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Late Pleistocene butchered *Bison antiquus* from Ayer Pond, Orcas Island, Pacific Northwest: Age confirmation and taphonomy

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ABSTRACT

Bone modifications on well-preserved *Bison antiquus* remains recently discovered during pond construction in the Pacific Northwest provide evidence suggestive of Late Pleistocene human activity. Since excavation and recovery conditions were not ideal careful evaluation of all observations separated those that can be made with confidence, and identified and discounted those less reliable. The report focuses on the context of the discovery, the taphonomic evidence, and compares modifications to those from other reported kill sites, considering evidence for human butchering and predator and scavenger damage. New test results confirm the bison is Late Pleistocene in age. A recent AMS radiocarbon date involving different pretreatment protocols places the event at 11,990 ¹⁴C BP, slightly older than the first test results of 11,760 ¹⁴C BP. These dates and observations were used to conclude that the bison was butchered by humans shortly after deglaciation.

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1. Introduction

Shortly after recession of last Glacial Maximum ice, an evolving postglacial landscape nearly connected the San Juan Islands to both mainland Washington and Vancouver Island (James et al., 2009; Wilson et al., 2009). Emergent glaciomarine substrates supported the early successional habitat suitable for large ungulates and their predators. Pollen core analysis indicates the presence of an open pine (*Pinus* sp.) parkland with buffaloberry (*Shepherdia canadensis*), northern wormwood (*Artemisia campestris*), and Sitka alder (*Alnus sinuata*) on Orcas Island by 12,000 ¹⁴C BP (Leopold et al., 2009). Extinct Late Pleistocene (LP) vertebrates including at least eleven bison (*Bison antiquus*) have been discovered in wetland deposits at several sites in the San Juans (Wilson et al., 2009) and additional bison from the Saanich Peninsula of Vancouver Island (Wilson et al., 2003). New discoveries of ground sloth (*Megalonyx jeffersonii*) and giant short-faced bear (*Arctodus simus*) confirm the great potential of such depositional settings for early postglacial discoveries (Barton, B.R., pers. comm., Dethier, D., pers. comm.). Radiocarbon dates

indicate the bison population persisted for over a millennium, from ~12,000 to 10,800 ¹⁴C BP. The oldest of three reported ¹⁴C dates from Orcas Island bison found in separate wetlands, 11,760 ± 70 ¹⁴C BP (Beta-216160), was from an apparently butchered mature male *B. antiquus* (45SJ454/1–98, Fig. 1) from Ayer Pond (45SJ454; Kenady et al., 2007; Kenady, 2008). The possible association of human activity with such an early date prompted a new effort to confirm the age of the material as well as a critical assessment of the context, taphonomy, and cultural evidence.

A new AMS date on bone collagen using more stringent methods to minimize contamination shows this bison to be even closer to 12,000 ¹⁴C BP. No artifacts were found with these bison bones so it cannot be assigned to any known lithic technology and the interpretation of cultural context rests with the evidence for butchering. However, both Clovis and early stemmed/lanceolate points are known in the Puget Sound region (Meltzer and Dunnell, 1987; Carlson and Magne, 2008; Kenady et al., 2008). It is noteworthy that the Clovis points thus far found in Washington state were inadvertent discoveries similar to those in this report. This pattern underscores the importance of such discoveries in understanding the Late Pleistocene settlement of this region and in development of targeted discovery strategies.

More rigorous excavations have produced evidence of nearly coeval human activity farther south in Oregon at Paisley Cave, dated 300 ¹⁴C years earlier (Gilbert et al., 2008); and the Manis

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Fig. 1. Cranial (above) and frontal (below) views of adult male *Bison antiquus* cranium from Ayer Pond on Orcas Island. Note the excellent preservation in the fine surface detail and the healed injury to the left nasal.

Mastodon Site (another accidental discovery), also showing evidence of cultural modification of bone, is dated to 12,000 ^{14}C BP (Gustafson et al., 1979; Gilbow, 1981; Peterson et al., 1983). The Ayer Pond bison does not stand alone as evidence of a human presence in the region during the LP.

We document both primary data – direct observations from the bones themselves – and secondary contextual data from a variety of sources including photographs, a wetlands inventory and our own systematic investigations adjacent to the pond. The butchering interpretation for the Ayer Pond bison rests upon a combination of multiple observations reported by others and direct observations by the authors. Analyses of megafauna with different taphonomic profiles provide an outline of attributes and lines of reasoning that can support or challenge an interpretation of butchering. Other researchers (Brain, 1981; Gilbow, 1981; Grayson, 1989; Blumenschine, 1995; Fisher, 1995b; Lyman 1985; Bement, 1999; Rogers, 2000; Morlan, 2003; Haynes, 2007; Galán et al., 2009: 273) have demonstrated that multiple lines of evidence must be integrated before human agency can be assigned, an approach necessitated by the apparent lack of a single diagnostic characteristic. Sequential critical analysis of the natural setting, recovery methods, skeletal element representation, and modification characteristics is required, each of which is examined separately below.

It is important to note that the San Juan Islands are within a region typified by coniferous forests and alder stands that tend to promote soil acidity and, consequently, poor bone preservation except under unusual conditions. *Sphagnum* bogs are also acidic, destroying bones, but wetlands in the San Juans with calcareous substrates have buffered waters and form taphonomic “windows of opportunity” in which bones can be locally preserved. These

taphonomic windows must therefore be relied upon to provide information for a wider landscape. They were formerly ponds and thus not specific areas of human activity, though such activity likely took place along their margins. The limited overlap between these taphonomic windows (i.e., the wetlands) and the actual loci of human activity (i.e., areas adjacent to the wetlands) significantly limits the possibility of finding associations between diagnostic stone tools and well-preserved megafaunal bones and helps to explain the paucity of such discoveries in the past.

