

ARTICLES

ON BONFIRE SHELTER (TEXAS) AS A PALEOINDIAN BISON JUMP: AN ASSESSMENT USING GIS AND ZOOARCHAEOLOGY

Ryan M. Byerly, Judith R. Cooper, David J. Meltzer, Matthew E. Hill, and Jason M. LaBelle

The Plainview/Folsom-aged bison Bonebed 2 at Bonfire Shelter, originally excavated in the 1960s, is argued to be the earliest North American bison jump (Dibble 1970; Dibble and Lorrain 1968). Yet, it is far older than all other known jumps, and well south of where the great majority of these sites are found. Dibble (1970) reasonably argued that its age and location was not compelling evidence against it being a bison jump. However, Binford (1978) observed that the skeletal composition of Bonebed 2 did not resemble a kill. To assess whether Bonfire Shelter could have been utilized as a jump and whether it was, we explore two lines of evidence bearing on the issue, a GIS analysis of the site and upland topography, and zooarchaeological analysis of the recovered bison remains. Although our GIS analysis indicates that Bonfire Shelter meets many of the criteria of a jump locality, our reanalysis of the faunal remains suggests this was not the primary kill locus, but instead a processing area to which high-utility portions of at least 24 bison were transported and butchered. Where the bison were killed, and how, is not known.

Se ha planteado que el Nivel de Huesos 2 del sitio de Bonfire Shelter, que es de la época de Plainview/Folsom, es el sitio norteamericano más antiguo donde se llevó a cabo el método de caída para la matanza de bisontes (Dibble 1970; Dibble y Lorrain 1968). Sin embargo, es mucho más antiguo que todos los otros sitios de caída que se conocen hasta la fecha, y está ubicado muy al sur de donde se encuentra la gran mayoría de tales sitios. Dibble (1970) planteó razonablemente que su antigüedad y ubicación no forman evidencia convincente de que no fuera una caída de bisontes. A pesar de esto, Binford (1978) observó que la composición esquelética del Nivel de Huesos 2 no parece ser de una matanza. Para investigar si Bonfire Shelter pudo haberse usado como sitio de caída, exploramos en el presente informe dos tipos de evidencia que tienen que ver con el problema: un análisis GIS del sitio y la topografía de terreno elevado, y un análisis zooarqueológico de los restos recuperados de los bisontes. A pesar de que nuestro análisis abarca muchos de los criterios para una localidad de caída, nuestro reanálisis de los restos de la fauna sugiere que ésta no fue la localidad primaria de la matanza, sino que fue una área de procesamiento a la cual se trasladaron y destazaron las porciones de alta utilidad de los 24 bisontes. No se sabe dónde y cómo se mataron los bisontes.

Bonfire Shelter (41VV218) is a multicomponent archaeological and paleontological site near Langtry, Texas (Figure 1), located at the base of a roughly 26 m high cliff. Excavation in the shelter from 1963 to 1964 (Dibble and Lorrain 1968), and again from 1983 to 1984 (Bement 1986), identified two extensive and stratigraphically well-defined bison bone deposits, and one less stratigraphically discrete deposit containing a Rancholabrean fauna. The lowermost bone deposit (Bonebed 1) yielded no unambiguous human artifacts (Grayson and Meltzer 2002; Wyck-

off 1999; cf. Bement 1986). The lower of the two bison bonebeds (Bonebed 2) contained a sparse Plainview/Folsom-aged, lithic assemblage (Dibble 1968:33–38). The overlying bison Bonebed 3 contained Castroville and Montell-aged, lithic artifacts (Dibble 1968:53–55). Our focus in this paper is on the Paleoindian-age Bonebed 2.

Dibble and Lorrain (1968) concluded that Bonebed 2 was actually composed of three separate horizons, which they inferred resulted from multiple jumps of bison (*Bison antiquus*) over the cliff edge, and down through a notch in that edge

Ryan M. Byerly, Judith R. Cooper, and David J. Meltzer ■ Department of Anthropology, Southern Methodist University, Dallas, Texas 75275-0336 (rbyerly@mail.smu.edu)

Matthew E. Hill ■ Department of Anthropology, University of Arizona, Tucson, Arizona 85721-0030

Jason M. LaBelle ■ Department of Anthropology, Colorado State University, Fort Collins, Colorado 80523-1787

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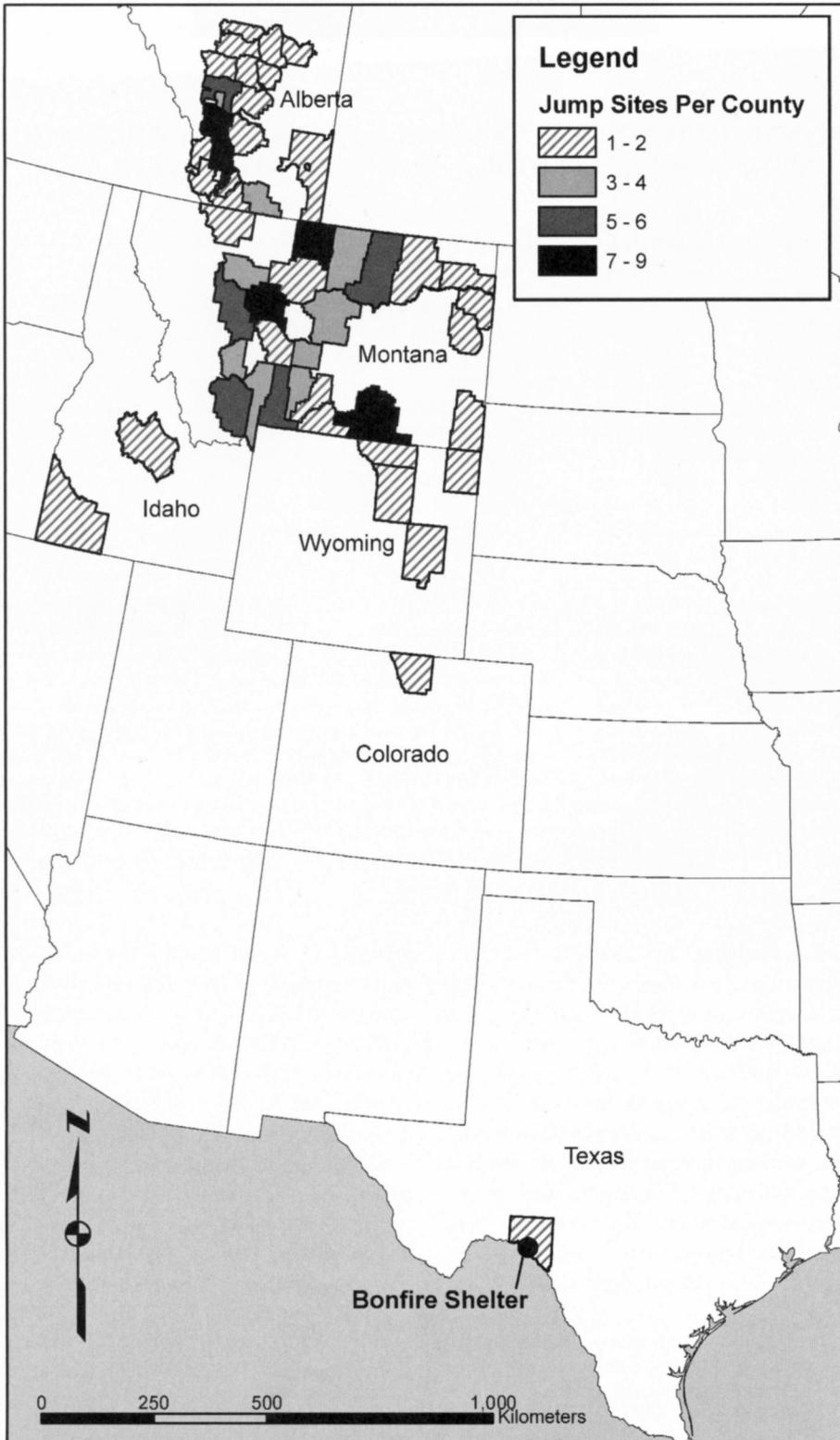


Figure 1. Location map of Bonfire Shelter and other known North American bison jump sites (majority of data from Polk 1979).

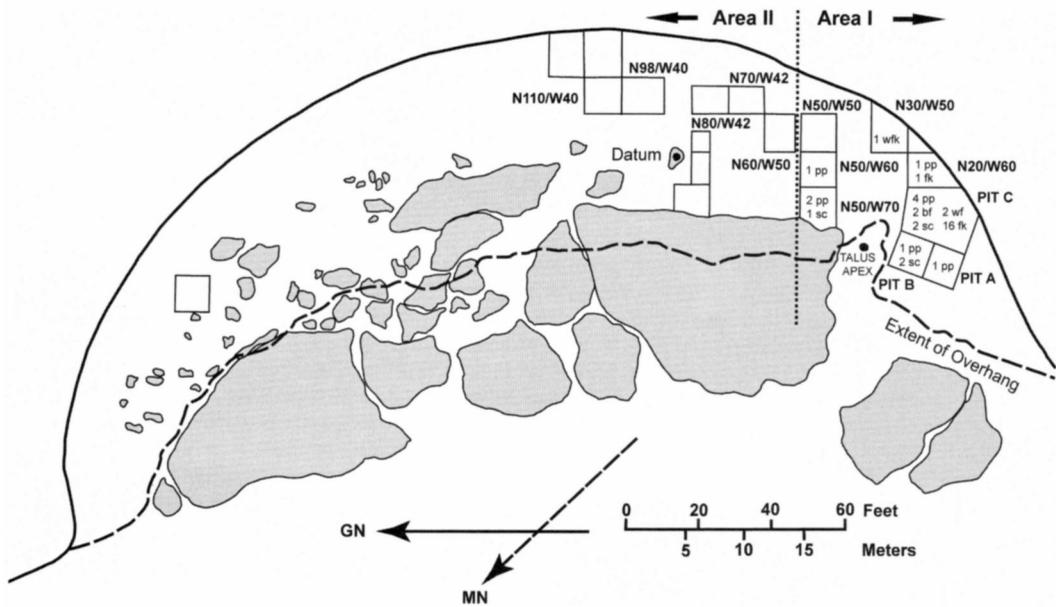


Figure 2. Plan map of Bonfire Shelter showing units excavated into Bonebed 2. Lithic distributions also shown: pp = projectile point; sc = flake scraper; bf = biface; wfk = worked flake; fk = flake. Areas I and II are arbitrary sections delineated in this analysis for the purposes of testing the potential effects of fluvial dispersal in Bonebed 2, they are not a part of any previous reports.

onto a talus cone below. They reached this conclusion because: (1) a visible separation of the Bonebed 2 stratum was observed in Pit C (see Figure 2); (2) the largest bone concentrations were thickest around the talus cone; and (3) a jump seemed the most parsimonious explanation given the apparent alternatives: that the bison were either driven up the canyon into the shelter or killed on the valley floor and their carcasses dragged up into the shelter (Dibble 1968:69). Since the canyon floor is 18 m below the shelter, these alternatives seemed unlikely.

However, this supposed Paleoindian bison jump(s) was anomalous in light of the known spatial and temporal distribution of bison jump sites, the vast majority of which occur on the northern and northwestern Plains, and fall in the latter part of the Prehistoric and into the Historic periods (Dibble 1970; Forbis 1969; see also Frison 1991, 2004). Still, as Dibble (1970) argued, this was not by itself compelling evidence against Bonebed 2 having resulted from a jump kill. Nonetheless, it did raise the question of how one might account for the temporal discontinuity between Bonebed 2 and all those later jumps: perhaps, Dibble argued, this was a case of cultural loss and reinvention (Dibble

1970:252; see also Forbis 1969:91; Frison 2004:79; Reeves 1990).

The supposition that the Bonebed 2 bison were run off the cliff does not square with the recovered skeletal elements—at least as originally reported (Dibble and Lorrain 1968). Element frequencies calculated by Lorrain (1965:114–115, 1968:80) are dominated by mandibles and high-utility limb and axial elements (Binford 1978:475). This pattern is unexpected for a kill locus where low-utility elements, such as crania, tend to be most abundant (Binford 1978; Landals 1990; Meltzer et al. 2002; Todd 1987c; Wheat 1972). After comparing Lorrain's (1968:100) published skeletal frequency data to an element selection model at caribou processing stations, Binford (1978:475) concluded that Bonebed 2 does not represent a kill-site assemblage, but rather a secondary processing locus to which skeletal parts were transported from a kill/primary processing area. That conclusion was supported by extensive element disarticulation (Lorrain 1968:132) and patterned stacking of like elements (Binford 1978:476; Dibble 1968:30; Lorrain 1968:93–96). Subsequent modeling by Sivertsen (1980) also suggested that Bonebed 2 resembled a butchering/processing area.

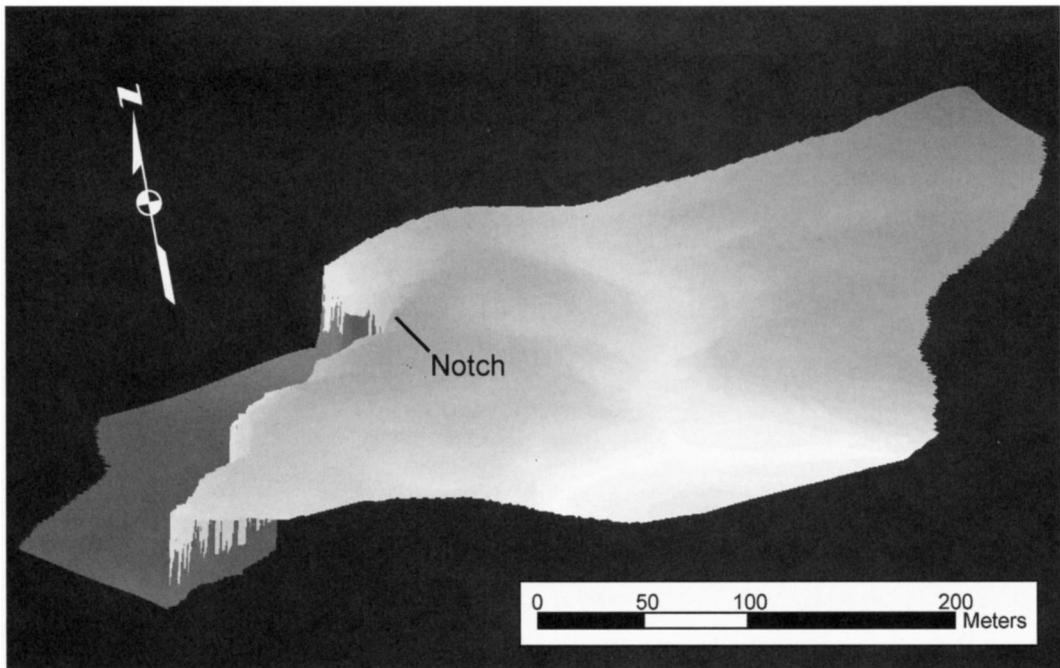


Figure 3. 3-D DEM of Bonfire Shelter and the immediately surrounding landscape. View from the south.

We recently conducted an extensive mapping and GIS analysis of the site area, and reanalyzed the bison skeletal material recovered during the 1963–1964 Bonebed 2 excavations. These independent avenues of investigation allow us to explore in more detail both Dibble and Lorrain's (1968) and Binford's (1978) hypotheses about whether Bonfire Shelter could have been utilized as a jump and, if so, whether recovered bison skeletal data support that inference. We also take this opportunity to provide new and updated data on this faunal assemblage and its taphonomic history.

Site Description

Site Setting

Bonfire Shelter is on the Edwards Plateau, on the southernmost edge of the Great Plains, located near the head of Mile Canyon, a tributary of the Rio Grande. The shelter is eroded into the edge of a northwest facing, ~26 m high cliff face, and is presently ~18 m above the valley floor, which at this point is ~50 m wide. The floor of the canyon is primarily exposed bedrock, indicative of a fluvial regime currently scouring rather than depositing sediment, perhaps as a result of historic

overgrazing (Dibble 1968:13, 69–70).

