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**Faunal Analysis of the Licking Bison Site (39HN570): An Early Archaic Bison Kill Site
from Harding County, South Dakota**

by

Monica Margaret Bugbee

A Thesis

Submitted to the Graduate Faculty of

St. Cloud State University

in Partial Fulfillment of the Requirements

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Master of Science

in Cultural Resources Management Archaeology

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Thesis Committee
Mark Muñoz, chairperson
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Abstract

The Licking Bison Site (39HN570) is located in Harding County, South Dakota and dates to 5570 ± 30 ^{14}C yr BP (6406-6301 cal yr BP), during the Early Archaic period. The site was discovered in 1994 and excavated between 1995 and 2000 by the South Dakota State Archaeological Research Center (SARC). The Early Archaic corresponds with a period of warm and dry climatic conditions on the Northern Great Plains often referred to as the Altithermal. Archaeological sites from this time are relatively rare compared to both earlier and later periods. The Licking Bison Site is one of only two known bison kill sites from the Early Archaic of the region, and as such it has the potential to provide valuable information on prehistoric ways of life during the arid climatic conditions, as well as providing data about bison evolution. The faunal collection, housed at SARC, was analyzed to identify the species of bison, herd demographics (age, sex, MNI), and season of death. The excavated portion of the bonebed contained at least twenty-two individual bison killed and butchered by Early Archaic peoples in a single late fall kill event. The herd most likely consisted of predominately adult females, juveniles, and calves. Analysis of metacarpals shows at least four adult females and one adult male in the assemblage. The species of bison could not be identified due to a lack of well-preserved crania, but postcranial metrics suggest a possible slight trend towards *Bison bison*-sized individuals.

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Chapter 1: Introduction

The Licking Bison site (39HN570) provides a unique opportunity to explore bison hunting on the Northern Great Plains during the Early Archaic period. The site, located in the northwestern corner of South Dakota, was partially excavated between 1995-2000, but a complete analysis of the bison remains has not been completed until now (Fosha 2001). Archaeological sites from this period are comparatively rare, with the Licking Bison site being one of only two known bison kill sites from this region of the Plains (Kornfeld et al. 2010).

Climatic conditions fluctuated throughout the Holocene, and much of the Early Archaic period on the Northern Plains is associated with warmer, drier conditions often referred to as the Altithermal (Frison et al. 1976; Meltzer 1999; Kornfeld et al. 2010). Changes to local environments during the Altithermal likely caused shifts in resource distributions including plant communities and bison herds (Reeves 1973). Bison also followed a trend of diminution throughout the post-glacial period, transitioning from larger Pleistocene forms into the smaller modern Plains bison we see today (McDonald 1981; Hill et al. 2008).

Human hunting strategies and settlement patterns on the Plains likely reflected changes in bison ecology, as bison were a staple resource throughout the Holocene (Bamforth 1988). Careful evaluation of Early Archaic sites like Licking Bison is required to determine how bison populations shifted through time, and how humans responded to those changes.

This study is designed to provide a base line of data about the bison present in the assemblage upon which inferences of human hunting behavior can be made and further research can be built. I analyzed the Licking Bison faunal assemblage to identify herd demographics (MNI, age, sex), the species of bison present at the site, and season of the kill event.

Chapter 2 presents an overview of the environmental and culture history of the Northern Great Plains, followed by a brief look at bison evolution and ecology. The chapter concludes with a summary of previous work at the Licking Bison site including excavation, geoarchaeological analysis, and previous interpretations. The methods and measurements used in this project are presented in Chapter 3.

While taphonomy of the site remains largely unstudied in a rigorous way, a brief description of notable taphonomic factors are presented in Chapter 4. Results of the cataloging, including the Number of Identified Specimens, and Minimum Number of Individuals, are presented in Chapter 5. Chapter 6 addresses the sex distribution of the herd by evaluating sexually dimorphic characters of skulls and select postcranial elements, and data relevant to species identification is reviewed in Chapter 7. Chapter 8 provides a description of maxillary and mandibular dentition used to assess age at death and the seasonality of the kill event represented by the Licking Bison assemblage. The study concludes with a discussion of results and directions for possible future research in Chapter 9. Tables of skeletal measurements collected during the study are presented in Appendix I, and details of the most recent radiocarbon dates acquired from Licking Bison material can be found in Appendix II.

Chapter 2: Background

Geographic Area

The Licking Bison site is located in Harding County, South Dakota. The surrounding study area addressed in this paper covers a broad region of the Northern Plains which encompasses a great deal of geographic and environmental variation (Figure 2.1). The landscape is dominated by rolling short-grass prairie, and is dissected by streams and river valleys, which often support denser woodland vegetation (Neusius and Gross 2014). The study area is part of the unglaciated Missouri Plateau physiographic subregion of North America (Fenneman 1946). A variety of hilly landforms are interspersed throughout the study area, including the Black Hills in Wyoming and South Dakota, the North Cave Hills of South Dakota, and the Badlands and the drainages of the Missouri River and its tributaries in both North and South Dakota. Further to the south and west, other features like the Bighorn Mountains and Hartville Uplift in Wyoming, and the Pine Ridge in northwestern Nebraska, break the monotony of the Plains.

Environmental Context

The environments of the Great Plains changed as climate fluctuated since the end of the Pleistocene (Kornfeld et al. 2010). Climate was already warming and the glaciers receding by the time humans entered the area around 11,200 ^{14}C yr BP (Kornfeld et al. 2010). Pleistocene inhabitants of the Northern Plains lived in a world cooler and wetter than today. Plant communities of this period and many of the animals, particularly megafauna, are now extinct due to changing climatic conditions, and in some cases, possibly human predation (Neusius and Gross 2014).



Figure 2.1. Location of the study area and surrounding geographic features. Licking Bison site marked with star. Image modified from Google satellite imagery (2018).

In addition to an overall increase in global temperature, the melting of the North American glaciers caused changes to oceanic and atmospheric patterns, affecting prevailing winds, precipitation, and effective moisture across the Great Plains (Lovvorn et al. 2001). A brief reversal of the warming trend called the Younger Dryas occurred roughly 11,000-10,100 ^{14}C yr BP, returning the Northern Plains to colder conditions (Widga 2013). Lake sediments from Moon Lake, North Dakota indicate a climate cooler and wetter than today with a forested landscape between 11,700 and 9,500 ^{14}C yr BP (Valero-Garcés et al. 1997). Warming

temperatures after 11,000 calendar yr BP correlate with a major shift in Paleoindian subsistence patterns, when distinct Plains and Foothills-focused groups emerged (Lovvorn et al. 2001).

Climate became progressively warmer and more arid into the mid-Holocene causing grasslands to expand (Kornfeld et al. 2010; Valero-Garcés et al. 1997). Temperatures peaked at a point warmer than today during the Altithermal period (7000-4500 calendar years BP), which corresponds roughly to the Early Archaic (Antevs 1955; Neusius and Gross 2014).

Archaeological sites from the Early Archaic period are relatively rare on the Northern Plains when compared to preceding and succeeding periods (Kornfeld et al. 2010; Gregg 1985). The arid climate of the Altithermal is hypothesized to have caused a period of environmental stress resulting in altered plant distributions and reduced bison population on the Great Plains (Reeves 1973). Bison populations likely fell due to poor quality graze, and restricted surface water availability (Meltzer 1999). In turn, human subsistence and population patterns likely shifted in response to availability of bison, which remained a dietary staple for Plains peoples (Kornfeld et al. 2010).

Reeves (1973) summarizes the positions of numerous mid-century archaeologists including Mulloy (1954; 1958 [cited in Reeves 1973]) who suggested the scarcity of sites during the Altithermal indicated a cultural hiatus when arid climatic conditions forced Plains peoples to completely abandon large swaths of the Northern Plains. However, others also suggested the apparent lack of sites was due to other factors such as sampling bias, geologic processes, and difficulty in distinguishing Early Archaic projectile points from those of later periods (Reeves 1973). Geomorphic processes during the Early Archaic increased the chances of sites being eroded or deeply buried, and survey methods often were not designed to locate sites in those geologic settings (Artz 1995, 1996).

As more Early Archaic sites were eventually found, mostly in the foothills and higher elevations, the idea of a complete cultural hiatus fell out of favor (Frison et al. 1976). Instead, Early Archaic people are hypothesized to have adapted to the changing environmental conditions, rather than abandoning the region (Reeves 1973; Kornfeld et al. 2010). Evidence from numerous rock shelters in Wyoming, suggests Early Archaic peoples were increasingly exploiting the higher elevation areas which remained cooler and wetter than the surrounding Plains (Kornfeld et al. 2010; Sheehan 1995). However, evidence from the Black Hills is mixed. Cassells (1986) suggests the elevation of the Hills may have been too low to retain enough snowpack and reliable water for regular habitation by Early Archaic peoples. Relatively few Early Archaic sites have been recorded in the Black Hills, but geomorphological evidence suggests the Black Hills, like the Plains, also experienced increased erosion during the Early Archaic, and so the scarcity of sites may represent preservation bias, rather than an accurate reflection of land use (Sundstrom et al. 2008; Yansa 2007).

Patterns of increased sand dune activity across the Northern Plains and proxy data from lake sediments (including pollen, diatoms, salinity, $\delta^{13}\text{C}$, $\delta^{18}\text{O}$, and strontium isotopes) indicate a shift to hotter, drier conditions during the Middle Holocene (Dean et al. 1996; Dean and Schwalb 2000; Forman et al. 2001; Valero-Garcés et al. 1997; Yansa 2007). However, the ‘Altithermal’ was not as consistent as once thought, instead representing a period encompassing several fluctuations of climate, which likely manifested differently across the region. Combined proxy data derived from sediment cores of Moon Lake, North Dakota, show increased aridity and a transition to increased grassland vegetation between 7,100 and 4,000 ^{14}C yr BP (Valero-Garcés et al. 1997). Three especially arid periods peak between 6,600-6,200 ^{14}C year BP, 5,400-5,200 ^{14}C yr BP, and 4,800-4,600 ^{14}C yr BP, with the period between 6,600-6,200 ^{14}C year BP marking

the lowest effective moisture during the entire Holocene record of Moon Lake (Valero-Garcés et al. 1997).

Yansa's (2007) review of environmental proxies from several lakes and wetlands across the Northern Plains largely agrees with the overall pattern of shifting periods of increased aridity and moisture, but provides slightly different dates for arid periods. Yansa places the beginning of maximum aridity around 8,000 ^{14}C yr BP, with a moister period lasting between 7,700 and 6,000 ^{14}C yr BP, before returning to severely arid conditions from 6,000 to 5,000 ^{14}C yr BP. Smaller fluctuations in moisture still occurred within these larger periods (Yansa 2007).

By approximately 4,400 ^{14}C yr BP sediments from Moon Lake indicate a shift away from Middle Holocene aridity into more modern conditions (Valero-Garcés et al. 1997). Climate fluctuations continued into the Late Holocene, but climate did not again reach the same high levels of temperature and aridity as in the Middle Holocene (Valero-Garcés et al. 1997). A similar overall pattern of Middle Holocene climate fluctuations appears in other lakes in the region including Pickerel Lake, SD and Elk Lake, MN (Dean and Schwalb 2000; Dean et al. 1996).

Culture History

The research locality is dated to the Early Archaic period, but I will describe briefly the preceding Paleoindian periods and the following Middle and Late Archaic periods for comparison. Most evidence will focus on the Northwestern Plains and Black Hills regions. Sites mentioned in the text are shown in Figure 2.2, and Table 2.1 provides a chart of the culture history of northwestern South Dakota and the surrounding area.

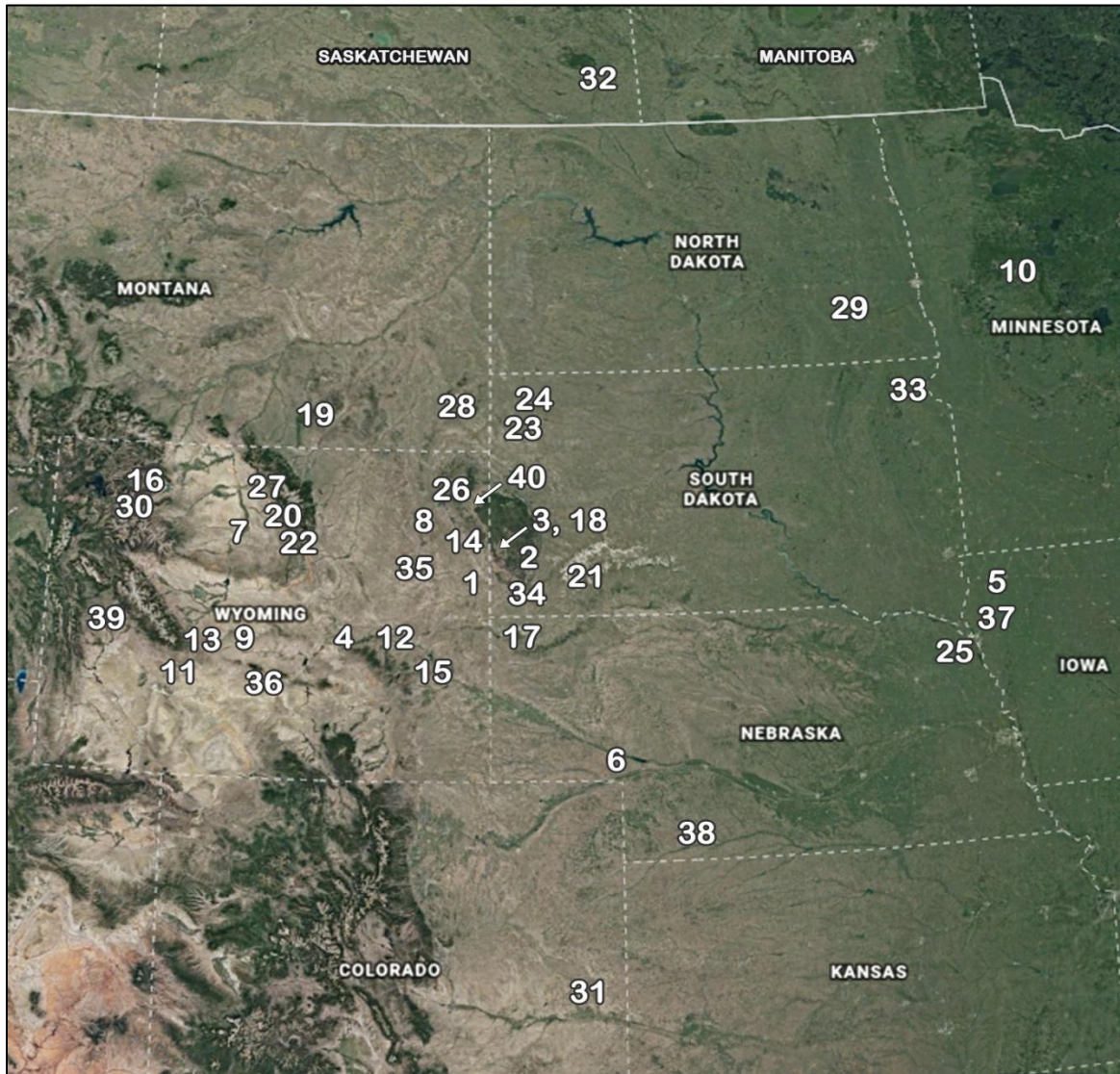


Figure 2.2. Map showing the locations of sites discussed in text. Image modified from Google Maps satellite imagery Landsat/Copernicus (2018). 1. Agate Basin (48NO201); 2. Beaver Creek Shelter (39CU779); 3. Blaine (39CU1144); 4. Casper (48NA304); 5. Cherokee Sewer (13CK405); 6. Clary Ranch (25GD106); 7. Colby (48WA322); 8. Cordero Mine (48CA75); 9. Dick Myal Housepit (48FR6256); 10. Elk Lake; 11. Finley (48SW5); 12. Glenrock (48CO304); 13. Graham Ranch (48FR4442); 14. Hawken I and III (48CK303); 15. Hell Gap (48GO305); 16. Horner (48PA29); 17. Hudson-Meng (25SX115); 18. Jim Pitts (39CU1142); 19. Kobold (24BH406); 20. Laddie Creek (48BH345); 21. Lange-Ferguson (39SH33); 22. Leigh Cave (48WA304); 23. Licking Bison (39HN570); 24. Lightning Spring (39HN204); 25. Logan Creek (25BT3); 26. McKean (48CK7); 27. Medicine Lodge Creek (48BH499); 28. Mill Iron (24CT30); 29. Moon Lake; 30. Mummy Cave (48PA201); 31. Olsen-Chubbuck (5CH3); 32. Oxbow Dam (DhMn-1); 33. Pickerel Lake; 34. Ray Long (39FA65); 35. Ruby (48CA302); 36. Scoggin (48CR304); 37. Simonsen (13CK61); 38. Spring Creek (25FT31); 39. Trappers Point (48SU1006); 40. Vore (48CK302).

Table 2.1. *A Culture History of Northwestern South Dakota and the Surrounding Area.*

Uncalibrated radiocarbon years BP in bold, with calibrated calendar year date range in parentheses	Cultural Periods			Phases/Complexes			Sites appearing in text
500 (616-502 BP)	Plains Village (PV)	Late Prehistoric (LP)		Middle Missouri (PV)	Coalescent (PV)		
1000 (963-800 BP)							
1500 (1450-1315 BP)					Old Women's Phase (LP)		
2000 (1997-1890 BP)	Plains Woodland		Late	Avonlea			
2500 (2719-2490 BP)				Besant			
3000 (3319-3080 BP)	Plains Archaic					Pelican Lake	
3500 (3834-3706 BP)		Middle	McKean			McKean; Scoggin; Cordero Mine; Lightning Spring; Beaver Creek; Oxbow Dam	
4000 (4522-4420 BP)							
4500 (5287-5052 BP)		Early	Oxbow	Logan Creek/Mummy Cave	Licking Bison*; Hawken I and III*; Blaine*; Dick Myal*; Beaver Creek*; Oxbow Dam; Laddie Creek; Medicine Lodge Creek; Mummy Cave; Logan Creek (CP); Cherokee Sewer (CP); Simonsen (CP); Spring Creek (CP)		
5000 (5875-5656 BP)							
5500 (6393-6218 BP)							
6000 (6899-6754 BP)							
6500 (7829-7464 BP)							
7000 (7929-7787 BP)							
7500 (8382-8215 BP)							
8000 (8997-8777 BP)							
8500 (9532-9483 BP)						Late	Angostura
9000 (10,234-9973 BP)		Frederick		Hell Gap			
9500 (11,066-10,678 BP)		Cody		Horner; Hudson-Meng			
10,000 (11,695-11,336 BP)		Middle	Hell Gap		Hell Gap; Casper		
	Agate Basin		Agate Basin; Hell Gap				
10,500 (12,628-12,392 BP)	Paleoindian	Early	Folsom		Hell Gap; Agate Basin		
11,000 (12,960-12,877 BP)			Goshen		Hell Gap; Mill Iron; Jim Pitts		
			Clovis		Lange-Ferguson; Colby		
11,500 + (13,389-13,289 + BP)	Pre-Clovis					La Sena?	

Note: Central Plains sites are marked by (CP). Dates and divisions are approximate; there is often temporal overlap between cultural complexes. Table adapted from Neusius and Gross Table 10.1 (2014:302), and from Kornfeld et al. Table 1.2 (2010:36). * denotes sites unaffiliated with a cultural complex.

Pre-Clovis

Evidence for Pre-Clovis presence on the Great Plains is limited and sites are often disregarded by archaeologists because either the dating is questionable, or the sites do not have a convincing lithic component. The La Sena site (25FT177) in southwestern Nebraska holds the remains of a mammoth that died around 18,000 ^{14}C yr BP (Holen 2006). There is some evidence suggesting the mammoth bone was quarried for tool making material (Holen 2006), but the site remains controversial and is generally dismissed due to the lack of culturally derived lithic materials.

Paleoindian

The Paleoindian period on the northern Plains begins around 11,500 ^{14}C yr BP and lasts until roughly 8000 ^{14}C yr BP (Frison 1991). Paleoindian lifeways on the Plains were largely focused on hunting megafauna, including now extinct species such as mammoths. As the climate warmed and many species disappeared, bison became the cornerstone of Paleoindian subsistence. Bison bones recovered from most Paleoindian kill or processing sites lack evidence of processing for marrow extraction, indicating this resource was not as highly valued as in later periods (Kornfeld et al. 2010).

Paleoindian hunters utilized both *Bison antiquus antiquus* and *B. antiquus occidentalis* (Frison 1991). Most studies of bison kill or processing sites use modern Plains bison as analogues for the seasonal and social behaviors of ancient bison variants. However, the extent to which the behaviors of ancient bison were comparable to modern bison is unknown, which could have large implications for interpretation of archaeological sites and inferred hunting behaviors of Plains groups (Kornfeld et al. 2010). The changing size of bison, or potential behavioral or

biological responses of bison to changing climate may have directly affected hunting strategies of Plains people (Kornfeld et al. 2010).

Clovis-aged sites represent the first conclusive evidence of humans in the Northern Plains. Clovis people were highly mobile hunter-gatherers who ranged widely across the landscape, as evidenced by the variety of exotic tool stones often found together at Clovis sites (Neusius and Gross 2014). Evidence of mammoth hunting from the Northern Plains comes from the Lange-Ferguson site (39SH33) in the White River Badlands of South Dakota, and the Colby site (48WA322) in the Bighorn Basin of north central Wyoming (Hannus 1990; Frison and Todd 1986). Clovis people, once thought to be exclusive big game hunters, are now known to have exploited other resources as well, including smaller terrestrial, aquatic, and avian faunas, as well as plant resources (Neusius and Gross 2014).

The Goshen complex, which is often associated with bison remains, follows Clovis in the Northern Plains and is dated from $10,450 \pm 15$ to $10,175 \pm 40^{14}\text{C}$ yr BP (Waters and Stafford 2014). The Goshen complex was first recognized from the Hell Gap site (48GO305) in southeast Wyoming, a well-stratified Paleoindian site that preserves nearly the entire Paleoindian record for the area (Kornfeld et al. 2010). It is best represented at the Mill Iron site (24CT30) in southeastern Montana, which contains a *Bison antiquus antiquus* bonebed and nearby encampment (Kornfeld et al. 2010). Goshen points are also found in the Black Hills at the Jim Pitts site (39CU1142), demonstrating that Goshen complex people were making use of varied environments (Sundstrom et al. 2008). Bison were the predominate animal resource recovered from the Goshen component of the Jim Pitts site, but mule deer and pronghorn were also represented, and long bones of all three species exhibit evidence of marrow extraction (Sellet et al. 2009).

The Folsom complex is recognized from about 10,900 ^{14}C yr BP to 10,200 ^{14}C yr BP and overlaps with both Clovis and Goshen to some extent (Kornfeld et al. 2010). Most of the Pleistocene megafauna were extinct by Folsom time, except for bison. Folsom is the likely beginning of the typical Northwestern Plains lifestyle of small, mobile groups, who gather seasonally for communal bison hunts (Sundstrom et al. 2008). The Agate Basin (10,500 to 10,000 ^{14}C yr BP) and Hell Gap (10,000 to 9500 ^{14}C yr BP) complexes follow Folsom and show a continued reliance on bison (Kornfeld et al. 2010).

The Cody complex takes its name from the Horner site (48PA29) near Cody, Wyoming. It encompasses a large diversity of point types from 10,000 to 8000 ^{14}C yr BP (Knell and Muñiz 2013), which are sometimes recognized as different complexes (Frison 1991). Bison remained a large part of the diet as seen in large bison bonebed sites including Hudson-Meng (25SX115) in northwestern Nebraska, but other smaller animals were also exploited including elk, deer, pronghorn, beaver, marmot, rabbits, birds, and occasionally aquatic species (Knell and Muñiz 2013).

