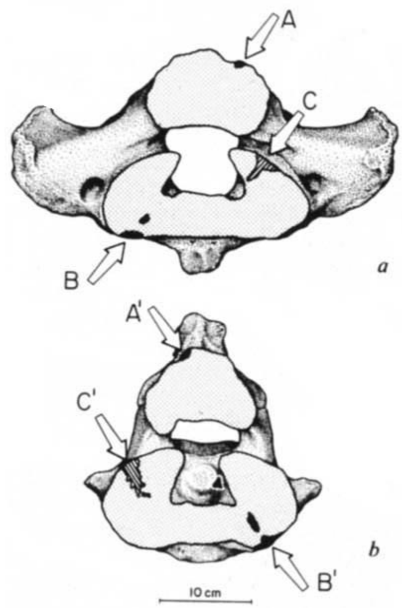

Fig. 2 Disarticulation marks on the atlas and axis vertebrae of UM 57705 (articular surfaces are indicated by even stippling). *a*, Posterior aspect of atlas, showing gouges (A and B, solid areas) and polished, striated mark (C, parallel lines indicate striae). *b*, Anterior aspect of axis, showing gouges (A′ and B′) and the polished, striated mark (C′) that are counterparts to the marks on the atlas. Superimposition occurs in the order B–A–C, as the bones are initially disarticulated and rotated slightly.

in a time of high physiological stress and heightened probability of accidental death. In contrast, all butchered animals died in mid-to-late autumn. This pattern is most plausibly explained in terms of hunting by humans[9,20].

The uniformity of patterns of bone modification at sites studied here suggests a highly standardized approach to hunting and carcass processing. This pattern shows similarities to other occurrences of modified proboscidean bone[10–13,21,22], and to certain occurrences of bison[23–25]. While lithic tools must have been used to some extent in butchery, none have been recovered from Michigan mastodon sites. Archaeological evidence of a high degree of conservation of lithic materials[26] suggests that this may be due largely to low rates of stone tool discard. Bone tools were apparently easier to acquire, and here they may have partly replaced stone tools for some purposes[13].

Comparative analysis of additional sites will be necessary to evaluate the incidence of butchery among preserved late Pleistocene mastodons and the impact of human hunting on mastodon populations[27]. However, the patterns emerging here suggest that mastodon butchery may have been much more common than previously recognized. These observations provide substantial, if indirect, support for the hypothesis that human hunting was an important factor in the ultimate extinction of mastodons.

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Desynchronization of the oral temperature circadian rhythm and intolerance to shift work

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The present study tested the hypothesis that subjects with a good tolerance to shift work maintain the circadian period τ of their temperature rhythm equal to 24 h, while τ may differ from 24 h when subjects exhibit one or several clinical signs of intolerance. These latter are mainly: persisting sleep disturbance, persisting fatigue, changes in mood and behaviour, and digestive troubles, from gastritis to overt peptic ulcer[1,2]. These symptoms were used here to classify the subjects studied. Medications, including all types of sleeping pills, are ineffective. As was the case in the present study, some subjects may tolerate shift work for 35 yr, reaching 57 yr of age without complaint, while others, after several months or many years, quite rapidly (within 6 months) develop symptoms of intolerance[1].

Three types of male subjects were involved in the study: (1) Thirty-eight with a good tolerance, aged 21–58 yr (mean age 41.0 yr); duration of shift work 6 months to 36 yr (mean 15.2 yr). (2) Twenty-seven subjects with a poor tolerance, aged 21–58 yr (mean age 41.1 yr); duration of shift work 6 months to 35 yr (mean 18.5 yr). Subjects in these two groups were shift working at the time of the study, while the 18 subjects of the third group had been transferred to positions of diurnal work due to their poor tolerance to shift work over 0.5–4.0 yr (aged 32–58 yr, mean age 46.6 yr; duration of shift work 8–27 yr, mean 16.7 yr). Different types of shift rotation and industry were investigated. (Particulars can be provided on request.)

Subjects volunteered for the study. During a 16–30-day span they measured and recorded their oral temperature at least every 4 h and at most at alternating hours (five to eight times a day, not during sleep) using clinical mercury thermometers (0.05 celsius precision). The actual time point of any measurement (clock hour and minute) was also recorded. They also