The cliff top is highest directly above the site, and gently declines in elevation toward the south. Above the southern end of the shelter there is a notch or cleft in the edge of the cliff, occupying an area of ~120 m² and a volume of ~835 m³ (Figure 3). On the upland surface the notch is semicircular in shape and angles steeply down at a slope of 30–40° (Dibble 1968:15) into a V-shaped pour-off above the shelter. The lowest elevation of the lip of the notch is still at least 15 m above the floor of the shelter.

Bonfire Shelter (Figure 2) is semi-circular and oriented northeast/southwest; it is ~80–90 m wide, and ~15 m deep (Dibble 1968:13). The shelter formed by fluvial undercutting of the cliff face when the canyon floor was much higher in elevation than at present (Bement 1986:3). In time, erosion undercut the cliff and very large limestone blocks (15 x 25 m) broke away; these now cordon off much of the front of the shelter. Bement (1986:3) suggests that the Late Pleistocene collapse of these blocks effectively diverted all down-canyon water flow away from the shelter. We concur.

Within the shelter and directly beneath the notch is a talus cone that is at present ~5 m high. In places it contains a substantial accumulation of bison

bone—primarily from Bonebed 3—that gradually tapers into the shelter. No drainage feeds into the notch, thus the talus cone detritus below it could not have come from an upland deposit any significant distance beyond the notch. When Bonebed 2 was deposited, the top of the talus cone was lower, and it is estimated that the plunge from the notch would have been ~23 m (Dibble 1968:13, 70).

Bonebed 2 overlies a portion of the talus cone, and both bison bone and artifacts cluster around the edges of it (see Figure 2). Because the talus deposits were not fully excavated, it is not known whether Bonebed 2 fully blankets the talus cone. Even if it does, this might not bear on how these remains entered the deposit. The talus is located in an open and well-aired front portion of the shelter; the presence of bison bones and artifacts atop it may simply mark where processing took place, and not where the animals died.

Could Bonfire Shelter Have Been Used as a Jump? A GIS Approach

Given the dense concentration of bone in and around the talus cone, Dibble argued that the bison entered the site via the notch which, acting as a trap, funneled them over the cliff edge and onto the talus cone below (Dibble 1968:69). The notch may have been especially effective as a trap because it is visibly obscured until a distance of ~1 m (Dibble 1968:70), leaving inadequate stopping time for a herd of fast moving bison. Other than the notch, features effective for driving bison—such as cairns or other drive line elements—were not found on the landscape leading to the site (Dibble 1968:70).

The acceptance of Bonfire Shelter as a jump has largely relied on a subjective assessment of the landscape and the nature of the archaeological deposits. This is not surprising given that the investigation occurred during the mid-1960s when neither computer modeling capabilities nor geographic information systems (GIS) were available. These powerful tools have proved valuable in addressing archaeological problems related to landscape use, including at a bison jump site. For example, at the Hokanson site, a Late Prehistoric bison pound in southern Manitoba, GIS was used to simulate a bison herd's perspective approaching the trap (DeChaine et al. 2002), which in turn helped model probable locations of an associated pound structure

(Scott Hamilton, personal communication 2005). An analysis of the area surrounding Bonfire Shelter, utilizing GIS, helps us better understand how Bonfire Shelter may have been used by prehistoric hunters, as well as assess its suitability as a jump kill locality.

The term “bison jump” is used to describe a communal hunting strategy in which hunters drove large numbers of bison over cliff edges in order to severely injure or kill the animals (Frison 2004; Hurt 1962). There are many tactical variants to the strategy (Frison 1991), but in general all aimed to put the bison in freefall, ending in impact. As such, archaeologically documented and historically known bison jump kills share a series of ecological and topographic conditions (Brekke 1970; Forbis 1962; Frison 1991, 2004; Hornaday 2002; Malouf and Conner 1962; Polk 1979; Verbicky-Todd 1984; Witkind 1971). These conditions include:

- proximity of the jump point to tracts of grass and permanent water sources, critical to attracting bison to a region and to serve as a gathering area;
- a long, flat, and relatively direct path connecting the gathering area to the jump point that served as a drive lane and enabled the herd to gain sufficient speed and momentum while offering few opportunities for escape;
- a herd large enough in number to ensure that once sufficient momentum is gained in the approach to the jump point, the chance of a last minute escape is minimized;
- an inability of the fast-moving herd to see the cliff edge until after it is too late to stop;
- concomitant orientation of the cliff face and prevailing wind direction (the latter fixed, the other contingent) so that the bison are *upwind* of the jump point and cannot smell the hunters as they approach;
- sufficient steepness and sharpness of the cliff face, to insure that bison stampeded over the edge are killed (e.g., Glenrock site [Frison 1970a]) or badly maimed (e.g., Vore site [Reher and Frison 1980]) by the fall.

While the success of Bonfire Shelter as a jump may not have been contingent on all conditions being in place, their co-occurrence may have bolstered the attractiveness of the site to hunters.

Paleoenvironmental data are not at a fine enough resolution to identify specifically where grasslands would have been located. However, pollen from the site does show a spike in the amount of grass (Graminae) as well as Compositae, during Bonebed 2 times (Bryant and Holloway 1985:Figure 3). The presence of bison in the region certainly suggests that conditions amenable to grazing were present.

As for a permanent water source, this is an extremely dry region, and Mile Canyon does not support permanently flowing water. While it may have at the time of occupation, no data are available concerning this. However, Bonfire Shelter is located <1 km from the Rio Grande. Bison herds could have relied on this permanent water source and may have wandered between the river and nearby grassy uplands, and thus been vulnerable to human predation.

Based on the published counts (Lorrain 1968:80–81), and our own analyses, over two-dozen animals are represented in Bonebed 2 (see below). Though two-dozen animals may not have been adequate for a successful jump (Frison 1991:218), the Bonebed 2 estimates are minimum counts. The original herd may well have comprised more animals as not all bison necessarily made the plunge. Whether the jump-off point would have been up- or downwind of the drive lane as those animals approached the site is unknown. If the bison were successfully driven off the cliff here, it might be assumed that the winds that day were favorable: say, out of the east/northeast. If, however, the animals had already detected the hunters (as they would if they had been driven) wind direction may have been irrelevant (Frison 1991:222).

Methods

In order to determine whether the landscape surrounding the site was topographically suitable for a jump, a digital elevation model (DEM) of the Langtry quadrangle was acquired from the USGS National Elevation Dataset (NED) (1999). At a cell size of 30 m², this DEM was not at a high enough resolution to perform a detailed analysis of the landscape immediately surrounding the site. To supplement these data, the SMU/QUEST crew mapped ~1 km² of the uplands immediately above Bonfire Shelter, and key points within the shelter itself (which had been previously mapped), during the summer of 2003. The resulting 850 data points

were used to create a high-resolution DEM, hereafter referred to as the Bonfire DEM. An elevation surface was created from these points at ~1 m² cell size using inverse distance weighted (IDW) spatial interpolation (Figure 3). The Bonfire DEM was overlain on the Langtry DEM to form a continuous surface covering the entire Langtry quadrangle, though at varying resolutions.

As noted, there are no surface manifestations of artificial drive lines at Bonfire Shelter from which to infer a drive lane. Hence, possible drive lanes leading to the proposed jump point above Bonfire Shelter were identified using GIS, specifically by calculating *slope* and *least-cost pathways*. While these calculations are not mutually exclusive—least-cost pathways are, in this analysis, derived from slope—they are used in different ways. Slope calculations identified suitable corridors of land that could be used as drive lanes, and least-cost pathway calculations permitted an assessment of the efficiency of each of those corridors as a drive lane.

It is assumed that a suitable drive lane required a relatively level and unobstructed stretch of land (Frison 1991). At other jump sites, such as at Big Goose Creek (Frison 1991; Frison et al. 1978), Glenrock (Frison 1970a), Head-Smashed-In (Reeves 1978a), and Kobold (Frison 1970b), where drive lanes are delineated by cairns and are often situated in natural draws, the paths follow these types of routes. It is also assumed that hunters would avoid an excessively serpentine route leading to the jump-off for fear of losing control of the herd. An overly complex drive lane would introduce more opportunities for error, thus increasing the chances for failure. It is possible, however, that the drive lane incorporated a 90° turn immediately before the jump, as other known jump sites do (Frison 1991:219). There is no reason to expect that other sharp turns were incorporated along the drive lane.

A slope calculation performed on the Langtry DEM identified corridors of contiguous flat land and produced a layer containing cells with percent slope values. Cells with high values mark areas of maximum topographic relief while cells with low values indicate areas of minimal topographic relief. This layer was reclassified *flat* versus *not flat* in order to simplify the landscape into a binary raster. A low frequency filter was performed to remove subtle landscape variations, such as slight depres-

sions or rises, given the assumption that these would not have impacted the effectiveness of a drive lane. Because the resolution of the final slope surface for the Langtry DEM was not high enough to closely examine the features immediately surrounding the cliff edge, slope was also calculated from the Bonfire DEM in order to ascertain the gradient and severity of the cliff edge at the assumed jump point—the notch.

Potential drive lanes were also identified by creating least-cost pathways. A least-cost pathway is a route that minimizes a specified variable—in this case, slope (see Bell and Lock 2000 for a detailed discussion). The cost of crossing a given land unit increases as slope increases (Whitley and Hicks 2003:80). A least-cost path is the path that accrues the least cumulative cost. In driving a herd of bison, a rough or bisected landscape could pose considerable difficulties to the hunter (Frison 1970b:7). The hunters probably would have avoided an irregular landscape to minimize losing momentum and/or members of the herd. Thus, it is assumed that a bison drive lane would follow a path that minimizes change in slope.

In order to create a least-cost pathway, both a start and end point must be defined. In the case of Bonfire Shelter, the end point is the notch directly above the talus cone. Where the bison herd originated is not known. That being the case, 16 arbitrary starting points were positioned along a circle radiating 4 km from the site. An anisotropic function was used to calculate travel cost based on degree of friction and direction of movement (Wheatley and Gillings 2002:152). Least-cost pathways were calculated between the starting points and the notch. We also derived the cumulative costs of generated routes (1–16) to compare the efficiency of each. Because we were concerned only with assessing *relative* efficiency (Whitley and Hicks 2003), we created a cost unit index by standardizing to the maximum value.

Although Dibble (1968:70) argued the notch operated as an effective trap because it remained invisible until a distance of ~1 m, that would vary by approach. Viewshed, or line-of-sight, analysis was therefore used to assess the visibility of the cliff edge from various angles of approach. This method determines which parts of the landscape are visible from a three-dimensional location or observer (Van Leusen 1999:218). All calculations were performed

on the artificial Bonfire DEM surface. While vegetation would have affected visibility (Tschan et al. 2000), there is no indication that tall-standing vegetation was a feature of the prehistoric landscape around Bonfire Shelter. Thus, an open landscape is probably a suitable model for prehistoric conditions. The output raster was a binary map divided into *visible* and *not visible* cells (see Wheatley and Gillings 2000, 2002 for a detailed discussion of visibility analyses). Because the eye-level of the observer, in this case the bison, would not have been flush with the ground, an offset of 1.7 m (the estimated ground to eye-level height for *Bison antiquus*) was added for all calculations. Viewshed layers were created from over 100 observer points. These points were placed along possible bison path lanes approaching the notch and cliff edge from various directions (Figure 4).

Results

Based on the slope calculations, there are several corridors of land in the region suitable as drive lanes. Only five of these actually approach a cliff edge (Figure 5). Of the remaining corridors, three approach the main channel of the Rio Grande. It can be argued that these locations would be less ideal for bison jumping because the water level in the river is higher and more permanent than it would be in Mile Canyon, and the height of the cliff face is much higher, making access to and removal of the bison carcasses more difficult (Frison 2004:80–81). In addition, the landowner affirms that the stretch of land approaching the Rio Grande is more rugged than the Langtry DEM suggests and is impossible to traverse on horseback (Jack Skiles, personal communication 2004). The discrepancy may be caused by less-complete topographic sampling on the Mexican side of the river. Nonetheless, it suggests that these corridors would not have served well as drive lanes. Of the two remaining corridors, one approaches Mile Canyon near the location of Bonfire Shelter (Figure 5, Line A).

The least-cost pathway analysis also suggests a similar pattern (Figure 6a). While the specific origin and approach of the herd cannot be determined, some routes appear less viable, assuming the hunters moved the animals along the path of least resistance. Although the hypothetical points of origin were placed equidistant from the notch, the connecting pathways vary in their cost efficiency

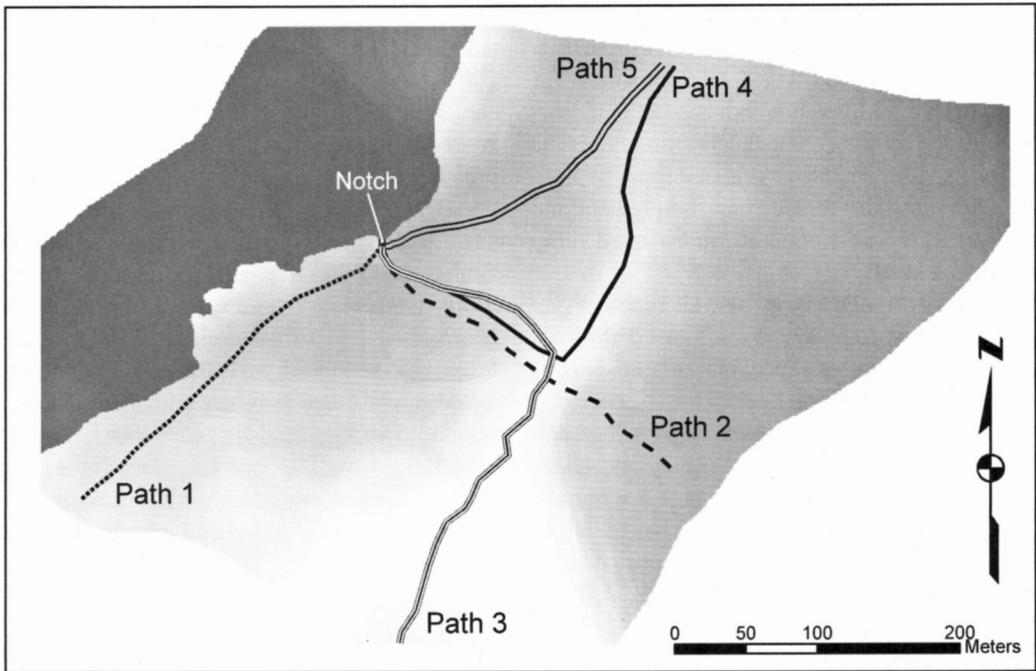


Figure 4. Five possible routes approaching the jump point. Paths used in viewedshed analysis.