Cody people likely followed seasonal rounds, sometimes focusing on regions for several months at a time, as evidenced by abundance of local lithic sources represented at Cody sites (Knell and Muñiz 2013). Prior to 9000 ^{14}C yr BP, Cody people may have come together from long distances in the autumn for communal bison hunts, after 9000 ^{14}C yr BP, this habit fell off, potentially a result of changing climate during the Early Holocene affecting the distribution of resources (Knell and Muñiz 2013).

Several other more geographically restricted variants of terminal Paleoindian complexes were present on the Northwest Plains, including the Frederick, James Allen, Lusk, and Angostura complexes (Kornfeld et al. 2010). The Ray Long site (39FA65), an Angostura

complex site located in southwestern South Dakota, was repeatedly used for small, temporary, likely seasonal encampments. The presence of manos and metates indicates an increased focus on plant resources (Buhta 2015).

Around 10,000 ^{14}C yr BP, evidence of Paleoindian occupations of higher elevation areas in the Northwest Plains begins to appear, collectively called Foothill/Mountain complexes (Kornfeld et al. 2010). Paleoindian Plains and Foothills groups may have been living concurrently but practicing very different subsistence strategies between the two ecosystems (Kornfeld et al. 2010). Plains groups continued to focus on communal bison hunting, and high elevation groups had a more diverse subsistence strategy focused on smaller game and plant resources, similar to later Archaic peoples (Sundstrom et al. 2008).

Variations of the Foothill/Mountain lithic assemblages appear more geographically restricted than other Paleoindian complexes and are generally found in caves and rockshelters in high elevation areas including in the Rocky Mountain foothills, the Hartville Uplift, and Bighorn Mountains (Frison 1991). Diagnostic Foothill/Mountain artifacts are relatively uncommon, and many of the variants appear to overlap both spatially and temporally (Kornfeld et al. 2010; Sundstrom et al. 2008). It is not clear whether the high elevations were occupied year-round or exploited seasonally (Sundstrom et al. 2008).

The Late Paleoindian Foothill/Mountain complexes may represent a transition into more Archaic style lifeways, with increased reliance on a more diverse suite of plant and animal resources (Kornfeld et al. 2010). A similar pattern may have existed in the Black Hills, but sites from this period are rare (Sundstrom et al. 2008).

Early Archaic

The transition from Paleoindian to Archaic lifeways on the Northern Plains was marked by an abrupt change in lithic point morphology when lanceolate Paleoindian types gave way to smaller side-notched points around 8000 - 7500 ^{14}C yr BP (Kornfeld et al. 2010). The shift may relate to increasing reliance on the atlatl, which became the main hunting weapon during the Archaic (Neusius and Gross 2014; Sundstrom et al. 2008). Climate also began shifting to more arid conditions across the region (Yansa 2007).

Bison continued to be an important resource throughout the Archaic and they were hunted communally in a variety of ways including using jumps, corrals, and arroyo traps (Kornfeld et al. 2010). Pronghorn were also exploited in seasonal communal hunts in Wyoming, as seen at the Trappers Point site (48SU1006) (Miller and Sanders 2000). Diet breadth expanded to include more small fauna, both terrestrial and aquatic, including deer, rabbits, fish, and birds (Neusius and Gross 2014). The Dick Myal Housepit site (48FR6256) in central Wyoming also shows evidence of communal jackrabbit hunting in the late Early Archaic (Rood 2018).

Social structures were likely flexible, with smaller groups moving in seasonal rounds, gathering together at certain times of the year to hunt bison and trade materials (Neusius and Gross 2014). Circular pithouses with hearths and storage pits became more common towards the end of the Early Archaic (roughly 5000 ^{14}C yr BP), denoting an increased level of sedentism (Frison 1991). In southeast Wyoming, stone-lined storage pits, likely associated with pithouse structures, suggest increased sedentism by about 6000 ^{14}C yr BP (Kornfeld et al. 2010), which may have reflected a return to more favorable climate (Albanese and Frison 1995).

Early Archaic sites of any type are comparatively rare for the Northern Plains (Kornfeld et al. 2010; Gregg 1985). Besides the Licking Bison Site (described later in the chapter), the

Hawken site (48CK303), which consists of three localities, is the only other known bison kill site from the Early Archaic of the northwestern Plains (Kornfeld et al. 2010). Bison at the Hawken Site (Hawken I) on the western edge of the Wyoming Black Hills were trapped and killed in a natural arroyo at about 6600 ^{14}C yr BP (Kornfeld et al. 2010). Nearly 100 animals were killed in three events at the site. It is unclear if the kill events took place over the course of one season, or several closely spaced seasons, though all occurred in the late fall or early winter (Frison et al. 1976). The bison were highly butchered with few intact meat-bearing anatomical units, and the longbones also show evidence of marrow extraction (Frison et al. 1976), which is a notable difference when compared to the earlier Paleoindian strategy.

Nearly 300 projectile points were recovered from the Hawken site, and many more were likely lost (Kornfeld et al. 2010), as the site was heavily disturbed by private collectors prior to archaeological excavations (Frison et al. 1976). The points have a high degree of variation, much of it due to reworking (Frison et al. 1976). One point was found embedded within an atlas vertebra from a calf; a similar situation is seen at the Licking Bison Site (Kornfeld et al. 2010:Fig 4.31; Fosha 2001). In addition to projectile points, several knives, choppers, and hammerstones were recovered, as well as several bone butchering tools, all of which were made of local materials (Frison et al. 1976).

Another nearby locality, Hawken III, dates slightly younger, to 6000 ^{14}C yr BP, contains more butchered bison bone and a group of nine bison skulls which appear to have been intentionally stacked (Kornfeld et al. 2010.) These bison were killed in the spring close to calving time, likely mid-March to early April.

Two Early Archaic layers dated to 6930 ± 55 and 7617 ± 35 ^{14}C yr BP were identified at the Hudson-Meng site, above the main Cody bonebed (Shelton 2019). These components show

short-term, intermittent use of a spring at the site during a period of increasing aridity. Shelton (2019) notes a shift towards local tool stone sources at this time, which is a pattern also seen at Hawken and Licking Bison. This could indicate a more restricted level of trade and level of mobility (Shelton 2019)

The Kobold site (24BH406) in Montana has a small Early Archaic component containing a small number of tools, flakes, and poorly preserved bones, which probably represent a temporary campsite (Frison 1970). The site has not been radiocarbon dated, but based on point morphology is estimated to be between 4950-5450 BP (about 4395-4715 ^{14}C yr BP) (Frison 1970). Later components show the site was used as a bison jump, but there is no evidence of this from the Early Archaic.

The Blaine site (39CU1144), another Early Archaic site in the western Black Hills, shows a focus on root processing. Blaine and other high elevation sites were likely used as smaller temporary camps by hunting parties from the Plains (Sundstrom et al. 2008). The Beaver Creek Shelter (39CU779) in the eastern Black Hills preserves deposits spanning the transition from Early to Middle Archaic (Martin et al. 1993). Analysis showed a similar subsistence base between the two periods with emphasis on small game and plants, warm season use, and focus on local lithic sources (Martin et al. 1993).

More abundant evidence of Early Archaic occupation sites on the Northern Plains can be found in caves and rockshelters further west in the foothills of Wyoming including Laddie Creek (48BH345), Medicine Lodge Creek (48BH499), and Mummy Cave (48PA201) (Kornfeld et al. 2010). Mummy Cave in northwestern Wyoming, which lends its name to the Mummy Cave complex, contains a nearly continuous sequence of Archaic occupation and has been very influential in defining Archaic period projectile point chronology (Husted and Edgar 2002;

Kornfeld et al. 2010). Lithic assemblages from these and other foothills sites show a high degree of variation in point types, many of which are not defined or named, because the chronology between sites is not well understood (Kornfeld et al. 2010).

The relationship between Early Archaic lithic assemblages on the Northwest Plains and further to the east and south in the Central Plains is unresolved, but similarities do exist (Kornfeld et al. 2010). Frison et al. (1976) state that the Hawken points resemble Late Paleoindian complexes in the area, like Frederick and Lusk, with added side notches. However, Hawken point bases also share similarities with point styles from several Early Archaic sites on the Central Plains including Logan Creek (25BT3) in Nebraska, and Cherokee Sewer (13CK405) and Simonsen (13CK61) in Iowa (Kornfeld et al. 2010). The Mummy Cave complex may be related to the Logan Creek complex on the Central Plains and they are sometimes considered together under the name Logan Creek/Mummy Cave Complex (Husted and Edgar 2002; Gregg 1985).

Central Plains Early Archaic sites show less of a focus on multi-animal kills than in the Northwest Plains, and more evidence of opportunistic single animal kills (Widga 2004). Logan Creek is a multi-component bison processing site, where bison were killed at various times of year both singly and in multi-kill events (Widga 2007). Bison processing is the focus at Logan Creek complex sites, but remains of other fauna are also common, including aquatic and avifauna (Widga 2007). The Spring Creek site (25FT31) in southwest Nebraska, also shows a pattern of high emphasis placed on bison, with smaller focus on more diverse fauna (Widga 2004). Isotope data from the Spring Creek site supports the hypothesis of a stable bison population in the Central Plains during the Early Archaic (Widga 2004).

Further to the north of the study area, the Oxbow complex, named for the Oxbow Dam site (DhMn-1) in Saskatchewan, appears late in the Early Archaic and persists through much of the Middle Archaic (Kornfeld et al. 2010). Oxbow sites were concentrated in Montana, Alberta, and Saskatchewan, but some points have been found in South Dakota and Northern Wyoming (Gregg 1985).

Middle Archaic

The Middle Archaic period lasted from roughly 5000-3000 ^{14}C yr BP and marked a return to a somewhat cooler, damper climate than that of the Early Archaic period (Kornfeld et al. 2010). The number of sites throughout the Northern Plains and Black Hills rises dramatically, but whether this is caused by higher human population resulting from returning bison herds and a more diverse resource base, better geomorphological conditions for preservation, or a combination of the two is not clear (Cassells et al. 1984; Sundstrom et al. 2008; Meltzer 1999). Bison remained a major component of Middle Archaic subsistence, but there is less evidence for large scale communal hunts, and the emphasis on plant resources continued to increase from the Early Archaic (Kornfeld et al. 2010). Evidence for use of crickets as a food source comes from the Leigh Cave site in the Bighorn Mountains of Wyoming (Keyser 1986). Archaic period rock art from the southern Black Hills has been identified by depictions of Archaic period hunting weapons which match those found in archaeological sites (Keyser and Sundstrom 1984). A direct date is difficult to determine, but the glyphs likely date to around 4500 calendar yr BP (about 4050 ^{14}C yr BP) or later.

The Middle Archaic is closely associated with the McKean complex, which appears to have spread rapidly through the Northwestern Plains (Kornfeld et al. 2010). The complex takes its name from the McKean Site (48CK7) in northwestern Wyoming. Two secondary burials were

recovered from the McKean site in shallow pits dug into occupation floors (Rennie 1994). One burial contained an adult which was associated with bison innominates, and the other contained a child associated with a deer innominate and a hematite slab (Rennie 1994).

There is a continuing focus on plant foods as grinding stones, which first appear in the area in Terminal Paleoindian levels, become common (Frison 1991). McKean complex sites in the Northwestern Plains show a heavy emphasis on plant use. Manos and milling stones are often found associated with stone-line roasting pits (Keyser 1986). Some sites even have preserved plant food remains, including the Lighting Spring site (39HN204) in northwestern South Dakota where hearth deposits contained at least 8 species of charred seeds (Keyser 1986). While increased use of plants is indicated by grinding implements, some grinding stones from the Middle Archaic of the Black Hills have wear patterns consistent with bone grease rendering, suggesting production of pemmican was also taking place (Cassells et al. 1984).

The McKean complex contains a large diversity in point types including: McKean Lanceolate with convex edges and an indented base; Duncan which was stemmed with sloping shoulders; and Hanna that had distinct shoulders and an expanding stem (Rennie 1994; Frison 1991). The great diversity of lithic assemblages in the Black Hills during this period may reflect ethnic diversity in the record (Sundstrom et al. 2008).

Points recovered from the Middle Archaic component of the Kobold site also show a large diversity in types, but at least some are similar to those from McKean (Frison 1970). The Kobold site was being used as a jump during this period, and while some bison bones show evidence marrow extraction, the activity was not prevalent (Frison 1970). No radiocarbon date exists for this component, but it is estimated to be between 3950-4450 BP (about 3650-4000 ^{14}C yr BP) (Frison 1970).

The Scoggin (48CR304) site in south central Wyoming provides strong evidence for use of bison corral traps at a McKean complex site at 4540 ± 110 ^{14}C yr BP (Neusius and Gross; Niven and Hill 1998). A fence made of posts and low stone walls, likely covered in hides, was built at the bottom of a talus slope; bison would be driven down the slope into the corral, which would help contain and slow the animals long enough to be dispatched (Kornfeld et al. 2010). Tooth eruption data indicate that the site was used at least twice during different seasons, and stone boiling pits located outside of the corral suggest some processing also took place on site (Niven and Hill 1998). Bison remains from Scoggin are well within the modern *Bison bison* size range (Kornfeld et al. 2010).

A later McKean bison processing site, Cordero Mine (48CA75), dated to 3520 ± 150 ^{14}C yr BP also contains nearby boiling pits (Niven and Hill 1998). Bones recovered from the site represent a majority adult cow herd, which was killed in late fall or early winter. Longbones show extensive processing, likely for recovery of marrow (Niven and Hill 1998).

The Black Hills were potentially used for a complete seasonal round during the Middle Archaic, with groups occupying the southern area in winter and the central Hills in summer (Cassells et al. 1984). Sites like Lightning Spring in the North Cave Hills of South Dakota were favored localities for short-term camps over hundreds of years as part of a seasonal migration pattern (Rennie 1994). Stone circles averaging 3-7 m wide begin to appear in the Middle and Late Archaic, marking the emergence of temporary lodge structures or tipis (Frison 1991).

Late Archaic

The Late Archaic period begins around 3000 ^{14}C yr BP and continues to 2500-1500 ^{14}C yr BP, depending on the area, and is characterized by an increase in the number of known sites compared to the Middle Archaic (Kornfeld et al. 2010). The Pelican Lake complex is prominent

in Late Archaic of the Northern Plains and continued to focus on bison hunting (Sundstrom et al. 2008). Source material in the lithic assemblage from the Pelican Lake component at the Blaine Site shows some connection to the Missouri River area in North Dakota and the White River Badlands (Sundstrom et al. 2008). Whether this represents trade between Plains and Black Hills groups, or seasonal use of the Black Hills by Plains-based groups remains unknown. A Pelican Lake cremation burial containing red ocher and a point cache was found in the Wind River Canyon, Wyoming (Rennie 1994; Frison 1991). Another Late Archaic variant, the Yonkee complex, is more restricted to the Powder River Basin of Montana and Wyoming and is often associated with bison jumps like the Kobold site, as well as arroyo traps (Kornfeld et al. 2010; Keyser and Sundstrom 1984).

Brief Review of Bison Studies on the Great Plains

Bison remains are abundant in both the archeological and paleontological records of North America and have been a central focus of Great Plains research throughout the last century. Dozens of species were once named in the paleontological and archaeological literature. The taxonomic relationships were refined over time, and many species synonymized, most notably by Skinner and Kaisen (1947) and McDonald (1981) (see also Guthrie 1980). In the early 20th century, prior to the advent of radiocarbon dating, the antiquity of humans in North America was not yet an established fact, nor was the timing of early bison extinctions known. Bison sites played a critical role in cementing the idea that humans inhabited North America since the Late Pleistocene (Meltzer 2006b).

Excavations at the Folsom site in New Mexico from 1926-1928, were the first to produce convincing evidence of human artifacts in primary association with extinct bison bones (Meltzer

2006a). Evidence from other sites soon followed, including the Scottsbluff Bison Quarry in Nebraska where lithic artifacts were found amongst extinct bison and Pleistocene invertebrate fauna (Barbour and Schultz 1932). The discoveries were initially met with skepticism by some, but soon embraced by the archaeological community as direct evidence for the antiquity of humans in North America (Schultz and Eiseley 1935; 1936; Meltzer 2006b).

Bison teeth and horn cores were long recognized as useful indicators of animal age prior to systematic archaeological applications to Plains bison bonebeds (Skinner and Kaisen 1947; Fuller 1959). Frison and Reher's (1970) influential publication on aging mandibles from the Glenrock site to determine seasonality of the kill fundamentally transformed the types of archaeological questions able to be addressed with bison bonebeds.

Knowing the season of death allows researchers to infer seasonally variable traits in bison including herd structure and behavior (ex. calving season vs rut), as well as physical attributes (winter vs summer coat, and percent body fat) (Olson 2005). Human hunting strategies and preferences can then be extrapolated from seasonality data for site-specific interpretation or regional scale chronologic comparison (Todd 1986, 1991; Hill 2013).

Analysis of dentitions to determine seasonality has become a standard approach in bison bonebed studies. Mandibular dentitions are most often used (Frison 1978; 1982; Frison et al. 1976; Reher 1974; Todd 1987a; Todd 1991; Todd and Hofman 1987; Todd et al. 1996; Widga 2004, 2007), but maxillary dentitions can also provide valuable age and seasonality data (Wilson 1974; Wilson 1980; Hill 2008; this study).

Wheat's (1972) investigations of the Olsen-Chubbuck bonebed in Colorado are regarded as one of the first modern foundational analyses of bison bonebeds as cultural features (Kornfeld et al. 2010). Wheat (1972) interpreted the patterned distribution of articulated and disarticulated

bones to be representative of human butchering practices. Earlier studies focused mostly on cultural artifacts, but Wheat's memoir marked the beginning of increased interest in bison remains as useful indicators of human behavior, preferences, and intention, as well as bison bones as sources of ecological information (Kornfeld et al. 2010; Frison et al. 1976; Agenbroad 1978).

The introduction of taphonomic principles and site formational processes to the study of bison bonebeds on the Great Plains led to more nuanced interpretations of bison assemblages (Todd 1987c). Analyses of modern vertebrate death assemblages provided comparison for patterns seen in Plains bonebeds (Behrensmeyer 1978; Haynes 1985, 1988; Weigelt 1927). The taphonomic approach applied to large bonebeds like Horner (Todd 1987a) and Hudson-Meng (Todd and Rapson 1999) shifted the interpretation of bonebeds from purely cultural features to the bonebed as a product of complex interactions of natural and cultural processes including weathering, erosion, bioturbation, and carnivore modification and dispersal. Accounting for taphonomic processes is now a necessity before inferring any human behavior through faunal analyses at a cultural site.

Because Plains cultures relied so heavily on bison resources through time, changes in bison populations were likely to affect human populations as well. Stable isotope studies provided an avenue to expand research questions about bison paleoecology, diet and environment. Carbon isotopes ($\delta^{13}\text{C}$) track the proportions of C3 and C4 plants in an individual's diet and relate that to cool and warm season grasses. $\delta^{13}\text{C}$ has been used to trace site-specific diet of bison (Widga 2006) and as part of regional scale analyses of vegetation changes through time (Lovvorn et al. 2001; Widga 2007). Widga et al. (2010) used strontium isotope ($^{87}\text{Sr}/^{86}\text{Sr}$) and oxygen isotope ($\delta^{18}\text{O}$) analysis to trace mobility of herds across the landscape by comparing

strontium isotopes extracted from bison enamel to environmental strontium signatures throughout a region.

The relative influences of climate changes and human predation on the causes and timing of diminution in Late Pleistocene-Holocene bison are still a debated topic. Martin et al. (2018) found a close correlation between diminution and increasing air temperatures derived from $\delta^{18}\text{O}$ ice core data. Hill et al. (2008) argue in favor of aridity-driven vegetation changes causing a step-wise diminution, rather than gradual change. Lewis et al. (2010) found a similar pattern on the Southern Plains correlated with changing grass patterns, and not human hunting. However, this pattern of punctuated loss of body mass is contradicted by Raymond and Prothero (2011) with a bison sample from the La Brea tar pits in California. A study of ancient DNA by Shapiro et al. (2004) identified a sharp decrease in diversity in bison populations around 37,000 years ago in Beringia, well before the generally accepted appearance of humans in the archaeological record of North America.

Genetic analysis has provided a new avenue for researching bison evolution, expanding and revising the earlier evolutionary models of Guthrie (1980) and McDonald (1981), which were based on skeletal morphology. However, the taxonomic status of some Late Pleistocene and Holocene *Bison* species and subspecies still remains to be resolved. An analysis by Cronin et al. (2013) indicates that the subspecific designations of *B. bison bison* and *B. bison athabasca* based on morphological distinctions are not supported by genetic data. Evolutionary relationships between Holocene “occidentalis” types and modern bison also need to be clarified (Wilson et al. 2008). This topic is addressed in more detail in the following section as it plays a role in the research goals of the thesis.

Bison Evolution and Taxonomy

Bison taxonomy in the 20th century was a chaotic subject. Early researchers based species designations largely on small morphological differences in horn core characteristics, unaware that horn cores tend to have a high degree of intraspecific variation, due in part to sexual dimorphism and ontogenetic change (McDonald 1981; Wilson 1978; Guthrie 1980). This led to numerous species being assigned with tenuous definitions, many of which have since been synonymized (McDonald 1981; Skinner and Kaisen 1947).

Bison were one of the few groups of megafauna to survive the Terminal Pleistocene extinction event in North America, but they did not survive unchanged. Beginning in the Late Pleistocene and continuing through the Holocene, bison have followed a trend of diminution, likely caused by changing climate (Hill et al. 2008; Lewis et al. 2010). Late Pleistocene bison were as much as 15-20% larger than modern day *Bison bison* (Hill et al. 2008).

The Beringian steppe bison, *Bison priscus*, was the first bison to enter the New World via the Bering Land Bridge between 195-135,000 years ago, ushering in the Rancholabrean Land Mammal Age (Froese et al. 2017). *Bison priscus* was larger than modern bison with long, curved horn cores (McDonald 1981). The species rapidly expanded and diversified across the continent, though some *B. priscus* persisted in Alaska until about 10,000 years ago (Figure 2.3) (Froese et al. 2017; Zazula et al. 2009). One branch of *B. priscus* which moved south into mid-latitude North America evolved into the largest of the Pleistocene long-horned bison, *B. latifrons*, by 120,000 years ago (Froese et al. 2017). DNA evidence indicates that bison populations above and below 60 degrees latitude were genetically distinct, likely due to geographic separation caused by the coalescence of North American ice sheets during the Last Glacial Maximum (Froese et al. 2017; Wilson et al. 2008).

Bison latifrons is the presumed ancestor of *B. antiquus*, a somewhat smaller and shorter horned bison, which is commonly found in Late Pleistocene and Early Holocene archaeological sites (Guthrie 1980; Kornfeld et al. 2010). The timing of the transition between the two is unclear (McDonald 1981). By roughly 5,000 years ago, *Bison antiquus* evolved into the smaller modern form *Bison bison*, which then split into two geographically separated subspecies: the Plains bison (*B. bison bison*) and the wood bison (*B. bison athabascaae*) (McDonald 1981).