2. Natural setting

2.1. Discovery location

The 1.2 hectare (3 acre) pond at the Ayer Site, 45SJ454, was created artificially in a headwater wetland in a large topographic trough (Fig. 2). The stream gradient through the wetland is very low, allowing fine sediment, organic material and volcanic ash to settle to the pond bottom in well-defined strata. The terrain surrounding the pond is rolling and gradually sloped with occasional bedrock outcrops. There are no cliffs or evidence of mass-wasting events that could have led to the observed modifications to the bison bones.

2.2. Reported discovery and collection

Workmen excavating the wetland to create a pond in 2003 discovered bison bones in basal lacustrine silts atop glaciomarine sediments and beneath a woody peat sequence. The find's special significance was not understood, so it was not initially reported.

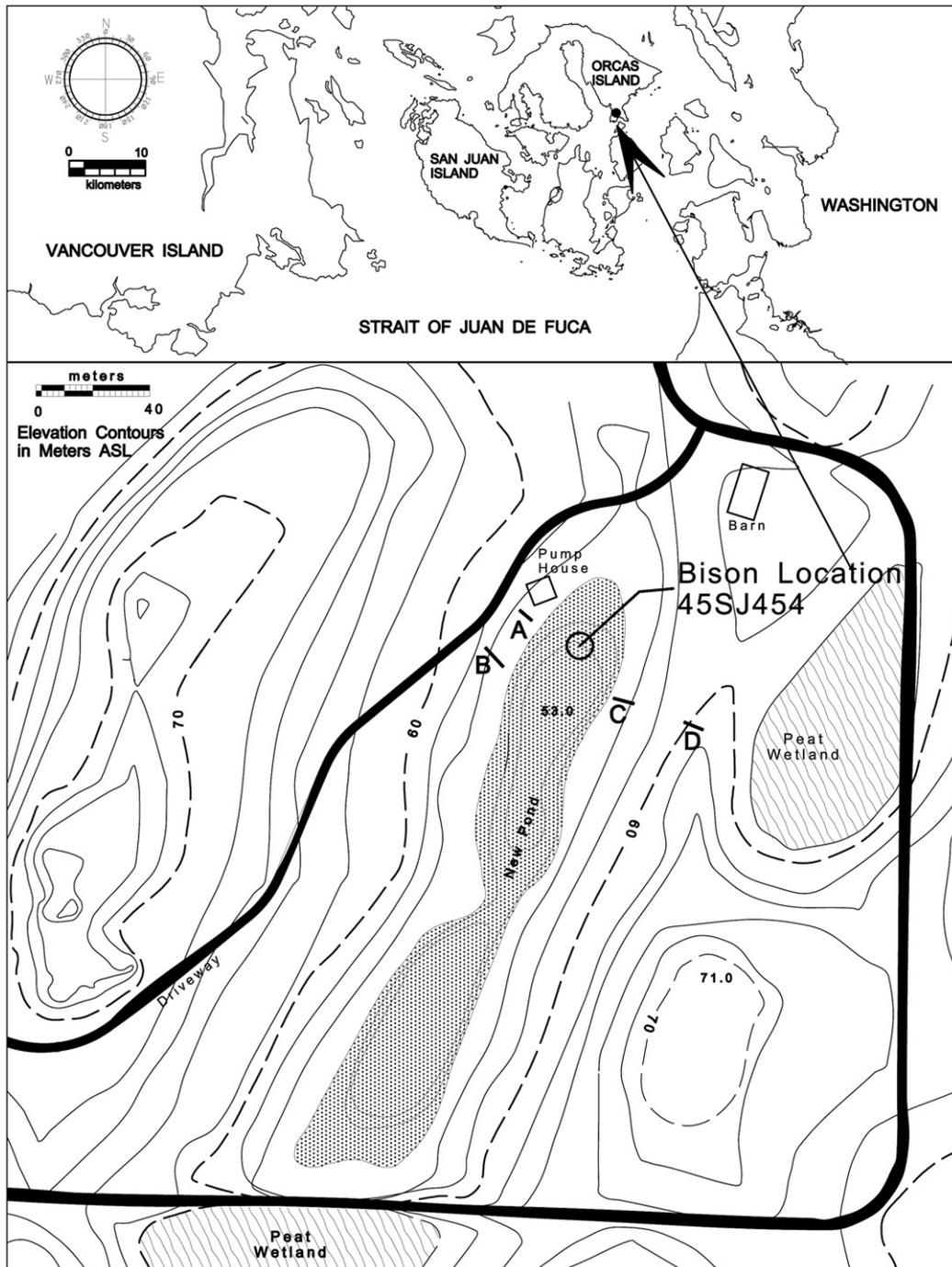


Fig. 2. Ayer Pond bison discovery location: San Juan Islands region in northwest Washington state (above); Ayer Pond and surrounding topography (below). The spillpoint of the pond is its north end. Locations A–D are 2007 soil profile trenches.

The description of the excavation methods and geological context presented here is based upon the first author's later interviews of the workman responsible for the discovery.

The project began during a dry summer with excavation of a drainage ditch through the spillpoint at the outfall (north) end of the wetland in order to dry out the peat. Excavation to remove the peat and create the pond was done by a tracked mechanical excavator (track-hoe) with a telescoping articulated arm and a 1.2 m-wide toothless bucket. Although the digging technique was crude by archaeological standards it was, nonetheless, planned and systematic. For example, conditions in the excavation permit

specified creation of a pre-designed terraced pond bottom to insure a variety of underwater and wetland habitats. This required coordinated excavation technique stripping away the peat in layers. The track-hoe operator was responsible for establishing correct elevations and was therefore focused on the surface being worked. The woody peat that was removed was loaded directly into dump trucks shuttling the tailings to a nearby dump site on the property. During this procedure the truck drivers would routinely assist the excavator and help to monitor the surface.