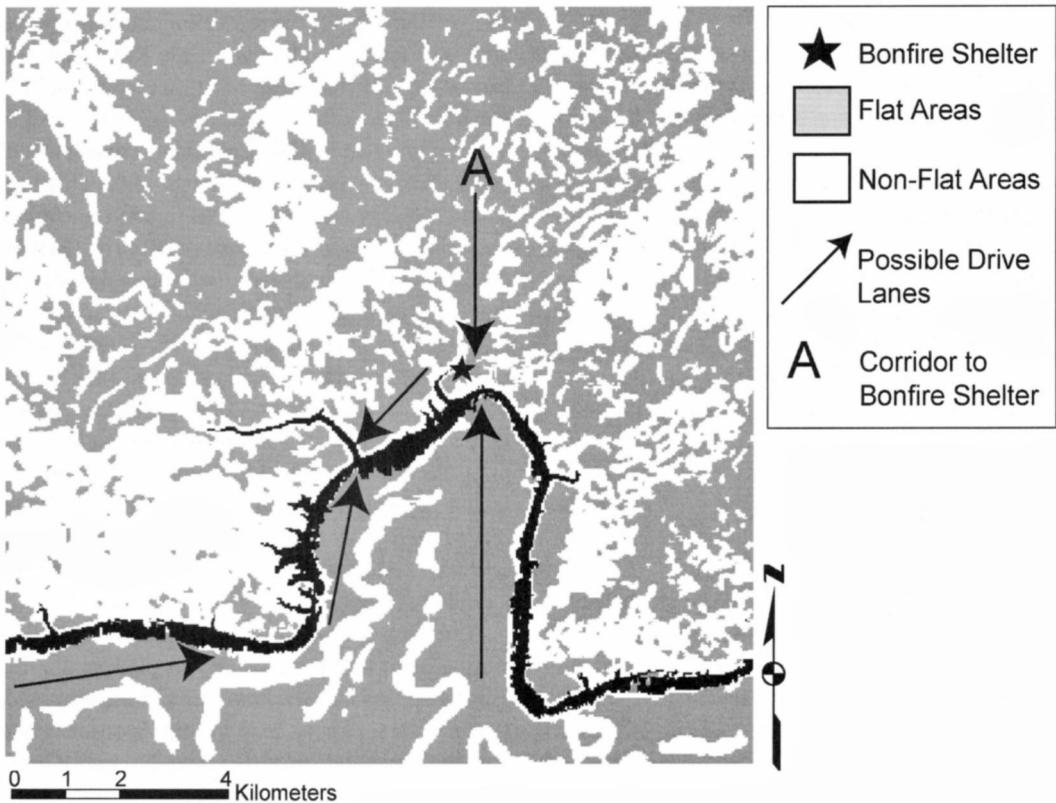


Figure 5. Simplified regional slope layer showing possible drive lanes that approach cliff edges.

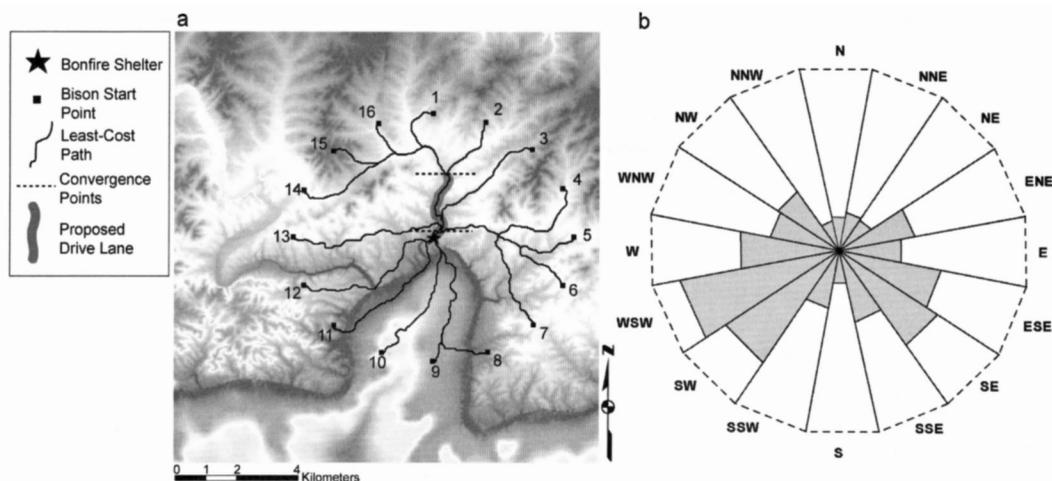


Figure 6. (a) Least-cost pathways (Routes 1-16) leading to Bonfire Shelter from arbitrary starting points 4 km from site. Graphic shows most probable bison drive lane originating from the north, running parallel to Mile Canyon leading to Bonfire Shelter. (b) Relative cost incurred along each route, displayed as cost unit index squared; longer bars indicate greater cost.

(Figure 6b). An approach from the west, southwest, or southeast (Routes 6, 7, 11, 12, and 13) would accrue significant cost because the drive would cross deep canyons, traverse rugged terrain, or follow a circuitous route. An approach from the east (Routes 4, 5) is entirely possible, but it would cross somewhat rough terrain. Also viable is a northwest approach (Routes 14, 15), though it meanders considerably. An approach from the south (Routes 8–10), though lower in cumulative cost, would require the drive lane to cross the deeply cut Rio Grande canyon and is therefore improbable. As such, we argue that an approach from the north (Routes 1, 16) or northeast (Routes 2, 3) may have been ideal, though this hinges entirely on bison being present in that area. While this analysis cannot eliminate any approach, it does offer a way of quantifying the relative advantages of the various approaches.

A closer examination reveals that all routes starting from the north and northwest converge approximately 3 km due north of the site (Figure 6a). Thus the same primary drive lane may have been used if approaching from either direction. This drive lane falls within the corridor identified above (Figure 5, Line A). If the bison had approached Bonfire Shelter within 1 km of the site from the west, east, or northeast, the bison would be funneled down the tail end of that same drive lane (Figure 6a). As the animals neared the site, they would still

approach the site from the north. Given that the pathways were derived from a slope cost surface, it is not entirely surprising that the least-cost pathways match the proposed corridor. It is interesting to note, however, that regardless of angle of approach or herd origin, if the bison were being guided toward the jump point above Bonfire Shelter, they would have been funneled down this natural draw from the north.

The viewshed analysis also helps determine at what point the cliff edge and notch would have become visible to an approaching bison herd. Two approaches are clearly less likely, although they cannot be eliminated all together. First, the southern approach (Figure 4, Path 1) along the canyon edge is unlikely. Along this path, the cliff edge becomes visible 250 m from the jump point and the notch becomes visible 130 m from the jump point. Under the circumstances, the notch could not have readily operated as successful trap. An approach from due east of the site (Figure 4, Path 2) is also unlikely. The cliff edge is visible at over 200 m from the jump point, though it does become obscured again until 25 m from the edge. Despite this, an early glimpse of the edge may have given the herd sufficient time to avoid the edge (Frison 2004) unless conditions such as bright sunlight or dense fog had reduced visibility (Wheatley and Gillings 2000:7).

The remaining approaches show a higher poten-

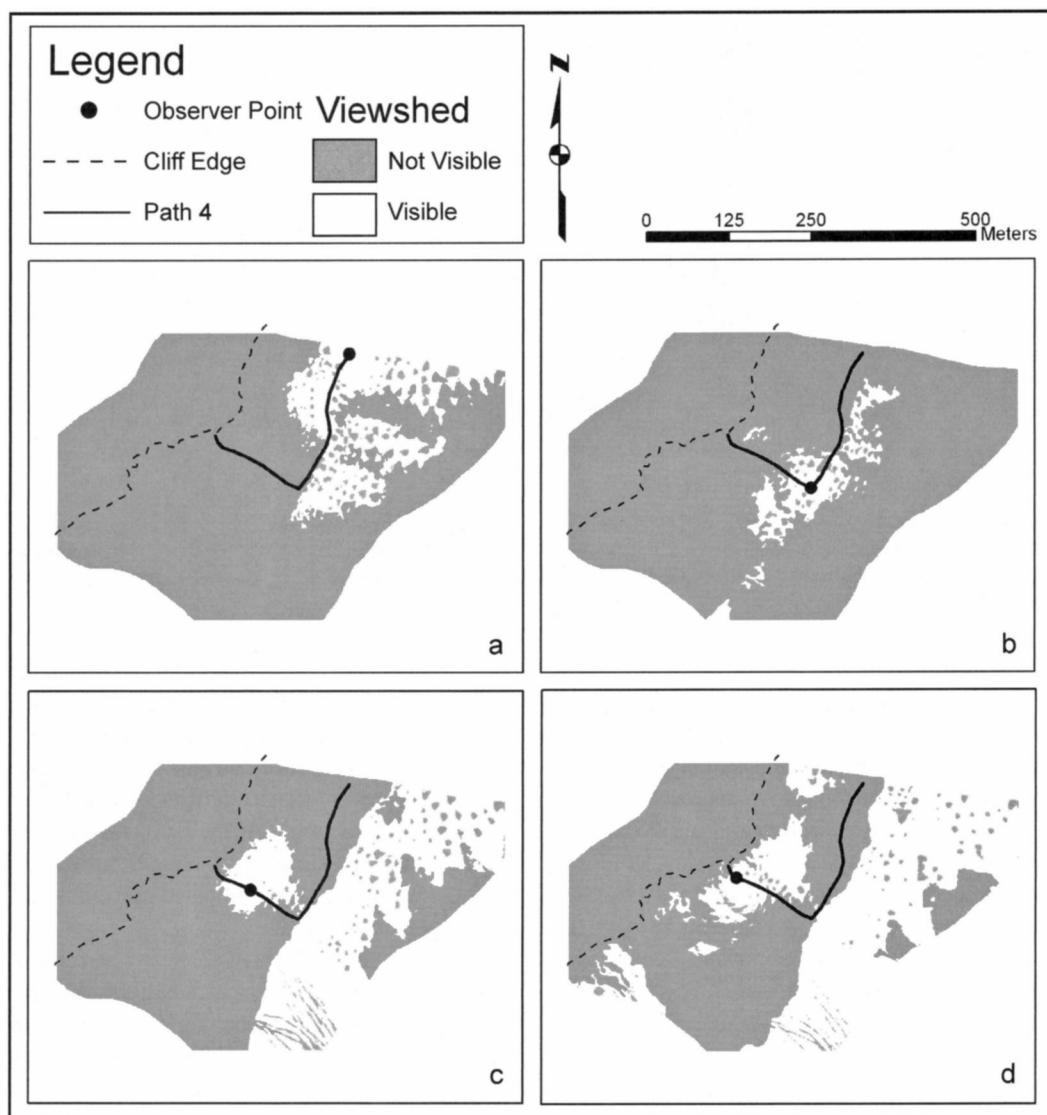


Figure 7. Visibility of landscape along Path 4: (a) view from beginning of path; (b) view at 90-degree turn; (c) view approximately 60 m from cliff edge; (d) view approximately 24 m from cliff edge, where edge and notch first become visible.

tial for success. A southern approach (Figure 4, Path 3) follows a drainage running parallel to Mile Canyon. Along this drainage, the cliff edge is obscured by a slight rise to the west. If the drive lane incorporated a sharp 90° turn immediately east of the jump point, the herd could have been driven straight into the head of the notch. From this approach, the edge remains obscured until a distance of only 24 m. The notch is not visible until 12 m away. A northern approach (Figure 4, Path 4) following the same drainage and incorporating a corresponding turn is a more likely path, given the

location of the predicted drive lanes. Similarly, along this path, the edge and notch remain invisible until only 24 m away, when it was probably too late for the herd to escape (Figure 7a–d). Running at top speed, perhaps 50 km/hr, a bison would cross those last 24 m in under 2 seconds.

A final approach (Figure 4, Path 5) that may have been successful could have involved moving the herd along the canyon edge from the north. Although the cliff edge is visible nearly 30 m from the jump point, the notch is obscured and could have been used as a trap if approached at a per-

pendicular angle. Running the herd parallel to the rim and then into the notch would have demanded careful timing, placement of the hunters, and positioning of the herd; if any factor were slightly miscalculated, the herd would have escaped. On balance, therefore, we suggest that Path 4 would have been the most efficient route in terms of landscape topography and visibility. Of course, this is not evidence that it was so used.

At the known jump point, the cliff edge is over 26 m above the shelter floor, though the fall of the bison would have been stopped short by the talus cone. But as noted above, during the Early Holocene the drop from the cliff edge to the top of talus cone would have been ~23 m (Dibble 1968:13,70). The height of the fall into Bonfire Shelter is only slightly greater than the modal height of other jump sites (Polk 1979:62). Far higher jump kills are known, though extremely high plunges may have been undesirable to hunters because they could result in too much carcass damage (Hughes 1986:60). Importantly, the fall from the Bonfire Shelter cliff edge would have severely maimed or killed any animal, for in a free-fall of that distance the velocity of the bison at impact would be ~76 km/hr (~47 miles/hr).¹

It appears that the cliff edge at the notch may have been much steeper than elsewhere along the canyon edge. The cliff edges immediately north and immediately south of the known jump point are in fact much more gradual. It would have been more difficult to jump bison at these sloped points because it may have offered the animals an opportunity to turn and escape the fall, or possibly scramble back uphill toward the hunters.

Based on the GIS analysis, it would appear that Bonfire Shelter could have worked well as a jump locality. In fact, within the 165 km² area encompassed in the Langtry quadrangle, this may have been one of few locations that offered the complete suite of strategic features, for it falls at the southern end of a natural draw suitable for a drive lane. Other flat portions of landscape in the area either do not lead to a jump off point or lead to the Rio Grande, where it may have been difficult to access the carcasses. In effect, the landscape leading to Bonfire Shelter would have been well suited as a drive lane, perhaps more so than other areas in the immediate vicinity (though, of course, this analysis does not eliminate the potential for other jump

sites in the area). Additionally, Bonfire Shelter probably fell along a path between grassy uplands and a permanent water source. This would help insure that bison could on occasion be found in close proximity to the site. Also, the cliff edge at Bonfire Shelter is fairly obscured by the topography of the surrounding features. The bison would not have been able to see the cliff edge until it was too late and the momentum of the herd had already forced them over the edge. Finally, the jump-off point above Bonfire Shelter may have been the last point along the proposed drive lane suitable for a jump. While the resolution of the regional DEM is not high enough to accurately assess the edge drop-off south of the site, it does appear that the edge becomes increasingly sloped. Bonfire Shelter may have offered the last opportunity for a successful jump along the proposed drive lane.

Although Bonfire Shelter was an aptly suited location for a bison jump kill, was it used as such in Paleoindian times? That question can be approached, in part, through analysis of the extant faunal collections and through a better understanding of the skeletal composition and taphonomic history of the Bonebed 2 bison remains.

The Bonfire Shelter Bonebed 2 Bison

The analyzed material reported here represents all known and catalogued bison skeletal remains recovered from controlled excavation of Bonebed 2 conducted between September 24, 1963 and February 27, 1964 by David S. Dibble and crew (Dibble and Lorrain 1968). These data do not include Bonebed 2 skeletal material left in situ during excavation (see Lorrain 1965:29), nor bones recovered in subsequent excavations (see Bement 1986:26). The absence of those data should not appreciably bias our results, since only a relatively small number of bison remains were recovered during the 1980s excavations (NISP = 51; <2.5 percent of the NISP from the 1963–1964 excavations).

However, data from the 1963–1964 excavations are not without bias: the majority of identifiable elements from Bonebed 2 are from Pit C where, owing to budget and time constraints, only the most readily identifiable elements were collected in the final days of excavation (Lorrain 1965:29–30). This is unfortunate, since Pit C is also where the highest concentration of skeletal material occurs, and

where there was evidence of stratigraphic separation and some burned skeletal elements. Likewise, though Dibble (1968:20) reports that a high-percentage (numbers were not provided) of matrix from cultural deposits was screened, this screening was coarse-grained (1/2 to 1/4 inch [12.7 to 6.4 mm]) and could have biased the recovery of small artifacts. Lorrain (1965:29) further notes that portions of N60/W42 and N70/42, as well as all of N80/W42, were left in situ. Thus, bone counts are lower in these units than they should be (Lorrain 1965:29).

Although we know bones from Pit C were discarded in the field (Lorrain 1965:30), we do not assume that the remainder of Bonebed 2 was similarly biased. Nonetheless, to test for that possibility, we compared NISP values between Pit C and the other excavation units. A contingency table analysis indicates that significant differences ($G = 134.821, p = .000$) do exist between Pit C and the rest of the sampled Bonebed 2 deposits. Freeman-Tukey deviates reveal that thoracics, lumbar, sacra, and innominates are significantly underrepresented in Pit C, while mandibles, femora, patellae, astragali, first and second phalanges, and proximal sesamoids (many of these being “readily identifiable”) are significantly overrepresented. These data suggest that there may have been significant collection bias against axial elements, but that this biased collection strategy was not directed at smaller elements (i.e., carpals, tarsals, and sesamoids). Because of this bias, thoracics, lumbar, sacra, and innominates are not included in our transport and utility analyses.