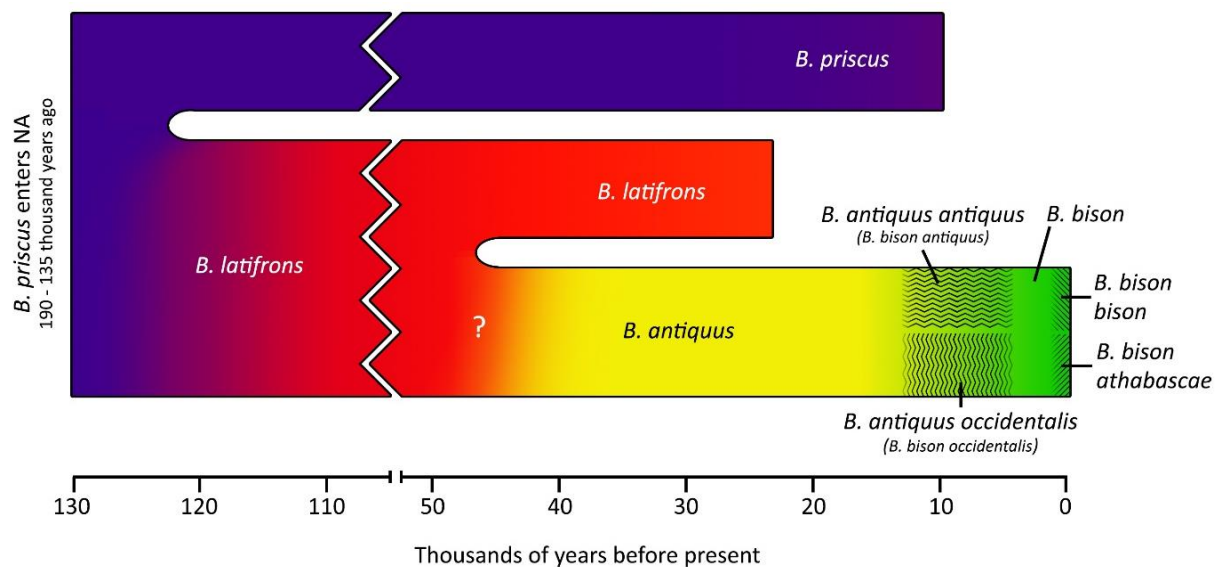


Figure 2.3. Bison evolution in North America during the Late Pleistocene and Holocene.

The evolutionary relationships between *B. antiquus*, *B. bison*, and a third variety of Holocene Plains bison, *B. occidentalis*, remain uncertain. *Bison occidentalis* was first described based on cranial characteristics of type material found in Alaska (Wilson et al. 2008). *Bison occidentalis* specimens have “narrow, flat frontals with upswept and backswept horn cores, their tips well behind the occipital plain”, while *B. antiquus* has “broad, arched frontals with downswept, laterally directed horn cores” (Wilson et al. 2008:830). The two forms probably

interbred, and the morphological and genetic differences are likely not enough to warrant designation as separate species (Wilson 1978; Wilson et al. 2008).

Many researchers refer to the “*occidentalis*”-type using subspecific designations, though not always with the same terminology. Wilson (1978) views “*occidentalis*” and “*antiquus*” as chronosubspecies of *B. bison*, referring to them as *B. bison antiquus* and *B. bison occidentalis*. Alternatively, McDonald (1981) recognizes “*occidentalis*” as a subspecies of *B. antiquus*. Under this scheme, *B. antiquus* evolved into two subspecies, *B. antiquus antiquus* and *B. antiquus occidentalis*, which diverged, then hybridized, before evolving into *B. bison* as the modern species.

Bison occidentalis was initially thought to be a northern form derived from the Alaskan steppe bison (*B. priscus*), whereas *Bison antiquus* evolved south of the ice sheet from *B. latifrons* (Wilson et al. 2008). However, mitochondrial DNA evidence now places the “*occidentalis*” morphotype within the southern clade (with *B. latifrons*, *B. antiquus*, and *B. bison*) as genetically distinct from northern forms. Because *B. occidentalis* was first described from an Alaskan type specimen, the name “*occidentalis*” may be inappropriate to apply to “*occidentalis*”-type bison on the Great Plains (Wilson et al. 2008), though it is still commonly in use (Kornfeld et al. 2010). For this project, I will follow the terminology used in McDonald (1981), which places “*occidentalis*” as a subspecies of *Bison antiquus*.

Bison populations in North America during the Holocene evolved gradually and likely interbred, making hard distinctions between species or subspecies somewhat arbitrary. The bison at the Licking Bison site have been hypothesized to be *B. antiquus occidentalis* due to the site’s temporal and geographic proximity to the Hawken Site (48CK303) in Wyoming, where the bison were identified as *B. bison occidentalis* (*B. antiquus occidentalis*) based on cranial morphology

(Fosha 2001; Frison et al. 1976). However, the Licking Bison Site is also close in age to what is generally considered the origin of modern *B. bison*, about 5,000 years ago. Because the specimens date to a period of transition, they may not show a clear affinity for any one group, but a mosaic of characters for each.

Bison ecology

Modern bison are frequently used as a model for interpreting the behaviors of earlier Holocene bison and their response to shifting environmental conditions (Kornfeld et al. 2010). However, modern *B. bison bison* populations are the result of a severe bottleneck event after they were nearly exterminated by European Americans in the late 19th century. Modern herds derive from only ~100 surviving individuals, and many modern bison also have some cattle genes from intentional cross breeding (Hedrick 2009). The lack of genetic diversity makes modern bison an imperfect comparison for earlier Holocene bison.

Bison herds today live in geographically restricted environments, and even free-roaming herds in large spaces like national parks are still managed to varying extents by way of culls and vaccinations (National Park Service 2019). The biological rhythms and preferences of modern bison, including tooth eruption schedules and breeding and birthing seasons, which are often integral to archaeological interpretations of bison kill sites, may not necessarily represent the variability seen in Holocene bison populations (Widga 2013). For example, Holocene bison exhibited a greater dietary breadth than living *B. bison* (Rivals et al. 2007; Widga 2006), which should be taken into account when assessing the response of Holocene bison to environmental change. Additionally, Widga's (2013) assessment of horn core morphology through the Early Holocene suggests that the large herds and strict social structure of modern bison did not develop until the Cody period.

The timing and synchrony of the birthing season can be affected by numerous factors including the physical condition of the mother and the abundance or absence of high-quality forage (Berger 1992; Gogan et al. 2005). Parturition times in *B. bison* herds inhabiting Yellowstone National Park have been linked to the beginning of growth of nutritious spring grasses, and onset of birthing season can vary based on area of the park and the florescence of spring grass (Gogan et al. 2005). Most calves are born in April and May, but some calves are usually born out of synch with the rest of the herd, potentially skewing the wear patterns visible on teeth from young individuals.

Walde (2006) offers a serious note of caution about the reliability and accuracy of the seasonality determination methods that rely on the assumption of a compact and reliable birthing period. Walde's review found that the birthing period in modern bison is not so tightly clustered as generally assumed, regularly lasting three to four months in addition to sometimes being variable from year to year. This could significantly undercut the accuracy of seasonality assessments, especially at a site with a small sample such as Licking Bison. Eruption and wear patterns for calves could show up to four months of variability in a single kill event, which could create significant uncertainty about the season of death and cultural interpretations of resource use (Walde 2006).

Research Locality

The Licking Bison Site (39HN570) is an Early Archaic period bison kill site located in Harding County, South Dakota. It was discovered in 1994 by a member of the South Dakota Archaeological Society on privately owned land (Fosha 2001). The site was excavated between 1995 and 2000 by the South Dakota State Archaeological Research Center (SARC) and teams of volunteers. The faunal collection from the excavations is curated by SARC in Rapid City, SD.

The site is located on an eroding stream terrace of Graves Creek (Figure 2.4), beneath approximately 1.5 m of Holocene alluvium (Fosha 2001). Geoarchaeological investigations by Albanese (1997) indicate a 2-3 meter-high buried escarpment on the paleosurface of the site, which was likely not large enough to have been used as a jump, but could have been used as part of a trap or corral. A small buried gully in the southeast portion of the excavation, possibly representing the old stream channel, may also have been used to help impede the bison (Fosha 2001).

Twenty-six square meters of the site were excavated, though much remains in place (Figure 2.5) (Fosha 2001). Excavation focused on areas of the site most susceptible to further erosion (Fosha 1995). The bonebed matrix consists of sandy alluvium, deposited in a floodplain under a low energy hydraulic regime. The deposit generally ranges between 7.5-10 cm thick, increasing up to 30cm in some areas, and it is thought to represent a single kill event (Figure 2.6) (Albanese 1997). Little post-depositional movement of bone was noted during excavation (Fosha personal communication cited in Albanese 1997:3). Most of the bone recovered from the sandy deposits is in good condition. However, some specimens in the gully area were too deteriorated to be collected, possibly due to higher clay content of the matrix within the gully (Fosha 2001).



Figure 2.4. Licking Bison excavation site (center) across Graves Creek. (Photo courtesy of Mike Fosha).

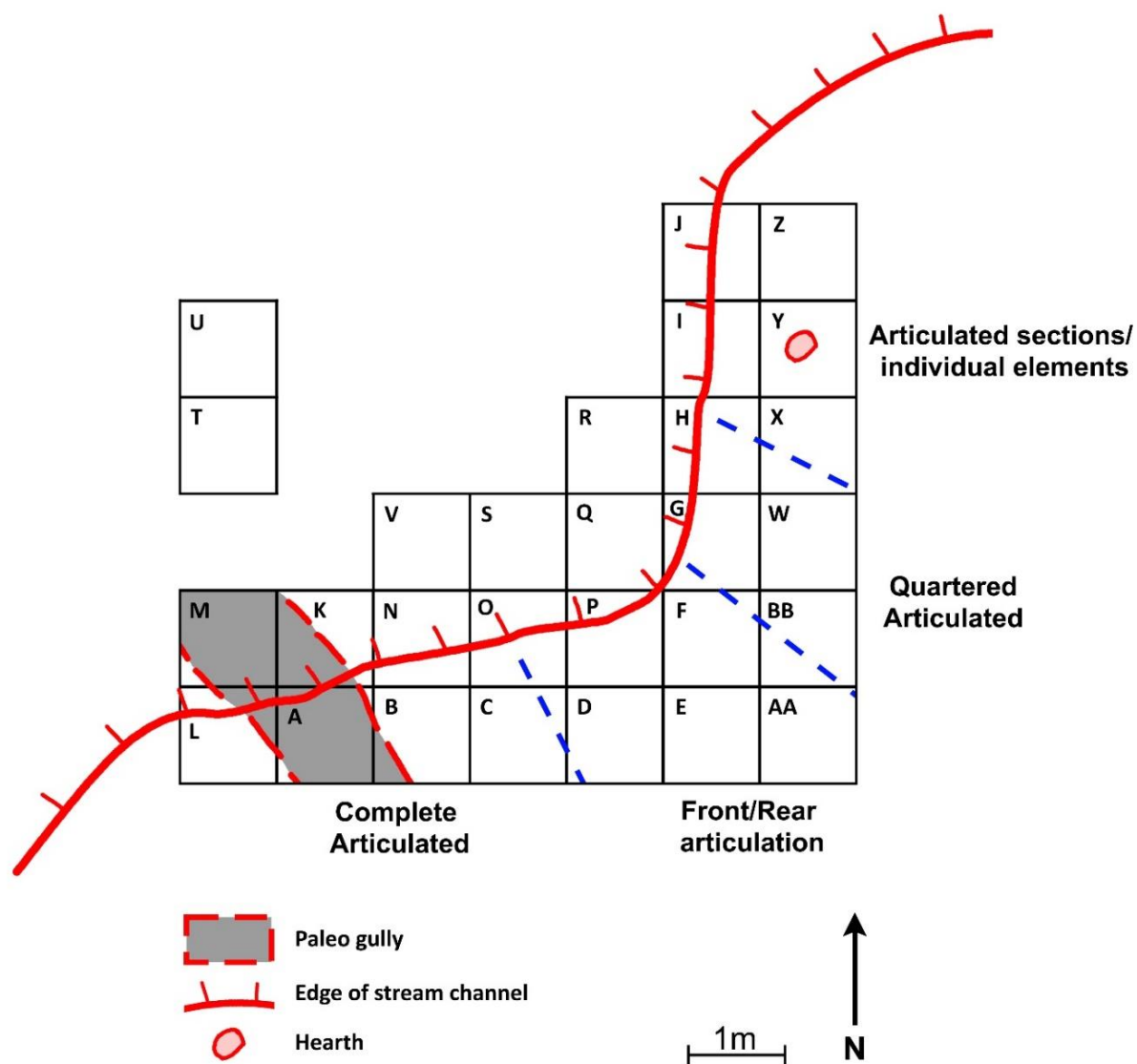


Figure 2.5. Excavated units of the Licking Bison site (39HN570). Image modified from Fosha (2001:Figure 3).



Figure 2.6. Cross-section of the Licking Bison bonebed (Photo courtesy of Mike Fosha).

Widga (2007) previously identified at least 8 individual bison in the collection, including four females and one male. Initial analysis of the bison dentitions suggested the animals were killed in the fall (Widga, unpublished data cited in Widga 2007:65). The species of bison present was hypothesized to be *B. bison occidentalis* (*B. antiquus occidentalis*) due to temporal and geographic proximity the Hawken site (Fosha 2001).

The degree of skeletal articulation varies throughout the excavated area, suggesting differential animal processing activities across the site (Fosha 2001). Moving east across the excavation, the animals become progressively more disarticulated, from full skeletons on the west end, through half articulated animals, quartered animals, to small articulated sections and

individual elements at the east end of the site (Fosha 2001). A small hearth was found with burned bone near the disarticulated bones on the eastern portion of the excavation (Fosha 2001). An unusual group of bison skulls arranged in a circle may represent ritualized activity at the site (Fosha 1996).

Nine side-notched lanceolate points with straight to concave bases were recovered during excavation, all made of local materials (Fosha 2001). Lithic artifacts from Licking Bison are similar to those found at the Hawken Site, though some variation in base morphology is present (Kornfeld et al. 2010). Widga (2007) suggests the Licking Bison points resemble the Logan Creek complex from the Central Plains. One projectile point was found stuck between two vertebrae, which likely would have severed the animal's spinal cord (Fosha 2001).

Three radiocarbon dates were obtained from the site, placing the kill event in the late Early Archaic. The most recently obtained date, a bone collagen sample from a left petrosal (Cat. # 1307), produced an AMS date of 5570 ± 30 ^{14}C yr BP (6406-6301 cal yr BP) (Beta-527954; See Appendix III). An earlier directly dated bone sample produced a date of 5870 ± 70 ^{14}C yr BP (6730-6410 cal yr BP) (LE-5478) (Fosha 2001; Albanese 1997). A third radiocarbon date on charcoal recovered from the hearth places the site at 5630 ± 40 ^{14}C yr BP (Beta-195191) (Kornfeld et al. 2010). The dates correspond with the warm and dry Altithermal Period (Albanese 1997) and the period of severe aridity identified by Yansa (2007) lasting from 6,000 to 5,000 ^{14}C yr BP.

Chapter 3: Methods

Research Design

Warming climate during the Holocene caused shifts in vegetation, surface water, and distribution and numbers of bison and other animals, all of which could have drastically affected human populations in terms of seasonal movements, population density, and diet (Reeves 1973; Meltzer 1999; Kornfeld et al. 2010). The overarching goal of this research is to determine how the Licking Bison site relates to the Altithermal climate stress hypothesis, which suggests that arid conditions on the Northern Plains during the Early Archaic resulted in depleted graze and reduced bison numbers, causing human populations to expand their diet breadth and seek refuge in cooler, higher elevation areas (Reeves 1973; Kornfeld et al. 2010; Sheehan 1995; Frison et al. 1976). Licking Bison represents one of only a few data points known for this time. This research project will establish a base upon which further research can build by describing the herd demographics and attempting to identify the species affinity of the bison. To accomplish this, several questions will be evaluated:

1. What is the Number of Individual Specimens (NISP) in the assemblage?
2. What was the herd composition of the bison present in the assemblage?
 - A. What is the minimum number of individual (MNI) bison represented in the assemblage?
 - B. What is the age distribution for the animals in the assemblage?
 - C. What are the ratios of males to females to juveniles in the assemblage?
3. What species of bison is represented at the site?
4. What time of year did the bison kill event take place?

Data Collection and Analysis

The Licking Bison collection is cataloged under the Accession # 95-0102. Each specimen within the faunal collection of the Licking Bison Site was assessed individually. Specimens were identified to skeletal element using comparative collections from the South Dakota State Archaeological Research Center (SARC) in Rapid City, SD and the Mammoth Site of Hot Springs, SD, and published references including Olsen (1960) and Balkwill and Cumbaa (1992). Stylohyoids were identified and sided using Lubniski and Hale (2018).

Characters recorded for each specimen include: catalog numbers, locational information, taxa, element, portion (ex. proximal, distal, complete), side (left, right, or axial), and level of epiphyseal fusion. The degree of epiphyseal fusion was recorded for applicable specimens as unfused (complete separation of epiphysis and the rest of the element), partial (partially fused, but with a noticeable gap or fusion line between the epiphysis and the rest of the element), or fused (complete fusion with little or no visible fusion line). Completeness for longbones was recorded as proximal, distal, shaft, or by anatomical description, ex. thoracic spine, or centrum for a partial thoracic vertebra.

The counts for each element, including the side, age, and portion of the bone were used to calculate the minimum number of individuals (MNI) represented in the assemblage. Counts represent only elements physically present in the collection at the time of analysis. Bones that were removed for testing or were not collected from the field due to their deteriorated condition are not included in MNI.

The number of identified specimens (NISP) was counted by assessing each bone in the assemblage. Fragments that occurred as the result of curation or other post-excavation processes will not be counted as separate specimens. If records indicate that a bone was mapped, numbered

and removed from the ground as one unit, it will be counted as an NISP of one, even if it has since broken into several pieces.

Age estimates by epiphyseal fusion follow Bement and Basmajian's (1996) study of fusion in *B. antiquus* from the Cooper site in Oklahoma. An early, often cited study of fusion by Duffield (1973) was based largely on previous studies by Koch, who looked at fusion in the European bison, *Bison bonasus*. There are several differences in the fusion schedule of Duffield and from Bement and Basmajian's data. Bement and Basmajian was chosen as the primary source for comparison, because *B. antiquus* is an ancestor to later Holocene plains bison, and is more closely related than the European species. Duffield's data were only used to assess the age of the vertebra, which was not addressed by Bement and Basmajian.

Identification of season of death for bison relies on the predictable nature of tooth eruption and wear to accurately assign an age at death. Frison and Reher (1970) pioneered a method to calibrate fossil bison eruption and wear patterns with those of modern comparative specimens, allowing for more precise age identification for individual bison within a large assemblage. Eruption can be used as a reliable age marker up until a bison is about five years old. After that, dental age groups are measured by the amount of dental attrition, which is somewhat less accurate (Kornfeld et al. 2010; Todd and Hofman 1987).

Bison are born during a calving period, which for modern bison (used as a comparison for earlier Holocene bison) peaks from the end of April to early May (Kornfeld et al. 2010). Calves born in the same year share similar eruption and wear patterns. This allows animals within a herd to be categorized in dental age groups spaced one year apart, representing each year's calving season (Frison and Reher 1970). Season of death is then approximated by comparing the age in months of juvenile animals to the April-May calving season.

Age at death for the Licking Bison assemblage was measured for each tooththrow that was sufficiently intact. Dental age estimates from many larger sites (Todd and Hofman 1987) focus on just the mandibular dentition, but due to the small sample size of the Licking Bison material, both maxillary and mandibular dentitions were evaluated. When paired mandibles and maxillae were present from the same individual, both left and right sides were measured for consistency.

Many of the tooththrows recovered from the Licking Bison site had significantly damaged or deteriorated alveolar bone. In several cases, the teeth were all that remained and the tooththrow had to be temporarily reconstructed to assess eruption and wear patterns. In several instances, teeth from multiple tooththrows and likely multiple individuals were bagged and mapped in the field under the same number. These teeth were sorted and identified in the lab (as left m1, right M2, etc.), and then tooththrows were reconstructed by matching the wear facets from adjacent teeth on the anterior and posterior surfaces of each tooth. Tooththrows were reconstructed only in cases where wear facets could be matched with confidence. Cases of ambiguous matches were excluded from analysis, as were single isolated specimens.

Identification of dental ages was accomplished through comparisons of published data and illustrations from numerous sources, including Frison et al. (1976), Frison (1978; 1982), Frison and Reher (1970), Hill (2001; 2008), Niven and Hill (1998), Reher (1974), Reher and Frison (1980), Todd (1987a), Todd and Hofman (1987), Todd et al. (1996), Widga (2004; 2007) and Wilson (1974; 1980).

All specimens of crania, humeri, radii, metacarpals, femora, tibiae, metatarsals, astragali, and calcanei in the Licking Bison assemblage, which are complete enough to measure, were evaluated for species and sex characteristics. Measurements were taken with a Fowler Electronic Caliper (Model No. 54-101-300-1), and osteometric board.

Species identification in bison is largely based on cranial measurements, including horn core characteristics. The measurements for Licking Bison skulls follow McDonald (1981), and Skinner and Kaisen (1947). Measurements were compared to available published datasets for “*antiquus*”, “*occidentalis*”, and *B. bison* (McDonald 1981; Skinner and Kaisen 1947; Frison et al. 1976), to determine which species the Licking Bison specimens most closely resemble. Limb measurements for species identification were taken after McDonald (1981, Figures 9 and 10) and were compared to ranges for several species reported by McDonald.

Volume measurements from astragali have been used as a proxy of individual animal size to track bison diminution throughout the Holocene (Zeimens and Zeimens 1974). Astragali often preserve well within archaeological samples because they are made of dense bone and are not as likely to be removed from the site during processing (Morlan 1991). Volumes of the Licking Bison astragali were compared to published measurements from other bison kill sites from the northern Plains ranging from Paleoindian to Late Prehistoric in age, including Casper, Agate Basin, Olsen-Chubbuck, Finley, Hawken, Vore, and Glenrock (Zeimens and Zeimens 1974; Zeimens 1982).

Volume measurements from previous studies (Zeimens and Zeimens 1974; Zeimens 1982) were produced by boiling the bones in paraffin and measuring volume by water displacement in a graduated cylinder. The paraffin method permanently alters the specimens, limiting future research potential, especially for chemical analyses. For this study, the astragali were digitally scanned in three dimensions to calculate volume, providing an accurate reading in a noninvasive way, preserving future research potential of the specimens. The drawback to this method, is that at least one complete astragalus had to be excluded from analysis due to expanding cracks which would have artificially increased the volume calculated from a surface

scan, due to the scanner's limited ability to scan deep undercuts. A second astragalus with more minor expanding cracks was included, see Chapter 6.

Complete astragali were scanned using an Artec Space Spider 3D scanner with up to 0.05mm 3D accuracy, and 0.1mm 3D resolution (Artec3D 2019). Scans were processed using Artec Studio 13 Professional software and volume measurements were calculated in MeshLab 2016.12. Scans were able to pick up minute surface features including root etching channels (Figure 3.1).

Skulls are the most reliable way to determine the sex of a bison skeleton because they show distinct morphological differences between males and females (McDonald 1981). In the absence of skulls, the overall size difference in certain elements can be used to distinguish between males and females, as adult males are consistently larger and more robust than adult females (Olson 2005). Many methods of sexing the bones rely on bivariate plots of limb or skull measurements, where mature males and females tend to fall into two separate clusters (Bedord 1974; Todd 1986; Todd 1987a).

Juvenile bones must be excluded from the sample, because young males often fall within the measurements of adult females. The small sample size from the Licking Bison assemblage necessitated that several sexually dimorphic elements were targeted for analysis including metapodials, humeri, radii, femora, and tibiae (Todd 1987b). Metacarpal and metatarsal measurements follow Bedord (1974), who reports measurements of both mature and immature individuals from several Northern Plains kill sites from Paleoindian to Late Prehistoric times (Casper, Olsen-Chubbuck, Finley, Hawken, Ruby, and Vore).