As the operator was transferring excavated material into a truck, one of the drivers noticed a bone protruding from the cutwall at the

base of the peat about 3 m below the present pond surface. Work stopped immediately while one workman searched the truck for any bone that might have been loaded unseen. One bone described as a vertebra was discovered in the truck and was set aside. Next, all three workmen sorted through the easily excavated in-place peat and immediately underlying silts by hand, without tools, looking for more bone. Digging down through the undisturbed peat by hand they eventually uncovered a surface of glaciomarine sediments about 10 m² in extent. They exposed 98 whole bones and fragments lying on this lighter contrasting surface with the lower limb bones in a partially articulated arrangement lying parallel to each other across the slope. They described the location and find as a “blue sand beach with shells” and “the skull uphill on a 1:1 slope.”

The bones were collected by hand and placed in a large cardboard box. The workers also examined the contents of the truck once more, as they observed that the rib cage was largely missing, but no additional bones were found. It is noteworthy that the workmen were able to identify and collect very small fragments and skeletal elements under these conditions. Visibility and recovery appear to have been relatively good. Although no one present had formal training in archaeology, they would certainly have been able to identify obvious lithic artifacts such as projectile points. The equipment operators had an acquired familiarity with formed artifacts through past inadvertent discoveries and self education. Less obvious artifacts such as cobble choppers or anvil stones may have been overlooked, although when questioned the workmen could not recall any stone objects fist-sized or larger. The only anomaly in terms of skeletal elements might be the absence of most phalanges of one hind foot, given the presence of a distal phalanx. These elements as a cluster may have been removed by the excavator and trucked to the dump site, to remain hidden even during subsequent blading.

Uncertain about what to do with the bones since the property owner was out of the country, a driver stored the box in his garden shed. Eventually in 2005 the first author was contacted for advice and visited the shed for an inspection. The bones, still in the original cardboard box, were encrusted with sandy marl. They had apparently not been handled or moved since being placed in the box. The magnificent, extremely well-preserved skull had been stored separately indoors and undoubtedly had been handled, though with care.

It is most significant to note that no shovels, trowels or other sharp tools were involved in the excavation that might have scratched or gouged the bones. The track-hoe bucket had no teeth and the leading edge had a 2 cm radius so it can be ruled out as a cutting edge. During the short period of transport, no coarse gravel was present with the bones that might have scratched bone surfaces and most of the specimens were handled only once. Since few bones had been displaced at the time of discovery, bone-on-bone scraping was also minimized.

Subsequently the woody peat and other sediments from the excavation were widely spread out by bulldozer for landscaping. The surface of this pile of material was inspected before being spread out and the bulldozing was closely monitored by authors Kenady and Wilson, assisted by landowner Tony Ayer and geographer Ineke J. Dijk. Not a single bone fragment was observed during these operations, even though a few isolated bones (bison vertebra, female bison phalanx, calf bison cranium, large cervid antler fragment) had been found elsewhere in the pond and the missing hind limb phalanges might have been present. Thus we are confident that no large bone elements, such as complete ribs or vertebrae, were missed.

3. Stratigraphy and soils

Observations by the original excavators, property owner Tony Ayer, and the authors document a stratigraphic sequence of glacial

diamict, overlain by shell-bearing glaciomarine sands, overlain by thin basal lacustrine marly silts and sands, then by woody peat. The geologic context of the bones is shown in Fig. 3, in relation to authors' observed and inferred stratal boundaries and radiometric time markers. Tony Ayer's observation of light bands in the peat was confirmed by the authors during a surface inspection of the excavation backdirt spread by a bulldozer. Volcanic ash clumps were noted across the graded surface together with woody peat. Scattered faceted dropstones were also observed, with adhering sandy matrix indicating they were from the basal glaciomarine sediments. The same coarse sandy matrix was observed on, and occasionally inside, articulated marine bivalve shells indicating the organisms were once living in the sediments and not present there as marine drift. On close examination the bone specimens recovered earlier were found to be encrusted with similar sandy matrix together with freshwater gastropods and to a lesser extent woody peat fragments. When considered together all of these observations are consistent with those reported by the workmen as to the discovery stratigraphic context. Additional corroborative stratigraphic information is detailed below.

3.1. Wetland description

Local wetland development regulations required a formal site evaluation by a registered wetlands scientist as a basis for the project design. This work was conducted by Azous Environmental Sciences and reported in May 2001 (Azous, 2001), and provides a description of the wetland deposits that is consistent with observations of the pond excavators and the authors:

...there is a layer of marine sands and silts containing numerous seashells. This layer was found between 10 and 15 feet below the peat surface in a test hole dug approximately midway the length of the wetland. Gray silty clay was observed at approximately 3 feet from the surface near the outlet at the northern end of the wetland and medium textured gravelly glacial till was located at about 20+ feet deep in the middle of the wetland. Soils samples taken from Wetland Or380 [Ayer Pond] show it to be native shallow to deep organic deposits of black to dark brown (Munsell colors 10YR 2/1 to 7.5YR 3/2) sapric and hemic material (mucks and mucky peats) generally ranging from 10 to over 30 inches thick overlying mucky silt loams and diatomaceous-rich silt loams. A single layer of light gray (10YR 7/1) volcanic ash ranging from 0.25 to 0.75 inches thick was observed at several locations within the wetland depression at variable depths.

3.2. Pond margin investigations

In 2007 the first author and archaeologists Randall Schalk and Robert Mierendorf revisited Ayer Pond with the purpose of examining the depositional sequence along the margins of the pond. The objective was to identify paleosol markers that might be useful in future attempts to locate evidence of human activity adjacent to the pond dating to the age of the bison bones.

