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Faunal exploitation by Early Holocene hunter/gatherers on the Great Plains of North America: Evidence from the Clary Ranch sites

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Abstract

Analysis of the faunal remains recovered from two penecontemporaneous Early Holocene archeological sites on the Clary Ranch in western Nebraska offers a series of functional insights on the organizational structure of Late Paleo-Indian subsistence behavior on the central Great Plains of North America. At each location, radiocarbon assays on charcoal and bone indicate occupation between 9100 and 9000 BP. The deposits appear to represent functionally divergent, although complementary, dimensions of a single, spatially differentiated settlement and subsistence system situated along a intermittent tributary of the North Platte River. The Clary Ranch site provides a view from the perspective of a late summer–early fall secondary processing area for bison carcasses derived from a nearby mass kill. The intensive character of carcass exploitation here, involving defleshing and marrow extraction, suggests that the bulk of the yield was destined for storage in anticipation of impending winter food shortages. The primary component at the partially excavated, stratified O.V. Clary site is a residential camp, with evidence for occupation during the mid-summer, mid-winter, and late winter/early spring. On-site activities there are organized around an intact hearth area, to which the carcass parts from at least six bison were transported for processing and subsequent consumption. Non-bison remains recovered from the hearth area include coyote, box turtle, raven, great horned owl, and several small, indeterminate passerines

1. Introduction

The evolution of human diet and subsistence behavior represents a significant domain of recent archeological research. Studies addressing specific aspects of the intensification of food resources, including variability in the contexts, strategies, and consequences of these behaviors, have received considerable attention. Several temporally and geographically diverse patterns are now well documented, including increases over time in the importance of food storage, adoption of complex technologies for the extraction of nutrients, dietary inclusion of "difficult-to-catch or difficult-to-process" (Winterhalder and Smith, 2000, p. 58) foods on a regular basis, and in several highly significant instances, domestication of plants and animals (Stiner, 2002). Available evidence suggests that these shifts relate, at least in part, to the dynamic interplay between human population growth, environmental changes, and their concomitant effects on food-resource distributions, as well as predator–prey interactions (Broughton, 1994; Edwards and O'Connell, 1995; Stiner et al., 2000; Munro, 2004).

With the obvious exception of plant or animal domestication, transformations in diet and subsistence behavior among Early Holocene hunter/gatherers on the Great Plains appear roughly to parallel those occurring elsewhere in the world during the Pleistocene/Holocene transition (ca. 12,000–8000 BP). Yet unlike other regions of the world, where changes in faunal exploitation have been measured in terms of taxonomic diversity or reconstructed via estimates of diverse prey behavior and ecology (Stiner and Munro, 2002), the Great Plains' faunal record

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throughout this period consists predominantly of bison remains derived from kill/butchery sites. Beginning with White's (1953, 1954, 1955) pioneering research during the middle of the last century, Plains' (zoo)archeologists have responded to this fact by developing sophisticated field and analytical methods designed to extract ever more information from such remains, in order to infer more about the human populations that preyed upon them (Davis and Wilson, 1978; Frison, 1991b; Bement and Buehler, 1997). Such analyses have also profited immeasurably from an unusually detailed body of middle-range knowledge on bison carcass economic anatomy (Emerson, 1990), death site taphonomy (Burgett, 1990; Kreutzer, 1992), and behavior (Berger and Cunningham, 1994). Taken together, these methods, combined with the rich archeological record of the Great Plains, offer an ideal venue for tracking changes in the exploitation of a single, large-bodied prey species over the course of some ten thousand years.

In this paper, we summarize recent research at two Early Holocene archeological sites on the Clary Ranch in western Nebraska, highlighting the bison remains at each as they relate to the diet and subsistence behavior of their Late Paleo-Indian occupants. The Clary Ranch site provides a view from the perspective of a late summer–early fall secondary processing area for bison carcasses derived from a nearby mass kill. The intensive character of carcass exploitation here, involving defleshing and marrow extraction, suggests that the bulk of the yield was destined for storage in anticipation of impending winter food shortages. The primary component at the stratified O.V. Clary site, on the other hand, represents a residential camp, with evidence for occupation during the mid-summer, mid-winter, and late winter/early spring. On-site activities there were organized around an intact hearth area, to which the carcass parts from at least six bison were transported for further processing and consumption. Taken together, data from these sites indicate that, at least during the Early Postglacial period (ca. 10,000–8000 BP), subsistence-related problems were alleviated primarily through increasing the "tenure time" (LaBelle, 2006) in resource-rich environments, in combination with more intensive processing of the focal prey species (bison), as opposed to the exploitation of a greater diversity of species, a pattern that emerges later in time (Meltzer, 1999).

2. The Clary Ranch Late Paleo-Indian locality

The Clary Ranch Late Paleo-Indian locality is located ~130 km west of the confluence of the north and south forks of the Platte River in Ash Hollow (Fig. 1), a well-known regional landmark that served as a major thoroughfare for Oregon Trail wagon trains crossing the North Platte River between 1843 and 1868. Two confirmed and two suspected Early Holocene sites have been identified on the ranch along a ~2 km stretch of Ash Hollow Draw, an intermittent tributary of the North Platte River bisecting the ranch. Of particular interest here are the faunal

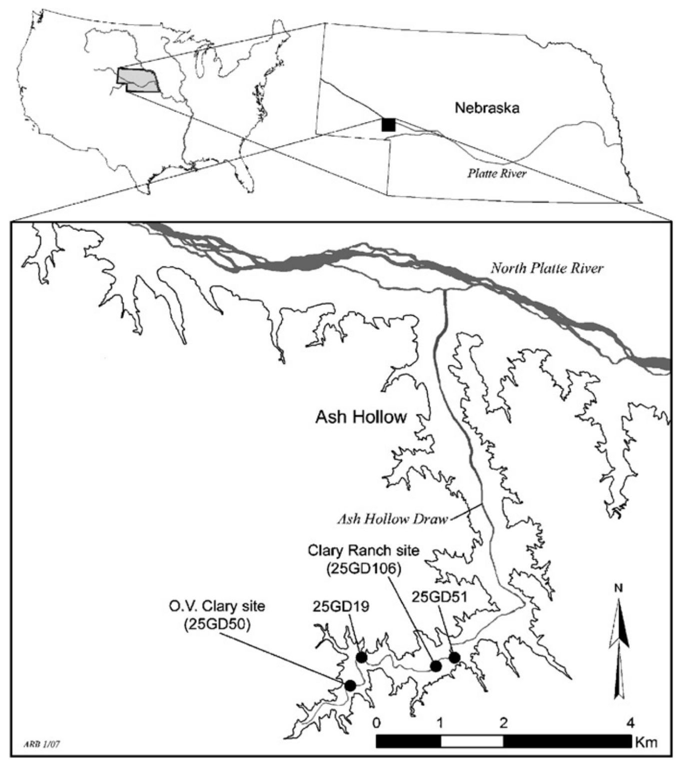

Fig. 1. Location of the Clary Ranch sites along Ash Hollow Draw.

assemblages from Clary Ranch and O.V. Clary sites, located ~1.4 km apart and belonging to the Allen/Frederick Complex (Hofman, 1989; Hofman and Graham, 1998). The other two (unnamed) sites, 25GD19 and 25GD51, are yet to yield time-diagnostic artifacts; however, these sites are encased in Early Holocene alluvium and almost certainly date to ca. 9500–8500 BP.[1] The spatial proximity of four, penecontemporaneous Paleo-Indian sites on the central Great Plains is highly unusual, emphasizing the potential significance of this locality for Early Holocene archeology. In this paper, we focus on inferences derived from analyses conducted to date on the faunal assemblages from Clary Ranch and O.V. Clary. Brief overviews of the archeology and the geoarcheology of each site are provided below.

3. The Clary Ranch site

3.1. Archeology

The Clary Ranch site was reported to the University of Nebraska State Museum in 1970 by rancher Oren V. ("O.V.") Clary, who observed artifacts, charcoal, and bison remains eroding from Early Holocene alluvium near the base of a high (~14 m), north-facing cutbank of Ash Hollow Draw (Fig. 2). In 1979, archeologist Thomas P. Myers, assisted by vertebrate paleontologists R. George Corner and Lloyd G. Tanner, coordinated the first of four

[1]All dates are presented here as uncalibrated radiocarbon ages.

consecutive month-long summer field seasons at the site (Myers et al., 1981). Since a final report on these investigations was never prepared, the site has seldom been mentioned in subsequent Paleo-Indian research. In 1997, with the encouragement of Myers, a comprehensive examination of the bison remains was initiated by Hill and completed several years later (Hill, 2001). This research led to renewed investigations at the site in 2001–2004, initiated in order to address several questions that could not be resolved with the extant information.

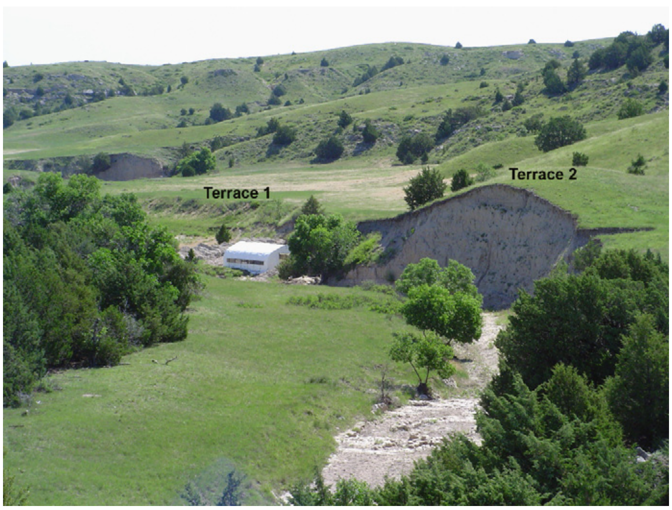

Fig. 2. View looking downstream (~east) of the Clary Ranch site area. The excavation cover is positioned over a portion of the 2004 excavation area.