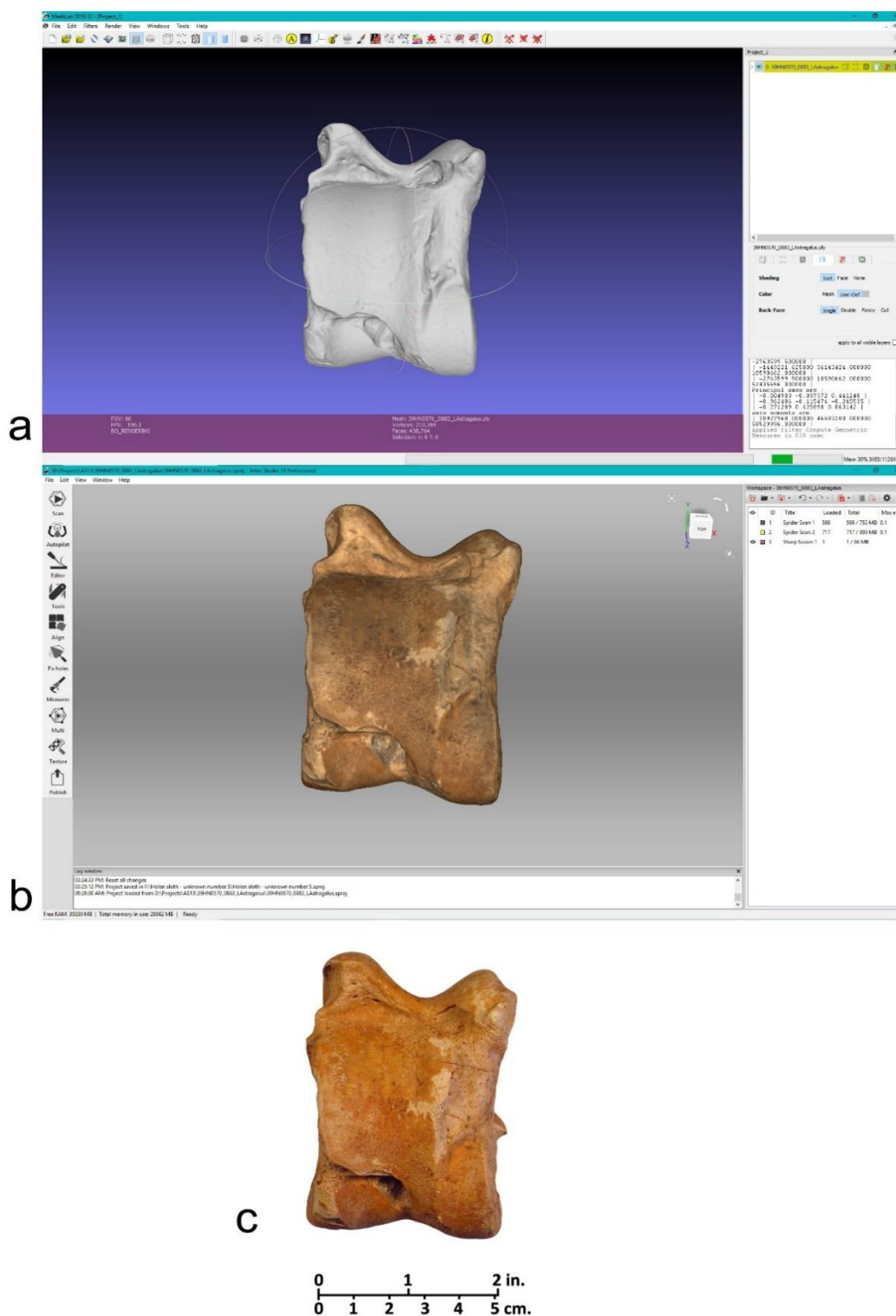


Figure 3.1. Astragalus 0883; a) scan of astragalus in Meshlab; b) scan of astragalus in Artec with overlaid color data; c) photograph of original specimen.

Data were collected from December 2018-March 2019 at SARC and at the Mammoth Site of Hot Springs, SD, and recorded in a Microsoft Excel spreadsheet. Figures 3.2-3.16 in the following section show visual depictions of the skeletal measurements used in this study.

Measurements

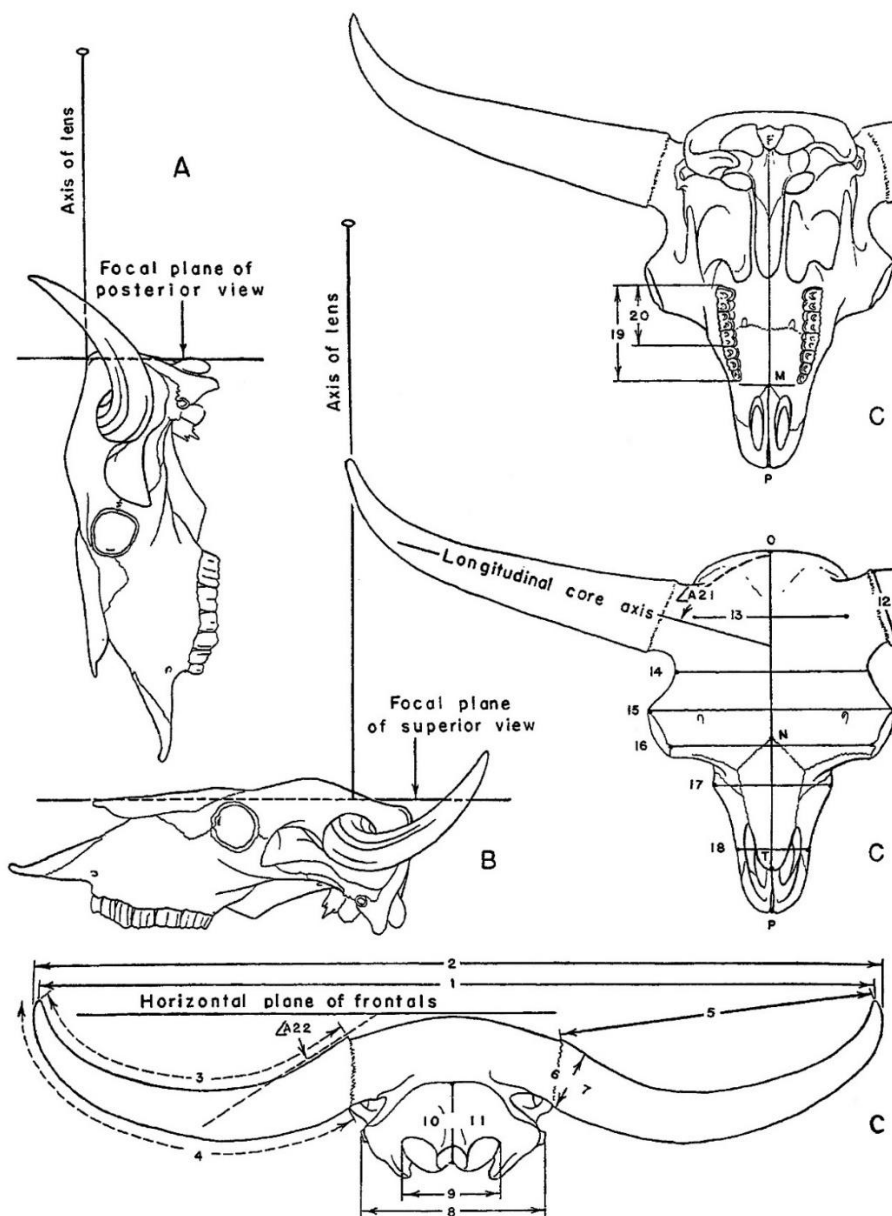


Figure 3.2. Skull measurements. Reproduced from Skinner and Kaisen (1947:Figure 1) with permission from the American Museum of Natural History.

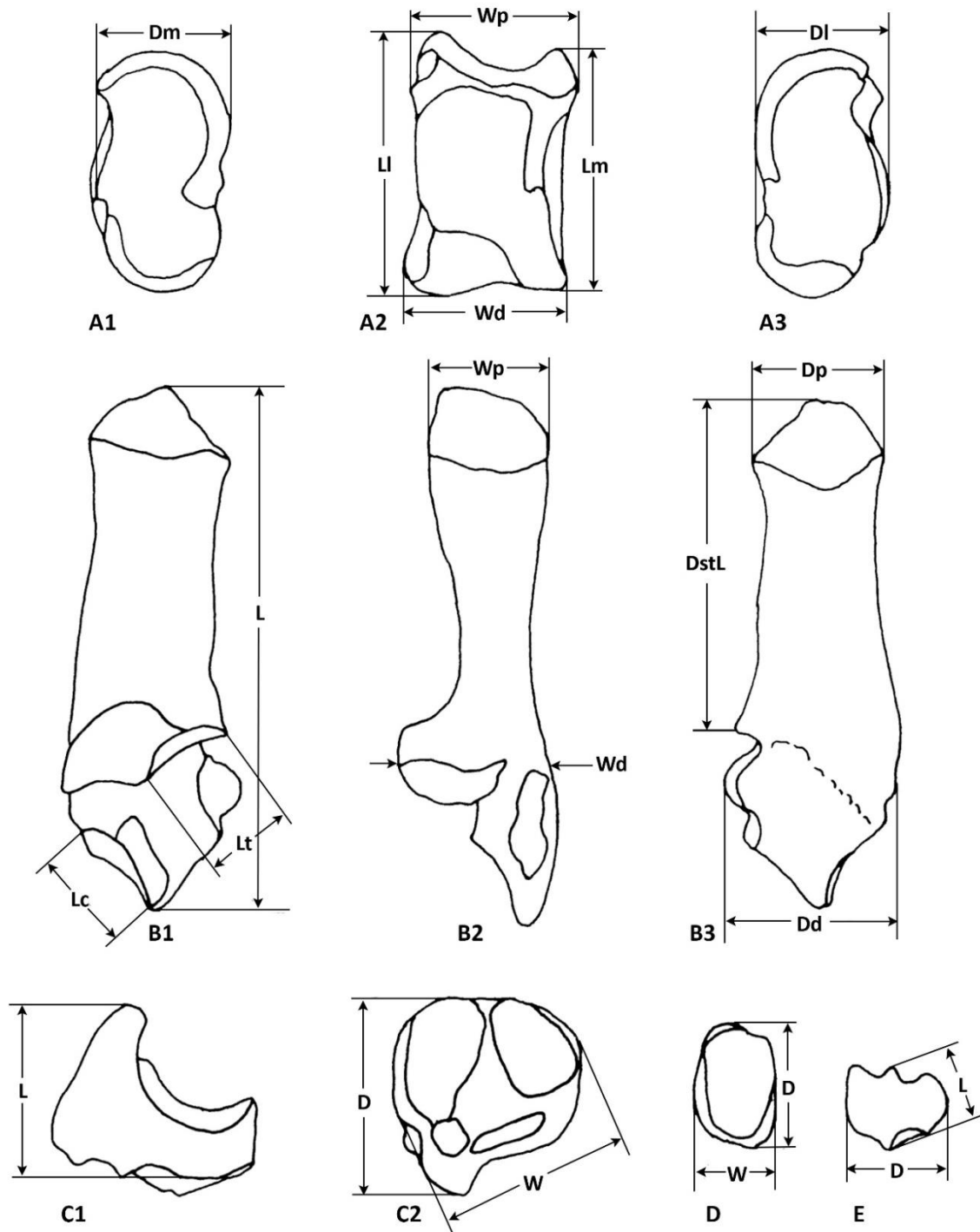


Figure 3.3. Tarsal measurements modified from Morlan (1991:Figure 5). Bison left tarsal bones. A) astragalus (1, medial view; 2, posterior view, 3, lateral view); B) calcaneus (1, medial view, 2, anterior view; 3, lateral view); C) tarsal C+4 (1, medial view; 2, distal view); D) tarsal 2+3 (distal view); E) lateral malleolus (medial view). Descriptions of measurements found in Morlan (1991). Additional calcaneus measurement (DstL) from Martin et al. 2018.

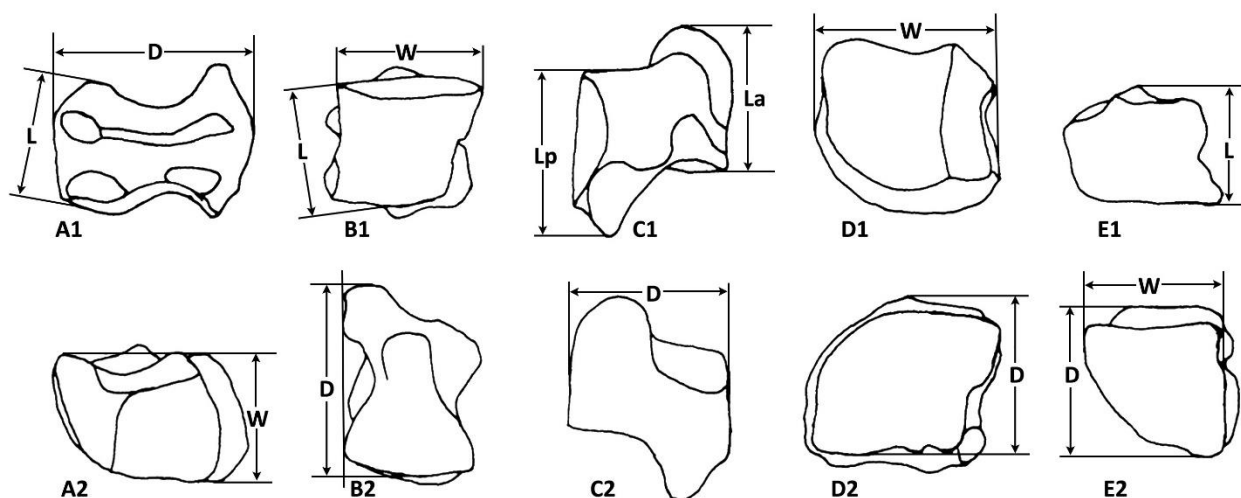


Figure 3.4. Carpal measurements modified from Morlan (1991:Figure 2). Bison left carpal bones; A) radial carpal (1, medial view, 2, distal view); B) intermediate carpal (1, anterior view, 2, proximal view); C) ulnar carpal (1, lateral view; 2, medial view); D) carpal 2 + 3(1, proximal view; 2, distal view); E) carpal 4 (1, anterior view, 2, distal view). Descriptions of measurements found in Morlan (1991).

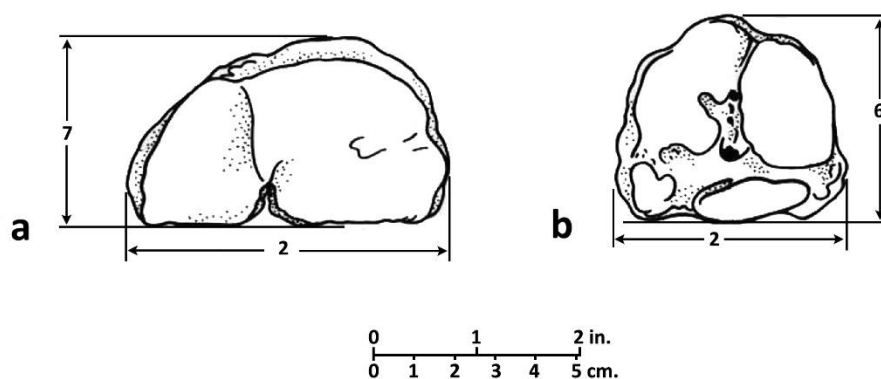


Figure 3.5. Measurements for proximal ends of metapodials; a) left metacarpal, dorsal view; b) right metatarsal, dorsal view. Descriptions of measurements found in Bedord (1974). Image reproduced and modified from Bedord (1974:Figure 6.2) with permission from Eliot Werner Publications, LLC.

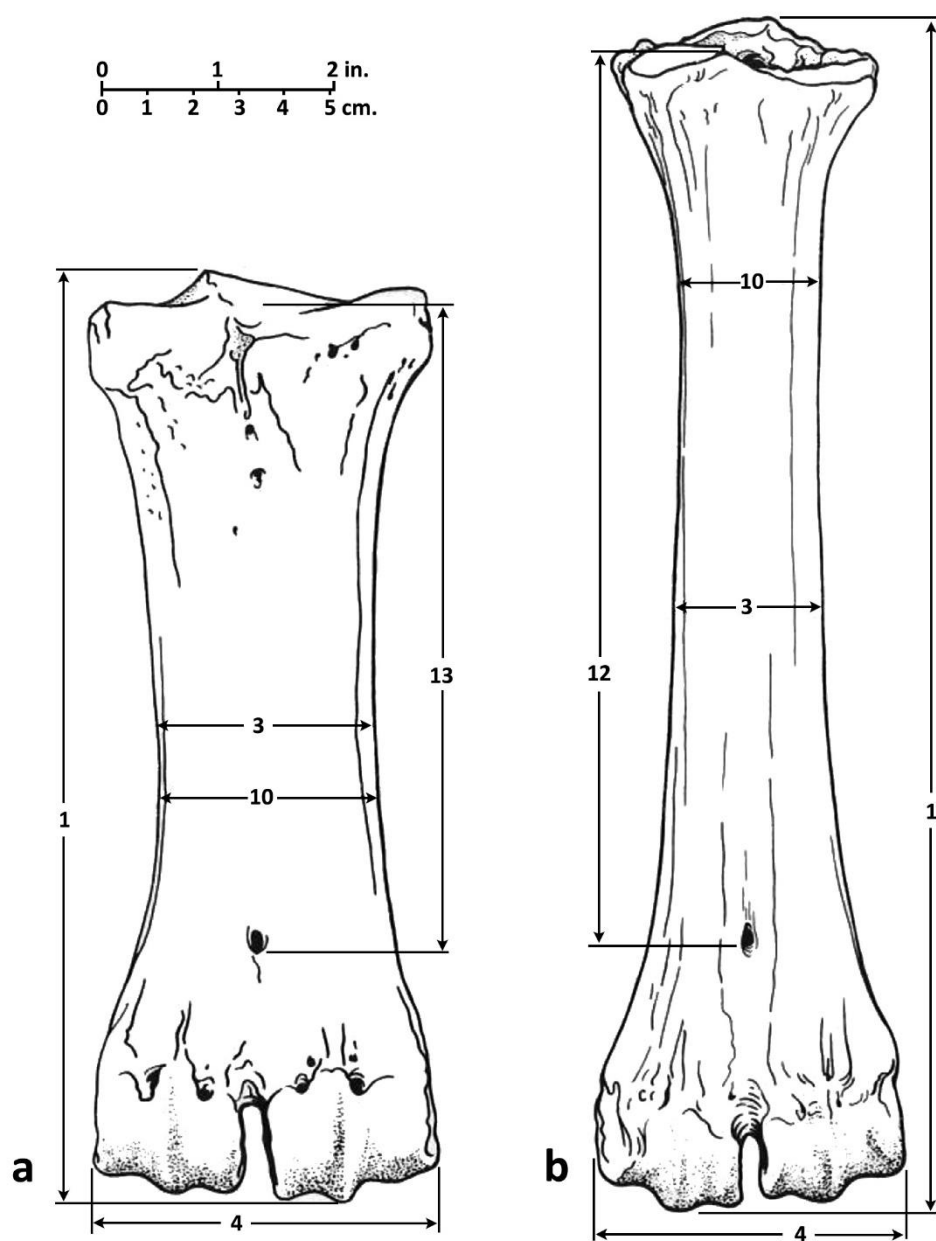


Figure 3.6. Measurements for metapodials; a) left metacarpal, posterior view; b) right metatarsal, anterior view. Descriptions of measurements found in Bedord (1974). Image reproduced and modified from Bedord (1974:Figure 6.1) with permission from Eliot Werner Publications, LLC.

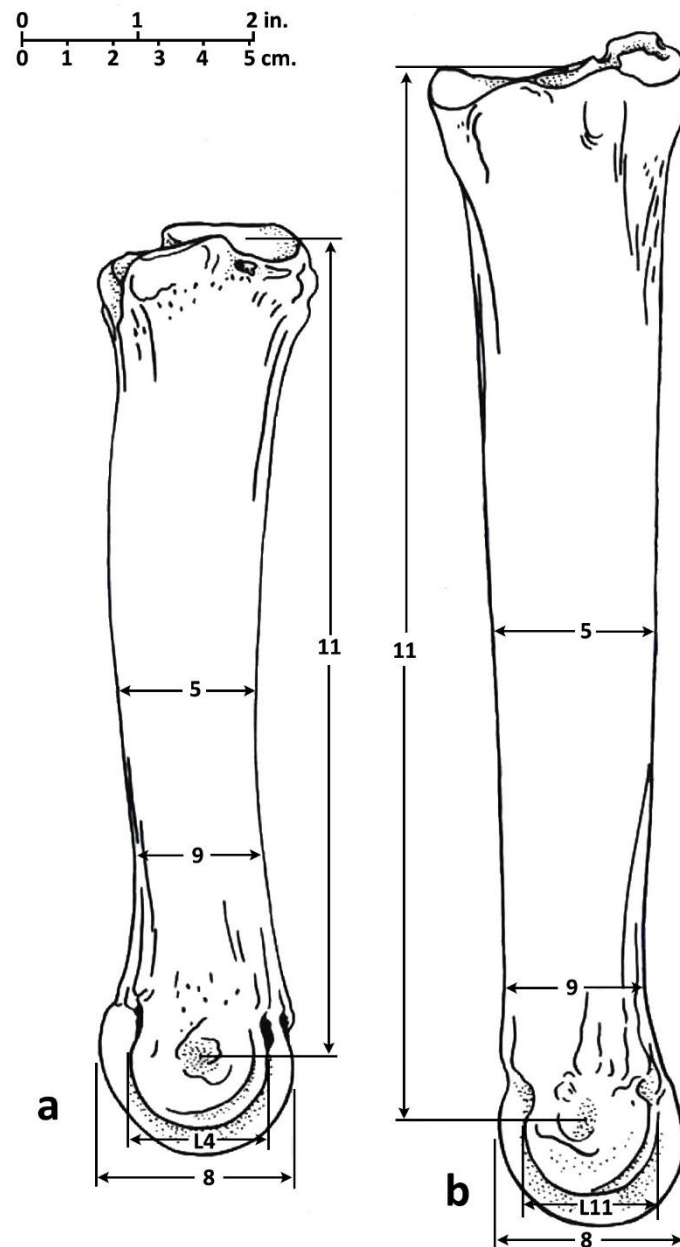


Figure 3.7. Measurements for metapodials; a) left metacarpal, medial view, and b) right metatarsal, medial view. Descriptions of measurements found in Bedord (1974); additional measurements (L4 and L11) after Lewis et al. (2005). Image reproduced and modified from Bedord (1974:Figure 6.3) with permission from Eliot Werner Publications, LLC.