Four track-hoe trenches were excavated roughly perpendicular to the pond shore line in locations noted in Fig. 2. Trench A, Fig. 3, confirmed Azous' observation of hydric soils near the outfall of the old pond and revealed the presence of a primary volcanic ash layer, presumably the same one observed in the center of the pond during Azous' earlier investigations. A sample of the ash from trench A was submitted for identification to F.F. Foit, Jr., School of Earth and Environmental Sciences, Washington state University. Based on microprobe analysis of major and minor elements encased in glass shards, the sample is a close match (0.99 Similarity Coefficient) to Mount Mazama O, from an eruptive event dated at 6730 ¹⁴C BP

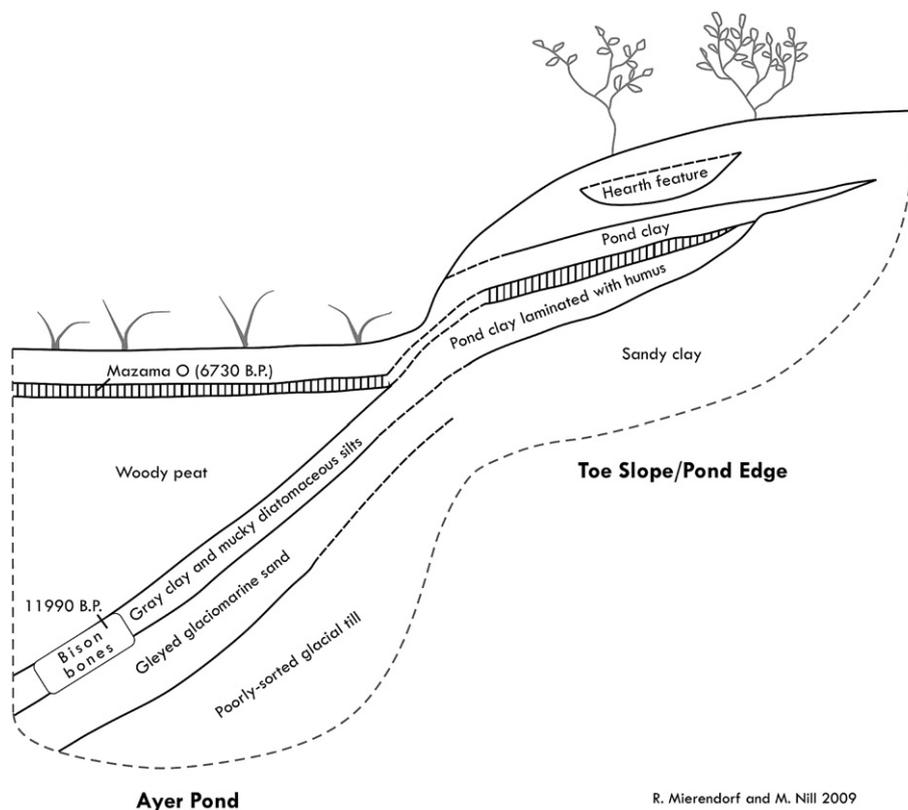


Fig. 3. Schematic cross-section, correlation diagram showing stratigraphic relations of Ayer Pond deposits to pond edge deposits, bison bones, and radiometric-derived time markers. Solid lines depict observed strata boundaries; dashed lines depict inferred strata boundaries. Not to scale.

(Hallett et al., 1997). Zdanowicz et al. (1999) provide a date of 7627 ± 150 cal BP based upon Greenland ice core evidence.

Unexpectedly, trench A also showed evidence of an anthropogenic hearth feature post-dating the Mazama ash and stratigraphically unrelated to the older bison (Fig. 1). Equally unexpected was the discovery of three small pieces of dacite lithic debitage in trench B during random screening of the trench backdirt. Neither the hearth nor the artifacts can be directly related to the bison remains, but it is notable that a low-effort, reconnaissance-level search along one portion of the pond edge has already revealed evidence of human presence for at least several thousand years.

4. Radiocarbon dates

The first radiocarbon date of $11,760 \pm 70$ ^{14}C BP was based on AMS dating of bone collagen prepared with a strong acid wash of a sample taken from a horn core. Recognizing concerns about sample contamination, a medial phalanx from the same animal was dated recently under the direction of Tom Stafford after pretreatment by a second method which processes the XAD-resin-purified hydrolyzate of extracted collagen (Stafford et al., 1991). This produced a new date of $11,990 \pm 25$ ^{14}C BP (UCIAMS-53549).

Both radiocarbon dates are in the range that can be expected in the stratigraphic sequence in which the bones were found. The underlying glaciomarine sediments predate the bones establishing a maximum possible age. Radiocarbon-dated bivalve shells from glaciomarine deposits on Orcas Island range from 12,600 to 12,480 ^{14}C BP before marine reservoir correction (Easterbrook, 1966) and those from the San Juans overall range between 13,240 and 12,000 ^{14}C BP before correction (Dethier et al., 1995, 1996). An appropriate marine correction is likely on the order of -800 yr (Wilson et al., 2009). All of these dates are from sites at lower

elevation than the Ayer Site, so their lower limit could overlap with the presence of bison on higher, exposed landscapes. The overlying peat deposit is banded and includes a primary layer of Mazama O tephra (Hallett et al., 1997; 7627 ± 150 cal BP, Zdanowicz et al., 1999; Bacon and Lanphere, 2006) which establishes a minimum age for the bison found below it. Thus the age of the bison bones can be expected to be bracketed between $\sim 12,200$ ^{14}C BP (Wilson et al., 2009: 55) and 6730 ± 40 ^{14}C BP.

5. Interpreting the find

Examination of recovered bones clearly underscored excellent preservation conditions, with even delicate bones such as the hyoids as well as small cranial and limb bone fragments present. Close examination revealed crescentic impact points on some bones, as well as a few cutmarks. Thus the possibility that the bones documented ancient human activity prompted critical review of all aspects of the discovery.

The discovery location in basal pond deposits beneath 3 m of woody peat cannot be explained as the result of geologic or hydraulic transport. The fine-grained matrix and setting within an old lake or pond basin are inconsistent with fluvial transport of large bones, especially the massive cranium, which is intact with even a partial maxilla, a premaxilla, and the nasals preserved. The great variety of sizes among the specimens indicates the absence of hydraulic sorting and the pond level was evidently controlled by a spillpoint. Minor downslope movement through mass-wasting cannot be completely ruled out, but the relatively close association of pieces of such varied sizes, many of which could be refitted, plus the near-absence of striations, indicates this to be unlikely. The bison could not have been butchered in the pond but could have been butchered on ice if the pond was frozen.