Field work in 2001 and 2002 was exploratory in nature, involving topographic mapping, and the relocation of the 1979–1982 excavation blocks, combined with a program of paleoecological sampling undertaken in order to determine if intact archeological deposits remained at the site, as well as evaluating whether sediments in Ash Hollow preserved proxy indicators of the Early Holocene environment. Since the answer to this two-fold question was a resounding yes, in 2003 and 2004 a renewed, large-scale interdisciplinary project was carried out. Considerable effort has been directed toward detailing the 1979–1982 large-scale excavation blocks, analyzing the extant lithic collection, and compiling this information, together with new data from the 2003 and 2004 small-scale, high resolution excavations. A final report on this research is currently nearing completion. Several of these results are noteworthy as they relate to our understanding of the site generally and to the interpretative context of the Late Paleo-Indian bison carcass exploitation activities conducted here.

On average, the University of Nebraska State Museum crews excavated approximately 50 1×1 m units each summer, completing a near-contiguous block of $\sim 193\,m^2$ by the end of the 1982 field season. The four seasons of excavation resulted in the recovery of a large faunal assemblage, consisting almost exclusively of the fragmentary, scattered, and disarticulated remains of 41 bison, distributed relatively evenly across the excavated area (Fig. 3). As revealed through an eruption–wear analysis of the dentitions, season of death information consistently indicates that the bison were killed at $y+0.3-0.5$ dental age years old.

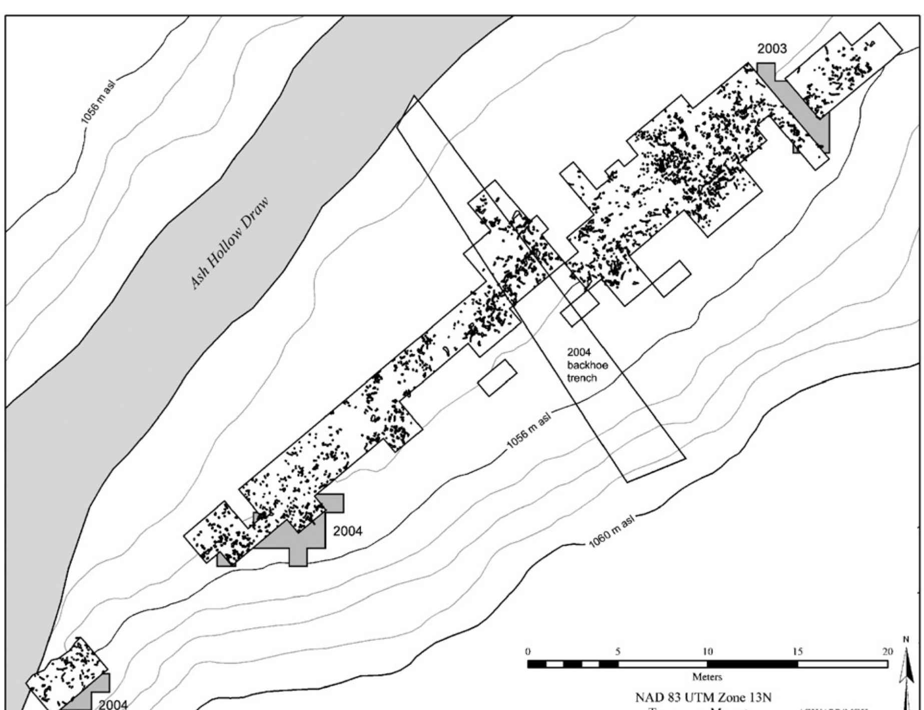

Fig. 3. Plan map of the Clary Ranch site showing the distribution of bison remains excavated by the University of Nebraska State Museum (1979–1982), and the location of the 2003 and 2004 excavations by Iowa State University.

Evidence for multiple, closely spaced mortality events is not detectable. The accumulation of bison remains represents a single kill/butchery event occurring in the late summer to early fall, roughly 4–6 months after the peak calving period. The significance of this assemblage is discussed in greater detail below. The associated lithic assemblage includes 12 Allen/Frederick projectile points in various states of completeness, approximately 75 other formal and informal tools, and some ten thousand pieces of microdebitage. Ten large rocks employed as hammerstones/anvils were also recovered.

Most of the Clary Ranch site chipped stone artifacts are made from Smoky Hill silicified chalk, which is also commonly referred to as Republican River jasper, Niobrara jasper, and Smoky Hill jasper, among other names. This toolstone is found well to the south and east of the site in outcrops along tributaries of the Kansas River in north-central Kansas and extreme south-central Nebraska (Stein, 2005). Holen (2001, p. 92) reports that a new source location was recently discovered in the Loup River Valley of east-central Nebraska. In addition to a handful of specimens made from quartzite river cobbles and permineralized ("fossil") wood, both available locally, several artifacts are made from Hartville Uplift chert and White River group silicates. Of special significance here is the fact that the former outcrops in the Hartville Uplift of southeast Wyoming (Miller, 1991), while the latter outcrops in several locations (Hoard et al., 1993; Koch and Miller, 1996), the best known of which is Flattop Butte in northeastern Colorado. Other reported sources of this toolstone are Table Mountain in extreme eastern Wyoming and in the White River Badlands of southwestern South Dakota. The presence of Hartville Uplift chert leads us to infer that the White River group silicate specimens from the Clary Ranch site are derived from Table Mountain, located along the North Platte River, some 200 km upstream from the site.

The accumulated corpus of evidence indicates that Clary Ranch is a secondary processing area, situated near a multianimal procurement locality. Complete or near-complete limbs removed from carcasses were transported from a nearby kill site; the long bones were then disjointed, processed for marrow, and discarded on site. Other inferred activities include the drying of meat stripped from postcranial axial elements, scapulae, and proximal long bones. The late summer–early fall season of occupation suggests that these activities were carried out in an attempt to ensure subsistence security during impending seasonal food-resource bottlenecks.

4. The O.V. Clary site

4.1. Archeology

The O.V. Clary site, discovered fortuitously on June 9, 2004, is situated along a straight, east–west trending section of Ash Hollow Draw, a short distance from a point bar

Fig. 4. View looking upstream (~southwest) of the O.V. Clary site area. The excavation cover is positioned over the 2005 and 2006 excavation area, and the backhoe trench is visible immediately west (right) of the excavation cover. The cut terraces truncate Early Holocene alluvium in the valley.

where the draw turns abruptly east (Figs. 1 and 4). An ongoing excavation program has identified a minimum of three stratified Late Paleo-Indian components (1–3), only one of which is discussed in this paper. Congruent artifactual, faunal, and site structural evidence from Component 2 indicates the presence of a residential base camp situated on the rapidly aggrading, Early Holocene floor of Ash Hollow Draw. On-site activities were organized around a shallow, basin-shaped hearth. Material culture recovered around this feature includes a spectacular variety of organic and non-organic remains (Fig. 5). The sample of organic artifacts includes 15 bird bone beads (or fragments thereof), 2 bone needles, 1 bone awl, and 1 antler billet.

The chipped stone assemblage ($n = 9914$) consists almost exclusively of microdebitage derived from resharpening working edges of unifacial tools, including use-spalls detached from the edges of these tools during contact with hard materials. Most of the tools ($n = 39$) are scrapers ($n = 11$) and utilized flakes ($n = 7$). Most bifaces are represented by tip, base, and edge fragments from finished weapon tips that are thought to have been introduced to the site in transported meat packages. Four anvils, 2 hammerstones, 1 shaft abrader, and 4429 small nodules of red ochre have also been recovered.

Dental eruption/wear analysis of teeth in a bison calf mandible and a bison calf maxilla, as well as size comparisons of fetal bison remains, indicates that this material was deposited over the course of a single, continuous occupation that stretched from mid-/late summer to very late winter/early spring. A mid- to late summer occupation is inferred from a partially carbonized calf mandible; the first molar is nearly fully erupted and unworn, and compares very favorably to that recorded for the youngest calves at the Clary Ranch site, which have