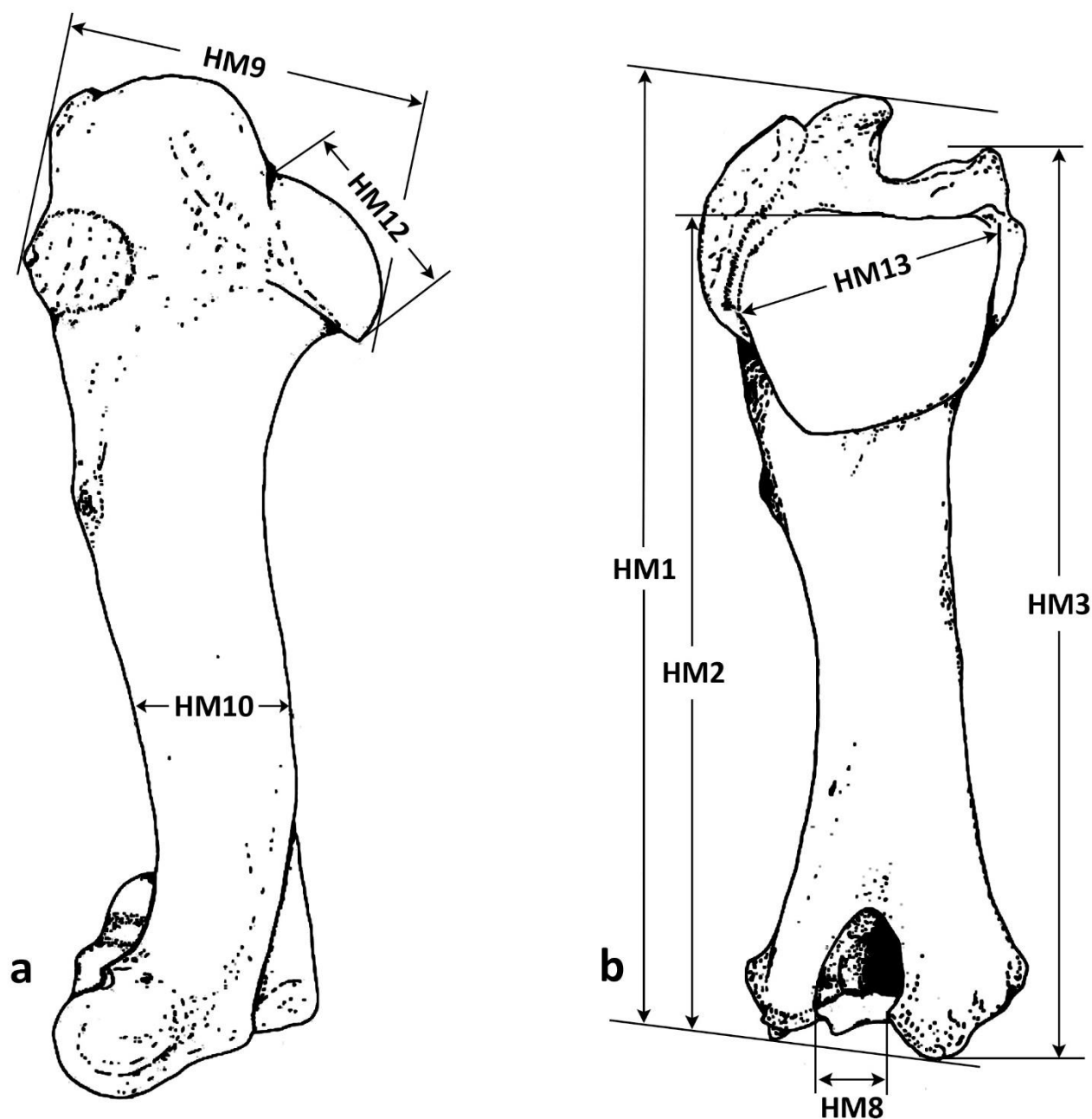


Figure 3.8. Measurements for humeri; a) left humerus, lateral view; b) left humerus, posterior view. Descriptions of measurements found in Todd (1987b). Image modified from Todd (1987b:Figure A1.1); reproduced with permission from Elsevier.

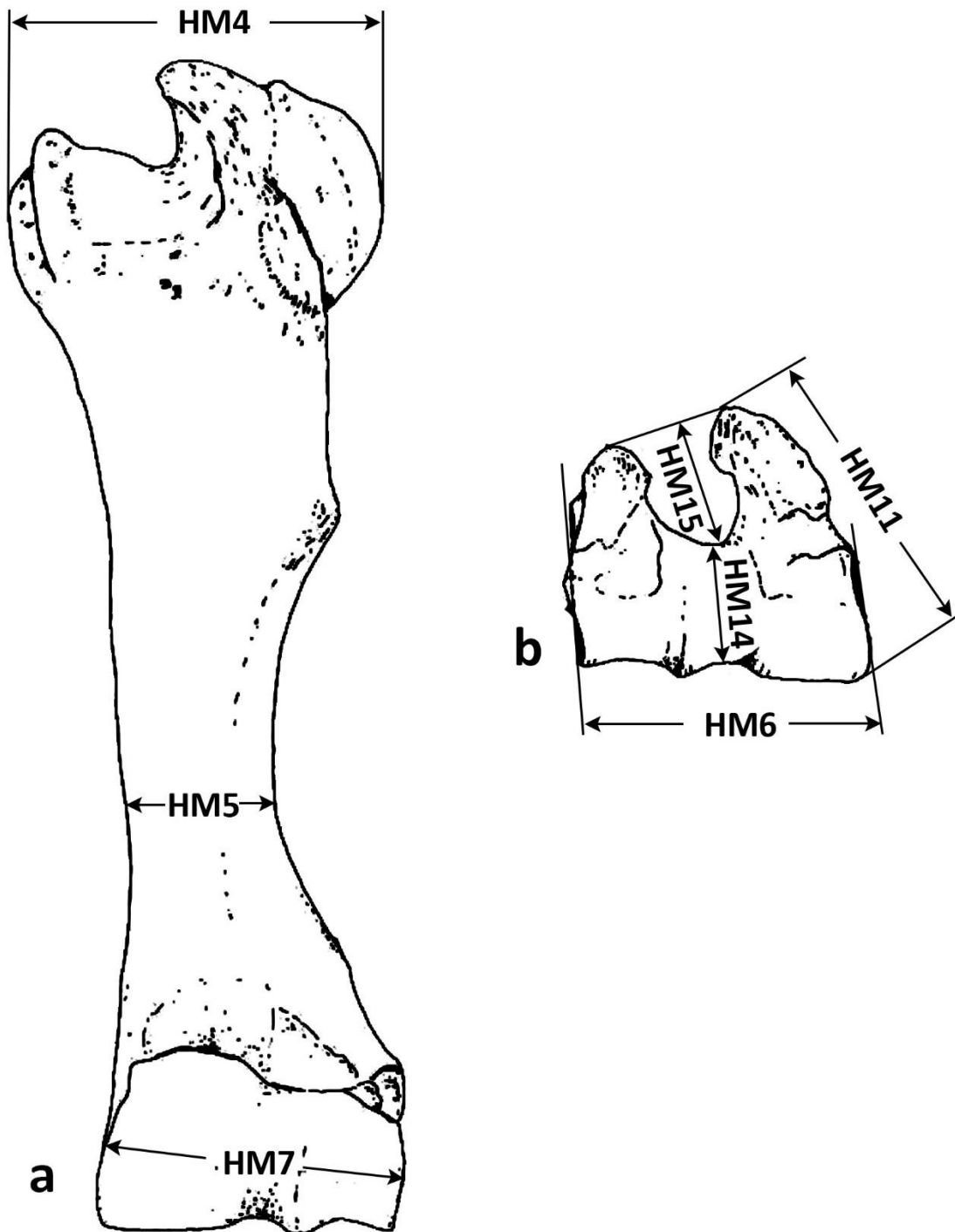


Figure 3.9. Measurements for humeri; a) left humerus, anterior view; b) left humerus, distal view. Descriptions of measurements found in Todd (1987b). Image modified from Todd (1987b:Figure A1.2); reproduced with permission from Elsevier.

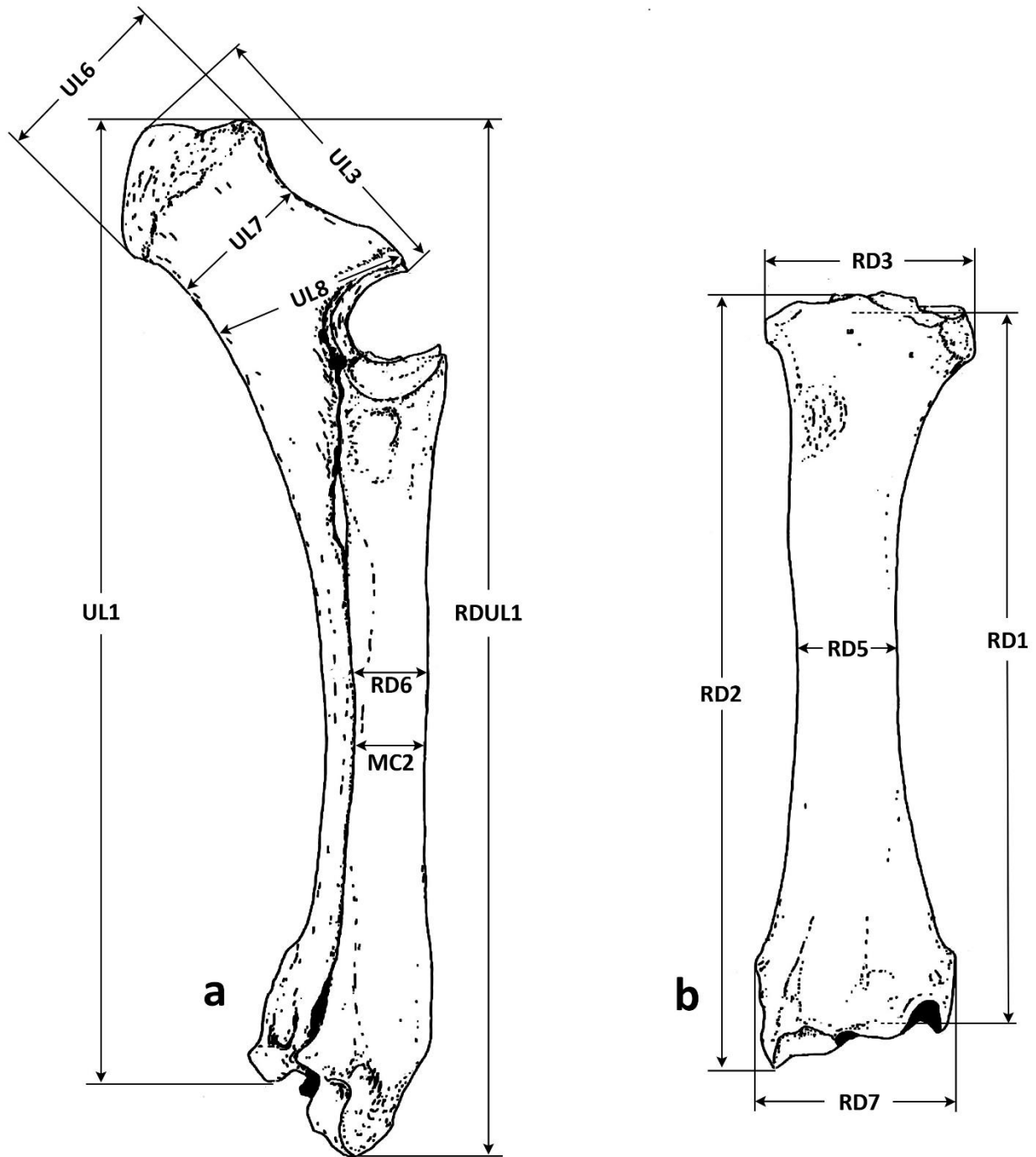


Figure 3.10. Measurements for radii and ulnae; a) left radius and ulna, medial view; b) left radius, anterior view. Description of measurements found in Todd (1987b) and McDonald (1981). Image modified from Todd (1987b:Figure A1.3); reproduced with permission from Elsevier.

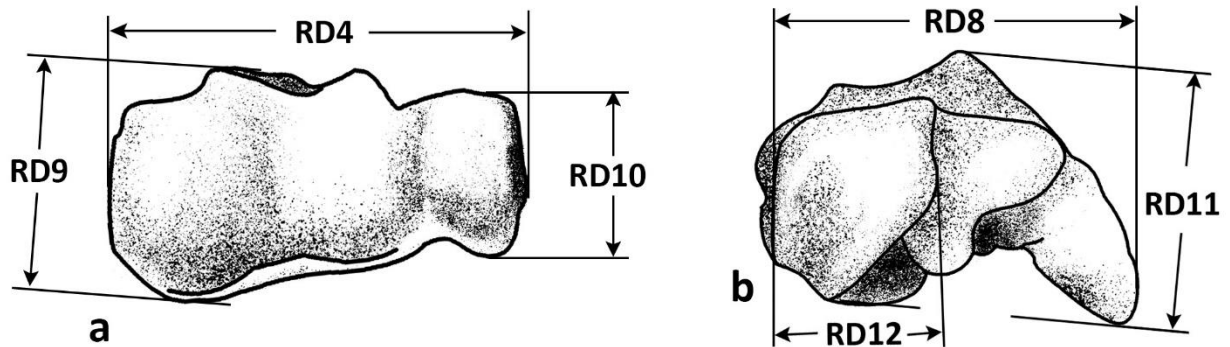


Figure 3.11. Measurements for radii: a) left radius, dorsal view and b) left radius, ventral view. Descriptions of measurements found in Todd (1987b).

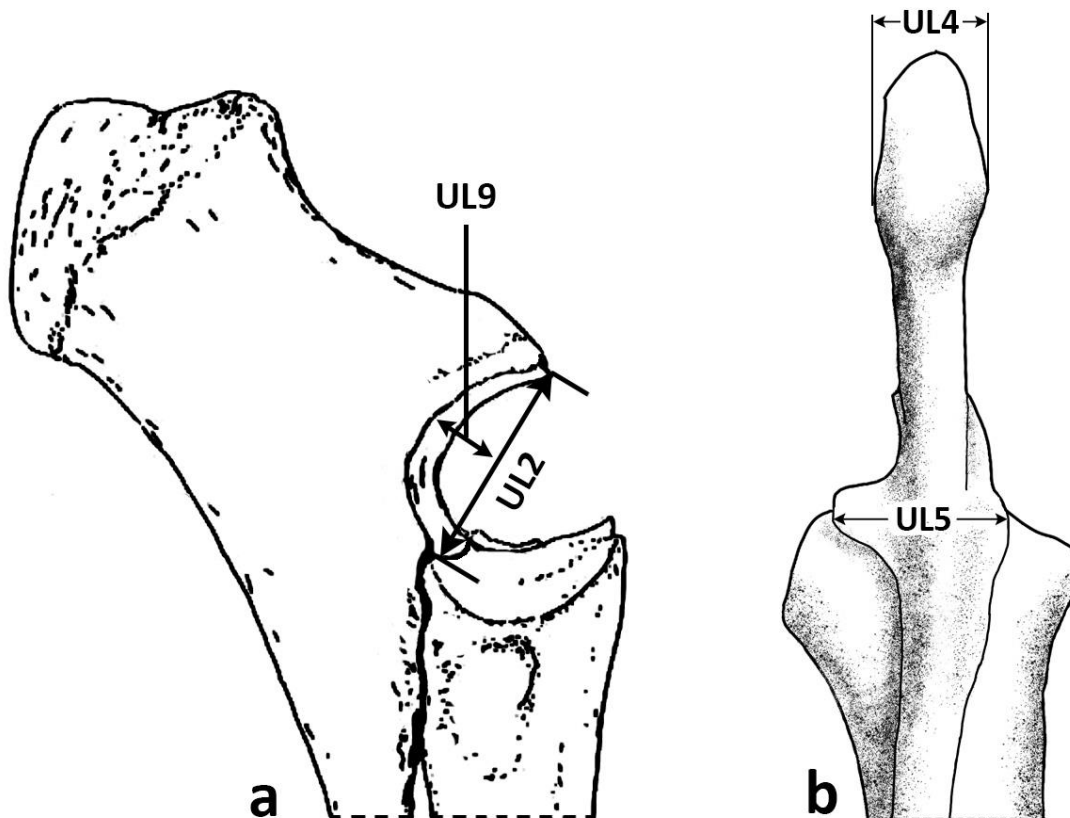


Figure 3.12. Ulna measurements; a) proximal left ulna, medial view; b) proximal left ulna, posterior view; measurement descriptions found in Todd (1987b). Figure 2.12a modified from Todd (1987b:Figure A1.3); reproduced with permission from Elsevier.

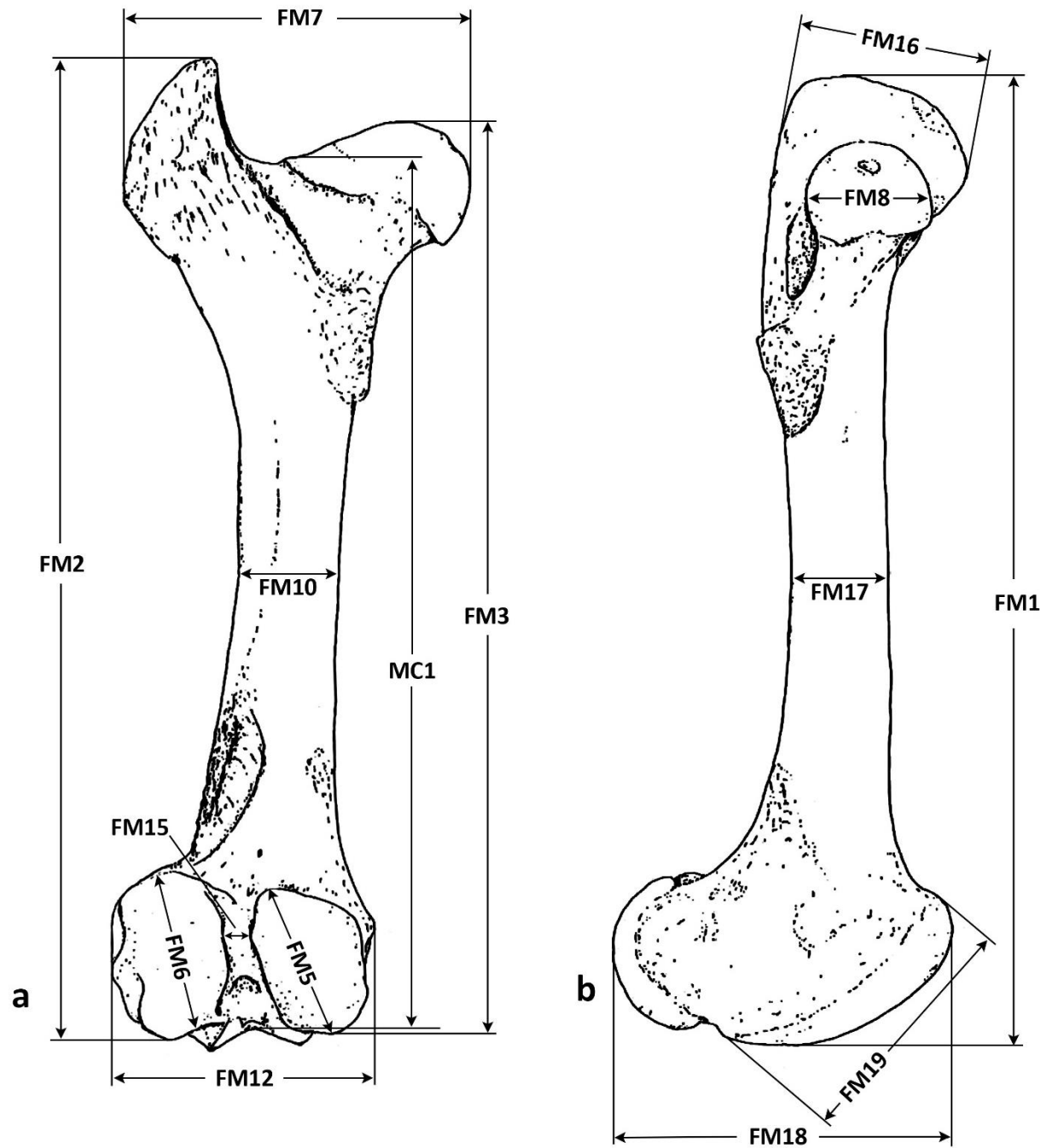


Figure 3.13. Femur measurements; a) left femur, posterior view; b) left femur, medial view. Image modified from Todd (1987b:Figure A1.4); reproduced with permission from Elsevier.

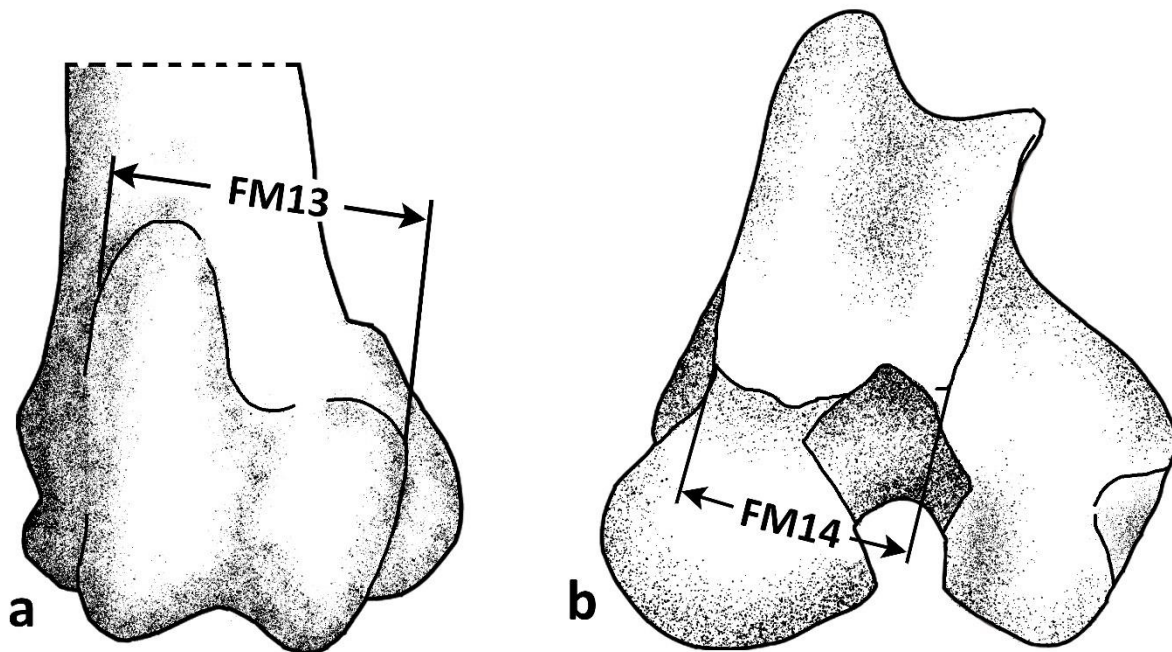


Figure 3.14. Distal femur measurements; a) left femur, anterior view; b) left femur, ventral view. Description of measurements found in Todd (1987b).

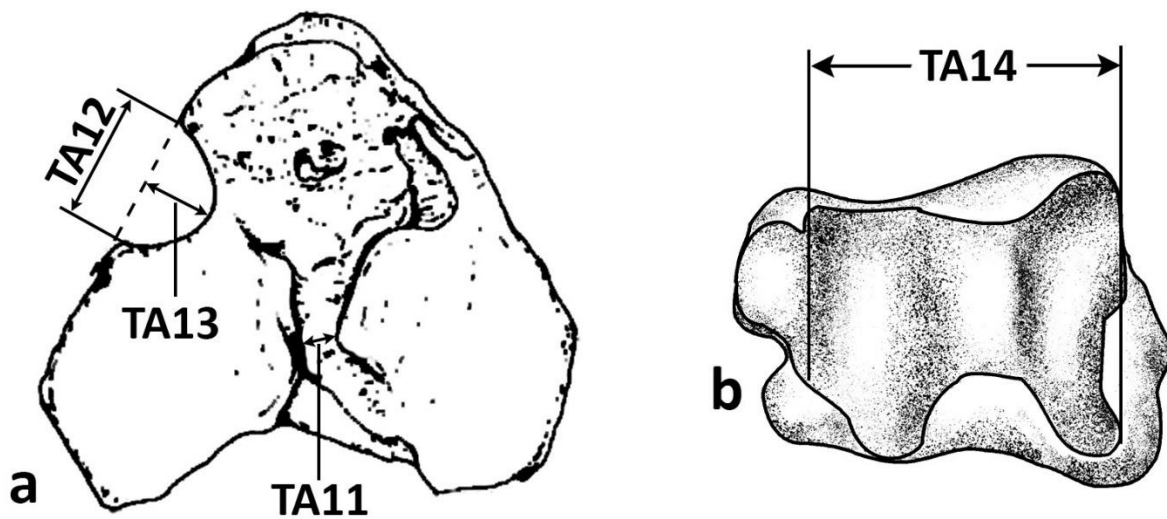


Figure 3.15. Tibia Measurements; a) left tibia, dorsal view; b) left tibia, ventral view. Description of measurements found in (Todd 1987b). Figure 2.15a modified from Todd (1987b:Figure A1.6); reproduced with permission from Elsevier.