Bottom vegetation near the pond margin could have contributed to a high rate of sedimentation, further protecting the bones (Haynes, 1982: 279). An alternative possibility is that the elements were discarded into water from the adjacent pond margin, but if so they were thrown as articulated units and one was the heavy head, still including flesh and brain, with the mandibular ramus and hyoids still attached.

5.1. Element identification

The first author tentatively identified the cranium as *B. antiquus* through biometric comparison with data provided by McDonald (1981: 87). This procedure was later duplicated by the second author (Wilson et al., 2009) confirming the identification. The horn core size is smaller than for coeval Great Plains *B. antiquus* populations, possibly reflecting an insular effect.

Individual skeletal elements and fragments were identified and catalogued by Kenady after visual and biometric comparisons with data from McDonald. Visual comparison with a *B. bison* osteological key (Todd n.d., online) and a final opinion by Wilson confirmed element identifications. Each of the 98 whole bones and fragments was then labeled and catalogued.

The individual age of the bison, based upon dental wear and sagittal suture fusion as compared with the Garnsey, New Mexico, sample (Wilson, 1980) was ~7–8 y. The right M³ was fully in wear, though still cross-crested (bilophodont). The entostyle was worn to a roughly triangular loop, still separate from the main wear surfaces. The paracone height of 37.0 mm indicates a crown about half worn away. Unfortunately, dental eruption and wear are not reliable enough to indicate seasonality once the tooth is in full wear, so an individual of this age cannot be assigned seasonality on this basis. Tooth cementum annuli show promise for determination of seasonality but analyses of later Holocene samples show considerable individual variation; hence cluster analysis is important and a single specimen is not definitive (Peck, 2004). We have not sectioned the tooth for cementum analysis.

5.2. Element distribution

Aside from any evidence for markings, the pattern of selective element representation at Ayer Pond is instructive. The mature male bison is represented by a cranium with nasals, one maxilla and premaxilla, one mandibular ascending ramus and the hyoids, one thoracic vertebra, right lower front limb from distal humerus to phalanges, left lower front limb from carpals to phalanges, both hind limbs from distal tibia to phalanges, and humerus and tibia shaft fragments. Lyman (1985, 1994) cautioned that denser elements tend to occur in parts of the carcass that are low in nutrition, making it problematic to distinguish butchering from differential preservation. At Ayer Pond, bones that should have been preservable and highly visible are clearly absent and delicate elements are present, suggesting that density-mediated attrition is not an issue.

Methodical dismemberment and breakage are inferred from the 98 bones and fragments and from the pattern of missing skeletal elements (Fig. 4a). Most of the remaining bones represent non-meaty, low-utility elements and the units lay in near-articulation, aside from the single thoracic vertebra. A similar pattern of selection and removal of high value portions is characteristic of a “gourmet butchering” pattern widely reported from other Paleoindian bison kill sites (Binford, 1981; Meltzer, 2009). Todd et al. (1997) observed that limb bones in Paleoindian kills were often smashed for marrow with hide and meat still attached while the remainder of the carcass was processed in another location. The Ayer Pond find is consistent with such a removal strategy. The pattern is unlike those of non-human predator kills or scavenged sites, as is discussed below.

5.3. Modifications

The excellent preservation of the bones, better than typical Stage 1 examples (Behrensmeier, 1978), makes post-mortem modifications distinct. Linear fracturing in response to subaerial drying before burial (Haynes, 1982: 268–269) was not observed in this sample, though some splitting appeared, together with minor exfoliation, during storage as the specimens slowly dried. The high quality of bone surfaces indicates rapid burial or submersion with little or no time for subaerial weathering. Surface detail and articulations suggest that at least some of the bones were covered with skin and/or flesh when buried.

Color is an important attribute of the modified surfaces. Nearly all fractured, cut, or polished surfaces are the same color as adjacent unmodified bone. One limb bone fragment (45SJ454/86) has a light colored impact fracture that intersects a darker fracture scar. The edges are slightly sharper to the touch and the surface has a comparatively gritty texture when compared to adjoining surfaces. This is interpreted as a single example of recent modification. The remaining modifications have a close color similarity to adjacent surfaces suggesting a common history of exposure to processes which have effected color change. They are therefore likely to be the same age and all are older than the single recent impact fracture. These interpretations support the conclusion that almost none of the modifications are the result of recovery methods or mishandling.

Modifications resulting from impact are dominant. Although there are no fine cutmarks that would result from slicing with a sharp edge, there are two larger V-section grooves that may be better described as cleaver-like chop marks. Depressions such as these having straight margins and steep walls may be definitive of butchering (Domínguez-Rodrigo and Barba, 2006) although Galán et al. (2009: 783) and others urge caution in the use of isolated criteria to make taphonomic inferences.

The fragments of the more proximal, meatier limb bones show spirally-fractured “green bone” breaks and points of impact, defined by concentric sub-angular fractures (ring fractures) around a single point or as impact notches. Such fractures have been viewed as highly suggestive of human agency (Morlan, 1980; Todd et al., 1997; Harington and Morlan, 2002) and typically produce “cone flakes” or segments of cones (Holen, 2006, 2007). Percussion marks (pits and grooves from hammerstones or anvils) have been suggested as diagnostic of human behavior in contrast to carnivore or scavenger activity (Blumenschine and Selvaggio, 1988; Blumenschine, 1995; Galán et al., 2009), though the depositional context must still be considered, including other potential site-specific impact factors such as roof-fall, trampling, or fluvial ice-push. There are no U-shaped grooves, splintered crushed bone, or opposing depressed fractures in the Ayer sample to suggest mastication or gnawing by scavengers or carnivores (Sutcliffe, 1970; Gilbow, 1981; Haynes, 1980, 1982: 269; Wilson, 1983; Lupo and O’Connell, 2002). Evidence of trampling (Haynes, 1982; Fiorillo, 1989; Bement, 1999) by heavy ungulates is absent.