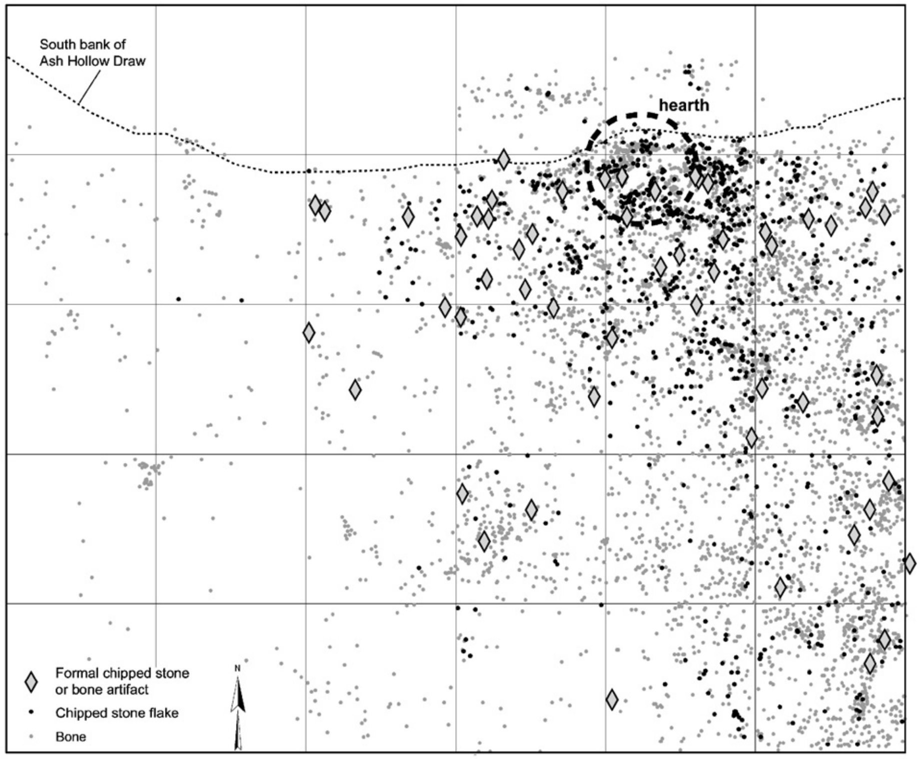

Fig. 5. Plan map of the O.V. Clary site showing the distribution of piece-plotted items from the 2005 and 2006 excavations by Iowa State University.

been assigned a dental age of 0.3–0.4 yr (Hill, 2001). A very late winter/spring occupation is indicated by a calf maxilla with dP^3-M^1. Although the teeth are damaged, the first molar is fully erupted and displays light to moderate wear on facets I–VIII. Occlusal wear is slightly more advanced than that recorded for the teeth in the calf crania recovered from the Folsom component at the Agate Basin site, which has been assigned a dental age of 0.9 yr (Frison, 1982; Hill, 2001). Based on these observations, this calf is 0.9–1.0 dental age years old, and was killed just prior to or during the spring birth pulse in late April/early May, the period when most pregnant cows would have dropped their calves.

Pinpointing the season of occupation from the fetal bison remains is complicated by differential estrous times (Berger and Cunningham, 1994, pp. 177–178), variable utero growth rates (Wilson, 1974, pp. 146–147), and the paucity of modern fetal material for the early stages of development (McKee, 1988). That said, three (MNI = 3) very small fetal scapulae of slightly varying sizes are of particular interest (Fig. 6). Based on metric and morphological comparisons with comparative specimens from the University of Wyoming Anthropology Department Osteology Collection, and a general size comparison with a sample of recent bison fetuses (Pac and Frey, 1991, Appendix I), a series of mid-winter (January–February) mortalities are inferred for these specimens. The preservation of fetal remains in open-air deposits of this age is exceedingly rare.

Fig. 6. Fetal bison scapulae from the O.V. Clary site.

In contrast to the situation downstream at the Clary Ranch site, the chipped stone artifacts at the O.V. Clary site are made almost exclusively from White River group silicates. Fifty-two specimens, all unmodified flakes, are made from Smoky Hill silicified chalk. Twelve specimens, including one end-scraper, are made from Hartville Uplift chert. The remainder of the assemblage consists of specimens made from permineralized ("fossil") wood and quartzite, both of which are locally available.

As detailed below, subsistence activities here revolved around the encounter hunting of bison. Segments of at least six bison were transported to the hearth area for further processing and subsequent consumption. Remains of raven, great horned owl, indeterminate small and medium passerines, and one box turtle are also represented.

5. Geoarcheological context and site settings

Each of the four Early Holocene archeological sites (two confirmed and two suspected) identified, to date, by this project occur within the lower portion of a 16 to 17 m thick Early to Middle Holocene fill sequence in the Ash Hollow Valley. The fill surface is Terrace 2 (also referred to as the Kersey Terrace) (Myers et al., 1981; Tanner, 1982). A total of five lithostratigraphic units (identified from oldest [II] to youngest [VI]) have been identified in the lower several meters of the Terrace-2 fill. These units are visible along a 2 km reach of the valley extending from downstream of the Clary Ranch site to upstream of O.V. Clary site (see Fig. 1). Unit II is a massive, generally brown silt loam containing up to 10% locally derived, subangular carbonate clasts. A buried soil (Brady Soil) is developed on the surface of this unit. Unit III is a coarse channel fill identified at the Clary Ranch site and in a downstream tributary valley. Unit IV, a horizontally-laminated dark grayish brown silt loam containing up to 5% subangular carbonate clasts, overlies Unit II and the buried soil. Unit V is a ripple- and horizontally-laminated brown coarse silt or very fine sandy silt, alternating with dark brown or very dark grayish brown silt loam. This unit contains the Late Paleo-Indian cultural components at both the Clary Ranch and O.V. Clary sites. Unit VI is generally more massive and coarser textured than Unit V and has only been recognized in two high cut banks. A series of nearly 40 AMS radiocarbon ages provide a chronology for the various lithostratigraphic units: Unit II, 10,230–9500 BP; Unit IV, 9500–9150 BP; Unit V, 9150–8750 BP; and Unit VI, $<$8750 BP.

5.1. Clary Ranch site

The Clary Ranch site is buried beneath eroded remnants of Terrace 2 ($\sim$14 m high) and Terrace 1 ($\sim$7.5 m high) (Fig. 2). Only the area beneath Terrace 1, where it has been eroded to a height of less than 3 m by Late Holocene erosion, has been investigated. Approximately, 2 m of Terrace-1 alluvium overlying the excavation area was stripped with a bulldozer prior to the onset of the field work in 1979 to expose the truncated, Early Holocene alluvium in which the cultural material is found. The potential extent of these artifact-bearing alluvial deposits southwest of the excavated area (and beneath the Terrace-2 remnant) remains unknown. However, the 14 m-high cut bank west–southwest of the excavation area affords a limited cross-section of the relevant strata.

Artifacts of Late Paleo-Indian Age associated with fragmentary bison remains are present within a shallow oxbow lake/channel scar formed within the active meander belt over channel sand and gravel. At the time of site occupation, the Ash Hollow Channel was northwest of the oxbow lake/channel scar. In the immediate site area the oxbow lake/channel scar displays a southwest–northeast orientation, differing slightly from the south–southwest to north–northeast directional trend of the modern channel (Fig. 3). A distinctive, organic-rich stratum located near the base of this paleochannel fill, dating to 9100 BP, offers an important stratigraphic marker here since the archaeological material lies within and just below this organic-rich stratum. Although the paleochannel reaches a maximum depth of $\sim$50 cm below the surrounding Early Holocene floodplain, very little of the former floodplain surface has been preserved due to Late Holocene erosion.

The sediments filling the oxbow lake/channel scar at the site (Unit V), as revealed in the backhoe trench (Fig. 3), indicate that moist conditions persisted here, probably continuously. The lower 20 cm of the sediments are gleyed. Furthermore, the clay in the oxbow lake/channel scar shows no evidence of dry cracks. Soft sediment deformation is also common, especially in the lower portion of the oxbow lake/channel scar fill, and at the northeastern end of the site.

Archeological materials have been recovered from the oxbow lake/channel scar fill (Unit V). The lower boundaries of the laminae in this fill are abrupt (non-bioturbated), indicating both rapid aggradation and rapid burial of the cultural deposits. Two laminae within the horizontally-laminated fill probably represent an individual flood event. Radiocarbon ages clearly indicate that almost 4 m of alluvium were deposited between 9150 and 8750 BP, although radiocarbon ages cannot resolve the sedimentation rate within the oxbow lake/channel scar.

5.2. O.V. Clary site

This site is located beneath two, Late Holocene terraces cut on Terrace-2 fill. The higher cut terrace is slightly more than 3 m above the Late Paleo-Indian component. A series of well-defined laminae, traceable across the entire site area, indicate that the cultural deposits are probably situated within the then-active aggrading meander belt of the floodplain. In contrast to the situation downstream at the Clary Ranch site, there is no evidence here of discrete channel banks or other evidence of valley-bottom morphology. Each of the three Early Holocene archeological components identified to date at the O.V. Clary site are inferred to have been deposited on a nearly level aggrading meander belt of the floodplain, with the entire site area subjected to multiple episodes of low-magnitude flooding.

The site preserves a remarkably high-resolution flood history within Unit V. Up to 30 individual laminae, ranging in thickness from 1.4 to 9.6 cm, have been identified across the entire excavation area, as well as upstream in the backhoe trench and downstream in the cut bank. In areas with little or no evidence of Late Paleo-Indian activities, the laminae are nearly horizontal and undisturbed, with abrupt lower boundaries. In areas displaying dense concentrations of cultural material, the laminae are contorted and difficult to identify. In the backhoe trench west of the excavation area the laminae become indistinct to the south; only a few, thicker, massive strata with diffuse lower boundaries are evident here.

Archeological materials are encased within the predominantly silty lower portion of Unit V. As at the Clary Ranch site, rapid deposition of silt laminae sealed the occupation surfaces of the three components almost immediately after abandonment, thereby preserving a high-integrity record of Late Paleo-Indian activities. The presence of paired laminae throughout all of the components appears to represent deposition during a series of low-magnitude floods.

This research indicates clearly that in comparison to today, local relief in this portion of the Ash Hollow Valley was significantly greater at the time of Late Paleo-Indian occupation. Although the valley was as deeply incised as at present, relief would have been significantly increased due to the presence of thick, Late-Pleistocene loess deposits mantling the bedrock along the valley margins. Given the constricted nature of the valley floor at the site, combined with the steeply inclined valley margins, the site would have been fairly well sheltered. In addition, active springs were almost certainly present in the first major tributary valley southwest (upstream) of the site, as well as in the Ash Hollow Formation outcrops scattered along the north side of the valley.