Methods

Data are recorded for each labeled specimen according to methods used by Byerly and Meltzer (2005), Hill (2001), Rapson (1990), and Todd (1987a). All limb bones (humeri, ulnae, radii, femora, and tibiae) are measured, where possible, according to osteometric standards defined by Todd (1987b) to aid in reconstructing herd sex composition and to add to available osteometric data collected by Lorrain. Season of mortality and herd age composition is estimated according to procedures outlined by Todd et al. (1996) and Niven and Hill (1998) for young bison (age groups 1–5), based on established stages of mandibular tooth eruption and occlusal wear. The age of older individuals is deter-

mined from measurements and observations of tooth wear. Broken teeth and those from very old animals were not examined.

Summary skeletal data are recorded according to the total number of specimens (NOST; see Byerly and Meltzer 2004), as well as NISP, MNE, MNI, percent MNI, MAU, and percent MAU per skeletal element and skeletal portion (see Hill 2001 and Lyman 1994 for detailed descriptions of bone frequency limits). Identified specimens include all elements definable to a specific taxonomic category or body size class and skeletal element. Unidentifiable specimens include all nondescript long bone, flat bone, cranial, tooth, vertebrae, rib blade, and unspecified fragments. Many of the unidentifiable specimens were not labeled but are still counted in the final NOST estimate. Weathering, breakage, gnawing, and butchery data are not recorded for unidentified specimens.

MNE calculations are comprehensive (Hill 2001:30), but since extensive mechanical refitting was not attempted (though a few refits were made during analysis), nor was carcass reassembly via bilateral matching or intermembral refitting undertaken, calculated MNIs (save mandibles) are not considered maximal distinction MNIs (Hill 2001:32).

Resultant percent MAU data are compared to skeletal element utility indices for modern Northern Plains bison (*Bison bison*) as defined by Emerson (1993:140) to elucidate potential trends in transport and carcass utilization. These include:

- standardized modified average total products, or **(S)MAVGTP**, which measures the sum caloric yields of skeletal fat, muscle protein, intramuscular and other dissectible fat;
- standardized modified average total fat, or **(S)MAVGTF**, which measures the caloric yield of just the skeletal, intramuscular and dissectible fat; and
- standardized modified average skeletal fat, or **(S)MAVGSKF**, which is calculated from the caloric yield of the fat present in bone grease and marrow.

We also compare element frequency data to the average marrow fat model, or **(S)AVGMAR**, a utility index calculated from the caloric yield of bone marrow alone. In this context, we see this index as

Table 1. Carcass Unit Utility Indices.

Carcass Unit	(S)AVGTP	(S)AVGTF	(S)AVGSKF	%MAU _{AVERAGE}
Skull	9.0	17.2		33.9
Neck	44.6	65.1	1.7	61.9
Rib	63.1	96.2	11.3	10.2
Upper Forelimb	53.5	62.8	79.0	78.0
Upper Hindlimb	100.0	100.0	100.0	100.0
Lower Limb	2.8	9.6	22.4	54.2

Note: Emerson (1990) derived element utility indices by first calculating the caloric yield of the nutritive constituents (e.g. total products, total fat, skeletal fat) for the skeletal elements of four bison carcasses representing various ages, sexes, and states of body condition. These values were then standardized by dividing the caloric yield of an element by that of the element with the highest yield, creating an index. These indices were averaged for the four bison to create a standardized average utility value (e.g. [(S)AVGTP]) per element. We did the same, only we calculated indices for carcass units, as described in the text, rather than for individual elements. %MAU_{AVERAGE} represents the average MAU of each element included in a carcass unit for Bonebed 2 bison.

a measure of processing strategy rather than transport.

A number of Emerson's modified utility indices are developed for element groups (e.g., radio-ulnae, sacrum-pelvis, phalanges, carpals, tarsals), as opposed to specific elements. Rather than "double-count" the utility values for, say, each radius and ulna, we instead take the more abundant of those two elements, and only incorporate that element in our analyses.

In turn, and as a simple measure of potential transport of bulkier carcass units, we also examine skeletal part representation based on element sets commonly cached or transported by Nunamiut hunters (Binford 1978:60). These are comprised of: (1) skulls, including crania; (2) neck elements, including all cervicals; (3) ribs; (4) upper forelimbs, including scapulae, humeri, radii, and ulnae; (5) upper hindlimbs, including femora and tibiae; and (6) lower limbs, including metacarpals and metatarsals.

Because Emerson's utility indices are calculated per element, carcass unit utility [(S)AVGTP_{UNIT}; (S)AVGTF_{UNIT}; (S)AVGSKF_{UNIT}] is derived by adding the total caloric yield of the available nutritive constituents (whether total products, total fat, or skeletal fat) of each element in defined carcass units (see Emerson 1990:618) and standardizing data to a maximum value (Table 1). These estimates are not, unlike per element models, modified for riders (see Emerson 1993). Element representation is variable within each carcass unit and, as such, representation for the unit as a whole is estimated by averaging the MAU of contributing elements.

Thoracic and rear axial packages are not considered, for reasons discussed above, and phalanges are not included with limb units because it was not possible to discern fore from hind for these elements. While we recognize the variability inherent in Nunamiut and other hunter-gatherer carcass processing and transport decisions (Bartram 1993; Binford 1978; O'Connell et al. 1988), these specific carcass units were chosen because they represent ethnographically defined ways of partitioning large mammal carcasses. We assume that utility values for modern Northern Plains *Bison bison* correspond to the utility values for *Bison antiquus*.

Summary Skeletal Data

Of a total of 7,736 counted specimens (NOST), 29.2 percent are identified as bison (NISP=2,261). The remaining specimens are fragments of large mammal elements that are probably bison but could not be confidently identified to element and/or genus and species. No other species were examined in the sampled Bonebed 2 assemblage, though both Lorrain (1968) and Bement (1986) report the recovery of horse elements from Bonebed 2. Summary skeletal element frequency data are presented in Table 2 and displayed in Figure 8.

In general, our data correspond to Lorrain's original counts; there is a significant correlation between our respective percent NISP ($r_s = .801, p = .000$) and percent MNI estimates ($r_s = .705, p = .000$). However, our NISP estimates are generally higher than those derived by Lorrain (1964–1965) and our percent MNI estimates are generally lower. These differences could stem from a number of

Table 2. Summary Skeletal Element Frequency Data.

EL	Element	Lorrain		This Analysis				Models					
		NISP	MNI	NISP	MNE	MNI	%MAU	TP	TF	SKF	MAR	VD	STDV
CRN	Cranium	53	11	102	5	5	30.3	10.4					
MR	Mandible	32	19	122	26	14	78.8					0.49	78.7
HY	Hyooid	3		6	4	2	12.1					0.36	
AT	Atlas	11	12	19	10	10	60.6	4.7	5.9	1.6		0.34	57.1
AX	Axis	11	12	24	10	10	60.6	5.7	7.1	1.1		0.38	
CE	Cervical	23		117	37	8	44.8	41.4	50.7	3.3		0.42	
TH	Thoracic	43	19	187	65	5	28.1	61.7	100.0	16.8		0.42	44.6
RB	Rib	42		117	43	2	9.3	73.3	93.0	38.7		0.35	38.3
CS	Costal Cartilage			15									
SN	Sternum	9		17				38.4	58.6	3.1			
LM	Lumbar	24		103	42	9	50.9	60.4	99.5	18.3		0.42	52.3
SA	Sacrum	13	12	32	13	13	78.8	39.8	54.0	70.6	3.9	0.26	33.5
CA	Caudal	22	4	27	25	2	8.4	1.1	1.8	2.9			
SC	Scapula	32	14	77	13	8	39.4	28.4	30.4	53.7	1.3	0.50	46.8
HM	Humerus	79	23	124	30	16	90.9	28.4	30.4			0.48	72.3
HM-PR	Proximal Humerus	30	16	38	8	5	24.2			95.6		0.24	
HM-DS	Distal Humerus	46	23	33	19	12	57.6			77.2		0.38	
RD	Radius	67	23	107	26	16	78.8	19.7	22.0			0.48	64.6
RD-PR	Proximal Radius	31	17	41	26	16	78.8			67.4		0.48	
RD-DS	Distal Radius	34	23	32	22	16	66.7			59.1		0.35	
UL	Ulna	23	13	42	18	11	54.5	19.7	22.0			0.69	
CP	Carpal (All)	70		94									
GPU	Ulnar Carpal			17	17	9	51.5	10.6	13.0	39.2		0.43	
CPI	Intermediate Carpal			15	13	8	39.4	10.6	13.0	39.2		0.35	
CPR	Radial Carpal			17	14	11	42.4	10.6	13.0	39.2		0.42	
CPS	Fused 2nd and 3rd Carpal			20	16	11	48.5	10.6	13.0	39.2		0.50	
CPF	4th Carpal			17	13	6	39.4	10.6	13.0	39.2		0.44	
CPA	Accessory Carpal			8	8	4	24.2	10.6	13.0	39.2			
MC	Metacarpal	26	12	30	18	12	54.5	6.0	8.4			17.3	80.9
MC-PR	Proximal Metacarpal	9	12	22	18	12	54.5			29.2		0.59	
MC-DS	Distal Metacarpal	6		13	13	7	39.4			24.2		0.53	
MCF	5th Metacarpal	3		2	2	1	6.1					0.62	
IM	Innominate	39	20	74	16	11	48.5	39.8	54.0	70.6	3.9	0.53	

FM	Femur	126	27	180	33	17	100.0	100.0	76.7	100.0	87.0	0.26	65.9
FM-PR	Proximal Femur	62	27	60	33	15	100.0	100.0		100.0		0.31	
FM-DS	Distal Femur	52	26	54	33	17	100.0	100.0		100.0		0.26	
PT	Patella	11	7	16	15	9	45.5						
TA	Tibia	64	19	119	26	15	78.8	58.1	48.6		100.0	0.41	80.6
TA-PR	Proximal Tibia	30	18	25	11	7	33.3			97.1		0.41	
TA-DS	Distal Tibia	33	19	34	26	15	78.8			78.0		0.41	
LTM	Lateral Malleolus	8		10	10	9	30.3	30.1	26.9	51.6		0.56	
AS	Astragalus	43	26	51	33	24	100.0	30.1	26.9	51.6		0.72	94.0
CL	Calcaneus	29	17	46	19	10	57.6	30.1	26.9	51.6		0.49	84.6
TRC	Fused Central and 4th Tarsal	26	15	34	18	11	54.5	30.1	26.9	51.6		0.77	
TRS	Fused 2nd and 3rd Tarsal	3		5	5	5	15.2	30.1	26.9	51.6		0.52	
TRF	1st Tarsal			2	2	1	6.1	30.1	26.9	51.6			
MT	Metatarsal	30	11	36	14	8	42.4	15.9	16.1		21.1	0.52	100.0
MT-PR	Proximal Metatarsal	5	11	32	13	8	39.4			37.5		0.52	
MT-DS	Distal Metatarsal	15		14	14	5	42.4			30.5		0.48	
MP	Metapodial	74		60									
PHF	1st Phalanx	81	18	104	68	10	54.5	5.9	7.3	23.5	2.5	0.48	74.5
PHS	2nd Phalanx	76	19	80	72	9	23.5	5.9	7.3	23.5	2.5	0.46	
PHT	3rd Phalanx	40	8	47	31	5	3.8	5.9	7.3	23.5	2.5	0.32	57.9
SE	Sesamoid (All)	36		30									
SEP	Proximal Sesamoid			23	23	2	2.7						
SED	Distal Sesamoid			7	7	1	0.8						
DC	Dew Claw			1		1							

Note: Lorrain's NISP data were derived from her original notes (1964–1965) and MNI data are from Lorrain (1968). Proximal and distal portions of long bones are those with at least some part of the epiphyses attached. Utility indices are from Emerson (1993): TP = (S)MAVGTP; TF = (S)MAVGTf; SKF = (S)MAVGSKF; MAR = (S)AVGMAR. Volume density data (VD) are from Kreutzer (1992, 1996). Settling velocity data (STDV) are from Todd (2003).

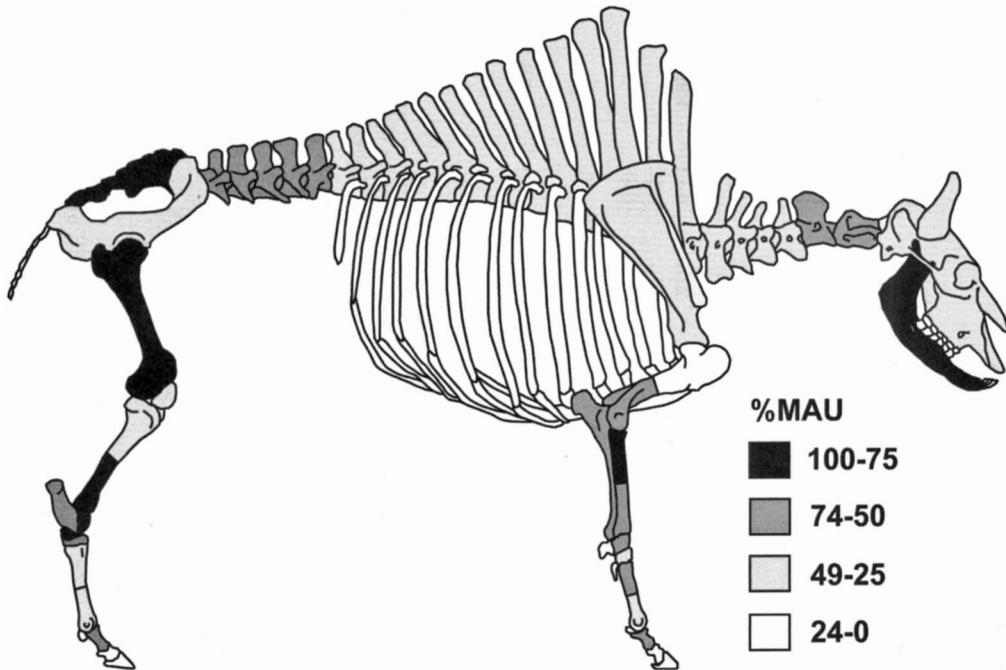


Figure 8. Bonebed 2 skeletal element frequencies presented as %MAU.

factors, including additional breakage of already fragile bone during storage and handling. Indeed, we found that 81.3 percent (NISP = 1,838) of identified specimens have recent breaks, manifest as cortical defoliation and crushing, resulting either from excavation or handling and storage since the early 1960s. This attrition would result in an increase in sample size and decrease in identifiability of some specimens. Other factors to account for the discrepancy in our counts include: our lack of access to tallies of in situ materials, inconsistencies between counting methods, or inconsistencies between bone identification abilities. It is not directly apparent from her original notes how systematic Lorrain's counting methodologies were, and, thus, we consider her counts a maximum estimate. Our higher NISP counts are almost certainly related to increased breakage since excavation and our lower percent MNI estimates probably represent a degree of conservatism in counting.

Dibble and Lorrain (1968) calculated an MNI of 27 bison in Bonebed 2 for proximal femora. We estimate an MNI of 24, based on astragalus counts. They in turn estimated that a total of ~120 animals had actually been killed at the site, on the assumption that only half the animals had been preserved,

and that only half the site had been excavated (Lorrain 1968:84). Although they considered this estimate "conservative" (Dibble 1968:30), it was based on unsupported assumptions about the degree of preservation and the number of animal remains possibly present in still-unexcavated portions of the site. The latter is especially problematic, since the 1963–1964 excavations showed (and the 1983–1984 excavations confirmed) that the bonebed thins and bone element frequencies diminish toward the edges of the excavation areas (Dibble 1968:29; also Bement 1986:19). MNI estimates are not likely to increase significantly if there is additional excavation in the site, and so we favor an estimate closer to 24–27 bison, not 120 animals.

Sex and Age Composition

Many articular ends are damaged, and thus osteometric data are sparse for the majority of measured elements. Available radii measurements (RD9 vs. RD4; see Todd 1987b:377–378) indicate a male to female ratio (MNI) of 1:3. These data contrast with Lorrain's (1965:51) observations, based on metapodial osteometric data, that equal proportions of females and males are present. However, the sample size of comparable specimens for other upper

Table 3. Mandibular Dentition Descriptions.