Altogether we have identified 61 modifications on 34 of the bone specimens recovered. The definitions of these modifications are listed below and the specific details and skeletal elements are tabulated in Table 1.

5.3.1. Modification definitions and abbreviations

GBF Green Bone Fractures. These have sharp regular edges with smooth fracture surfaces. Some radiate from a point of impact and some do not.

POI Point of Impact. Sub-angular point of impact with GBF radiating out creating <180° angle.

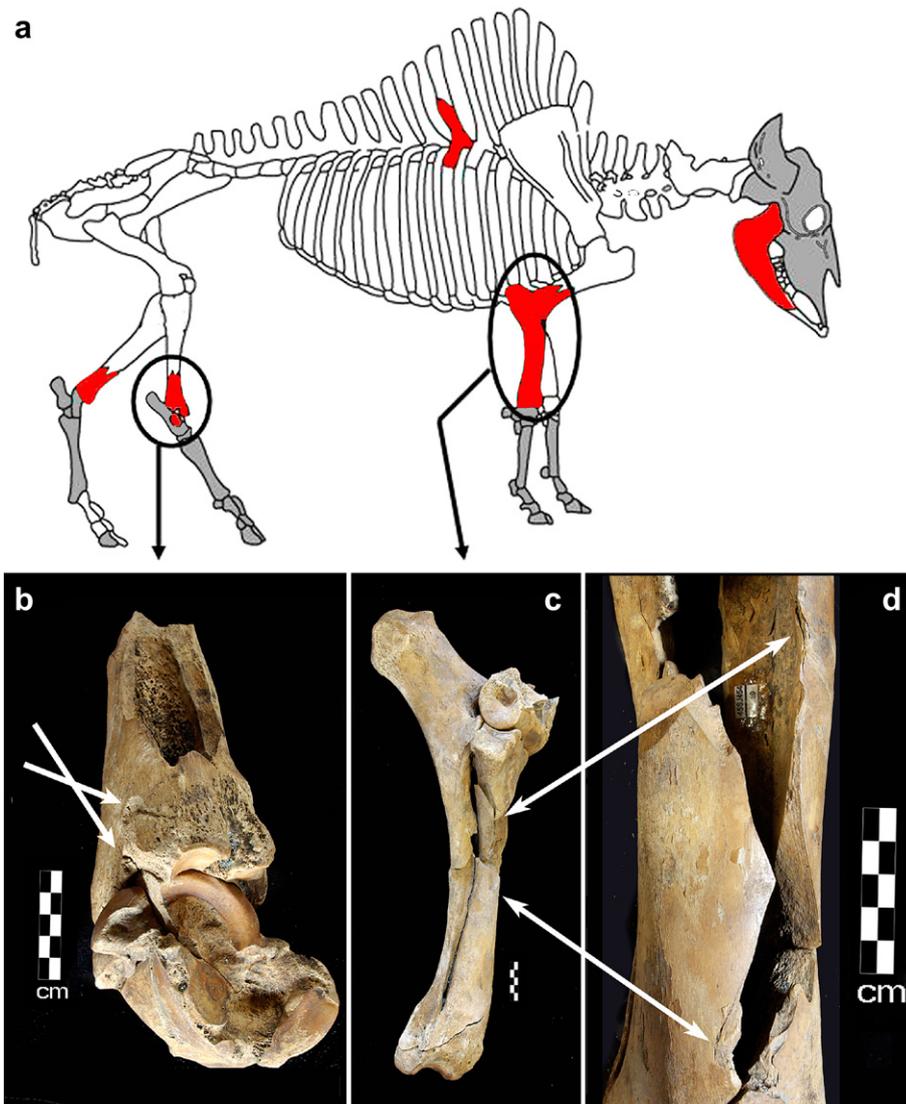


Fig. 4. Recovered elements and fragments with modifications: (a) skeletal diagram; modifications only found in black areas (red in color) and unshaded bones absent; (b) two deep V-section chop/cutmarks to right distal tibia, one split astragalus; (c) refit green bone fractures of right radio-ulna and distal humerus; (d) concentric fractures (ring fractures) partially encircling points of impact.

POIC Point of Impact with concentric fractures (ring fractures) encircling a single point.

P Polish. Characterized by a rounded visibly shiny edge or point.

RGM Rodent Gnaw Marks. These are generally parallel (paired) repetitious straight striations, sets of which sometimes intersect. These marks are about 5 mm width and length and no more than 1 mm deep. They are rarely parallel to the longitudinal axis of the bone.

PSCT Parallel straight scratches. These are very light, V-shaped in section, straight and no more than 1 mm deep.

DVCT Deep V-Cut Marks. These are V-shaped in section and more than 2 mm deep.

The locations of the cutmarks and points of impact (Fig. 4a, Table 1) are significant when compared to other reported evidence of Late Pleistocene butchering of bison (Frison, 1974; Jodry and Stanford, 1992; Todd et al., 1997; Byers, 2002; Hill et al., 2008). Of butchered bones from the 10,000-year-old Casper Site, Wyoming, the elements most frequently showing signs of modification (as % of NISP) were tabulated by Todd et al. (1997). Impact marks were most

frequent on radii and femora (20.7%), humeri (18.1%), tibiae (15.9%), and metatarsals (9.6%). All other elements were less than 2.5%. Casper Site tibiae showed extreme fragmentation except for distal ends. Recomputed values for impact marks when shaft fragments were excluded (to eliminate any bias from fragmentation) showed tibiae as highest (30.2%), followed by radii (23.7%), humeri (20.0%), femora (19.5%), metatarsal (9.6%), and others again much lower. The highest percentage of cutmarks at Casper was on tibiae. The Ayer Pond sample fits this pattern closely with metapodials complete and humeri, radii and tibiae fragmented as illustrated in Hill et al. (2008: Figs. 7 and 12). The locations of Ayer Pond impact marks also agree with examples logged for Casper: lateral surface of humerus, cranial surface of radius near proximal end, and all four surfaces of tibiae near the distal end. The same patterning is reported by Byers (2002) at the Hell Gap Site and again at the Stewart's Cattle Guard Site by Jodry and Stanford (1992). In both of these sites the patterning was interpreted to be evidence of efforts to harvest the nutrient-rich marrow.