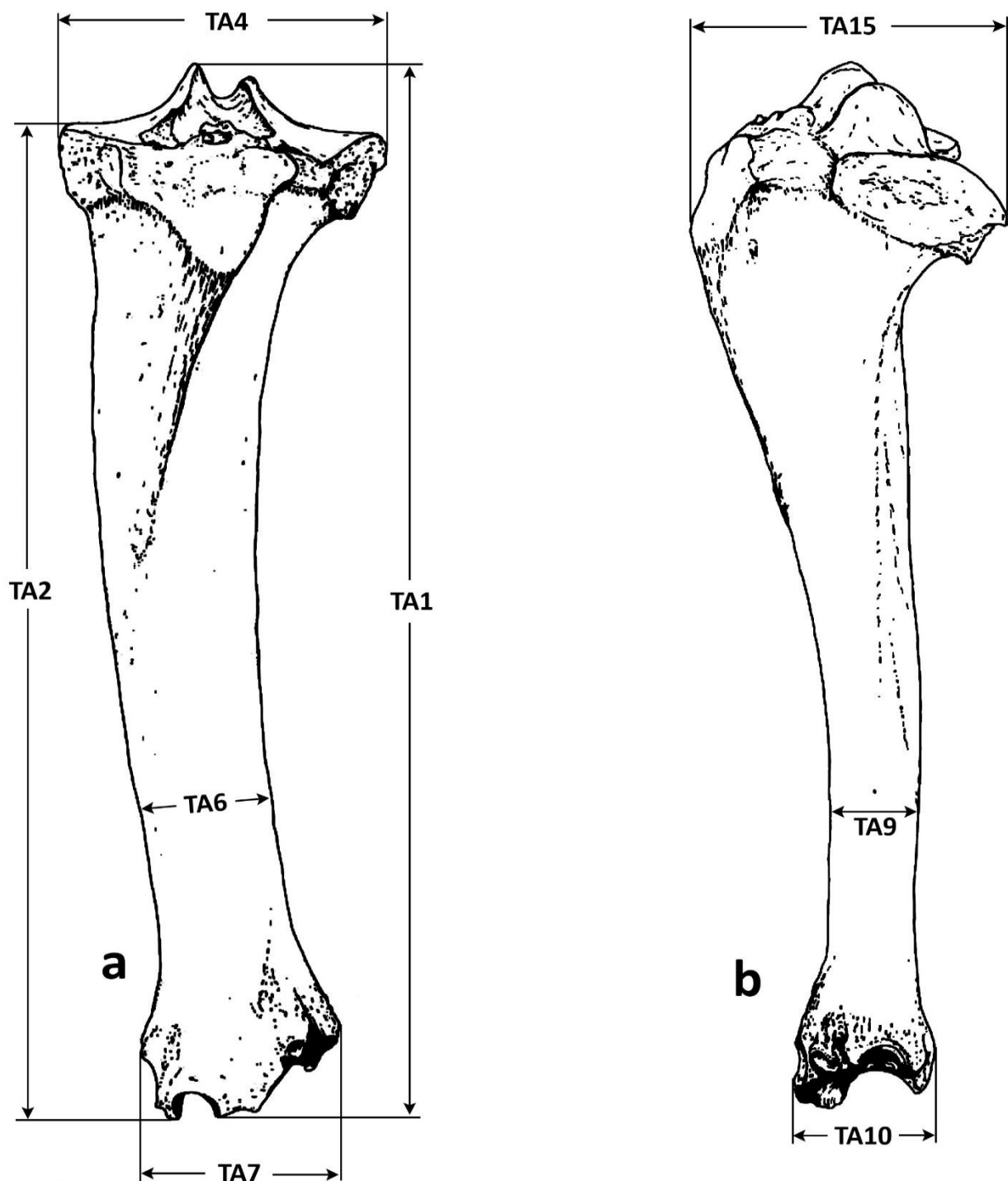


Figure 3.16. Tibia Measurements; a) left tibia, anterior view, b) left tibia, lateral view. Descriptions of measurements found in Todd (1987b). Image modified from Todd (1987b:Figure A1.5); reproduced with permission from Elsevier.

Chapter 4: A Brief Description of Taphonomy and Preservation

A systematic study of taphonomy of the Licking Bison site was beyond the scope of the current project. The following brief description of taphonomic and preservational factors affecting the assemblage is based on unquantified observations.

The level of skeletal articulation is patterned across the site. Specimens in the southwest corner of the site were more highly articulated and became progressively less articulated when moving towards the northeast corner of the site (Fosha 2001). This patterning is likely a result of the butchering process and not due to fluvial action as the site was covered with sandy alluvium in a low-energy depositional environment (Albanese 1997).

Condition of the bone is variable across the site. Specimens recovered from the paleochannel running through the southwest portion of the excavated area of the site (Units A, L, etc.) were poorly preserved (Figure 4.1). The soils in the channel were more clay-rich than the rest of the site, and many bones were so degraded that they were unable to be recovered (Mike Fosha, personal communication 2018). Bones excavated from units set deeper into the hillside were better preserved (Figure 4.2).

Specimens from units within the paleochannel have also suffered from a greater degree of degradation since excavation. Many bones from these units are dry and exhibit fragmentation, crumbling, and surface exfoliation which occurred post-excavation. Some specimens are difficult to identify to element due to fragmentation. The surface exfoliation may preclude future analysis of certain taphonomic factors including root etching, cut marks, carnivore or rodent marks, and other cultural modification.



Figure 4.1. Excavation photographs showing the decomposed, friable nature of the bone in the paleogully, Unit M (top), and Unit A (bottom). Photos courtesy of Mike Fosha



Figure 4.2. Excavation photograph of Unit AA showing the condition of bone in the southeast part of the site. Photo courtesy of Mike Fosha.

The majority of fractures within the assemblage appear to be post-excavation damage based on the ‘fresh’ look of the fracture surfaces, which have color and mineralization patterns distinct from the exterior bone surfaces. A few bones exhibit spiral fractures which could be a result of injury suffered during the kill/entrapment event, or possible post-mortem processing for marrow or expedient tools by the occupants of the site.

Despite the increased weathering of specimens in the paleochannel, small and delicate bones were recovered from both in and outside of the channel, including rodent bones, stylohyoids (Figure 4.3), and ossified costal cartilage (see Chapter 8). A few fragments of burned bone were recovered from unit Y where there was a hearth feature, as well as Units J, and M.

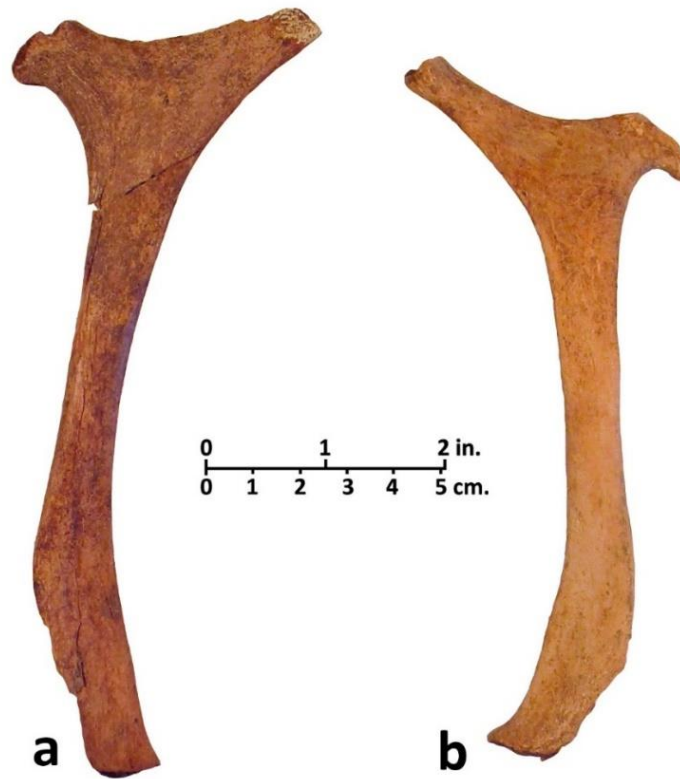


Figure 4.3. Complete stylohyoid bones from the Licking Bison site; a) left stylohyoid 1164, medial view; b) right stylohyoid 1459, medial view.

Many specimens were treated with at least one unknown glue post-excavation, which was most likely Elmer's or a similar white glue (Fosha, personal communication). Elmer's is a polyvinyl acetate (PVA) emulsion that can be difficult to remove from bones, especially if it cross-links under UV exposure (Florida Museum 2019). Bones targeted for treatment include the skulls, articulated limb sections, scapulae, and other complete or nearly complete bones (longbones, mandibles, vertebrae, etc.). Several of these specimens were prepared inside of their plaster support jackets and are now glued to the plaster. In many cases glue was applied thickly, sometimes over top of sediment, obscuring surfaces and making some measurements difficult or impossible to acquire.

This method of preparation has prevented morphological analysis of some specimens and may disrupt the potential for future chemical analysis. PVA glues can sometimes be softened with water and scraped away, however this method of removal puts the specimens at risk of damage. The water can soften the bones and make them crumbly or soft, leading to deterioration. Removal of the outer layer of glue was only undertaken for one specimen, mandible 1032 where considerable dirt was present under the glue, to better assess tooth wear on the occlusal surface.

Despite the fragmentary nature of some specimens and the challenges of evaluating characters for glued bones, the vast majority of specimens were able to be identified to element. Results of this study are presented in the following chapters.

Chapter 5: Results

Number of Identified Specimens

The total Number of Identified Specimens (NISP) for the Licking Bison collection is 2688 specimens. The degraded nature of the bone from units within the paleochannel made it difficult to assess the NISP for each cataloged bag. The bone was very dry, flakey with easily damaged surfaces. Many bags had powdered bone in the bottom, as the surface bone flaked away. Bags of unidentifiable fragments were counted as 1 for NISP.

Minimum Number of Individuals

The Licking Bison site is interpreted to be single component, and so the bonebed assemblage is considered as a whole for calculating the minimum number of individuals (MNI). The MNI was calculated for most elements in the assemblage. Ribs, most vertebra, sternebrae, and ossified costal cartilage were not included due to the fragmentary nature of the recovered specimens.

Table 5.1 shows the minimum number of elements (MNE) for the left and right sides of each paired bone. Most bones were incomplete, so MNE was determined by accounting the presence of landmarks (ex. proximal ends) for each element. Because there is no evidence of elk or other large animals besides bison contributing to the assemblage, incomplete bones and small bones like sesamoids that are usually difficult to identify to species, are all assigned to *Bison* sp. and included in MNI counts.

The highest MNI calculated for the assemblage comes from combined maxillary and mandibular dentitions. A minimum of 22 individual bison were counted in the assemblage, after determining the Dental Age Group (DAG) for each tooth or toothrow based on wear and eruption patterns (Figure 5.1). See Chapter 8 for a description of age groups. Based on dental

ages, the herd is more skewed towards immature animals (DAG 1-4) than mature adults (DAG 5+).

Several teeth in the collection were not included in the current analysis due to fragmentation. Some of these teeth could be reconstructed with time, potentially increasing the MNI. Because of the uncertainty in separation of age groups past the eruption of permanent teeth (see Chapter 8), DAGs 7-8 and 9+ were considered together as DAG 7+ to calculate MNI.

Many of the longbones are difficult to use for MNI because they are broken or even fragmentary. The carpals and tarsals proved to be more reliable, because they are generally more completely preserved. For example, the right carpal 4s provided an MNI of 13, which along with right petrosals, provides the highest MNI for a single element in the assemblage, though this is still well below the dental MNI (Figure 5.2). The low number of complete longbones could be a result of potential cultural use like marrow extraction, and post depositional factors like preservation and excavation methods.

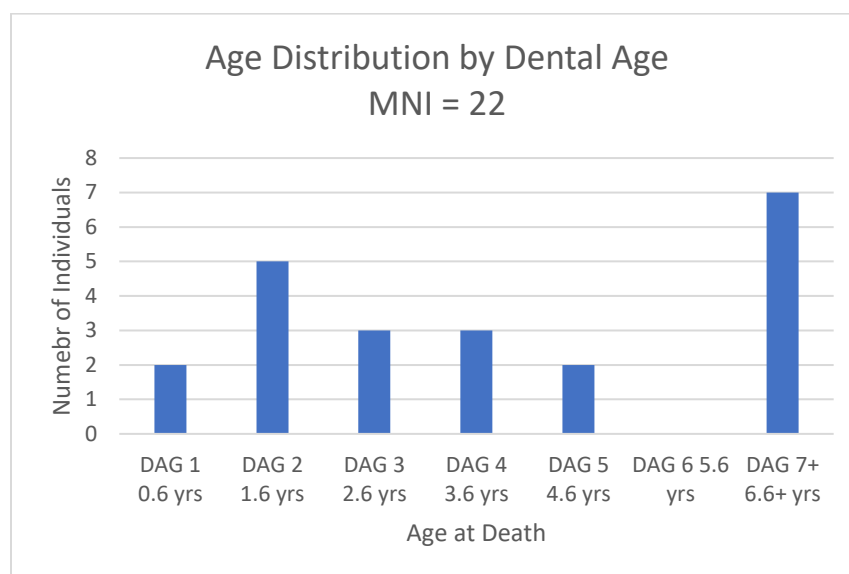


Figure 5.1. Age distribution of Licking Bison individuals from combined mandibular and maxillary dentition data.

Table 5.1. *Minimum Number of Individuals by element for bison in the Licking Bison assemblage.*

Element	Left	Right	Not Sided	Axial	MNI	
Skull (petrous portions)	12	13	-	-	13	
Mandible	6	6	-	-	6	
Stylohyoid	9	9	1	-	10	
Atlas	-	-	-	5	5	
Axis	-	-	-	7	7	
Sacrum	-	-	-	6	6	
7th Cervical Vertebra	-	-	-	11*	11*	
Scapula	5	5	-	-	5	
Humerus	4	4	-	-	4	
Radius	6	11	-	-	12**	
Ulna	4	7	-	-	7	
Radial Carpal	12	9	-	-	12	
Intermediate Carpal	7	8	-	-	8	
Ulnar Carpal	5	7	-	-	7	
Carpal 2+3	8	12	-	-	12	
Carpal 4	10	13	-	-	13	
Accessory Carpal	5	7	-	-	7	
Metacarpal	9	11	1	-	11	
Metacarpal Sesamoid	-	-	11	-	6	
Pelvis	6	4	-	-	6	
Femur	6	5	2	-	6	
Patella	6	9	-	-	9	
Tibia	9*	8	-	-	9*	
Lateral Malleolus	6	5	-	-	6	
Astragalus	9	9	-	-	9	
Calcaneus	8	10	-	-	10	
Tarsal C+4	9	7	-	-	9	
Tarsal 2+3	8	6	-	-	8	
Tarsal 1	-	-	9	-	5	
Metatarsal	6	7	3	-	8	
Metatarsal Sesamoid	-	-	10	-	5	
Metapodials	-	-	9	-	3	
Element	Left of pair	Right of pair	Not Sided	-	MNI	
First Phalanx	38	37	6	-	11	
Second Phalanx	39	34	-	-	10	
Third Phalanx	36	31	1	-	9	
Distal Sesamoid	28	21	-	-	7	
Element	Right toe- Right side	Right toe- Left side	Left toe- Right side	Left toe-Left side	Not Sided	MNI
Proximal Sesamoid	29	32	30	29	18	9

Note: *One complete tibia (1838), and one mostly complete 7th cervical vertebra (1837) may not actually be from the site, though they are cataloged together with the rest of the collection. **See Table 5.2.

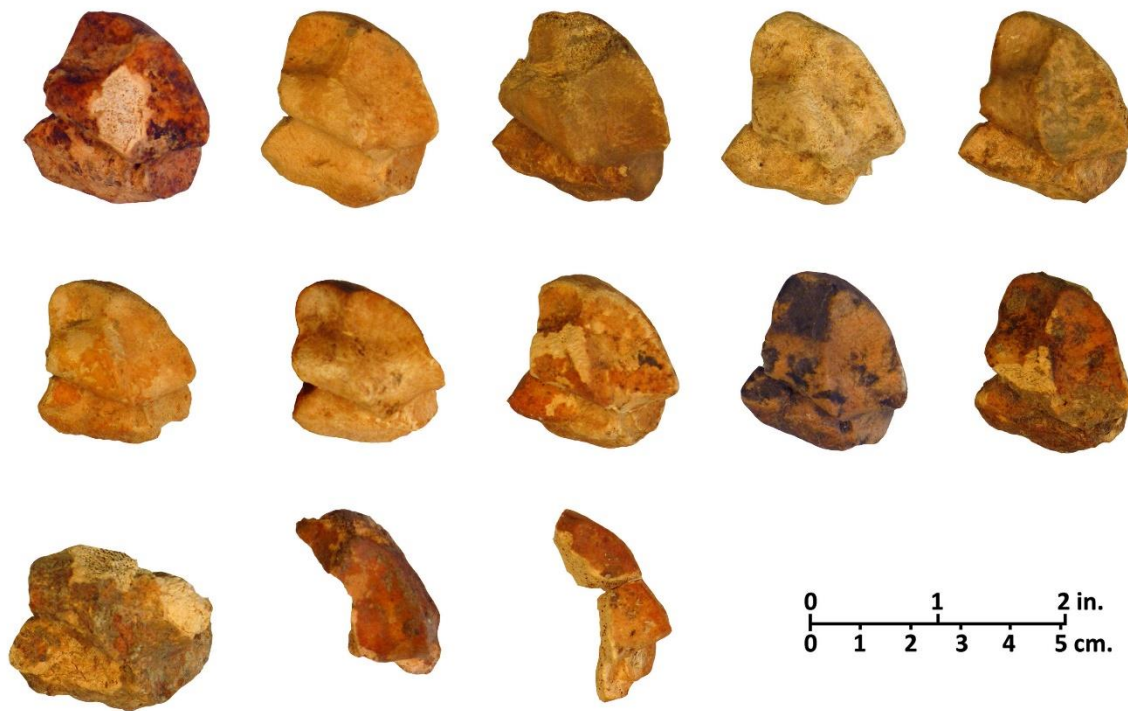


Figure 5.2. The right carpal 4 bones from the Licking Bison site. The carpal 4s, along with the right petrosals, provide the highest MNI per element of 13 individuals. Specimen numbers, left to right, top row: 0017; 0354b; 1330; 0720c; 1520b; middle row: 0219b; 1434a; 0131d; 0054b; 0626c; bottom row: 0128c; 1411; 1268.

Several partial metapodials were recovered that were too fragmentary to identify as metacarpal or metatarsal, including several unfused distal epiphyses. The fragmentary nature of these specimen makes it difficult to assess a reliable MNE. The fragments likely represent at least an additional 9 metapodials, representing an MNI of 3.

Proximal and distal sesamoids are well preserved in the collection. Each bison foot has four proximal sesamoids, two per toe, each with a distinct morphology (Figure 5.3). Each toe also has a distal sesamoid, which can be easily sided (Figure 5.4). For both proximal and distal sesamoids, identifying left versus right limb or forelimb versus hind limb is problematic, and not attempted here.

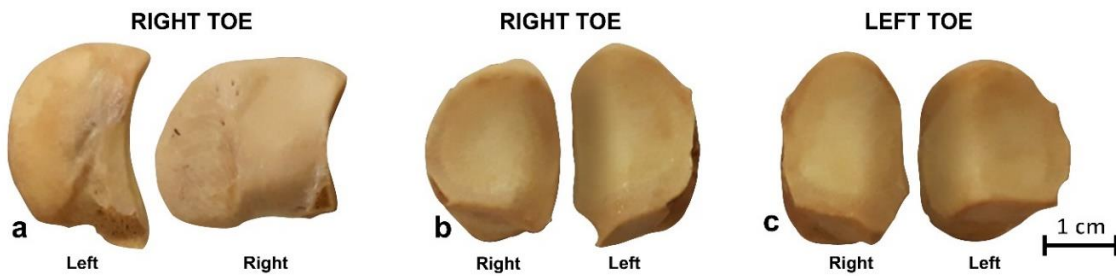


Figure 5.3. Proximal sesamoids from a modern comparative *Bison bison* specimen from the Mammoth Site of Hot Springs, SD; a) lateral view of the left and right proximal sesamoids from the right toe; b) anterior view of articular surfaces of proximal sesamoid from right toe; c) anterior view of articular surface of proximal sesamoids from left toe.

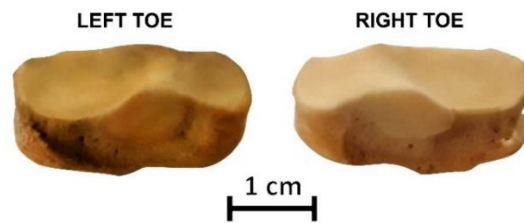


Figure 5.4. Antero-ventral view of distal sesamoids from a modern comparative *Bison bison* specimen from the Mammoth Site of Hot Springs, SD.

Probable Number of Individuals

In sites where the extent of the death assemblage is not known because of erosion or incomplete excavation (both of which are factors at Licking Bison), calculating an MNI likely does not adequately reflect the full size of the death assemblage. Calculating a probable number of individuals (PNI) can potentially offer some interpretive value by attempting to quantify how many animals were likely to be present in the original death assemblage versus how many are accounted for in the collected assemblage (Lyman 2008).

PNI is calculated with the Lincoln-Peterson Index (also referred to as the Peterson Index) (Lyman 2008; Klein and Cruz-Urbe 1984). The Lincoln-Peterson Index uses the frequencies of bilaterally paired bones to calculate a PNI that contributed to the assemblage.

Application of the Lincoln-Peterson Index was attempted with the Licking Bison assemblage, but ultimately proved not to be a useful interpretive tool. The incomplete nature of the longbone assemblage meant that largest of the potential PNIs that could be calculated from longbone data (18 individuals) was still less than the confirmed MNI calculated from dentitions (22 individuals).

Age by Fusion

Age was estimated for elements by assessing the level of fusion of epiphyses where applicable. Due to the incomplete nature of many long bone specimens, it is possible that broken specimens could have pieces in multiple age categories. For example, an unfused proximal tibia epiphysis would be labeled as <5.3 years, but the fused distal end from the same individual (if broken and found separately), would be labeled ≥ 3.3 years. If the bone had been found complete, it would be labeled 3.3-5.3 years old, between the ages of fusion for the distal epiphysis and the proximal epiphysis. To prevent double counting, only the MNI of elements in mutually exclusive age groups are reported in Table 5.2. However, partial specimens in non-exclusive groups were considered in determining MNI based on completeness in Table 5.1.

Fusion data from the radii indicate there were seven individuals with full fusion of the distal end, which occurs by 5.3 years of age. Both calcanei and tibiae provide an MNI of seven individuals near or below 5.3 years of age (partial or unfused epiphyses). Taken together, there are seven individuals above 5.3 years old and seven individuals near or below. This is consistent with MNI calculated from dental ages.

One complete and fully fused sacra (0986) was recovered from the site. According to Duffield (1973) sacra in *B. bonasus* do not fully ossify until the individual reaches 11 years of age, suggesting at least one animal in the assemblage had reached old age.