Group	Age	MNE	MNI	Description
1	full term fetus/neonate	0	0	No group 1 dentaries are present.
2	1.2 to 1.4 years	2	2	Deciduous premolars (dP ₂ , dP ₃ , and dP ₄) and first molars (M ₁) are not preserved. Second molars (M ₂) lack occlusal wear. M ₂ metaconids and entoconids are just above the alveolar bone, but well below the level of other teeth (code E). Third molars (M ₃) are forming within the jaw, but the alveolar surface is not open (code Z).
3	2.2 to 2.4 years	4	3	Where present, dPs are heavily worn and the cemento-enamel junctions are visible above the alveolar surface. Second and third premolars (P ₂ and P ₃) are forming in the dental crypt (code O) or have just breached the alveolar surface (code M). M ₁ s are in full wear with their ectostylids below the level of the occlusal surface. M ₂ cusps are pointed with moderate wear along facets I-IV and light or discontinuous wear on facets V-VIII (code 6b or 6d). M ₃ first and second cusps are erupted (code E), although wear varies from none to light polish on facets I-II.
4	3.2 to 3.4 years	3	3	Premolars are not preserved. All M ₁ s and M ₂ s are in full wear (codes 11a and 9e). M ₁ wear is such that the ectostylids are incorporated into the edge of the enamel. M ₂ ectostylids are not yet in wear. M ₃ s are mostly erupted and display variable amounts of wear. All three cusps are erupted for most, but not all have reached the same level of wear. M ₃ occlusal wear varies from moderate to light on facets I-IV with no wear or very light polish on facets V-VIII (code 3e or 5c). The hypoconulid is erupted but unworn on all specimens.
5	4.2 to 4.4 years	1	1	M ₂ is in full wear except on the ectostylid, which is well below the level of the occlusal surface (code 9e). M ₃ is in full wear including the hypoconulid (code 11c).
6-7	>5 years	6	5	M ₂ ectostylids are worn into a circle (code 10a) and M ₃ s are in full wear (code 11c or 11d). M ₃ ectostylids are not at the level of the occlusal surface although the depth to wear varies significantly. The ectostylids of younger specimens (~group 6) are erupted 6-8 mm above the alveolar surface, while the ectostylids of older specimens (~group 7) are 2-3 mm below the level of the rest of the tooth.
Total		16	14	

Note: Wear codes are from Payne (1987) and Todd et al. (1996).

limbs is too small to support our radii sex ratio. As such, Lorrain's original sex estimate cannot be rejected.

Lorrain (1965:51) further estimated that ~50 percent of the Bonebed 2 bison were immature, referencing dental age cohorts established by Skinner and Kaisen (1947) and Fuller (1959), and long-bone fusion rates developed by Silver (1963). Our analysis finds that, although age groups 2 and 3 are represented, mandibular molar measurements and wear patterns suggest that the Bonebed 2 bison are dominated by group <4 individuals (MNI ratio 9:5; Table 3). Our age estimates, based on bone fusion sequences, concur with the dental approximation.

Bone fusion sequences useful for identifying group <4 individuals include: (1) fusion of the cen-

tral and fourth tarsal; (2) fusion of the vertebral neural arch with the body; (3) fusion of the ilium, ischium, and pubis; (4) fusion of the three sections of the atlas; (5) fusion of the supraglenoid tuber on the scapula; (6) fusion of the distal epiphysis of the humerus; (7) fusion of the proximal epiphysis of the radius; and (8) fusion of the proximal epiphyses of the first and second phalanges (Bement and Basmajian 1996; Walker 1998). Based on these attributes, no more than two individuals can be classified as group <4.

Season of Death

Lorrain (1968: 92, 132) was unable to ascertain the season of the kill. The sample of teeth from Bonebed 2 we analyzed suggests a tight clustering

of dental ages from $N + .2$ to $N + .4$. Based on the modern bison eruption/wear schedule reported by Reher and Frison (1980:64–70), Bonebed 2 group 2 specimens are older than 1.1 to 1.2 years (when the second molars begin erupting) and younger than 1.5 years (when it begins to wear). Bonebed 2 bison teeth do, however, exhibit more advanced eruption/wear than Todd et al. (1990:817) report for the late spring/early summer kill at Scottsbluff. In particular, the Scottsbluff group 2 M_2 s are either un-erupted or their metaconids are at or slightly below the alveolus. Conversely, group 2 M_2 s from Bonebed 2 are erupted but are below the level of the other teeth. On the other hand, Bonebed 2 teeth exhibit slightly less advanced eruption/wear than those from the fall season kills at Folsom (Todd et al. 1996), where M_2 s are unworn but nearly at occlusal level or have slight wear on the first cusp. Bonebed 2 bison teeth have generally consistent eruption/wear patterns with those from Lipscomb (Todd et al. 1990) and Cooper (Bement 1999). This suggests that, based on an assumed mid-to-late April birth pulse (Halloran 1968) for Southern Plains bison, Bonebed 2 bison likely died during the summer.

One Event or Several?

Dibble and Lorrain (1968) argued that three kills were represented in Bonebed 2. However, it was only possible in one area—along the north walls of Pit C and N20/W60—to see an apparent stratigraphic differentiation of Bonebed 2 into three layers, from bottom to top labeled Components A, B and C (Bement [1986:Figure 5] uses the same designations, but reverses their order). However, that differentiation was not based on significant stratigraphic differences, nor was such seen during the later excavations (Bement 1986:25), but instead was based on the observation that bones in the middle stratum (Component B) were burned, while the bones in the over- and underlying strata were not. The burning of Component B appeared to have occurred in place, given the co-occurrence of burned limestone spalls, and the overlying unburned bone of Component C (Dibble 1968:30). Otherwise, these components “were sandwiched together to form essentially a single stratum” (Dibble 1968:29–30).

That said, differential burning may have no bearing on the number of kills, but instead may reflect

postdepositional processes that redistributed skeletal elements. Bonebed 2 is draped over an uneven, sloping surface, with the highest portion on the edge of the talus cone, sloping down and thinning out toward the rear and upstream ends of the shelter. The physical separation of Bonebed 2 into three components occurs only on the lowest portion of the slope. This raises the possibility that the three components represent pulses of slope washed-bone from the same original deposit, one of which was subsequently burned in place. Dibble had expressed concern over the “seemingly illogical” fact that Bonebed 2 was covered by both slope wash and ceiling detritus (Dibble 1968:29), but reasonably concluded that both processes could have been operating simultaneously.

Also relevant to the question of the number of kills are data on age classes. Although only a small sample of teeth from Bonebed 2 are available for analysis, the tight clustering of wear stages for analyzed dentition does not provide support for multiple death events occurring at different times of the year. It is, of course, possible that the assemblage originated from multiple, closely timed death events or separate events that coincidentally occurred at the same time of year. However, dental cohorts support the inference that Bonebed 2 represents the remains of a single death assemblage, and we treat it as such.

Whether this was one kill or several or, more broadly, what role humans played in the accumulation of this deposit, requires a better understanding of the taphonomic history of the bonebed (Lyman 1994; Todd 1990, 2003; Todd and Rapson 1999). Some of the kinds of data useful to taphonomic analyses (e.g., orientation and inclination of in situ bone) are unavailable because collecting those data was not a regular feature of bonebed excavation methods in the 1960s. However, it is possible to elucidate some of the taphonomic processes that created the Bonebed 2 archaeological record without these data.

Bonebed Taphonomy and Bone Modification

Bonebed 2 bone is in relatively poor condition, due to both in situ attrition and post-excavation treatment. Lorrain (1965:27) reported that excavated bone was extremely fragile and would often crumble at the touch of a brush. Indeed, many bones disintegrated after removal and prior to analysis,

apparently breaking during transport from the field to the lab (Lorrain 1965:28). To ensure the recovery of complete elements, excavators treated some bone with an Alvar solution in situ, causing varying amounts of surrounding matrix to adhere to intact bone surfaces (Lorrain 1965:27). Lorrain (1965) later coated many phalanges, carpals, and tarsals in paraffin wax for a volumetric study. Thus, due to poor preservation and the variety and extent of chemical treatment of bones, cortical surface modifications are difficult to observe.

That said, a total of 2,039 identifiable specimens have some observable cortical surface and could be assigned to a weathering stage (see Rapson 1990:370 for description of weathering stages). The majority of these bones (NISP = 1198 or 58.8 percent) are lightly weathered (weathering stages 1–2), and the numbers decline proportionately with advanced weathering stages: 34.2 percent (NISP = 697) fall into weathering stages 3–4, and 7.1 percent (NISP = 144) are in weathering stages 5–6. It is important to note that these weathering stages only represent the state of preservation for observable cortex on a particular specimen, not preservation of the cortex as a whole. Still, these data suggest skeletal remains were not long exposed on the surface within the shelter.

Once deposited on that surface, there is evidence of horizontal size-sorting of sediment away from the talus cone (Dibble 1968:26, 29) that suggests the bones may have experienced some degree of slope washing. Indeed, Dibble used the fact of “some post-depositional movement” in Bonebed 2 as a possible explanation for the presence of both Plainview and Folsom materials in the same unit (Dibble 1968:75). Even so, Dibble took pains to stress that “no water activity other than minor, localized drainage seems to have been a factor in accumulation of fill within the shelter” (Dibble 1968:27). He further noted that the hearth in Component C of Bonebed 2 showed no sign of disturbance by water action (Dibble 1968:33).

Although it is undoubtedly true there was no significant downstream flow from Mile Canyon within the shelter, at least at this period in time, it is certainly the case that minor and localized flows from the notch could readily move bone elements—especially down the talus slope. It is clear from the interior relief of the Bonebed 2 surface, and better preservation of material in the Fiber Layer to the

east and south of the talus cone, that the southeastern wall of the shelter interior remained dry while deposits north of the talus cone were regularly wet. Indeed, it has been observed that ponds regularly form in the upstream portion of the shelter (Elton Prewitt, personal communication 2003).

Element frequencies were compared to bison bone settling velocity data collected by Todd (2003) to test the possibility that some slope wash occurred. There is no significant correlation between settling velocity and element frequency (percent MAU), but a scatterplot does show that well-represented elements (percent MAU >50) have high-rank settling velocities, suggesting that more transportable elements were possibly winnowed out by fluvial activity (Figure 9). If so, and if the origin of the fluvial disturbances was the notch, then the relative abundance of those lower-ranked elements should be significantly greater farther away from the talus cone compared to higher rank bones.

To test this assumption, the site was arbitrarily divided into two areas, those adjacent to (Area I) and away from (Area II) the talus cone (see Figure 2). A contingency table analysis reveals that the relative frequencies of bone specimens (NISP) in the two areas are significantly different ($G = 41.784, p = .000$). Freeman-Tukey deviates further indicate that ribs and scapulae are overrepresented in Area II, and first and third phalanges and calcanei are underrepresented. These data support the inference that fluvial activity within the shelter, probably originating in the notch, affected the Bonebed 2 bone distribution. This apparent winnowing, however, was not enough to significantly diminish relative frequencies of low-rank elements in Area I.

Data on orientation and inclination of bones would help resolve water-flow issues, but insufficient data exists, since after a certain point in the excavations circumstances and budgets unfortunately forced the crews to cease making plan maps or taking comprehensive photographs (Dibble 1968:19). The one map available from which bone orientation data can be derived (this of the scapula concentration) reveals no clear indication of preferred bone orientation in the shelter (Dibble 1964). Future analysis focused on collecting data on orientation and inclination of bone elements from intact deposits, and understanding the dynamics of

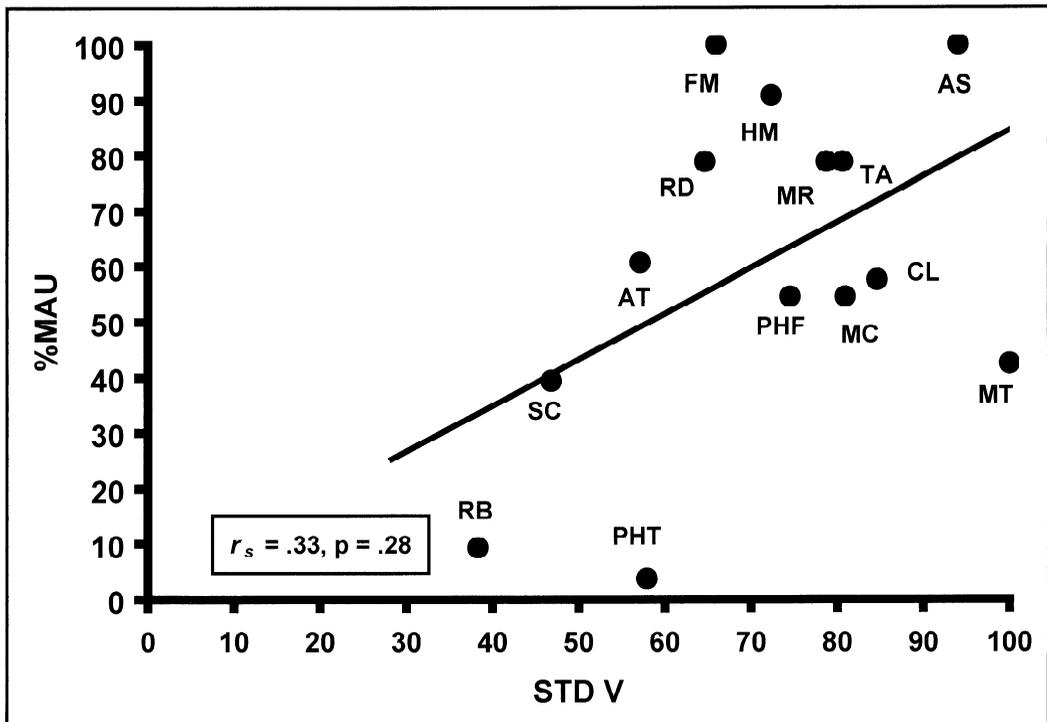


Figure 9. Bivariate plot of %MAU vs. STDV (standardized settling velocity; see Todd 2003:244).

notch water flow and detritus distribution, would help resolve this matter.

As for the possible effects of colluvial action within the shelter, we observe that 197 identified specimens (8.8 percent) displayed green/fresh bone breaks (Table 4). Many agents can cause green-bone fractures (Lyman 1994:324–325). But in a shelter setting such as this, where large roof-spall fragments fall, fresh fracture of exposed or even slightly buried bone from roof-spall may occur. Such breaks could also occur from the animal falling; Hughes (1986) observed, for example, that metapodials from elk driven off a cliff were transversely fractured through the shaft, and notes that for much heavier bison the resulting limb bone damage would have been greater. It may be telling that metapodials are, besides a single femur and radius, the only complete long bone elements observed in the Bonebed 2 assemblage. Nonetheless, without such experimental breakage data for bison bones we can say little of limb bone damage in Bonebed 2 resulting from a fall or roof-spall. We can, however, test to see if other agents (e.g., carnivore or human activity) caused the observed green-bone breakage in Bonebed 2.

In terms of carnivore activity, only a single proximal humerus bears evidence of gnawing or cracking, suggesting in this instance removal of a grease-rich epiphysis. However, poor cortical surface condition and break-edge preservation may mask other evidence of carnivore action. Likewise, density-mediated attrition may have selectively removed the grease-rich, low-density epiphyses preferred by carnivores (Lyman 1994). Our analysis indicates that density-mediated attrition was not a significant agent of bone preservation ($r_s = -.125$, $p = .425$; see Kreutzer 1992, 1996). Therefore, if carnivore activity was a significant contributor to the taphonomic history of Bonebed 2, we might expect to see an overabundance of limb shafts compared limb epiphyses. To test this assumption, we examined the relative abundances (NISP) of limb epiphyseal fragments compared to shaft fragments. These prove to be significantly different ($G = 9.594$, $p = .022$), with tibia epiphyses and radii shaft fragments significantly underrepresented, and tibia shafts significantly overrepresented (as shown by Freeman-Tukey deviates). While these data may indicate that tibia epiphyses were potentially preferentially destroyed by carnivore activity, the insignificant rela-

Table 4. Summary Modification Data.