6. Archeological affiliation, age, and inter-site contemporaneity

Both the Clary Ranch and O.V. Clary sites are assigned to the Allen/Frederick Complex based on the presence of lanceolate projectile points displaying concave bases, parallel–oblique flaking, and beveled resharpening of blade edges (Hofman, 1989; Hofman and Graham, 1998). Points as well as point fragments from each of these sites variably display these defining characteristics. Although such points are commonly recovered from surface contexts as isolated finds (LaBelle, 2005), only rarely have they been excavated from secure stratigraphic contexts, at high-integrity sites with good faunal and floral preservation (Hill, 2005). Taken together then, the Clary Ranch and O.V. Clary sites hold enormous interpretive potential, offering multiple lines of evidence concerning the behaviors of their Early Holocene hunter/gatherer occupants.

Until recently, few reliable radiocarbon age estimates were available for the Allen/Frederick Complex. Historically, most researchers have followed the lead of Irwin-Williams et al. (1973, pp. 51–52) in suggesting the temporal placement of the complex at 8400–8000 BP (e.g., Frison, 1978, p. 34; Frison, 1991a, p. 66). More recently, Hofman and Graham (1998, p. 113) have pushed this back to 9000–8500 BP, while Holliday (2000, p. 270) has expanded the range to 9400–7800 BP. This frustrating situation improved recently with the publication of several precise radiocarbon assays placing the complex at 9100–8800 BP (Hill, 2005). Collagen extracted from bison bone collected from the Norton and Winger sites produced radiocarbon ages of 9080 ± 60 BP (CAMS-16032) (Hofman et al., 1995, p. 20) and 9080 ± 90 BP (ISGS-4934) (Mandel and Hofman, 2003, p. 63), respectively. Slightly younger ages of 8830 ± 130 and 8910 ± 130 BP on "charcoal with some burned bone fragments" from a hearth in Zone 88 at Red Smoke have also been reported (Knudson, 2002, Table 7.2). Turning to the sites under consideration here, collagen extracted from a butchered bison femur shaft fragment from the Clary Ranch site produced an age of 9040 ± 35 BP (CAMS-105849) (Hill, 2005, p. 252). Several dates are available for Component 2 at the O.V. Clary site, including one on wood charcoal collected from hearth fill (8993 ± 54 BP, AA65425). Two other assays, also on wood charcoal, produced radiocarbon ages of 9076 ± 62 BP (AA65421) and 9043 ± 52 BP (AA65422).

Thus, not only are both Clary Ranch sites affiliated to the Allen/Frederick Complex, they are also penecontemporary. To the best of our knowledge, a similar situation—characterized by overlapping dates, spatial proximity, contextual integrity, and functional dissimilarity—has not been reported previously for this general time period on the Great Plains. As such, these sites provide a unique opportunity to investigate variability in Late Paleo-Indian faunal exploitation within a single valley over a limited period of time.

7. Inter-site patterns of Late Paleo-Indian faunal exploitation

7.1. The Clary Ranch site

The bison assemblage from the Clary Ranch site consists of 1966 (NISP) specimens, 1666 of which are identified to skeletal element, representing no fewer than 41 bison.[2] With the exception of small compact elements such as carpals, tarsals, and phalanges, most identified remains are fragmentary specimens. Unbroken long bones are few in number, and 247 indeterminate long bone shaft fragments account for a majority of the 300 specimens not identified to element. Most remains are disarticulated and scattered, the most obvious exception being a series of 14 distal radius–carpal and 14 distal tibia–tarsal units recovered in articulation (Hill, 2005, p. 275). Cortical surface preservation on most specimens is excellent.

[2]In some instances, the counts reported here differ slightly from those reported previously (Hill 2001, 2005) due to the inclusion of a box of bison remains that was recently relocated.

Numerous cutmarks and other butchery damages are visible.

Two characteristics of the bison assemblage are especially informative with regard to Late Paleo-Indian diet and subsistence behavior. First, the predominance of appendicular elements, and, second, the presence of a remarkable record of cortical damage linked directly to carcass exploitation. Overall, the assemblage represents the most intensively, as well as the most extensively, processed sample of bison remains from this time period on the Great Plains. Complete or near-complete limbs removed from carcasses at a nearby mass kill site were transported here; the long bones were disjointed, breached for marrow extraction, and then discarded. Drying of meat stripped from postcranial axial elements, scapulae, and proximal long bones is strongly suspected as well. Each of these defining characteristics is discussed below.

7.2. Long bone breakage

Evidence indicates that complete limbs or articulated sublimb packages were hauled to the site for disarticulation, in order to facilitate systematic marrow extraction. Remarkably, 90% (145 out of 160) of all long bones were broken during the course of these activities. As exemplified by the sample of specimens in Fig. 7, breakage patterns are redundant, with remnants of percussion-generated fracture present on a number of specimens.

Patterns in hammerstone impact placement, cutmark location, and articulations indicate that long bones were initially disarticulated and then broken in order to extract their marrow. The only direct evidence for the processing of articulated long bones is provided by a distal radius–proximal metacarpal articulation and analogous hindlimb articulation. However, paired impact clusters on the medial aspects of the distal tibia and proximal metatarsal offer additional evidence for the processing of articulated distal hindlimbs. Cutmark and articulation data indicate that long bones were typically disjointed prior to breakage and processing. The fact that carpals and tarsals often remained in articulation was of little apparent concern. Employing volumetric data from modern bison elements (Emerson, 1990, Table 5.25), processing of 90% of this long bone assemblage equates to the acquisition of approximately 17 l (4.5 gallons) of marrow. Interestingly, although metapodials are underrepresented in the assemblage, the incidence of breakage for all long bones is remarkably similar (Hill, 2005, Table 4). This pattern indicates that, once transported, virtually all long bones were subjected to marrow processing, despite their relative nutritional ranking, an inference supported by the observation that long bone breakage is not correlated with medullary capacity ($r_s = 0.26$, $p = 0.31$). Overall, these data are strongly indicative of a procedure that Stiner (2003, p. 28) has termed ''cold'' marrow extraction.

Inspired by a lack of relevant information on breakage of bison long bones, two of us (Hill and Boehm) recently completed a comprehensive experiential project designed, in part, to shed light on the marrow extraction activities represented in this assemblage. Among the questions initially posed by this research: how much effort is required to break defleshed bison long bones using hammerstone-to-anvil technology (employing a 2.8 kg hammerstone and a 0.6 kg anvil). Although an in-depth discussion of this study is beyond the scope of this paper, one result deserves brief consideration here. This research indicates that, in general,

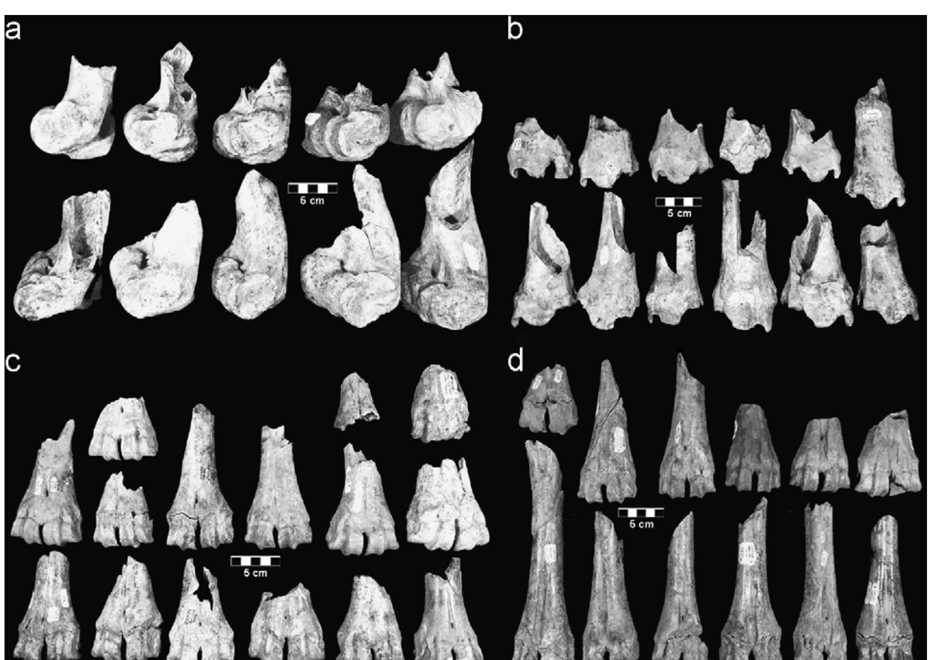

Fig. 7. Sample of spirally fractured bison long bones from the Clary Ranch site: (a) humeri; (b) metacarpals; (c) tibiae; and (d) metatarsals.