Additional indications of butchering are found at two anatomical locations. The hind limb evidence includes nearly identical fracture patterning on both distal tibiae (Fig. 5, 45SJ454/40, 79, 80 and 14),

Table 1
Modified Bison bones in the Ayer Pond (45Sj454) sample.

Cat. no., 45Sj454/x	Skeletal element	Portion	Side	GBF	POI	POIC	P	PSCT	RGM	DVCT	Impact surface	
	<i>Cranial</i>											
1	Cranium			X								
91	Mandible		R	X								
92	Maxilla		R	X								
95	Ascending ramus		R	X								
89	Hyoid		R	X								
3	Cranial fragments			X								
5				X								
7				X								
8	Bag of very small fragments			X								
	<i>Axial bone</i>											
93	Thoracic			X								
	<i>Appendicular</i>											
	Front limb											
11	Humerus	distal	R	X								
12			R	X							Lateral	
13			R	X							Lateral	
14			R	X								
15	Radius	proximal	R	X								
16		distal	R	X								
17			R	X								
18			R	X								
19			R	X								
20	Ulna	proximal	R	X								
21			R	X								
40	Hind limb											
	Tibia	distal	L	X								
79			L	X								
80			L	X								
41		distal	R	X								
44	Astragalus											
45			R									
46			R									
81	Limb bone fragments			X								
82				X								
83				X								
84				X								
85				X								
86	Humerus?			X								
87	Tibia?			X								

R indicates right side, L indicates left side and X indicates present.

both being broken through the same region of dense cortical bone tissue. This suggests an exacting agenda by the butchering agent, not simply the similar shapes of the bones. Another line of evidence is evident where the right distal tibia refits the astragalus (Fig. 4b). Two deep “V”-section grooves indicate roughly parallel strikes by a sharp

heavy object. One blow struck the tibia and continued through the joint, splitting the astragalus in line.

Experimental butchering studies using large ungulate bones have shown no relationship between carcass processing intensity and creation of cutmarks, so cleaver-like blows such as these in the

near-absence of cutmarks are by no means anomalous (Egeland, 2003). Cutmarks are infrequent in Paleoindian contexts as compared to later kill sites (Meltzer, 2006).

Refitting of several fragments shows forelimb modifications including smashing of a right distal humerus and radio-ulna (45SJ454/11, 15–19, Fig. 4c). The humerus (45SJ454/11–14, Fig. 6) was smashed across the lower diaphysis above the olecranon fossa in an area of thick cortical tissue. Below the spirally-fractured humerus are at least two impact fracture points on the radio-ulna cranial (anterior) surface (Fig. 4d). These marks show evidence of blows by a heavy object with a gritty surface, likely a cobble chopper. These fractured bones could only have been struck with the limb segment rotated and supported so that the cranial surface was uppermost. Without support, the large paddle-like olecranon process of the ulna would have caused the limb segment to roll to its side, making the cranial surface difficult to strike, so this positioning required the butchering agent to supply the support. Such positioning may also have been influenced by the limb being stiffened through rigor mortis at the time of fracture (Lupo, 1994). Similar fracture patterns have been interpreted as evidence for butchering on other bison (Zeimens, 1982; Todd et al., 1997; Harington and Morlan, 2002) and almost identical fractures are known from Plains bison kills spanning the Holocene.

6. Discussion and conclusions

The Ayer Pond specimen shows evidence consistent with butchering by humans, based on element selection, spiral fracturing, and character and location of blows. Such evidence at Holocene sites has been routinely accepted as indicative of butchering. However, alternative explanations must be rigorously examined. Previous researchers have reported taphonomic analogues that warrant consideration for purposes of comparison. A concern is the issue of equifinality, that even if humans were the agent, other pathways could have produced indistinguishable

results. However, Rogers (2000) argues that butchering should not be strictly equifinal (identical) with evidence from other processes, though they may be substantially similar, and that definitive criteria can be sought.

6.1. Context and strategy

Factors relating to the location of the discovery must be considered. Haynes (1982: 279) found that dried lake or pond bottoms often yield ungulate bones and those in his study seemed not to be predator related. Natural deaths, such as by winter-kill, could account for many. A carcass on pond ice would be protected by freezing and by snow cover, then could settle gently to the bottom in a thaw. However, in such a case the selective element distribution noted at Ayer Pond would still require a second factor such as scavenging.

The hypothesis that a butchered carcass was left on the surface of the frozen pond is in agreement with several aspects of the find. First, a butchered and then rapidly frozen carcass would not draw scavengers and there is no evidence of large carnivore gnawing. Additionally, thawing and breakup of the ice could have allowed the frozen carcass simply to settle or to drift a short distance toward the outfall (north) end of the pond, Fig. 2, where it then settled to the bottom.

Caching of meat in water (Fisher, 1995a) is a potential explanation at Ayer Pond though unlikely in view of the low-yield nature of the remaining bones, unless this was a utilized cache from which pieces had already been removed. It may be that this is an example of caching on ice, with partial utilization. The cranium could have been left at the cache to assist hunters in relocating it, as suggested for other such cases. A mammoth cranium rested atop a pile of bones from more than one individual, possibly representing a frozen meat cache, at the Colby Site, Wyoming; and frozen caches may have been widely used by Paleoindians (Frison, 1981). Binford (1978) described Nunamiut use of antlered caribou crania to mark frozen meat caches covered with snow.



Fig. 5. Left (a) and right (b) distal tibiae showing similarity in breakage patterns and sides struck.



Fig. 6. Posterior (a) and anterior (b) views of right distal humerus showing “green bone” spiral fractures of dense cortical bone nearly 1 cm thick.