EL	Total		Green Break		Impact Fracture		Cutmarks	
	NISP	MNE	NISP	MNE	NISP	MNE	NISP	MNE
MR	122	26	3	2	0	0	2	2
TH	187	65	3	2	0	0	0	0
RB	117	43	10	3	0	0	0	0
SC	77	13	10	2	0	0	1	1
HM	124	30	36	13	3	3	1	1
RD	107	26	28	9	2	2	1	1
UL	42	18	5	2	0	0	0	0
MC	30	18	7	3	0	0	0	0
IM	74	16	4	4	0	0	0	0
FM	180	33	32	9	4	3	1	1
TA	119	26	38	12	5	3	0	0
AS	51	33	4	3	0	0	0	0
CL	46	19	1	1	0	0	0	0
MT	36	14	13	5	2	2	0	0
PHF	104	68	1	1	0	0	0	0
PHS	80	72	2	2	0	0	0	0
Total			197		16		6	

Note: Data presented as both NISP and MNE per element.

tionship between epiphyseal and shaft fragment representation for other limb elements (including humeri), as well as the overall lack of carnivore gnaw marks, speaks against carnivore activity being a significant source of bone breakage.

Several lines of evidence may bear on the role of humans in the accumulation of this bone deposit. One is the structure of the bonebed, and the degree to which skeletal remains were articulated and/or stacked or otherwise spatially partitioned. Unfortunately, precise provenience data on the bones were not recorded during the original excavations; instead, the majority of material was collected by lot per excavation unit. Likewise, in her original analysis, Lorrain (1965) tallied related lots (i.e., lots from similar or adjoining units) under a single number to save time, which adds further ambiguity to the exact unit provenience of reanalyzed material. If, however, Lorrain's (1968:75) interpretations of element distribution are correct, significant skeletal disarticulation occurred. A concentration of mandibles, cranial parts (primarily maxilla fragments), and atlas and axis vertebrae was observed in the rear of the shelter (Lorrain 1968:96), and a cluster of at least seven scapulae was left in situ in N60/W50 (Ray Little notes that nine are present, Dibble 1964). Lorrain (1968:97) mentions that sacra, pelves, femora, tibiae, and phalanges are concentrated in various discrete loci as well (also Bement 1986:29–32).

Whole or partial articulation of skeletal parts is common in jump site bonebeds (e.g., Glenrock and Vore, Frison 1973; Reher and Frison 1980). For that matter, Bonfire Shelter Bonebed 3 (the Late Archaic component) included a "larger number of articulations" and relatively few instances of deliberate stacking of elements (Lorrain 1968:98). In contrast, Bonfire Shelter Bonebed 2 more closely resembles the bone distribution patterns seen in the butchery/processing areas of other Late Paleoindian sites (e.g., Casper, Jones-Miller, and Olsen-Chubbuck; Bamforth 1988:180); notably, a lower number of articulated elements, and evidence of element stacking. Bonfire Shelter Bonebed 2 contained only seven element articulations and no complete skeletons (Lorrain 1968). Element disarticulation, and lack of significant articulation, do not alone identify human agency. Rather, when considered in terms of both element stacking and direct butchery evidence (e.g., cutmarks and impacts), the extensive disarticulation recorded in Bonebed 2 suggests human activity.

Direct evidence of human modification of the bones is, however, rare. Lorrain found no traces of butchering marks (1965:37) or grease rendering (1965:66), but observed that marrow-yielding bones were deliberately crushed (Dibble 1970:251; Johnson and Holliday 1980:105; Lorrain 1968:102). Our examination of Bonebed 2 skeletal material confirms the sparseness of direct evi-

dence for butchering. Only 22 specimens (less than 1 percent of the identifiable assemblage) display marks consistent with meat removal/disarticulation and marrow acquisition. Locations of observed impacts and cuts are displayed in Figure 10; two mandibles with multiple cuts are not shown.

The distribution of observed cutmarks suggests some disarticulation and stripping of flesh (Binford 1978). The paucity of butchery marks may be indicative of less-intensive processing, particularly in comparison with some northern plains Paleoindian bison kill-butchery sites (e.g., Clary Ranch, Casper, Agate Basin Main Folsom; Hill 2001:219). Again, however, given the condition of the bones, this may not accurately reflect processing intensity. Indeed, data from limited experimental trials of medium-to-large mammal butchery suggest that frequencies of individual cutmarks do not well represent the intensity of activity actually invested into flesh removal (Egeland 2003).

Identified impact fractures are consistent with human-induced percussion, having typical loading point characteristics (see Hill 2001:233 and Lyman 1994:326 for descriptions). Impact locations appear random and may indicate that marrow acquisition activities were conducted after elements were disarticulated (Todd et al. 1997). This pattern, in tandem with a paucity of carnivore activity, is often considered sufficient evidence of humans as the primary fracture agent (Lyman 1994:326). A possible test of that proposition is whether the frequency of fractured elements corresponds to the marrow fat utility of that element, assuming the goal of marrow acquisition is to maximize caloric yield.

Figure 11 shows derived fresh-fractured element frequencies (in percent MAU) compared to Emerson's (1993) (S)AVGMAR whole-bone values. A very strong correlation results ($r_s = .886$, $p = .001$), suggesting that humans may indeed have been the primary agents of fresh-bone fracture. Still, other agents such as roof-spall cannot be eliminated as a possible contributor, because it is not known whether falling spall creates impacts similar to human-induced impacts.

Burned bone (NISP = 412) is highly concentrated in Pits A, B, and C (NISP = 393; 95.4 percent), with Pit C containing the highest proportion (NISP = 180; 45.8 percent). All elements, save fifth metacarpals and dew claws, have some specimens that are charred and/or calcined, suggesting that

selective burning of skeletal portions—in the case of cooking, for instance—did not occur. But, again, when the bone was burned and by what specific agent is uncertain. Regardless, Bonebed 2 specimens do not reflect the intensity of burning observed in Bonebed 3 (Dibble and Lorrain 1968).

Skeletal Element Representation and Utility

The relative frequency of skeletal elements in Bonebed 2 varies. Mandibles, sacra, humeri, radii, femora, and tibiae occur in greater relative abundance; cranial elements, most vertebrae and ribs, and lower limb elements, occur in lesser relative abundance. As noted, while this pattern could be the result of density-mediated attrition (Lyman 1994), there is no significant correspondence between element frequency and bone volume density.

Overall, lower limb element representation (save astragali) does not reflect that of upper limb elements. As discussed, there is no indication that lower limb elements were biased by excavator collection preferences. However, as noted, thoracics, lumbar, sacra, and innominates are excluded from our analyses of transport and utility because of a potential field discard bias against these elements. We also counted 274 small rib blade fragments and 68 vertebrae body fragments that were not useful for deriving MNEs. Though we do not expect these counts to appreciably alter our MAU estimates or affect our interpretations, we urge the reader to keep these facts in mind when considering our arguments concerning utility and transport presented below.

We utilize simple linear models to evaluate potential transport of high-utility elements and carcass units, which raises issues of statistical accuracy and reliability. We recognize that linear models expressing the relationship between skeletal element frequencies and utility indices, particularly where significance tests are made, are inappropriate because: (1) they violate basic assumptions about the statistical methods used (i.e., the independence assumption fails); and (2) a basic body of theory identifying the relationship of r_s to a particular level of carcass part selectivity does not exist (Beaver 2004; Rogers 2000; Rogers and Broughton 2001). However, as Beaver (2004) notes, in light of other techniques for identifying patterns in element frequency data (e.g., abcml, see Rogers 2000),

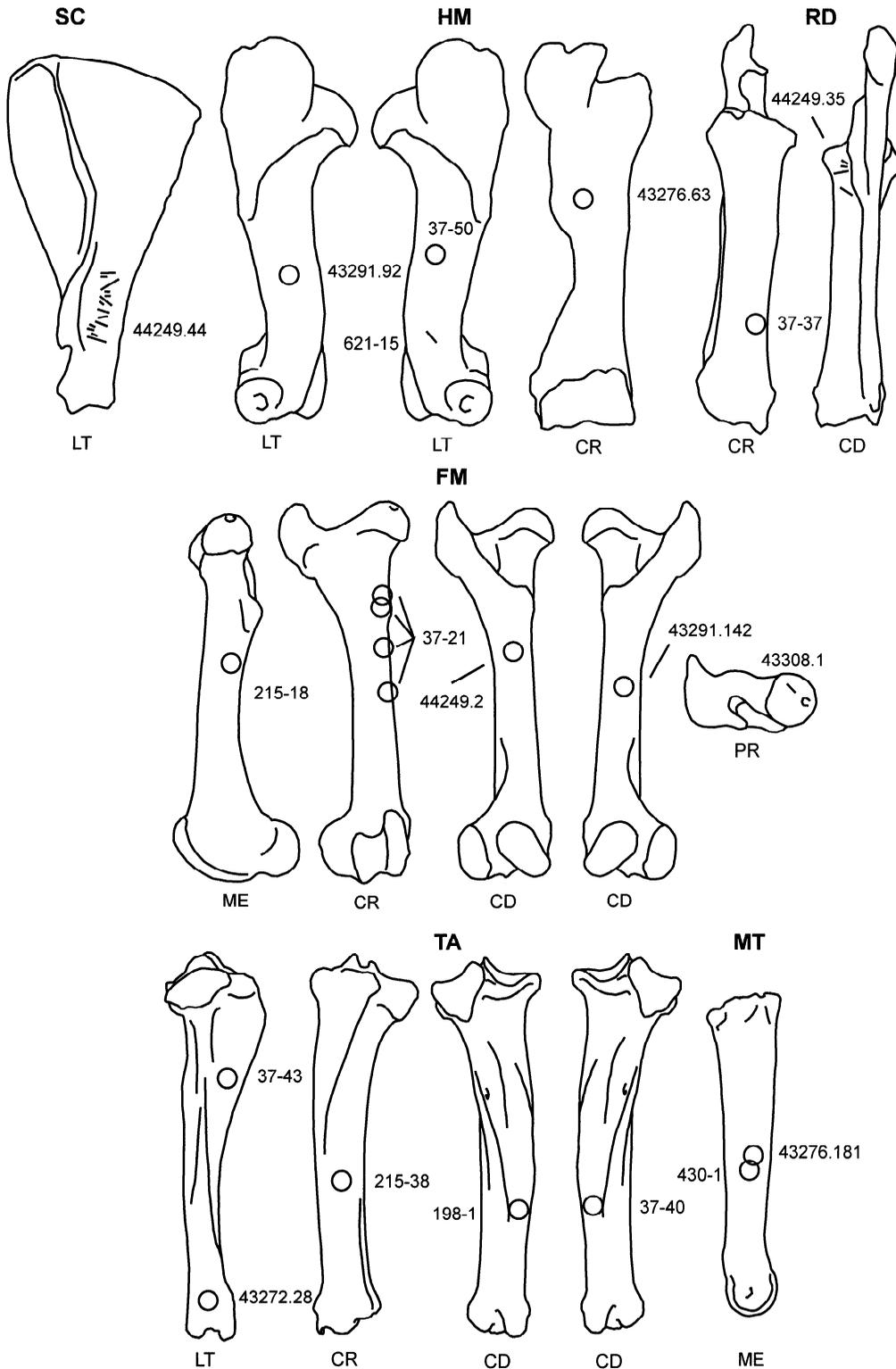


Figure 10. Locations of all observed impacts and cutmarks, except as noted. Circles are impacts, lines are cutmarks. Specimen numbers shown.

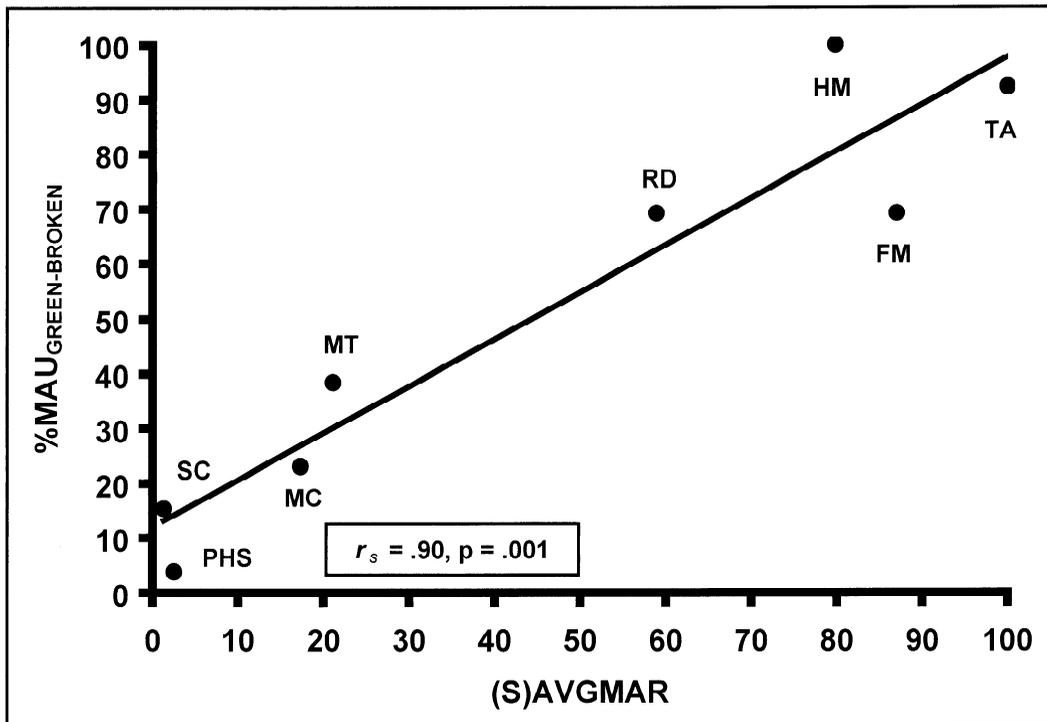


Figure 11. Bivariate plot of %MAU_{GREEN-BROKEN} vs. (S)AVGMAR. %MAU derived by dividing MAU of only green-broken elements against highest MAU for those green-broken elements.

scatterplot comparison remains the most utilized and most directly intuitive analytical technique. Thus, to keep the Bonebed 2 skeletal data set comparable to other site data sets, all transport and utility models are tested using Spearman's r_s . Remember, also, these models are meant to elucidate simple trends in element frequency for specific element groups and ethnographically defined transportable large mammal carcass units, not to statistically determine selectivity.

Binford's (1978:475–476) plot of Bonebed 2 skeletal frequencies against a skeletal part selection model of processing and meat stripping for transport or drying for caribou showed a bulk utility curve indicative of a processing location to which parts were preferentially transported from an initial field butchering locus. Our re-analysis confirms Binford's (1978) observation using Lorrain's (1965, 1968) data and Emerson's (1993) (S)MAVGTP for bison. A similar pattern is apparent for our data, with significant correlations between element/carcass unit representation and total product utility (Figure 12a, 12b). However, such correlations only exist if ribs are removed

from inclusion in statistical analyses; ribs are clearly underrepresented compared to their utility. Though trends are positive, significant correlations do not exist between element or carcass unit frequencies and other utility models.