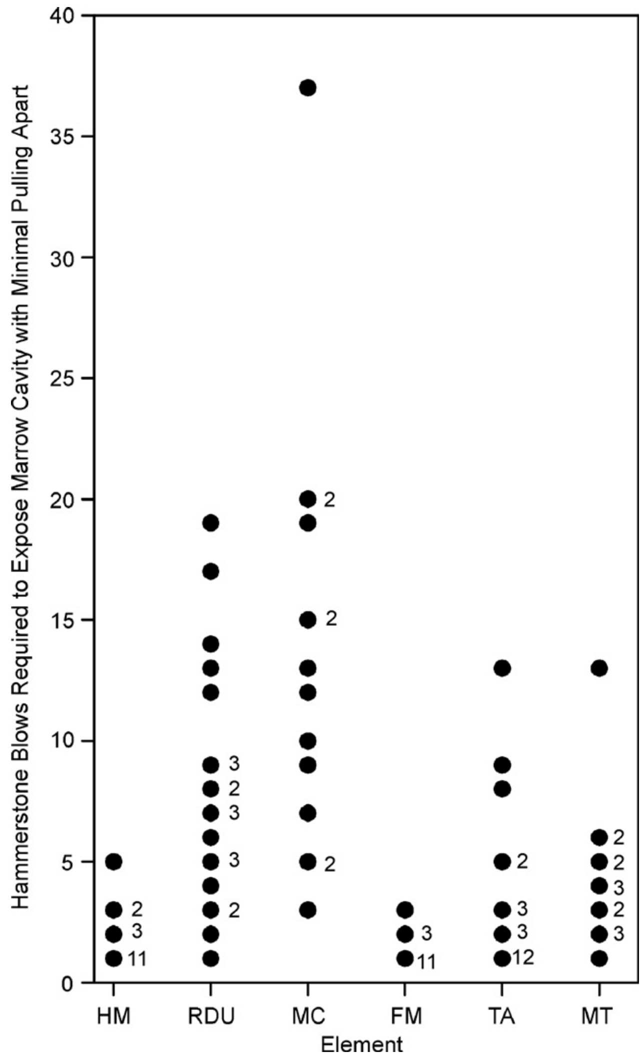

Fig. 8. Summary of the number of hammerstone blows required to breach bison long bones for marrow extraction. The number of occurrences with the same result are indicated to the right of some data points.

accessing the marrow cavity "with minimal pulling apart of fractured shafts" (Bunn, 1989, p. 303) is not as difficult as expected; in fact, it is relatively easy. In most instances, five or fewer hammerstone blows are required to breach the shafts of humeri, femora, and tibiae (Fig. 8). Accessing marrow contained within radii and metapodials is somewhat more difficult, usually requiring five or more blows. The breaking of metacarpals, however, requires considerably more work.

The significance of these experimental observations is two-fold. Marrow extraction requires that an element be defleshed and then (usually) disarticulated (see Todd et al., 1997, for an example of extracting marrow from articulated bison limbs). Using data provided by Lupo (1998), defleshing Class 3 femora and humeri, for example, requires, on average, 12 and 11 min, respectively, while the disarticulation of defleshed bison femur–tibia and humerus–radius joints requires, on average, 4.7 min ($n = 24$ events) and 2.3 min ($n = 20$ events), respectively

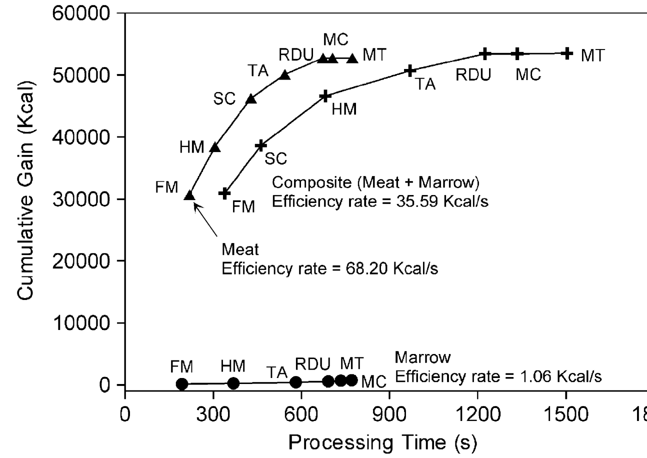

Fig. 9. Experimentally derived return rates for different exploitation strategies for bison long bones.

(Hill and Boehm, unpublished data). Accessing the marrow cavity usually requires only a few additional seconds, with the exception of radii and metapodials. While one might propose that extracting the fat-rich marrow from long bones would significantly increase return rates (see Kelly, 1995, p. 80), thereby easily recouping the costs incurred during defleshing and disarticulation, this is, in fact, not the case.

Fig. 9 summarizes return rate information for different exploitation strategies for bison limbs using meat and marrow yields for bison (Emerson, 1990), and defleshing, disarticulation, and marrow extractions times for zebra (Lupo, 2006, Table II).[3] These data indicate clearly that efficiency rates *decrease* as carcass exploitation is intensified (taken beyond defleshing) via cold marrow extraction (note that efficiency is defined here following Kelly (1995, p. 73) as k/cal of energy derived per unit time). As long bones are processed for marrow (following defleshing and disarticulation), efficiency drops considerably (by ~30%). All else being equal then, the most cost effective strategy, based on these data, would entail defleshing of only the upper limbs. Thus, in purely energetic terms, the acquisition of marrow is a relatively inefficient undertaking, given that the breaching of long bone shafts requires element defleshing and disarticulation. Although it is possible that the processing of defleshed, but still articulated long bones would alleviate some of these costs, we suspect that articulated bison limbs pose far too large and unwieldy a resource target for such a strategy to pose a viable alternative, at least in situations where obtaining a large quantity of marrow is desired.

Based on these facts, the decision by Late Paleo-Indian site occupants to "unlock" this food resource appears

[3]Egeland and Byerly (2005) provide defleshing times for Class 4 animals; however, to maintain better control over experimental variables (i.e., methods, taxa, and butcher experience), Lupo's (2006, Table II) defleshing, dismemberment, and marrow extraction times for zebra (Class 3) are used here, in conjunction with bison meat and marrow yields (Emerson, 1990).

somewhat unexpected (Church and Lyman, 2003), especially given the intensive nature of the evidence observed at the Clary Ranch site, which clearly cannot be subsumed under the rubric of "snacking" at a kill/butchery site or around a hearth. In this particular case, it appears that time constraints in the late summer–early fall were comparatively relaxed, thus mitigating the initial "opportunity cost" (Kelly, 1995, p. 83) of intensively and extensively exploiting carcasses for meat and marrow. Support for this interpretation is provided by the fact that 38 of the 44 (86%) metapodials were processed for marrow (Fig. 7). As hide-covered bone cylinders containing only small medullary reservoirs, metapodials are relatively poor sources of nutrition, an observation that is exacerbated by the additional effort required to break them (Fig. 8). However, in this case, the specific, situational benefits of undertaking large-scale, systematic cold marrow extraction during the late summer/early fall would have emerged months later, during the inferred period of critical nutritional stress (winter and spring), as a function either of mobility restrictions or non-availability of alternative food resources.

7.3. Underrepresentation of axial elements

The second major element frequency pattern observed here involves the underrepresentation of those parts high in meat utility, but low in marrow utility, that is, scapulae, vertebrae, and ribs. The overall character of carcass exploitation, combined with other evidence (Fig. 10), indicates that these elements were selected for drying (probably at a nearby location). Support for this assertion is provided in Fig. 11, which presents ratio MAU values for scapulae, long bones, and the four major axial subgroups, plotted against Friesen's (2001, p. 329) "dryability" index for each element, employing bison carcass data supplied by Emerson (1990, Tables 5.16, 5.26, and 6.2). The underrepresented elements here are the best suited for drying since they do not (in general) contain marrow and are characterized by thin, evenly distributed muscle masses.

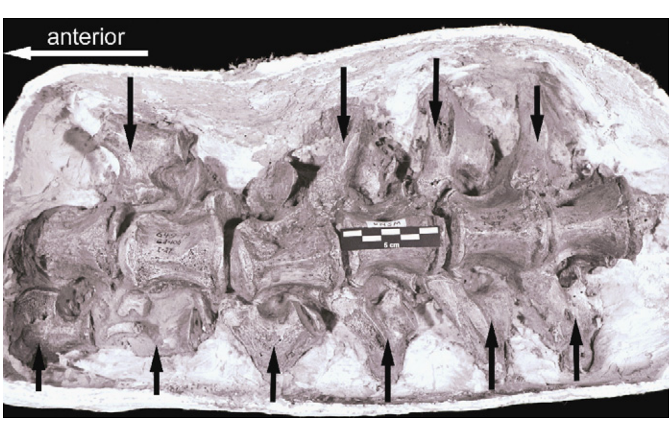

Fig. 10. Midregion bison thoracic vertebrae–rib articulation (ventral view) from the Clary Ranch site. The ribs are spirally fractured proximal portions (arrows).

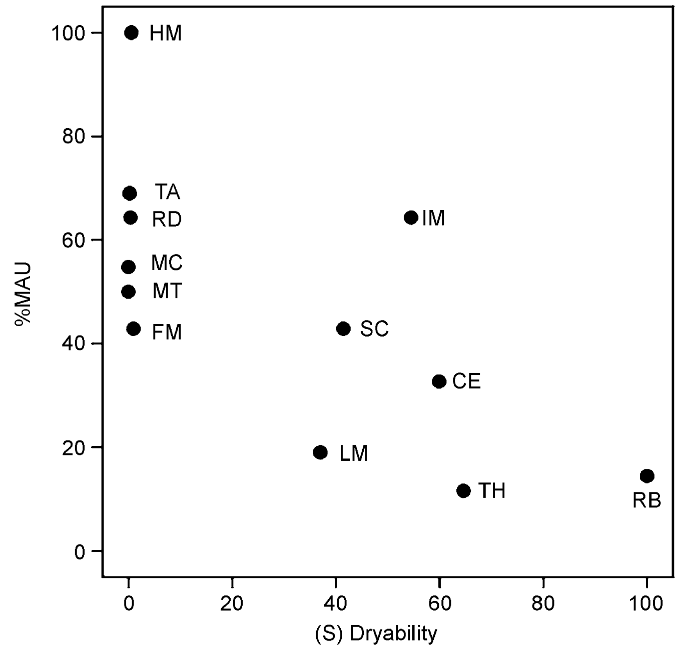

Fig. 11. Plot of ratio %MAU values for selected elements in the Clary Ranch site bison assemblage against (*S*) "dryability" for the element.