Table 5.2. MNI by age groups for elements evaluated for epiphyseal fusion.

Calcaneus				
Age	L	R	Unk.	MNI
≥5.3	2	3	0	3
~5.3	1	1	0	1
<5.3	5	5	1	6
Total MNI				10

First Phalanx				
Age	L of pair	R of pair	Unk.	MNI
≥2.3	23	18	0	6
~2.3	2	1	0	1
<2.3	10	6	2	3
Total MNI				10

Metatarsal				
Age	L	R	Unk.	MNI
≥3.3	2	2	1	3
~3.3	0	0	0	0
<3.3	2	3	0	3
Total MNI				6

Second Phalanx				
Age	L of pair	R of pair	Unk.	MNI
≥1.3	33	28	0	9
~1.3	2	3	0	1
<1.3	3	1	0	1
Total MNI				11

Metacarpal				
Age	L	R	Unk.	MNI
≥3.3	4	4	0	4
~3.3	1	0	0	1
<3.3	2	3	2	4
Total MNI				9

Ulna			
Age	L	R	MNI
≥5.3	2	4	4
<5.3	2	2	2
Total MNI			6

Humerus			
Age	L	R	MNI
≥5.3	3	1	3
<1.3	1	0	1
Total MNI			4

Tibia			
Age	L	R	MNI
≥5.3	5*	2	5*
~5.3	0	1	1
3.3-5.3	0	2	2
<3.3	4	1	4
Total MNI			12

Radius			
Age	L	R	MNI
≥5.3	2	7	7
~5.3	2	0	2
1.3-5.3	1	2	2
<1.3	0	1	1
Total MNI			12

Femur			
Age	L	R	MNI
≥5.3	4	3	4
~5.3	0	0	0
<5.3	2	2	2
Total MNI			6

Note: Ages based on Bement and Basmajian (1996). *Tibia data includes specimen 1838 which has questionable provenience and may not be from the site.

Skulls

There were at least 13 skulls present at the site based on the number of recovered petrous portions, which is the densest part of the skull and more likely to preserve than other delicate sections of the cranium. Several skulls were too deteriorated to be collected (Mike Fosha, personal communication). Only five skulls in the assemblage remain reasonably intact, and they are described below (Figures 5.4-5.10). Most skulls were too incomplete to obtain measurements to assess age, sex, and species. All of the skulls have been preserved with an unknown glue, which in some cases was applied thickly and over sediment, obscuring some surfaces.



Figure 5.5. Skull 0049 (DAG 9+), lateral view, left side. Skull is glued into a plaster support jacket, which is visible along the bottom and right margins above.

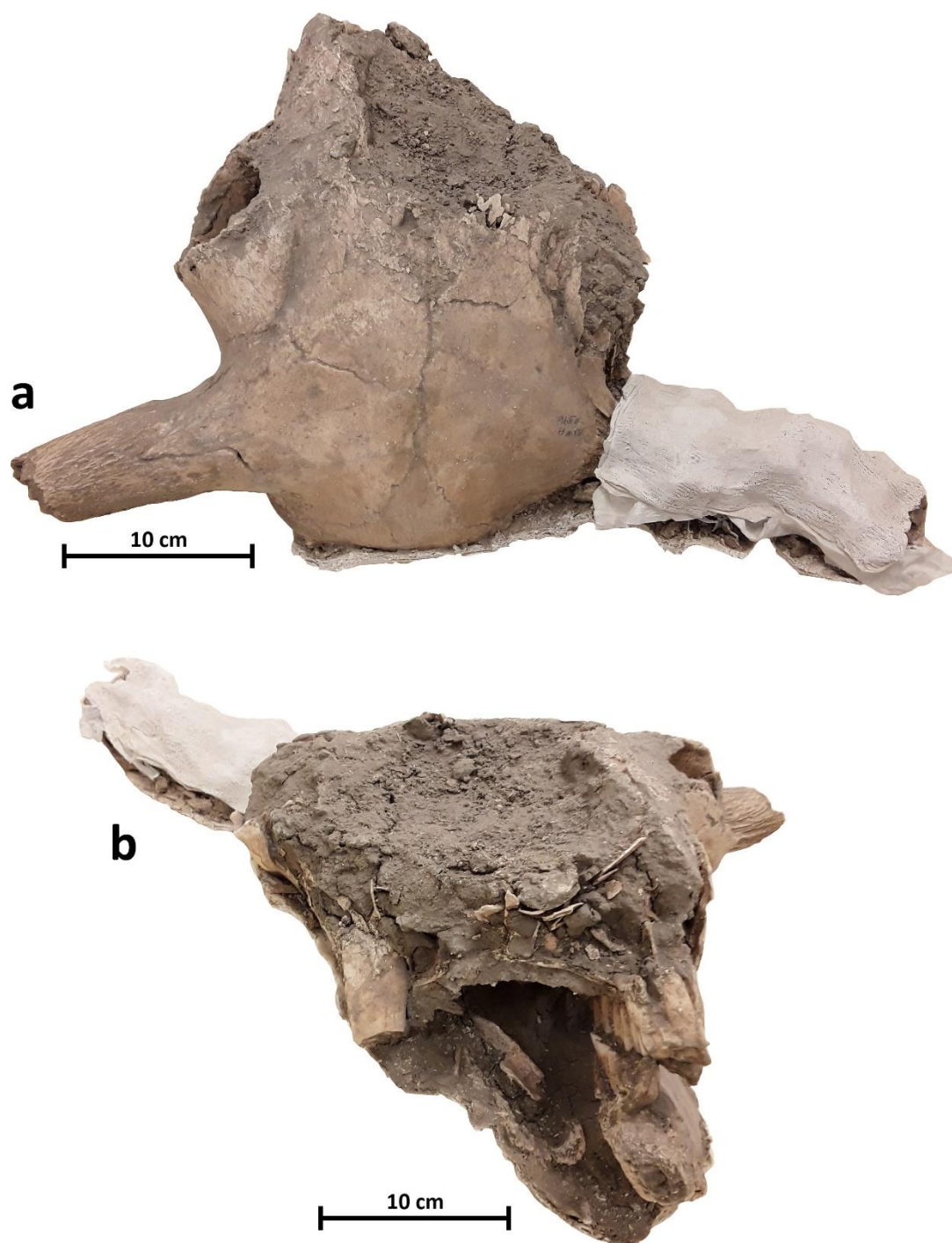


Figure 5.6. Skull 0049 (DAG 9+); a) dorsal view; b) anterior view.

Skull 0049: Partially jacketed. The skull is missing most of the anterior and right sides (Figures 5.5 and 5.6). There are two bags of loose fragments associated with the skull which include fragments of the ventral side of the skull. The left orbit is largely intact, though somewhat fragmented along the anterior and dorsal margins. The right horn core is severely fragmented, and largely obscured by the jacket. The left horn core base is present, but the distal half of the core is missing. This represents the only intact horn core base in the Licking Bison collection. The lack of burr or flare at the base of the horn core suggests this is a female skull (McDonald 1981). The interfrontal and parietofrontal sutures do not appear to be fully fused, but fusion is not a reliable measure of maturity in female bison (McDonald 1981).

All permanent teeth are fully erupted. The left P4-M3, and the right M3, remain *in situ*. A right P2 or P3 and a right m3 are loose in the associated bags of fragments. The partial left mandible, which retains the m2-m3, is glued to the skull in partial occlusion, preventing evaluation of wear patterns on the teeth on the left side. However, the right M3 is exposed enough to assign Skull 0049 to Dental Age Group (DAG) 9+ (see Chapter 8).

Skull 0236: Partially jacketed laying on its right side. The left side of the skull is largely present, but the dorsal surfaces are damaged and show significant loss of surface bone (Figure 5.7). There is an associated bag of fragments stored with the skull. The left premaxilla and maxilla are in fair condition, but some deformation is present around the anterior of the orbit. The left horn core is missing, the remainder of the horn core base is severely fragmented and coated with dirt and glue. Despite the significant damage to the skull, the broad base of the horncore and the projecting, tubular profile of the orbit suggests this skull belonged to mature male bison (Skinner and Kaisen 1947).

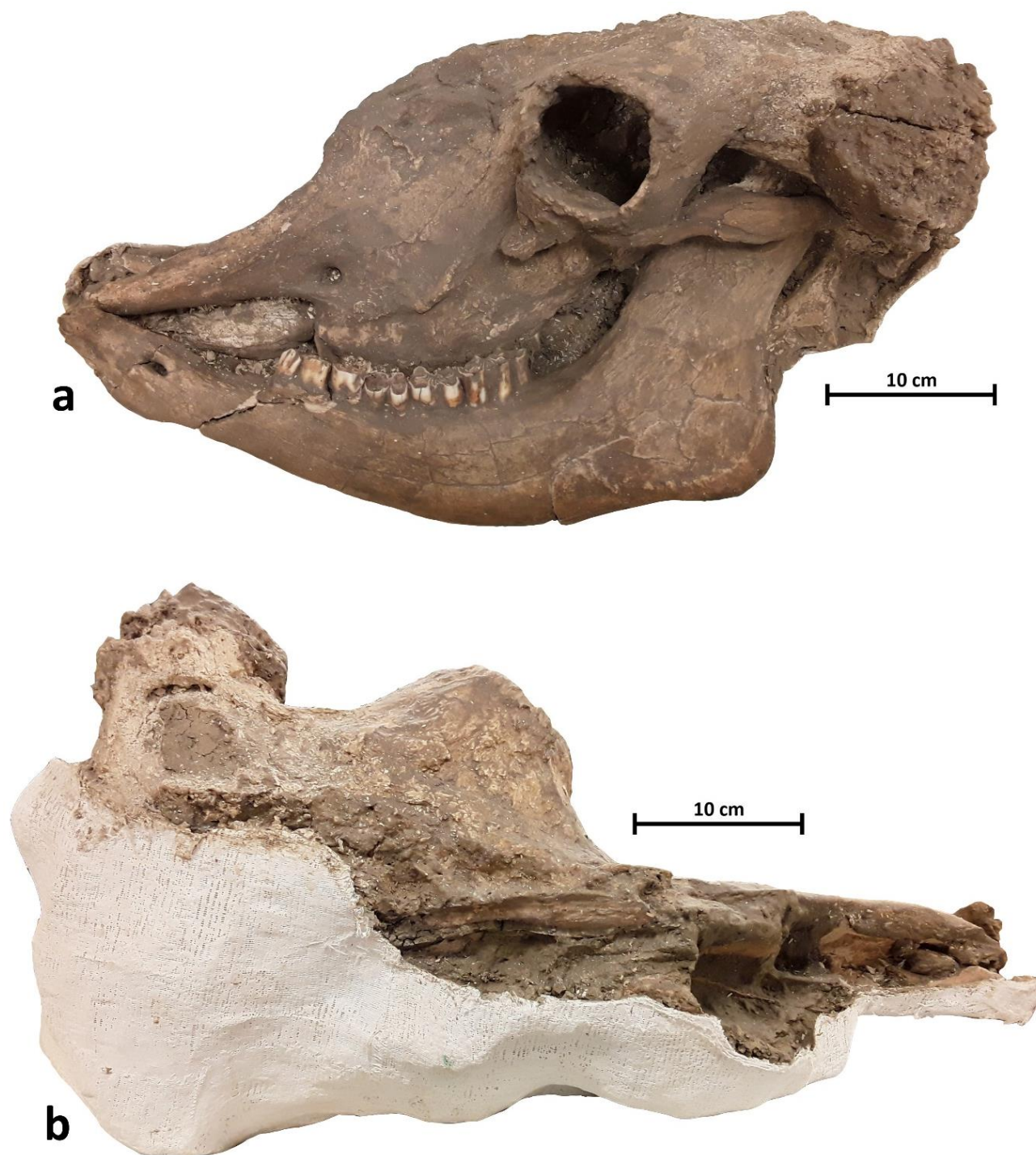


Figure 5.7. Skull 0236 (DAG 9+); a) lateral view, left side; b) dorsal view. Skull is glued into a plaster support jacket, which is visible between mandible and premaxilla.

The left mandible is jacketed and glued to the skull. The mandible is largely intact with a complete tooththrow, except for the missing incisors. A small section of the mandibular symphysis from the right mandible is visible in the jacket. The teeth exhibit wear consistent with a mature-old age individual and was assigned to DAG 9+. The maxillary dentition appears to be present, but is obscured, and was unable to be assessed for age at death.

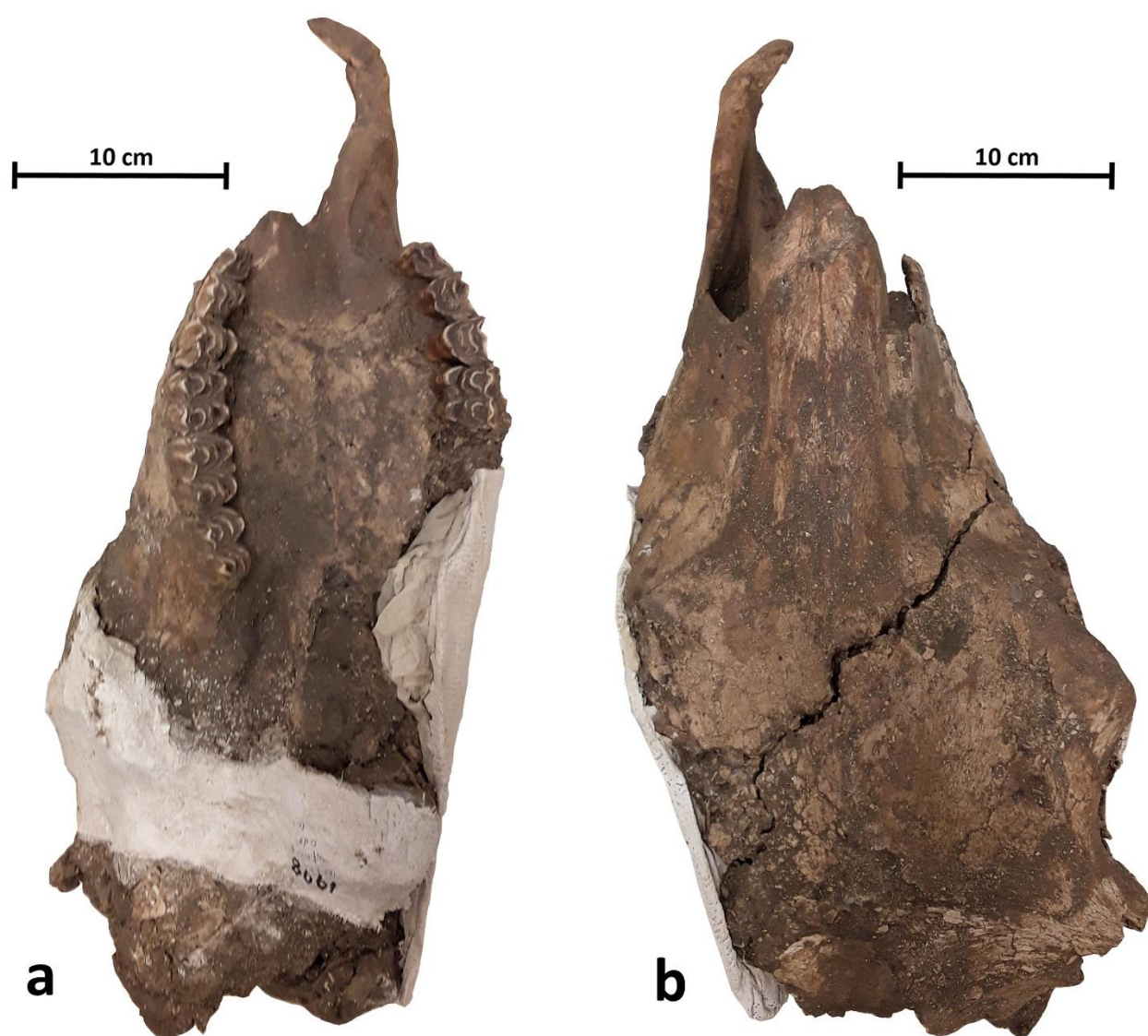


Figure 5.8. Skull 0614 (DAG 7-8), jacketed to sit on its left side; a) ventral view; b) dorsal view.

Skull 0614: Partially jacketed to lay on its left side. A strip of plaster runs up the ventral surface and around the base of the right orbit obscuring some surfaces of the skull (Figures 5.8 and 5.9). Skull is missing the posterior half of the left side, most of the posterior and ventral surfaces, as well as the right premaxilla and anterior portion of maxilla. Most surfaces are weathered. The right orbit is partially preserved, but damaged, and neither of the horncores are present. The left premaxilla, portions of the left maxilla, and left and right nasals are intact.

All permanent adult teeth are erupted. The right P2-M3, and the left P2-M1 are intact. Based on wear patterns, this skull has been interpreted to be a mature individual in DAG 7-8.



Figure 5.9. Skull 0614 (DAG 7-8), partially obscured by jacket; a) right side; b) left side.

Skull 0745b: This skull is in poor condition. It is severely distorted, missing significant sections, and glued into its jacket (Figure 5.10). The jacket contains a partial left maxilla and mandible in near occlusion, and a partial right maxilla and mandible in partial occlusion. These sections, which are separated with the left side offset, and lying partially on top of the right maxilla. The skull has a flattened appearance. The poor condition of the bone, and the way the bone and remaining dirt have been glued into the jacket make this specimen difficult to assess. Only the left maxillary dentition, and right mandibular dentition are visible. Both have been assigned to DAG 2. Because of the matching wear patterns, all cranial material in this jacket is interpreted to be from one 1.6-year-old individual.

The left dP2-M1 are *in situ*, with the M2 erupting. The right maxillary dentition is partially obscured, but the dP3-M1 appear to be *in situ*. The dp3-m1 and erupting m2 are present in the right mandible. The dp4-m1 and erupting m2 are present in the left mandible.

Skull 1456: This is a partial skull, represented by a left and right maxilla glued into a jacket, and several loose pieces, including occipital condyles, basioccipital, and the partial right petrosal/tympanic bulla (Figure 5.11). The right tooththrow shows dP2-M2 *in situ*, with a partial dP4 and M1-M2 present on the left. Based on eruption and wear patterns, this individual was placed in DAG 2 and was 1.6 years old when it died.

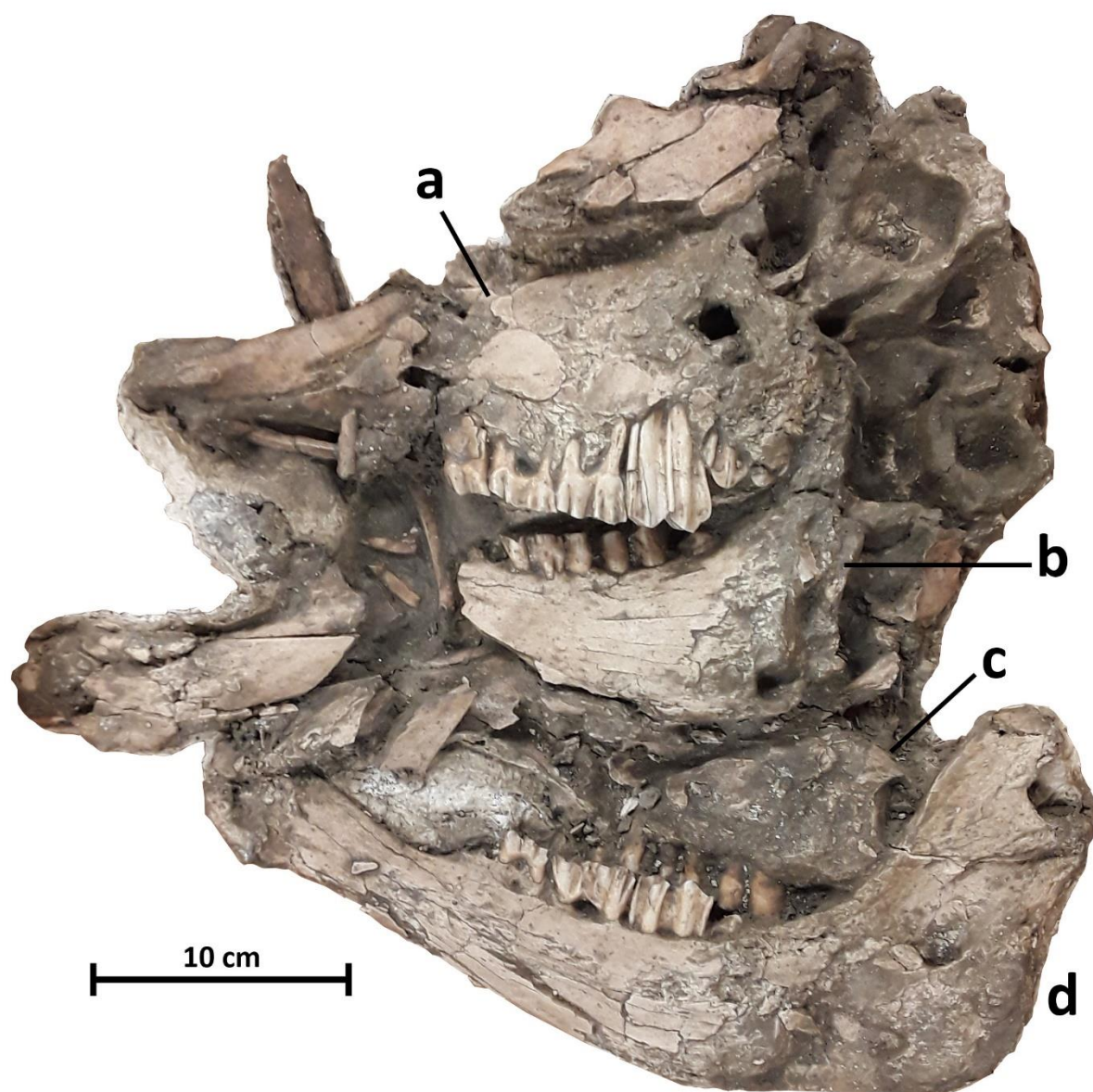


Figure 5.10. Skull 0745b (DAG 2); a) left maxilla, lateral view; b) left mandible, lateral view; c) right maxilla, medial view; d) right mandible, medial view.