In summary, skeletal data indicate that: (1) lower limb elements (e.g., carpals, tarsals, metapodials, phalanges, and sesamoids) are underrepresented compared to upper limb elements, but it is not apparent this pattern is due to excavator bias; (2) excavator collection bias against thoracics, lumbar, sacra, and innominates is apparent in Pit C, but not for other elements; (3) fluvial activity is suggested as an agent of bone dispersal within Bonebed 2; (4) carnivore activity does not appear to be a significant agent in epiphyseal vs. shaft fragment representation for most elements; (5) density-mediated attrition is not a factor in bone preservation; (6) butchery evidence indicates that some long bones were broken to access marrow cavities, a fact emphasized by the significant correlation between fresh-fractured bone frequencies and marrow utility; (7) ribs are underrepresented compared to their food utility, which may be related to fluvial dis-

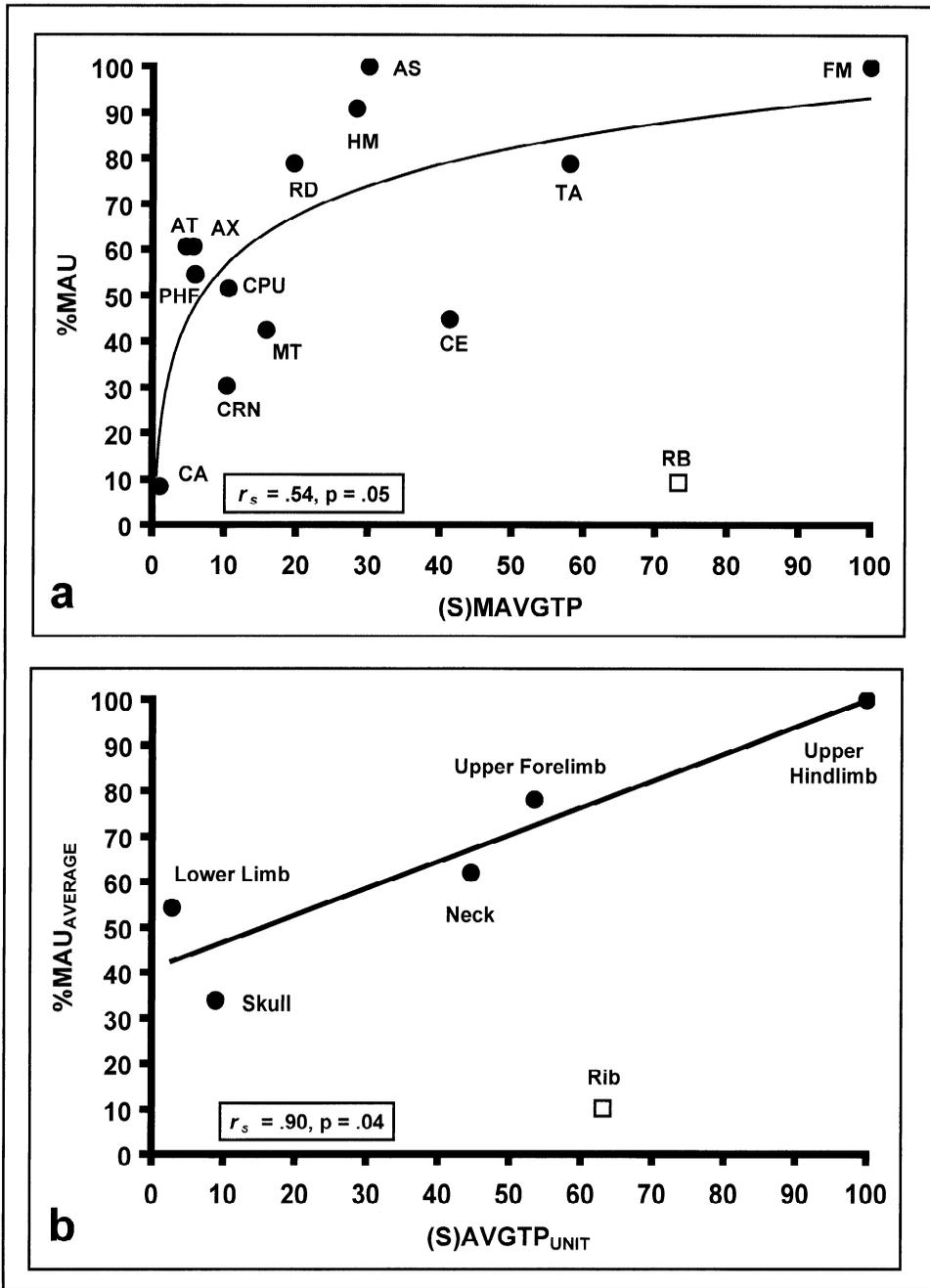


Figure 12. (a) Bivariate plot of %MAU vs. (S)MAVGTP for individual elements (Emerson 1993). Idealized bulk utility curve shown. (b) Bivariate plot of %MAU vs. (S)AVGTP_{UNIT} for carcass units (derived from Emerson 1990). Statistical analyses for both element and carcass unit data do not include ribs.

persal; (8) skeletal frequencies are biased toward high total product upper limb elements; and (9) carcass unit representation is directly related to total product yield.

These conclusions suggest, in agreement with

Binford's (1978) hypothesis and Sivertsen's (1980) model, that Bonebed 2 represents an area where high-utility carcass portions were preferentially transported from an initial kill-butchery locale and further processed for meat and within-bone nutri-

ents. That all elements are represented, though in varying frequency, suggests that the primary kill locality was very close to Bonfire Shelter, as is seen in other Late Paleoindian kill-butcher sites (Bamforth 1988; Johnson and Holliday 1980; Wheat 1972). Low frequencies of ribs may indicate that these were winnowed out by fluvial activity or, alternatively, further transported by humans away from the shelter.

Furthermore, many researchers note that the carcass transport decisions expressed by modern hunter-gatherers are not so simply, nor singly, confined to maximizing nutritional gain (Bartram 1993; Monahan 1998; O'Connell et al. 1988). Modern groups are constrained by—amongst other things—carcass size, time of day, number of available carriers, and distance to camp. Specific transport strategies will vary accordingly (Bartram 1993:121). While these same governing principles would certainly have applied to Paleoindian transport and utilization decisions, it is important to keep in mind that the majority of extant ethnoarchaeological data, save for Binford's (1978) analysis of Nunamiut subsistence behavior, are from hunter-gatherer groups who do not generally engage in multi-animal kills of large gregarious prey, as North American hunter-gatherers did occasionally from Late Glacial times on. Utility models for groups such as the Nunamiut who do engage in multi-animal kills—and one could assume (however periodically) Paleoindian hunter-gatherers also—seemingly work well for identifying and explaining transport decisions (Bartram 1993).

This is not to say that transport models based on modern African hunter-gatherers are not applicable to prehistoric North American hunter-gatherers. Indeed, the Great Plains archaeological record indicates that mass bison kills of the scale of Bonfire Shelter and other, much larger sites are the exception rather than the rule in terms of prehistoric North American subsistence strategies (Hill 2001:253; Landals 1990). However, comparing Bonfire Shelter and other mass bison kill-butcher sites with Nunamiut-like strategies is probably more revealing.

Additionally, as Marean and Cleghorn (2003) argue, modeling transport behavior based on nutritional return must be understood in the context of the realities of skeletal element destruction and survival. This argument does not just simply apply to

on-site taphonomic issues of density-mediated attrition or carnivore destruction; it must also apply to on-site excavator selection as well as off-site taphonomic issues such as storage destruction and collections loss, as noted previously in regards to Bonfire Shelter assemblages. Bonebed 2 is the result of a complex postdepositional and post-excavation taphonomic history—fluvial activity, excavator selection, and storage damage have all, in some way, affected element representation at the site.

Bonfire Shelter Bonebed 2 in Archaeological Context

The oldest, uncontroversial bison jump site in North America is Head-Smashed-In, Alberta, the earliest use of which was ~5,700 ¹⁴C yr B.P. (Dyck and Morlan 2001; Reeves 1978b).² The next oldest bison jumps are in Alberta (the Calderwood and DjPp-5 sites, and the later components at Head-Smashed-In), Montana (Kobold), and Texas (Bonfire Shelter Bonebed 3) (Dibble and Lorrain 1968; Dyck and Morlan 2001; Frison 1970b, 1991; Morlan 2002; Polk 1979).

Save for Bonfire Shelter, all other recorded bison jumps (Figure 1) are located on the northern and northwestern Plains, extending from northern Colorado into Canada (Agenbroad 1976; Brekke 1970; Brink and Dawe 1989; Brink and Rollans 1990; Brumley 1990; Butler 1971; Davis and Stallcop 1966; Forbis 1962; Frison 1967, 1970a, 1970b, 1971, 1973, 1991, 2004; Hlady 1970; Hurt 1963; Malouf and Connor 1962; Marshall and Brink 1986; Plew 1987; Polk 1979; Reher and Frison 1980; Witkind 1971). Forbis (1962:65) reports a bison jump kill apparently excavated by Hibben in 1961 at Corrupa Creek near Des Moines, in north-eastern New Mexico. However, no records exist confirming such an excavation, though collections at the University of New Mexico do contain a *Bison antiquus* cranium collected near Des Moines by Hibben in the early 1960s (Bruce Huckell, personal communication 2004).

In addition to being located almost exclusively on the northern and northwestern Plains, bison jumps—including Bonfire Shelter Bonebed 3—are all post-Altithermal in age, and indeed the majority are Late Prehistoric (Dyck and Morlan 2001:118; Frison 2004; Polk 1979; see Figure 13).

Clearly, Bonfire Shelter Bonebed 2 is a spatial

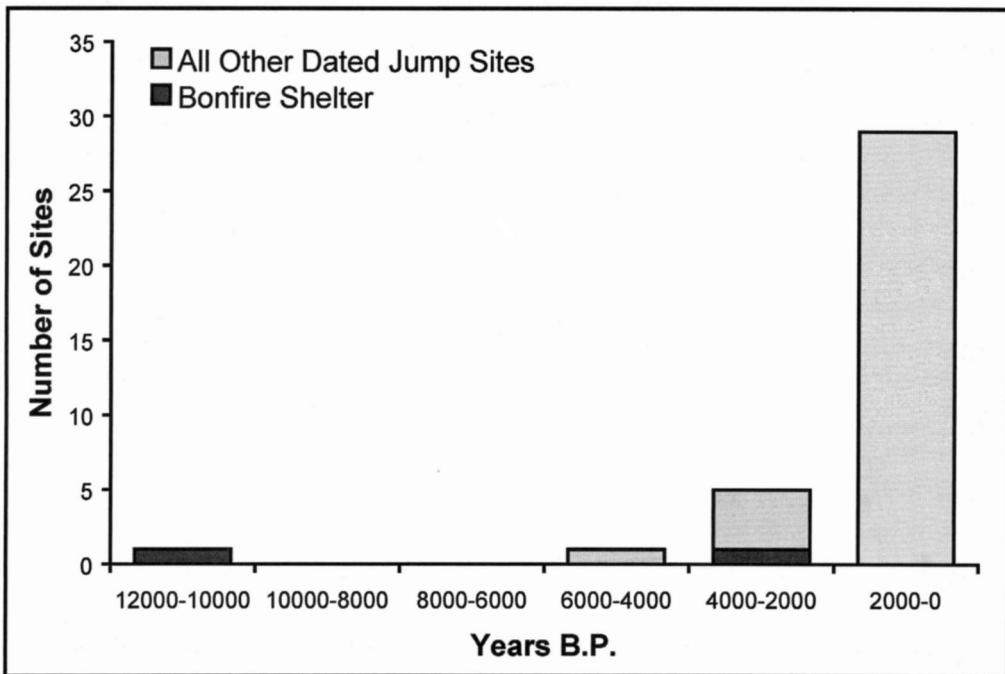


Figure 13. Histogram showing time ranges of known North American bison jump sites.

and temporal outlier, as Forbis (1969) observed over three decades ago. But Forbis supposed that the spatial/temporal gap between Bonfire Shelter Bonebed 2 and other jump sites was more apparent than real and would be “closed when more archaeologists act to learn how prehistoric hunters made a living” (Forbis 1969:91, also see Frison 2004:79). Either that lesson has not been learned, or the spatial/temporal gap is real, or Bonebed 2 is not the result of a bison jump, but is instead the processing area of a kill that occurred elsewhere.

A comparison of Bonebed 2 element data with known Paleoindian bison bonebeds kill-butcher sites (Figure 14) suggest that this assemblage is different from primary kill sites (e.g., the Agate Basin component at Agate Basin [Hill 2001], Cooper [Bement 1999], and Horner II [Todd 1987c]). Indeed, the patterns at Bonfire Shelter Bonebed 2 more closely resemble those at camp/processing sites (e.g., the main Folsom component at Agate Basin [Hill 2001], Cattle Guard [Jodry and Stanford 1992; Jodry 1999], and Clary Ranch [Hill 2001]), dominated as it is by upper limb elements with lower limbs comprising much less of the assemblage.

Likewise, Bonfire Shelter Bonebed 2 green-

bone fracture frequencies fall between those observed in primary kill/processing and camp/secondary processing sites (Figures 15a and 15b). Clearly, marrow-processing intensity at Bonfire Bonebed 2 is nowhere near that observed at Clary Ranch (secondary processing area; Hill 2001) or Cattle Guard (camp site; Jodry 1999) for most elements. Given that Bonfire Bonebed 2 is inferred to be a summer mortality, however, the body condition of hunted animals may have been sufficient enough, or the timing of the kill early enough, to discount the need for accessing large amounts of marrow.

While these generalizations cannot, as such, confirm that Bonfire Shelter Bonebed 2 was a secondary processing area (Binford 1978), they do lend support to the interpretation of it as a processing area where meat and marrow were accessed, rather than a kill locality. If this so, why is the recovered lithic assemblage so sparse (see Dibble 1968)?

Bonebed 2 Lithics

Only 37 lithic artifacts were recovered from Bonebed 2 (Figure 2). Bement (1986:25) did not recover any additional lithic artifacts during sub-

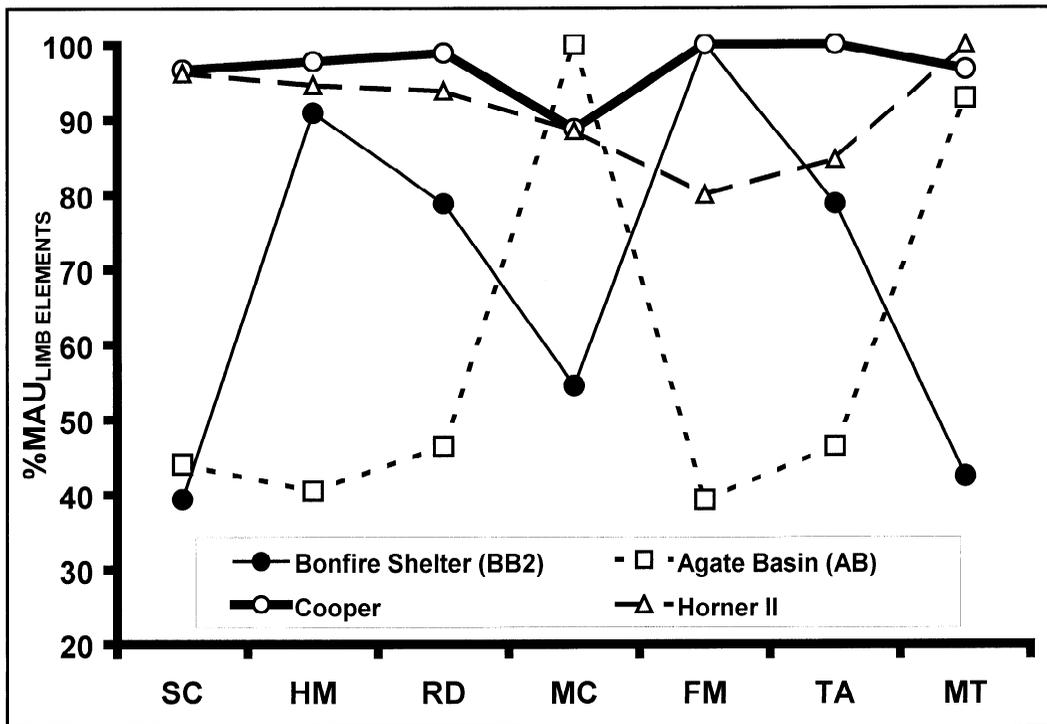


Figure 14. Plot of %MAU_{LIMB ELEMENTS} for Agate Basin (Agate Basin Component; Hill 2001); Bonfire Shelter Bonebed 2; Cooper (Bement 1999); and Horner II (Todd 1987c). %MAU derived based only on those limb elements listed.

sequent work in Bonebed 2. The vast majority of bone and lithic artifacts occurred around the unexcavated talus cone, immediately below the notch. The densest concentration of tools was found in Pit C, which yielded a diverse assemblage of projectile points and/or fragments, crude bifaces, flake scrapers, worked and unworked flakes. Lesser numbers of tools were found in nearby excavation areas. Plainview artifacts were scattered around the talus cone, although the Folsom point was found near the front of the shelter in Pit A, thus making the horizontal and vertical association (and temporal association) between the two complexes difficult to determine. No lithic artifacts were found in the rear of the shelter, which mirrors the pattern in the distribution of bison bone.