Meat weights tend to be low and bone weights high, resulting in large surface areas ideal for drying. Innominates are an outlier, although the highest MNE for this element is based on acetabula. Butchery modifications indicate that a combination of leveraging, bashing, and cutting was used on these elements in order to separate hindlimbs from carcasses, reflecting the transport of acetabula as riders along with (proximal) femora.

In summary, the overabundance of long bones combined with the underrepresentation of meaty postcranial axial elements at the Clary Ranch site supports the interpretation of differential transport by Paleo-Indians. The former were hauled to the excavated area for marrow extraction, while the latter were taken elsewhere for drying. It is inferred that these subsistence activities were stimulated by anticipated food-resource shortages.

7.4. The O.V. Clary site

An unusually diverse and exceptionally well-preserved sample of faunal remains has been recovered from Component 2 of the O.V. Clary site over the course of our on-going program of research and excavation.[4] Although bison remains comprise the bulk of the specimens identified with species, the other remains are by no means insignificant. The non-bison fauna includes several birds, one coyote, one box turtle, and several microfauna. With the exception of the microfauna, interpreted as natural background fauna, the remains of the other taxa display evidence of Paleo-Indian butchery and/or were recovered around the hearth.

[4]Specimens recovered between 2004 and 2006 are summarized here.

7.5. Bison remains

Approximately, one-third of the faunal specimens recovered, to date, from Component 2 are bison (NISP = 245) and probable bison (NISP = 986) remains. Three thousand (NISP = 3017) small, completely unidentifiable mammal bone fragments are also probable bison remains. Twenty (NISP) fetal bison remains have also been recovered. Considered together, these remains offer a variety of insights on Late Paleo-Indian bison hunting, carcass transport, and provisioning behavior, as well as secondary exploitation of portions transported to the residential camp.

No fewer than six bison are discernable in Component 2. Osteometric evaluation of four proximal radii reveals the presence of two bulls and two cows (Fig. 12), and tooth eruption/wear indicates the presence of two calves. One calf is 0.3–0.4 dental age years old, while the other is 0.9–1.0 dental age years old. The age/sex mix, consisting of two bulls, two cows, and two calves of markedly differing ages, suggests that hunters were not preferentially targeting animals of a particular age or sex, while also indicating that the animals were procured singly during encounter-type hunting, and not derived from a multianimal kill. This inference is consistent with an extended period of residential occupation during which hunters provisioned consumers on a regular basis with fresh food packages.

Although the sample of identified bison remains is not large, two important pieces of evidence support the interpretation that hunters provisioned consumers with carcass segments cut from animals killed singly during logistical forays in the general vicinity of the site, either within Ash Hollow or on the uplands immediately surrounding the valley. First is the presence of two crania, one belonging to a calf and the other to an adult animal. The head of a modern bison bull is not an exceptionally heavy burden, weighing ~28 kg (Dickinson, 1976, p. 2); however, its overall large size and awkward shape would seemingly render it a cumbersome load for long distance transport, an inference consistent with transport decisions by modern hunter/gatherers. For example, in a sample of 22 kill/butchery events involving (generally) bison-sized animals (i.e., eland, Cape buffalo, wildebeest, zebra), the head was taken from the kill location in only half of the cases ($n = 13$) (Monahan, 1998, Table 2). Second, the pattern of skeletal part representation reveals that long bones far outnumber vertebrae and ribs, offering further evidence for the preferential transport of limbs. The presence of scapulae, metapodials, carpals, and tarsals further suggests that the transported packages often consisted of complete, or nearly complete, articulated limbs. As Bunn (1993, pp. 161–163) notes, "an articulated limb is, without any modification, an especially convenient package for transporting over the shoulder…[and] a Hadza man has no noticeable problem carrying even the larger hindquarter of a [Cape] buffalo (35–40 kg) for a distance of 5 km" (see also Bunn et al., 1988, pp. 428–429).

At the O.V. Clary site, transported carcass segments were defleshed, disarticulated, and then processed for marrow. All 14 (MNE) of the long bones display fracture angles and outlines consistent with breakage of fresh, nutritive bone. No complete, unbroken long bones exist in the assemblage. However, in contrast to the Clary Ranch site, where the objective was to quickly and systematically amass a large quantity of marrow as part of a future-oriented subsistence strategy, marrow processing at O.V. Clary is best characterized as a hearth-centered, down-time subsistence activity occurring throughout the duration of the occupation. This inference is bolstered by the fact that extremely marginal sources of marrow were extracted, including first six phalanges, as well as several rib blades.

Interestingly, only 14 long bone articular ends are present, which is half the number expected if each of the complete long bones represented by these portions was, in fact, introduced to the site and then broken into proximal

Fig. 12. Bison radii from the O.V. Clary site.

and distal halves for marrow extraction. Given the outstanding physical condition of the bison remains and the absence of indications of carnivore scavenging, the comparatively small number of articular ends is best explained as a function of site maintenance activities. In this scenario, the long bone articular ends and the two crania (one calf, one adult) were transported to the site and processed relatively late in the occupation, shortly before site abandonment. Articular ends from earlier transport and processing events were discarded elsewhere (outside the current excavation area) in order to facilitate continued use of the space, leaving behind only the associated mid-shaft fragments. The apparent overabundance of small, compact elements (e.g., dew claws and sesamoids), plus thousands of very small bone fragments, would thus represent primary refuse (Schiffer, 1987, p. 18) that escaped cleanup activities due to their small size.

All of the fetal bison remains (NISP = 20) were recovered around the hearth. At least three fetuses, represented by the scapulae in Fig. 6, were harvested from pregnant cows. Since bison rarely give birth to twins (Berger and Cunningham, 1994, p. 114), the specimens provide indirect evidence for the deaths of three individual cows, one more than is represented in the extant sample of bison remains. More important, however, is the hearth-centered recovery context of the fetal remains, suggesting that they were gathered here for a specific purpose(s). Their consumption, either as a delicacy or to alleviate problems associated with a diet high in lean meat (Malainey et al., 2001, p. 147), seems probable. In addition, the hides may have been used to manufacture bags and/or clothing for children (Speth, 1983, p. 2).

7.6. *Avifauna*

Though not large (NISP = 54, MNI = 4), the avifauna offers a fascinating glimpse into the role of birds in Late Paleo-Indian adaptations. It includes the proximal wing of a raven (*Corvus corax*) represented by a partially burned left proximal humerus, plus six distal wing elements belonging to a great horned owl (*Bubo virginianus*) (Fig. 13). The complete right radius–ulna of an indeterminate medium passerine, as well as the left distal ulna of an indeterminate small passerine, was also recovered from hearth fill. The remainder of the avifauna consists of 17 long bone shaft fragments and two flat bone fragments belonging to indeterminate medium to large birds. All of these long bone shaft fragments display spiral fractures, and two are also partially burned. It seems probable that these specimens are either great horned owl or raven remains (or a bird of this general size class).

To our knowledge, no other Paleo-Indian site has produced such a diverse avifauna, and the fact that the remains were recovered in secure cultural context makes them all the more significant. The only other site of this general age to produce raven remains is Charlie Lake Cave in British Columbia (Driver, 1999). Jones (1999, p. 43) reports a distal metatarsus from a great horned owl in Zone 1 at the Lime Creek site in southwestern Nebraska. Unfortunately, the precise recovery context of the specimen is unknown. In addition, it lacks signs of cultural modification and displays a dry-bone fracture, all of which render its relationship to the Late Paleo-Indian occupation at the site unclear. Thus, O.V. Clary is the first Paleo-Indian site to produce great horned owl remains from a secure cultural context, as well as the first to document the co-occurrence of great horned owl and raven.

Ethnographic accounts indicate that these ravens and owls held (and continue to hold) very special significance for native Americans. In his comprehensive ethnographic review, Driver (1999, Table 1) notes that ravens reportedly assist hunters in locating and procuring prey as well as in finding lost or missing people. They also scavenge traps, old kills, and human corpses on the battlefield, and communicate with people about such things as bad weather, impending disasters, and vision quests. Similar cross-cultural information is yet to be assembled for the great horned owl, although the literature is rich in statements along these lines. Among the Pomo, for example, the great horned owls "were considered to be doctors and to have the power to effect cures" (Barrett, 1952, p. 358). Likewise, the great horned owl is a central

Fig. 13. (a) Raven and (b) great horned owl remains from the O.V. Clary site. Modern comparative specimens are positioned next to the archeological specimens for reference.

figure in Ojibwa and Navajo folklore and ceremonialism (Jenness, 1935; Kluckhohn et al., 1971). Based on the data reported here, it appears that Late Paleo-Indians may have held these birds in high regard as well.