It is also possible, given the presence of scavengers like *Arctodus*, that unwanted carcass remains were disposed of underwater to mask odors that might attract unwelcome animals to the processing area. The *Arctodus* from nearby San Juan Island appears to date from the same time interval as the bison remains (Barton, B., pers. comm.; Dethier, D., pers. comm). *Arctodus* has been interpreted as a hyena-like bone crusher (Matheus, 2003:112–113), but would have left tooth marks on the bones in addition to crushing marks. Crushing should have left opposing marks on the other side of the bone in contrast to the one-sided pattern of smashing typical of butchering. None of the Ayer Pond specimens have any modifications that can be attributed to *Arctodus* and scavenging from that source appears unlikely.

6.2. Patterns left by predators and scavengers

Predation or scavenging by other species must be carefully considered on the basis of documented observations. For example, in the case of predation by wolves, adult bison long bones are rarely fractured, even though entire articular ends may be chewed away and adjacent cortical tissue snapped off (Haynes, 1982: 273). Humeri therefore become open-ended tubes (cylinders) with scoring on the shaft; while tibiae lose their proximal ends and may show adjacent fractures and rounding, though they still tend to be articulated distally with the tarsals (Haynes, 1982: 274–275). These patterns were not present in the Ayer Pond sample and the bones were more heavily fractured.

Experiments with African lions and hyenas showed that if they are allowed first access to a carcass the long bone shafts are often heavily tooth-marked (Blumenschine, 1995). At the feeding sites of contemporary African carnivores (Brain, 1981; Binford, 1981, 1984; Blumenschine, 1986a,b) heads and lower limbs are commonly the only consumable portions left, which resembles the pattern of element representation at Ayer Pond. However, such bones typically show abundant other evidence in the form of tooth scoring.

Wolves and dogs are predictable in terms of element preference even though seasonal and situational exigencies no doubt affect the sequence. The results of canid scavenging are as strongly patterned as

butchering by humans and far from “haphazard” with consistent preferences in selection of elements and repetitive patterns of breakage and tooth-marking (Binford, 1981; Haynes, 1980, 1982; Wilson, 1983; Garvin, 1987; Mearns and Spencer, 1991). In discussing predation by North American wolves, Haynes (1982: 269–270) observed even for deer carcasses that vertebral segments with proximal ribs and scapulae may remain articulated for a long time after a kill event. Among the elements remaining from heavy carcass utilization are upper and lower dentitions, glenoid portion of scapula, acetabulum of the innominate, and distal limb portions with articulated phalanges; there may also still be articulations involving the distal tibia and distal humerus (Haynes, 1982: 269–270). In wolf-killed bison articulated thoracic segments with vertebrae and proximal ribs, sometimes with pelvic material, can persist for months. Only one vertebra was present in the Ayer Pond sample, and ribs, scapulae, and pelvic elements were absent. For large prey such as bison (Haynes, 1982: 270–274), wolves damage the nasal bones early in carcass reduction, before separation and fragmentation of limbs. The Ayer Pond nasals are intact, showing no signs of damage by canids.

In early stages of carcass reduction by wolves, lower legs and crania are rarely stripped of their hide, which can keep limbs in nearly anatomical order (Haynes, 1982: 272). Skulls are protected longest by unpeeled hide, save for the nasals, which soon show distal chewing (Haynes, 1982: 276). Kills fully utilized by wolves usually have the cranium and mandibles with two lower legs left at abandonment (one or two are typically dragged away). Crania remain even after a season or two of scavenging by other species, such as wolverine and other mustelids. The most common isolated bones, dragged up to hundreds of meters from the kill, are vertebrae, scapulae, and metapodials. The most extensive scattering of scavenged carcasses may not occur until after soft tissue is gone, after several months (see also Toots, 1965). Ten or more vertebrae can remain as an articulated unit even several months after a kill, though some vertebrae may be dragged away. Vertebral spines may be snapped away from the centra and show bilateral tooth punctures at the base of the spine (Wilson, 1983: 125). When evaluated strictly on the basis of present and absent skeletal elements, some

attributes of Ayer Pond bison might be attributed to methodical scavenging by canids. However, this conclusion is rejected because of the absence of bone modifications associated with canid scavenging such as highly patterned chewing and breakage (Binford, 1981).

Scavenging bears eat the hide from the lower limbs, causing disarticulation, the opposite of the situation noted at Ayer Pond. Despite some examples of breakage by captive animals, bears typically do not seem to break ungulate long bones (Haynes, 1982: 277), though *Arctodus* was likely an exception given its stronger mandibular musculature and scavenging habits (Matheus, 2003). Wolverines, which can fragment long bones, tend to remove and cache bones away from a kill (Haynes, Matheus, 2003), so the more easily movable elements would not be expected together with the cranium. Wolves, dogs, bears, and wolverines would all have left surface marking on the scavenged bones. There is scant evidence in the Ayer sample for such scavenging. In particular, the smashing of the humerus near the densest portion of the distal shaft, with evidence of direct impact, is in strong contrast to carnivore activity.

While good bone surface condition could reflect protection by hide for an undetermined time after death, its uniformity is also consistent with rapid burial in a lacustrine depositional environment with minimal prior exposure. Three minor examples of rodent gnawing, stand as the only evidence for any subaerial exposure. The Ayer Pond bones show no evidence of gnawing or chewing by large mammals.

6.3. Conclusions

Butchering by humans is the explanation that is most consistent with all of the physical evidence that is currently available for the male *B. antiquus* from Ayer Pond. Trampling by heavy ungulates and gnawing or crushing by large carnivores or scavengers are ruled out on the basis of the taphonomic evidence. The assemblage of elements present suggests discard of low-utility elements, possibly onto the ice of a winter-frozen pond, after a nearby kill event.

The new date of $11,990 \pm 25$ ^{14}C BP reported here places the butchered Ayer Pond bison nearly 800 ^{14}C years older than the cluster of most reliably dated Clovis assemblages (Waters and Stafford, 2007), at a location where both hunters and bison could have ranged within a few tens of kilometers of the retreating Cordilleran ice sheet.

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