Point provenience data is available for 9 of the 20 tools (Dibble 1968:Table 2). Comparing their locations against an interpolated Bonebed 2 thickness reveals that 78 percent of the provenienced tools were found in the thickest portion of Bonebed 2 (~.23–.38 meters thick). It is not known whether this was the result of cultural or taphonomic fac-

tors, as the thickest areas also yielded the majority of all tools and bison bone.

Dibble (1968:37) identified only a single burned tool, a crude biface (tool #470) recovered from Pit C. This unit, as noted, also contained the greatest concentration of burned bone. The lack of additional burned flakes or tools might again have to do with site formation processes, as only one tool is recorded from the burned Component B. This tool is not described by Dibble as being burned (Tool #492; Dibble 1968:37), but a recent examination of this specimen suggests that it bears dark coloring that may be indicative of burning. Unfortunately, Dibble was not able to identify the specific component of the burned biface. The lack of burned tools in other areas of the site suggests that the fire was limited in horizontal (and perhaps vertical) position within Bonebed 2, conforming to the noted distribution of burned bone.

The general paucity of flakes ($n = 17$) from such a disarticulated assemblage is unexpected. Indeed, Dibble (1968:40) commented on the small number of recovered flakes, stating that it "is surpris-

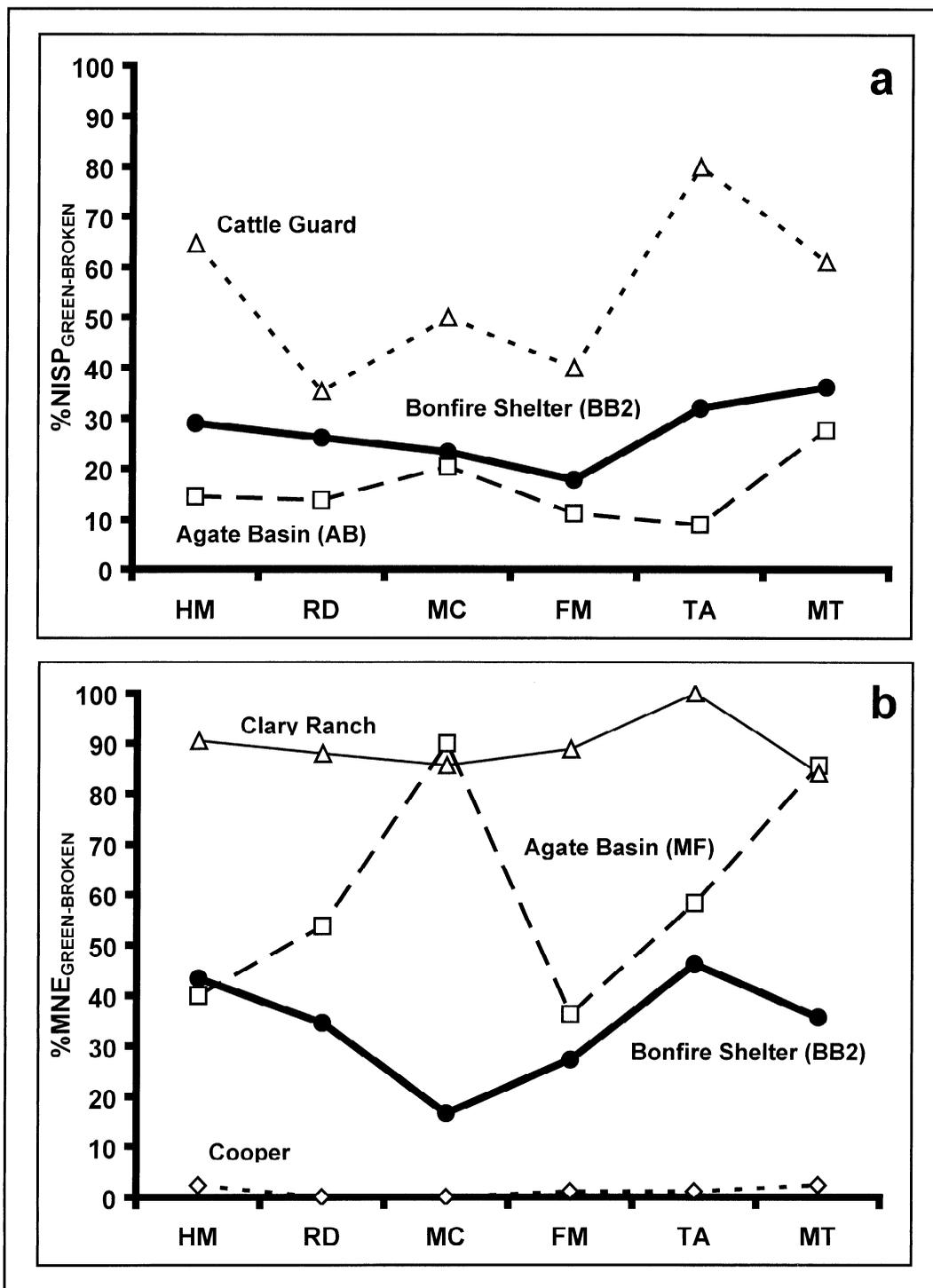


Figure 15. (a) Plot of %NISP_{GREEN-BROKEN} per long bone for Agate Basin (Agate Basin Component; Hill 2001); Bonfire Shelter Bonebed 2; and Cattle Guard (Jodry and Stanford 1992). (b) Plot of %MNE_{GREEN-BROKEN} per long bone for Agate Basin (Main Folsom Component; Hill 2001); Bonfire Shelter Bonebed 2; Clary Ranch (Hill 2001); and Cooper (Bement 1999).

ing; apparently little chipping was done at the site of the kill." Paleoindian kill-butchery sites with such heavy skeletal disarticulation generally have moderate-to-high numbers of flakes, usually related to tool resharpening and maintenance (Amick 1996). For example, the Jones-Miller site in eastern Colorado contained over 11,500 resharpening flakes spread across the bonebed (Stanford 1999:448).

Several possibilities might account for the paucity of flakes in Bonebed 2. First, recovery techniques might have biased recovery of small flakes and shatter that would result from tool resharpening. For instance, many of the flakes at Jones-Miller were recovered during water screening of the bonebed (Stanford 1999:448). Baumler and Downum (1989) found through experimental trials that when using 1/4 inch (6.35 mm) mesh screens excavators lost the majority (84–92 percent) of debitage common to butchery tool production and resharpening. Ideally, to test whether this was the case during the Bonfire Shelter excavations, we would examine all recovered material from all components. Unfortunately, the bulk of the artifact assemblage could not be examined. We were, however, able to locate and measure a sample of Bonebed 2 lithic debitage ($n = 7$). As the smallest of these was >8.9 mm, this indicates that only flakes larger than 6.35 mm were recovered in the excavation and screening of Bonebed 2, suggesting that screening bias may indeed have significantly shaped the composition of the lithic assemblage.

Second, post-kill taphonomic processes may have simply removed the lithic debris through, for example, colluvial and fluvial action. Third and finally, a simple behavioral explanation might be that tool sharpening or manufacturing activities did not take place in this portion of the site. Hill (2001) notes, for example, that screening methods were thought to have biased the Clary Ranch assemblage before re-excavation confirmed a mass concentration of debitage in a separate activity area than the bonebed. Thus, before the lithic artifacts can be included as useful indicator of site-use, a more thorough understanding of the artifact composition is needed. This could be accomplished by revisiting the site and re-excavating intact deposits and/or rescreening excavated matrix.³

Where Were the Bonfire Shelter Bonebed 2 Bison Killed?

If, indeed, Bonebed 2 is a processing area, it raises the question of where these bison died, and how. Unfortunately, there is no obvious answer, as no traces of a Paleoindian bison kill have been located near Bonfire Shelter. But if the kill was nearby and the carcasses were dragged in, as we suspect, it begs the question, first posed by Dibble (1968:69): if the floor of the canyon was no higher in Late Glacial times than it is at present (~18 m below the shelter entrance), is it conceivable that the animals died on the floor of Mile Canyon, and the hunters hauled the carcass parts up the steep slope into the shelter? Dibble (1968:69) thought it unlikely.

However, the present slope into the shelter and its elevation above the valley floor may have little bearing on the question. As noted, historic overgrazing has led to erosion of Mile Canyon, lowering the floor to scoured bedrock—and, perhaps, removing any traces of a kill site. If the floor of Mile Canyon at the time of the accumulation of the Bonebed 2 bison was significantly higher than at present, as anticipated by Bement (1986:2), that would have made for a relatively easy haul of carcasses and carcass parts into the shelter. Unfortunately, we have only circumstantial evidence bearing on this issue.

The base of Bonfire Shelter, as Bement (1986:2) reported, and we subsequently observed, has bedrock crevices that contain stringers of sandy sediment distinctively darker and more reddish than the remainder of the fill in the shelter. These also contained many small, subangular pebbles. This was a waterlain deposit, but the lack of roundedness of some of the clasts suggests the gravels had not been extensively waterworn. The presence of a fluvial deposit atop the bedrock within the shelter implies its floor was once close to the base level of Mile Canyon, or at least close enough that the shelter filled with floodwaters during heavy flooding. Precisely when this deposition occurred, however, is not known; no dateable remains were recovered from the fluvial sand and gravel in the crevices.

It is known, moreover, that by ~12,500 B.P. (the age of Bonebed 1; Bement 1986) the shelter was no longer receiving fluvial sediment, either because

of a lowering of the canyon floor, or major roof- and wall-collapse that dropped large blocks of limestone that diverted the flow of floodwaters away from the shelter entrance. There is no direct measure of how far below the shelter the floor of the canyon may have dropped, if indeed it fell.

Still, a very rough estimate of the position of the canyon floor in Late Glacial times can be inferred from a ~49 m long, horizontally discrete packet of coarse sediment and fine gravel cemented onto the valley wall of Mile Canyon, ~450 m downstream of Bonfire Shelter. This packet of sand and gravel occurs high above the present valley floor deposits, well above any historically known high water marks (Jack Skiles, personal communication 2003), and higher in elevation than the Archaic and later Prehistoric sedimentary deposits in nearby Eagle Cave (Ross 1965), and thus presumably predates all of those deposits. This opens the possibility this deposit is a remnant of Late Glacial-age valley-fill. Unfortunately, careful examination of this deposit failed to yield any charcoal, and of the several bone elements found in situ none were dateable. A fossil *Equus* metapodial was recovered in association with these deposits, but was not in a secure context, and did not yield sufficient organic material for radiocarbon dating.

If these gravels do represent a Late Glacial-age valley fill, and assuming the floor of the canyon was at or near the level marked by these cemented sands and gravel, and that the canyon slope then was comparable to what it is now, then extending the level of this deposit upstream puts the floor of Mile Canyon in Late Glacial times to within just a few vertical meters of the floor of Bonfire Shelter. A bison kill could have been located on the floor of Mile Canyon, and the carcass parts easily carried into Bonfire Shelter. This stratigraphic inference could be tested if intact Late Glacial deposits are found preserved on the slope in front of Bonfire Shelter.

Summary and Conclusions

Bonfire Shelter Bonebed 2 is comprised of the remains of 24 to 27 *Bison antiquus*, of which most individuals are of age group 4 or older. The ages of the animals fall into a relatively tight set of cohorts, suggesting there was but a single kill that took place in the summer. We hypothesize that the

apparent stratigraphic division of bone components in Pit C is a localized phenomenon resulting from postdepositional burning and slope wash, and does not represent separate events. Limited data on bone distribution indicate that fluvial activity may have winnowed bones (e.g., ribs and scapulae) out of the main bone deposit around the talus cone. Future work at Bonfire Shelter, with particular focus toward recording the orientation and inclination of deposited bone, could provide the necessary data for testing this hypothesis.

The long-standing interpretation of this bonebed is that it represents a jump kill. Our GIS analysis of upland terrain and possible drive routes, and comparisons with other known bison jumps (see Polk 1979), suggests this would have been an ideal setting for jumping bison. There are nearby sources of water and (apparent) upland pasture; the topography lends itself to natural drive lanes; and on those lanes the cliff edge would have been obscured from fast-moving animals that, when they finally saw it, would not have had enough time to avoid the injurious (if not fatal) plunge over the edge. Indeed, based on the GIS analysis, it would appear that Bonfire Shelter would have been one of few locations in the region that offered the best suite of features for a bison jump. Likewise, as Dibble and Lorrain (1968) originally surmised, a jump would be the most plausible explanation of the bison bonebed if, indeed, the assemblage represented the locus of the kill.

Still, our analysis of the Bonebed 2 faunal remains suggests that even though Bonfire Shelter could have been used as jump site, it is not apparent that it was. Bonebed 2 appears to represent a processing area where bison remains were brought in and butchered for meat and within-bone nutrients, displaying a utilization preference for high total product yield elements and carcass units (see also Binford 1978). Skeletal element frequencies indicate an assemblage dominated by high-utility upper limb elements and not an assemblage where low-utility elements were abandoned. Heavy disarticulation and lack of significant articulation, as evidenced by Lorrain's (1968) observations on skeletal element distribution, may be indicative of intensive processing of transported remains, though green-bone fracture frequencies suggest less-intense processing than is observed at Paleoindian camp/secondary processing areas. Limb element

marrow acquisition is supported by impact evidence on long bones and the significant positive correlation between the frequency of fresh-fractured bone and marrow utility values.

It is important to note that while we argue that Bonebed 2 is not likely the kill locus, this does not preclude the possibility that these bison died in a jump kill, their carcasses having landed elsewhere on the canyon floor (Binford 1978:475). The periodic flash floods that scour the canyon bottom may have long since removed any evidence of such a kill, but close proximity between the kill and processing areas is suggested by the presence, though in varying frequency, of all carcass parts, including portions of crania, from Bonebed 2. Conceivably, skeletal material may still be buried in the steep talus in front of the shelter. Future work geared toward testing such a hypothesis could shed light on this matter.

Additional work will be needed to test the much larger issue all of this raises: notably, even if Bonebed 2 represents a jump kill, it was an event isolated by almost 1,800 kilometers and by nearly 4,300 years from anything like it; why was bison jumping so rarely practiced over such large areas of the Central and Southern Plains?

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Notes

1. This would be the equivalent momentum (with no regard to force or time) of a small motor vehicle (~1,315 kg (2,900 lbs.) hitting a concrete wall at ~107 km/hr (67 miles/hr). If force and time are considered, then the force that the bison suffers is substantially greater than that experienced by the vehicle, because the impact time for the bison is much less (Ethan Meltzer, personal communication 2005).

2. Agenbroad (1978) argued that the Early Holocene site of Hudson-Meng was a possible jump, though Frison (1991:179) considered it a trap, while Todd and Rapson (1999) argue that the Hudson-Meng bonebed is the result of a natural (i.e. non-cultural) mass-mortality.

3. During the 2005 field season 1.38 m³ of backdirt from the 1963–1964 excavations was screened in ¼ inch (1.59 mm) mesh in search of discarded lithic debitage. Although this sample represented only .6 percent of the total volume of sediment removed from flake bearing units, twice the density of unworked flakes (N = 5, 3.62 flakes/m³) was recovered. These flakes range in size from 9.16 and 21.68 mm, well within the catch range of the ¼ and ½ inch mesh used during the 1963–1964 excavations.

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