7.7. Herptefauna

One turtle is represented among 53 burned and unburned carapace pieces. Although the specimens are too fragmentary for definite taxonomic identification, they almost certainly belong to the Ornate box turtle (*Terrapene ornata*), a small, high-domed terrestrial turtle found today throughout the central and southern Great Plains in prairie-type settings (Ernst et al., 1994). This taxonomic assessment is bolstered by the fact that at least two Ornate box turtles have been securely identified at the Clary Ranch site; one individual recovered in 1979 by the UNSM crew, the second recovered during the 2003 excavations. Although none of the box turtle remains from the Clary Ranch site are burned, several carapace fragments display scrapes and cutmarks on the ventral aspect that are similar to those recorded on specimens from the O.V. Clary site. Interestingly, only carapace fragments are represented at both sites, and none of the specimens display damage from hammerstone blows directed toward extracting the meaty core (sensu lato Stiner and Tchernov, 1998, Fig. 6). As well, at the Clary Ranch site, the centrums and transverse spines on several neurals were intentionally removed by scraping, cutting, and carving. These observations are consistent with the inference that Late Paleo-Indians exploited box turtles primarily for their carapaces, perhaps treating them as curated, container-like tools.

8. Summary and conclusions

Expanding and refining our understanding of the range of variability within Paleo-Indian settlement and subsistence systems on the Great Plains requires not only a clearer picture of regional environmental conditions and their associated resource structures, but also, and perhaps most significantly, an increased appreciation for how these and related variables interact on seasonal, decadal, and longer term bases (Hofman and Todd, 2001; LaBelle, 2005). Investigation of high-integrity, high-resolution deposits situated within alluvial basins such as Ash Hollow can provide the sorts of paleoecological and archeological information required to realistically address these multifaceted and complex issues. In this light, the on-going research on the Clary Ranch provides the basis for several new insights on poorly documented aspects of Late Paleo-Indian behavior—as observed from the monitoring perspectives of a secondary processing area for bison carcasses (Clary Ranch site) and an extended residential occupation (O.V. Clary site). These include:

1. The Clary Ranch sites are strategically located for easy access to a suite of (non-toolstone) resources critical to survival on the central Great Plains. Ash Hollow was used intensively by both bison and Late Paleo-Indians as a natural corridor between the North Platte River and the surrounding uplands. Water would have been available from seeps and springs located in the numerous side drainages along the draw, many of which are inferred to have been lined with trees and brush providing hearth fuel, as well as wood for tools and other uses.
2. Bison were the focal prey species throughout the year. They were procured en masse, as well as singly, during encounter-type hunting. Food storage is highly probable, and may have been one of the "pulls" of Ash Hollow during certain seasons. Other (non-bison) large/small mammal prey were likely taken when encountered, although these animals appear to have played a minor role in the diet. Box turtle, raven, and great horned owl may have been sought primarily for reasons other than consumption. Although edible plants were undoubtedly gathered when available, significant storage of plant foods as a winter buffering strategy is rare among modern hunter/gatherers living in analogous environments (Binford, 1990), making it highly improbable that this food resource played a major role in the diet here.
3. White River group silicates and Smoky Hill silicified chalk are the predominant toolstones at the O.V. Clary and Clary Ranch sites, respectively. Trace amounts of Hartville Uplift chert occur at both sites. The source locations of these toolstones occur like "beads on a string" along the North Platte and Platte Rivers. The presence of Hartville chert leads to the inference that the White River group silicate specimens recovered here are derived from the Table Mountain quarries, as opposed to source locations in northeastern Colorado or southwestern South Dakota. This in turn implies that group residential movement among the Late Paleo-Indian occupants of Ash Hollow was structured primarily in terms of resource-rich riverine environments and their major tributaries (although other situationally favorable microhabitats, including playas, dune fields with interdunal ponds, springs, and foothill settings, were undoubtedly utilized). Significantly, such riverine settings have, to date, received limited archeological recognition on the central Great Plains, due in part to their enhanced potential for deep burial, and/or erosion and deflation.
4. Despite the recovery (to date) of a diverse assemblage of 39 chipped stone tools at the O.V. Clary site, the vast majority of which are made from non-local raw materials, there is virtually no evidence of tool or weaponry manufacture. This assemblage-level insight has important implications, not only for modeling the organization of Late Paleo-Indian lithic technology at residential sites, but, more generally, in terms of increasing our awareness of the comparatively low archeological visibility of such deposits in alluvial settings; in comparison, for example, to the more

commonly discussed quarry/camp localities (located either on or near major raw material source areas) (e.g., Allen; Bamforth, 2002; Hell Gap; Irwin-Williams et al., 1973; Lindenmeier; Wilmsen and Roberts, 1978), or to bison kill/butchery bonebeds (e.g., Mill Iron; Frison, 1996; Agate Basin; Frison and Stanford, 1982; Hill, 2001; Stewart's Cattle Guard; Jodry, 1999).

5. At the O.V. Clary site, a well-defined hearth-centered activity area is present, with evidence for a variety of tasks undertaken, including secondary butchery of transported bison carcass segments, tool resharpening, hide processing, and bone working. Site maintenance activities identified here, including hearth clean-out and discard of long bone articular ends, are consistent with the inference of an extended period of occupation. Evidence for repeated reoccupations, of this individual site, as well as the Ash Hollow Valley during this period, reinforces the behavioral "pull" of situationally favorable, resource-rich microhabitats (cf. Hofman, 1994) in structuring Late Paleo-Indian decisions involving residential site location on the central Great Plains during the Early Holocene.

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References

Bamforth, D.B., 2002. High-tech foragers? Folsom and later Paleoindian technology on the Great Plains. Journal of World Prehistory 16 (1), 55–98.

Barrett, S.A., 1952. Material aspects of Pomo culture. Bulletin of the Public Museum of the City of Milwaukee 20.

Bement, L.C., Buehler, K.J., 1997. Southern plains bison procurement and utilization from Paleoindian to Historic. Plains Anthropologist Memoir 29, Lincoln.

Berger, J., Cunningham, C., 1994. Bison: Mating and Conservation in Small Populations. Columbia University Press, New York.

Binford, L.R., 1990. Mobility, housing, and environment: a comparative study. Journal of Anthropological Research 46 (2), 119–154.

Broughton, J.M., 1994. Late Holocene resource intensification in the Sacramento Valley, California: the vertebrate evidence. Journal of Archaeological Science 21 (4), 501–514.

Bunn, H.T., 1989. Diagnosing Plio-Pleistocene hominid activity with bone fracture evidence. In: Bonnichsen, R., Sorg, M.H. (Eds.), Bone Modification. Center for the Study of the First Americans, Orono, pp. 299–315.

Bunn, H.T., 1993. Bone assemblages at base camps: a further consideration of carcass transport and bone destruction by the Hadza. In: Hudson, J. (Ed.), From Bones to Behavior: Ethnoarchaeological and Experimental Contributions to the Interpretation of Faunal Remains. Center for Archaeological Investigations. Occasional Paper No. 21, Southern Illinois University, Carbondale, pp. 156–168.

Bunn, H.T., Bartram Jr., L.E., Kroll, E.M., 1988. Variability in bone assemblage formation for Hadza hunting, scavenging, and carcass processing. Journal of Anthropological Archaeology 7, 412–457.

Burgett, G.R., 1990. The bones of the beast: resolving questions of faunal assemblage processes through actualistic research. Ph.D. Thesis, University of New Mexico.

Church, R.R., Lyman, R.L., 2003. Small fragments make small differences in efficiency when rendering grease from fractured artiodactyl bones by boiling. Journal of Archaeological Science 30 (8), 1077–1084.

Davis, L.B., Wilson, M.C., 1978. Bison procurement and utilization: a symposium. Plains Anthropologist Memoir 14, Lincoln.

Dickinson, C.E., 1976. Carcass characteristics of a bison steer (*Bison bison*). Technical Report No. 302, Natural Resource Ecology Laboratory, Colorado State University, Fort Collins.

Driver, J.C., 1999. Raven skeletons from Paleoindian contexts, Charlie Lake cave, British Columbia. American Antiquity 64 (2), 289–298.

Edwards, D.A., O'Connell, J.F., 1995. Broad spectrum diets in arid Australia. Antiquity 69 (265), 769–783.

Egeland, C.P., Byerly, R.M., 2005. Application of return rates to large-mammal butchery and transport among hunter–gatherers and its implications for Plio-Pleistocene hominid carcass foraging and site use. Journal of Taphonomy 3, 135–158.

Emerson, A.M., 1990. Archaeological implications of variability in the economic anatomy of *Bison bison*. Ph.D. Thesis, Washington State University.

Ernst, C.H., Barbour, R.W., Lovich, J.E., 1994. Turtles of the United States and Canada. Smithsonian Institution Press, Washington, DC.

Friesen, T.M., 2001. A zooarchaeological signature for meat storage: rethinking the drying utility index. American Antiquity 66 (2), 315–331.

Frison, G.C., 1978. Prehistoric Hunters of the High Plains. Academic Press, San Diego.

Frison, G.C., 1982. Bison dentition studies. In: Frison, G.C., Stanford, D.J. (Eds.), The Agate Basin Site: a Record of the Paleoindian Occupation of the Northwestern High Plains. Academic Press, New York, pp. 240–260.

Frison, G.C., 1991a. The archeological record for the northwestern plains and mountains. In: Frison, G.C. (Ed.), Prehistoric Hunters of the High Plains. Academic Press, San Diego, pp. 15–137.

Frison, G.C., 1991b. Prehistoric Hunters of the High Plains. Academic Press, San Diego.

Frison, G.C., 1996. The Mill Iron Site. University of New Mexico Press, Albuquerque.

Frison, G.C., Stanford, D.J., 1982. The Agate Basin Site: a Record of the Paleoindian Occupation of the Northwestern High Plains. Academic Press, New York.

Hill, M.G., 2001. Paleoindian diet and subsistence behavior on the northwestern Great Plains of North America. Ph.D. Thesis, University of Wisconsin.

Hill, M.G., 2005. Late Paleoindian (Allen/Frederick Complex) subsistence activities at the Clary Ranch site, Ash Hollow, Garden County, Nebraska. Plains Anthropologist 50 (195), 249–263.

Hoard, R.J., Bozell, J.R., Holen, S.R., Glascock, M.D., Neff, H., Elam, J.M., 1993. Source determinations of White River Group silicates from two archaeological sites in the Great Plains. American Antiquity 58 (4), 698–710.

Hofman, J.L., 1989. Prehistoric culture history: hunters and gatherers in the southern Great Plains. In: Hofman, J.L., Brooks, R.L., Owsley, D.W., Jantz, R.L., Marks, M.K., Manhein, M.H. (Eds.), From Clovis to Comanchero: Archeological Overview of the Southern Great Plains. Arkansas Archeological Survey Research Series, vol. 35. Fayetteville, pp. 25–60.

Hofman, J.L., 1994. Paleoindian aggregations on the Great Plains. Journal of Anthropological Archaeology 13 (4), 341–370.

Hofman, J.L., Graham, R.W., 1998. The Paleo-Indian cultures of the Great Plains. In: Wood, W.R. (Ed.), Archaeology of the Great Plains. University of Kansas Press, Lawrence, pp. 87–139.

Hofman, J.L., Todd, L.C., 2001. Tyranny in the archaeological record of specialized hunters. In: Gerlach, S.C., Murray, M.S. (Eds.), People and Wildlife in Northern North America: Essays in honor of R. Dale Guthrie. BAR International Series, vol. 944. Oxford, pp. 200–215.

Hofman, J.L., Hill Jr., M.E., Johnson, W.C., Sather, D.T., 1995. Norton: an Early-Holocene bison bone bed in western Kansas. Current Research in the Pleistocene 12, 19–21.

Holen, S.R., 2001. Clovis mobility and lithic procurement on the central Great Plains of North America. Ph.D. Thesis, University of Kansas.

Holliday, V.T., 2000. The evolution of Paleoindian geochronology and typology on the Great Plains. Geoarchaeology 15 (3), 227–290.

Irwin-Williams, C., Irwin, H.T., Agogino, G.A., Haynes Jr., C.V., 1973. Hell Gap: a Paleo-Indian occupation on the High Plains. Plains Anthropologist 18 (59), 40–52.

Jenness, D., 1935. The Ojibwa Indians of Parry Island: Their Social and Religious Life. Patenaude, Ottawa.

Jodry, M.A., 1999. Folsom technological and socioeconomic strategies: views from Stewart's Cattle Guard and the Upper Rio Grande Basin, Colorado. Ph.D. Thesis, American University.

Jones, D.C., 1999. Late Paleoindian/Early Archaic archaeology and subsistence: a taphonomic analysis of the Lime Creek site (25FT41), southwest Nebraska. Master of Arts Thesis, Colorado State University.

Kelly, R.L., 1995. The Foraging Spectrum: Diversity in Hunter–Gatherer Lifeways. Smithsonian Institution Press, Washington, DC.

Kluckhohn, C.W., Hill, W.W., Kluckhohn, L.W., 1971. Navaho Material Culture. Harvard University Press, Cambridge, MA.

Knudson, R., 2002. Medicine Creek is a Paleoindian cultural ecotone: the Red Smoke assemblage. In: Roper, D.C. (Ed.), Medicine Creek: Seventy Years of Archaeological Investigations. University of Alabama Press, Tuscaloosa, pp. 84–141.

Koch, A., Miller, J.C., 1996. Geoarchaeological investigations at the Lyman site (25SF53) and other cultural resources related to Table Mountain quarry near the Nebraska/Wyoming border. Nebraska State Historical Society, Lincoln.

Kreutzer, L.A., 1992. Bison and deer bone mineral densities: comparisons and implications for the interpretation of archaeological faunas. Journal of Archaeological Science 19 (3), 271–294.

LaBelle, J.M., 2005. Hunter–gatherer foraging variability during the Early Holocene on the central plains of North America. Ph.D. Thesis, Southern Methodist University.

LaBelle, J. M., 2006. Re(occupation) of place: Late Paleoindian land use strategies on the central and northwestern plains. Paper presented at the Annual Meeting of the Society for American Archaeology, San Juan, PR.

Lupo, K., 2006. What explains the carcass field processing and transport decisions of contemporary hunter–gatherers? Measures of economic anatomy and zooarchaeological skeletal part representation. Journal of Archaeological Method and Theory 13 (1), 19–66.

Lupo, K.D., 1998. Experimentally derived extraction rates for marrow: implications for body part exploitation strategies of Plio-Pleistocene scavengers. Journal of Archaeological Science 25 (7), 657–675.

Malainey, M.E., Przybylski, R., Sherriff, B.L., 2001. One person's food: how and why fish avoidance may affect the settlement and subsistence patterns of hunter–gatherers. American Antiquity 66 (1), 141–161.

Mandel, R.D., Hofman, J.L., 2003. Geoarchaeological investigations at the Winger site: a Late Paleoindian bison bonebed in southwestern Kansas. USA Geoarchaeology 18 (1), 129–144.

McKee, D.F., 1988. A faunal analysis of the River Bend site (48NA202): evidence of Protohistoric subsistence patterns on the northwest plains. Master of Arts Thesis, University of Wyoming.

Meltzer, D.J., 1999. Human responses to Middle Holocene (altithermal) climates on the North American Great Plains. Quaternary Research 52 (3), 404–416.

Miller, J.C., 1991. Lithic resources. In: Frison, G.C. (Ed.), Prehistoric Hunters of the High Plains. Academic Press, San Diego, pp. 449–476.

Monahan, C.M., 1998. The Hadza carcass transport debate revisited and its archaeological implications. Journal of Archaeological Science 25 (5), 405–424.

Munro, N.D., 2004. Zooarchaeological measures of hunting pressure and occupation intensity in the Natufian: implications of agricultural origins. Current Anthropology 45 (S), 5–33.

Myers, T.P., Corner, R.G., Tanner, L.G., 1981. Preliminary report on the 1979 excavations at the Clary Ranch site. Transactions of the Nebraska Academy of Sciences 9, 1–7.

Pac, H.I., Frey, K., 1991. Some population characteristics of the northern Yellowstone bison herd during the winter of 1988–1989. Montana Department of Fish, Wildlife and Parks.

Schiffer, M.B., 1987. Formation Processes of the Archaeological Record. University of New Mexico Press, Albuquerque.

Speth, J.D., 1983. Bison Kills and Bone Counts: Decision Making by Ancient Hunters. University of Chicago Press, Chicago.

Stein, M., 2005. Sources of Smoky Hill Silicified Chalk in Northwest Kansas. Anthropological Series, vol. 17. Kansas State Historical Society, Topeka.

Stiner, M.C., 2002. Carnivory, coevolution, and the geographic spread of the Genus *Homo*. Journal of Archaeological Research 10 (2), 1–63.

Stiner, M.C., 2003. Zooarchaeological evidence for resource intensification in Algarve, southern Portugal. Promontoria 1, 27–61.

Stiner, M.C., Munro, N.D., 2002. Approaches to prehistoric diet breadth, demography, and prey ranking systems in time and space. Journal of Archaeological Method and Theory 9 (2), 181–214.

Stiner, M.C., Tchernov, E., 1998. Pleistocene species trends at Hayonim cave: changes in climate versus human behavior. In: Akazawa, T., Aoki, K., Bar-Yosef, O. (Eds.), Neanderthals and Modern Humans in Western Asia. Plenum Press, New York, pp. 241–262.

Stiner, M.C., Munro, N.D., Surovell, T.A., 2000. The tortoise and the hare: small game use, the broad spectrum revolution, and Paleolithic demography. Current Anthropology 41 (1), 39–73.

Tanner, L.G., 1982. Geologic relations at the Clary Ranch site, Ash Hollow, Garden County, Nebraska (abstract). Proceedings of the Nebraska Academy of Sciences 92, 52.

Todd, L.C., Hill, M.G., Rapson, D.J., Frison, G.C., 1997. Cutmarks, impacts, and carnivores at the Casper site bison bonebed. In: Hannus, L.A., Rossum, L., Winham, R.P. (Eds.), Proceedings of the 1993 Bone Modification Conference, Hot Springs, SD. Occasional Publication No. 1, Archeology Laboratory, Augustana College, Sioux Falls, pp. 136–157.

White, T.E., 1953. A method of calculating the dietary percentage of various food animals utilized by aboriginal peoples. American Antiquity 18 (4), 396–398.

White, T.E., 1954. Observations on the butchering technique of some aboriginal peoples: nos. 3, 4, 5, and 6. American Antiquity 19 (3), 254–263.

White, T.E., 1955. The technic of collecting osteological materials. American Antiquity 21 (1), 85–87.

Wilmsen, E.N., Roberts Jr., F.H.H., 1978. Lindenmeier, 1934–1974: concluding report on investigations. Smithsonian Institution Contributions to Anthropology No. 24.

Wilson, M.C., 1974. The Casper local fauna and its fossil bison. In: Frison, G.C. (Ed.), The Casper Site: a Hell Gap Bison Kill on the High Plains. Academic Press, New York, pp. 125–171.

Winterhalder, B., Smith, E.A., 2000. Analyzing adaptive strategies: human behavioral ecology at twenty-five. Evolutionary Anthropology 9 (2), 51–72.