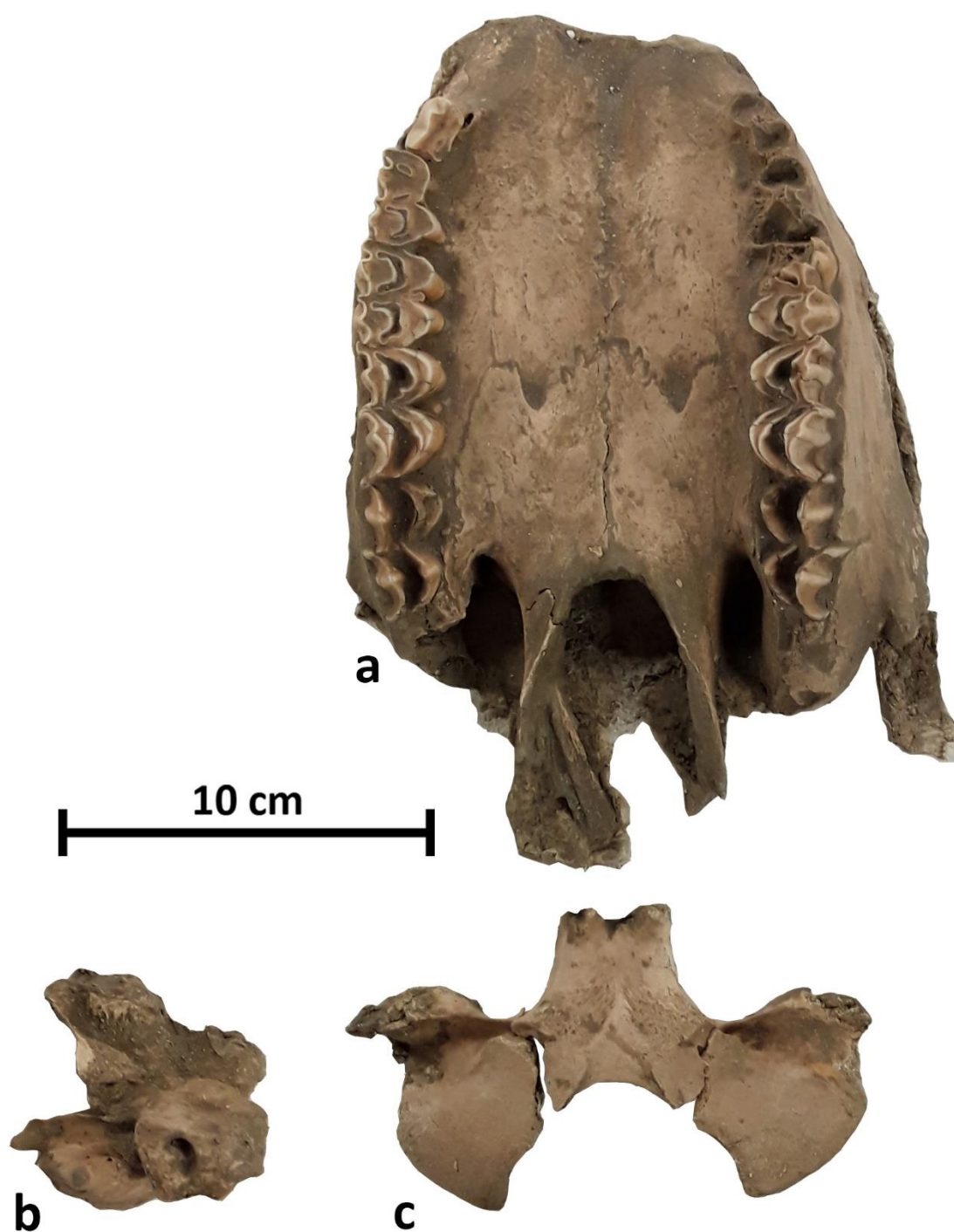


Figure 5.11. Skull 1456 (DAG 2); a) maxilla glued into jacket; b) right petrosal and partial tympanic bulla; c) occipital condyles and basioccipital.

Pathologies

Two pathological specimens were noted in the collection. A complete right metatarsal (0900) has a pathological lump on the medial side of midshaft, which has a smooth surface but is raised several millimeters from the normal bone surface.

One lumbar vertebra (0482) has a large foramen running dorso-ventrally through the centrum and possible arthritic bone development around the caudal articular surface. The cranial centrum epiphysis is partially fused, and the caudal epiphysis is fully fused, placing the individual in the 6-7-year-old range (Duffield 1973).

Non-*Bison* fauna

Several dozen small mammal bones are present in the assemblage but were not assessed as part of this project. Some were recovered as part of the heavy fraction of floatation samples. Most are in the size class of small rodents. Several small unidentified snail shells were also recovered.

One partial molar crown of a carnivore (1830) was recovered from the site but lacks provenience information. It has been tentatively identified as a canid. No evidence of other large non-bison artiodactyls (elk, deer, bighorn sheep, or pronghorn) was found in the assemblage.

Chapter 6: Sex Distribution

Identification of males versus females in the Licking Bison assemblage has been limited by small sample size. Because *Bison* experienced a significant reduction in body size throughout the Holocene, comparisons of bison from sites of different geological ages are often inappropriate. Most methods thereby rely on intrasite comparison of adult specimens to determine sex, but these often require a larger sample than is present in the Licking Bison assemblage (Bedord 1974, Todd1987a). The problem of small sample size can be avoided by combining Licking Bison specimens into a wider data set of similarly aged Archaic bison metacarpals from the Great Plains.

Skulls

Only two skulls were complete enough to be identified to sex (see descriptions and figures in Chapter 5). Skull 0049 is identified as a mature adult female based on the narrow horncore base. Skull 0236 is tentatively identified as a mature adult male based on the broad horncore base and prominent orbit, however this specimen is damaged, so the identification is somewhat uncertain.

Metapodials

Metapodials are often used to identify sex in bison, because in addition to being sexually dimorphic, their dense cortical bone makes them more likely to be preserved. The lower meat yield of metapodials also makes them more likely to remain at the kill site (Lewis et al. 2005). Bivariate plots of Licking Bison metapodials were created after Bedord (1974), whose study showed good separation between male and female metapodials at a number of Holocene bison localities. Only six adult metacarpals (Figure 6.1) and three adult metatarsals (Figure 6.3) were complete enough to include in the analysis.

These sample sizes are too small to form distinct clusters in an intrasite analysis. In an effort to identify them another way, the Licking Bison data were compared to Bedord's plots from the Hawken and Ruby sites. This method is less reliable than intrasite analysis because there is no independent test of average body mass between sites to ensure the populations are comparable. The Hawken site was chosen for comparison because it is closest in age to Licking Bison, and most likely to have similarly-sized animals. The data were also evaluated against metapodials from the Late Archaic Ruby Site (48CA302), which dates to A.D. 280 ± 135 , well within the range of modern *B. bison* (Bedord 1974).

When compared to Hawken graphs, the Licking Bison data show five metacarpals in the female cluster and one within the male cluster (Figure 6.2). Of the five female metacarpals, four are right-sided and one is left. This provides an MNI of 4 females, and 1 male, which agrees with Widga's (2006) principal component analysis. Two immature specimens plot with the female cluster but cannot be accurately assigned to sex. The same patterns hold when compared to the Ruby data. The Licking Bison specimens fall out with five metacarpals in the female cluster and one in the male cluster, but most are located towards the upper limits of the clusters, which may be an indication the Licking Bison individuals were larger than Ruby individuals overall.

Only three metatarsals were complete enough to plot (Figure 6.3). One left metatarsal (0016) falls within the female cluster from both the Hawken and Ruby sites. The other two specimens, one right (0900) and one left metatarsal (1511), fall between the male and female clusters on the Hawken graph, and plot at the upper side of the female cluster on the Ruby graph (Figure 6.4). These two specimens cannot therefore be assigned to sex.

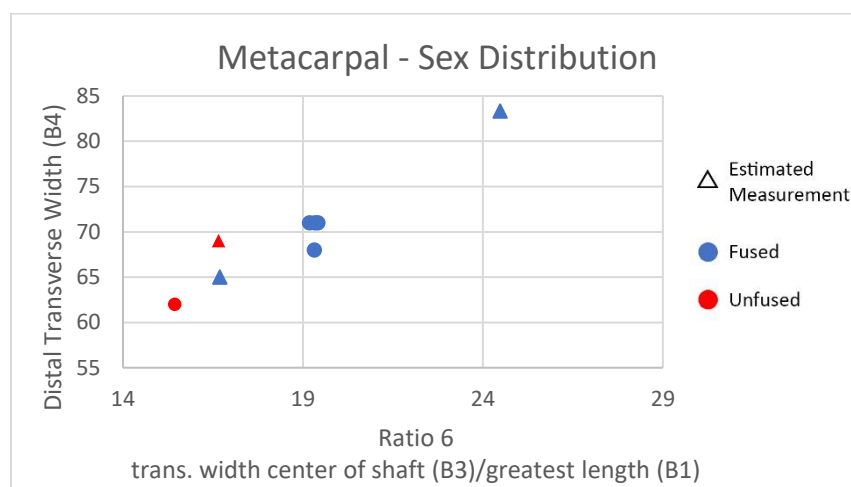


Figure 6.1. Metacarpal sex distribution, transverse width at distal end (B4) versus ratio 6 (transverse width at center of shaft/greatest length; B3/B1) after Bedord (1974). Specimens 0448a, 0626a, 1005, 1335, 1434a, 1520a, 1639, and 1654a. Triangles indicate specimens for which one or both measurements are estimates. See Table A1.6 in Appendix I for additional information.

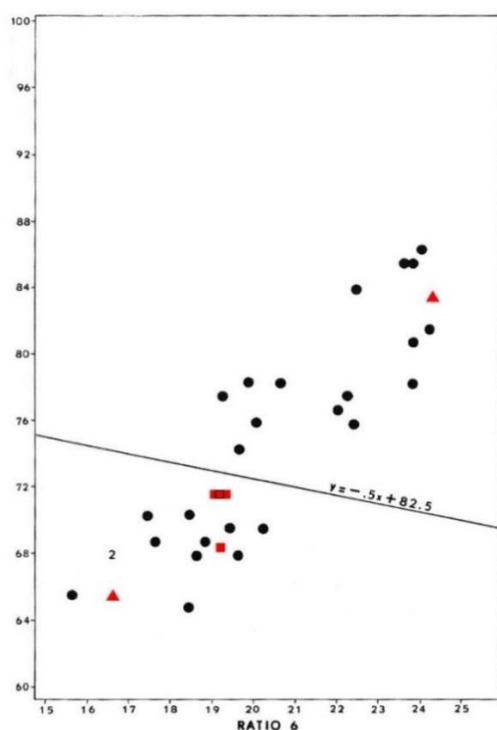


FIGURE 6.7 Hawken mature metacarpals.

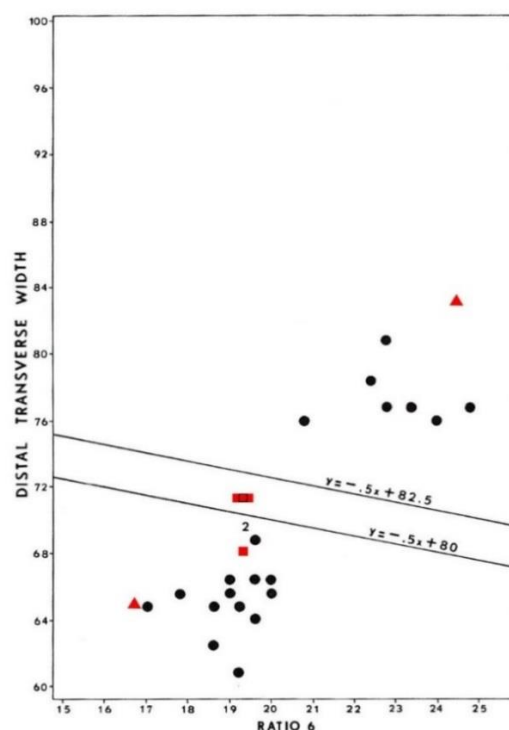


FIGURE 6.8 Ruby mature metacarpals.

Figure 6.2. Metacarpal plots from the Hawken and Ruby sites with mature Licking Bison specimens in red; red triangles represent specimens with estimated measurements. Reproduced from Bedord (1974:Figures 6.7 and 6.8) with permission from Eliot Werner Publications, LLC.

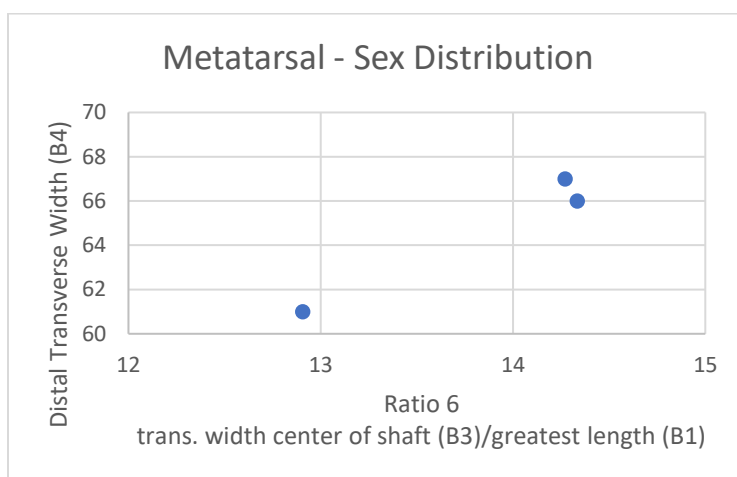


Figure 6.3. Metatarsal sex distribution, transverse width at distal end (B4) versus ratio 6 (transverse width at center of shaft/greatest length; B3/B1) after Bedord (1974). Specimens 0016, 0900, and 1511. See Table A1.14 in Appendix I for additional information.

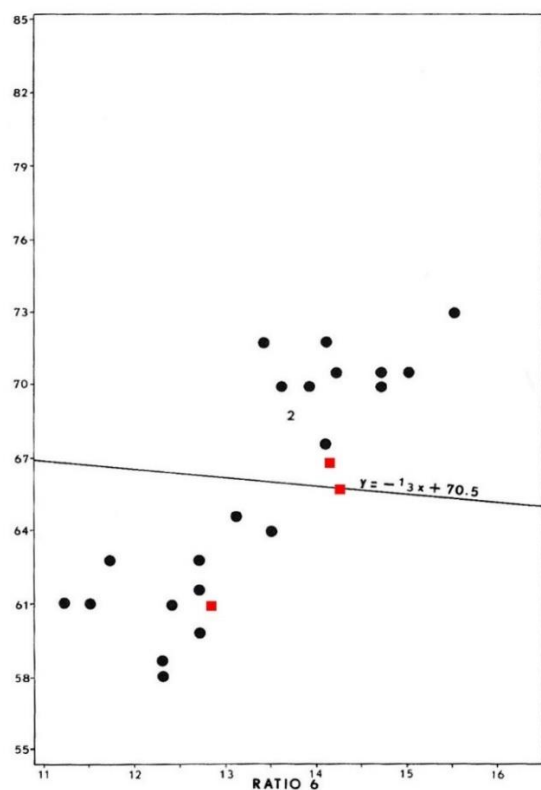


FIGURE 6.15 Hawken mature metatarsals.

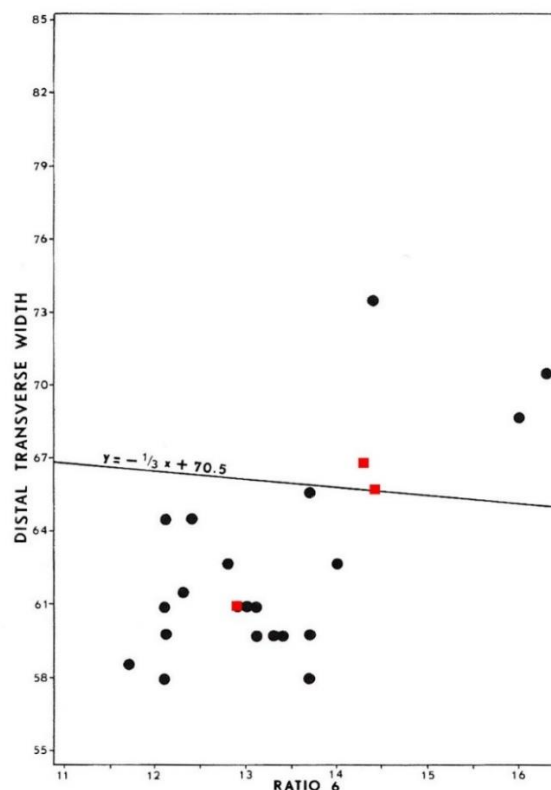


FIGURE 6.16 Ruby mature metatarsals.

Figure 6.4. Metatarsal plots from the Hawken and Ruby sites with mature Licking Bison specimens in red. Reproduced from Bedord (1974:Figures 6.15 and 6.16) with permission from Eliot Werner Publications, LLC.

Limb bones

Due to the incomplete, sometimes fragmentary nature of many long bones, several limb elements did not provide enough data points to construct meaningful bivariate plots to interpret sex distribution. Several specimens could not be measured because they were glued into their support jackets, obscuring or obstructing critical morphology. The humeri, femora, and ulnae were not able to be used. All following longbone, carpal and tarsal plots include both left and right specimens to increase sample size, but many still do not display distinct clustering.

A plot of proximal articular breadth versus proximal articular depth for the radius after Todd (1987a), shows one specimen (0585, left) clearly larger than the rest, which is interpreted here as being male (Figure 6.5). Two additional specimens (0128a and 0957, both right) plot towards the high end of the graph, and could potentially be interpreted as male, increasing the minimum number of identified males to two.

A second radius plot of distal end breadth versus depth (Figure 6.6) also shows one specimen (1701, right) distinctly larger than the rest. Combined with data from Figure 6.5, three right radii plot as higher than the rest of the group (1701, 0128a, and 0957). This could indicate as many as three adult males in the assemblage, but the low sample size prevents a confident assessment.

The tibia assemblage was too incomplete to use proximal end measurements after Todd (1987a). The distal tibiae were more intact, so a plot of the breadth of the distal end versus the breadth of the distal articular surface was attempted (Figure 6.7). The plot shows a positive correlation between the two measurements but does not show distinct divisions that could be easily identified as adult male and adult female. The immature specimens (<3.3 years of age) are clustered at the bottom of the graph.

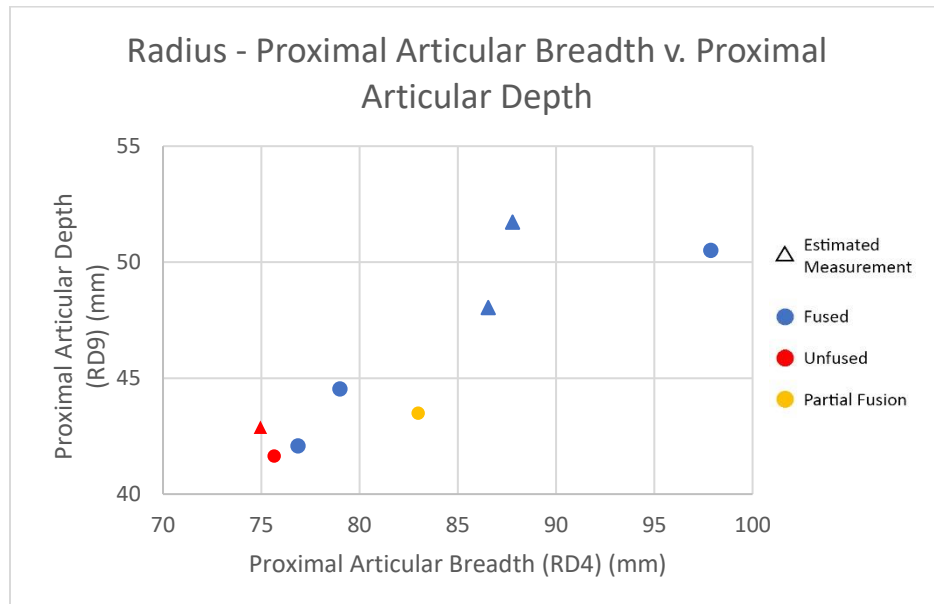


Figure 6.5. Radius proximal articular breadth (RD4) versus proximal articular depth (RD9) after Todd (1987a) for specimens 0128a, 0459, 0585, 0957, 0963, 1441a, 1447, and 1728. Triangles indicate specimens for which one or both measurements are estimates. See Table A1.4 in Appendix I for additional information.

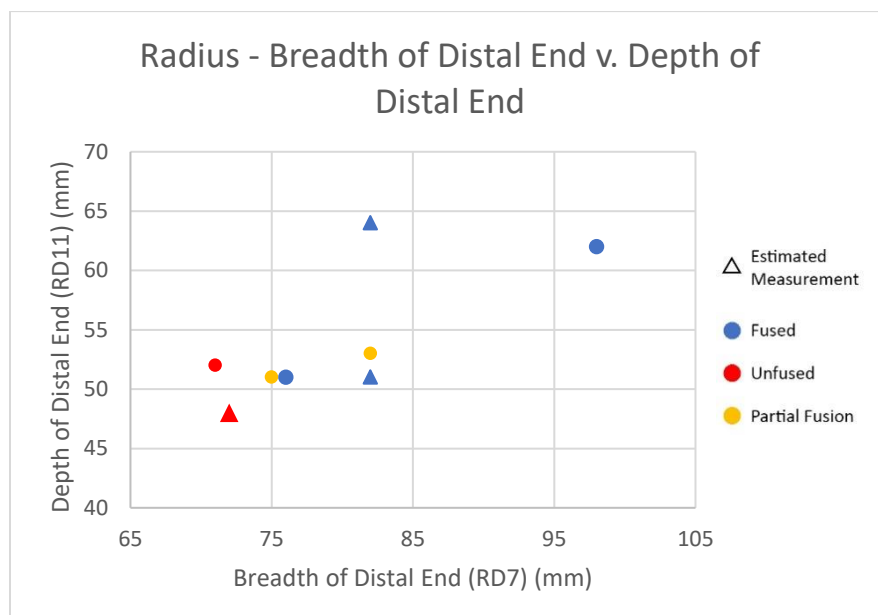


Figure 6.6. Radius breadth of distal end (RD7) versus depth of distal end (RD11) after Todd (1987a) for specimens 0142a, 0957, 0963, 1519, 1638, 1653, 1701, and 1728. Triangles indicate specimens for which one or both measurements are estimates. See Table A1.4 in Appendix I for additional information.

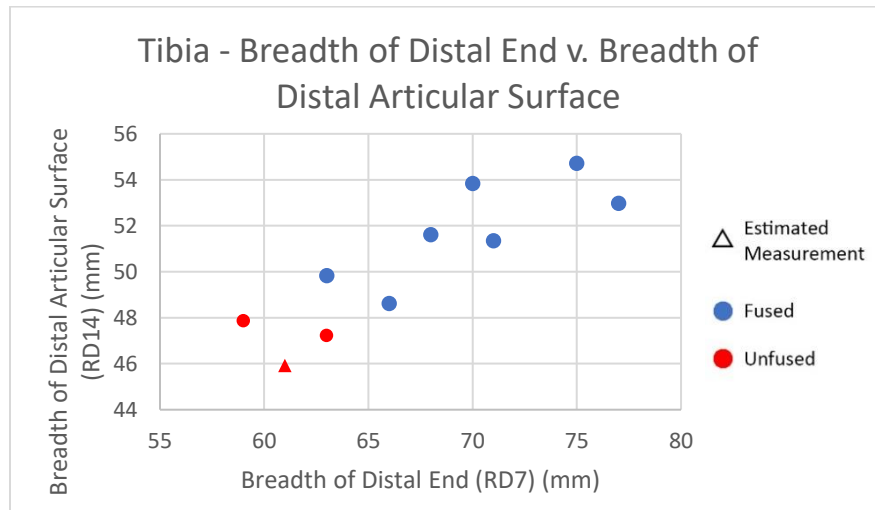


Figure 6.7. Tibia breadth of distal end (RD7) versus breadth of distal articular surface (RD14) after Todd (1987a) for specimens 0001, 0567, 0682, 0959, 1627, 1642, 1660, 1740, 1752, and 1838. See Table A1.13 in Appendix I for additional information.

Carpals and Tarsals

Measurements and plots for carpals and tarsals follow Morlan (1991). With the exception of the calcaneus, it is not possible to separate out immature animals from adults when assessing carpals and tarsals, because they lack epiphyses to estimate age by fusion (Morlan 1991).

Bivariate plots of carpal and tarsal size data can only separate adult males from a combined group of adult females and juvenile animals (which generally plot with females). Many of the graphs of Licking Bison material do not show strongly grouped data, but several suggest the presence of one and possibly up to three males. Figures 6.8-6.20 illustrate plots of carpal and tarsal data.

The majority of calcanei have unfused tuber calcis epiphyses, indicating they come from immature individuals aged less than 5.3 years (Bement and Basmajian 1996). Morlan (1991) found good separation between bulls and cows/calves by plotting distal width against distal depth (Figures 6.8) and by plotting the length of the astragalus articular facet against the length

of the C+4 articular facet (Figure 6.9). Neither plot provided distinct groupings for the Licking Bison specimens, but distal width versus distal depth does show a positive correlation.

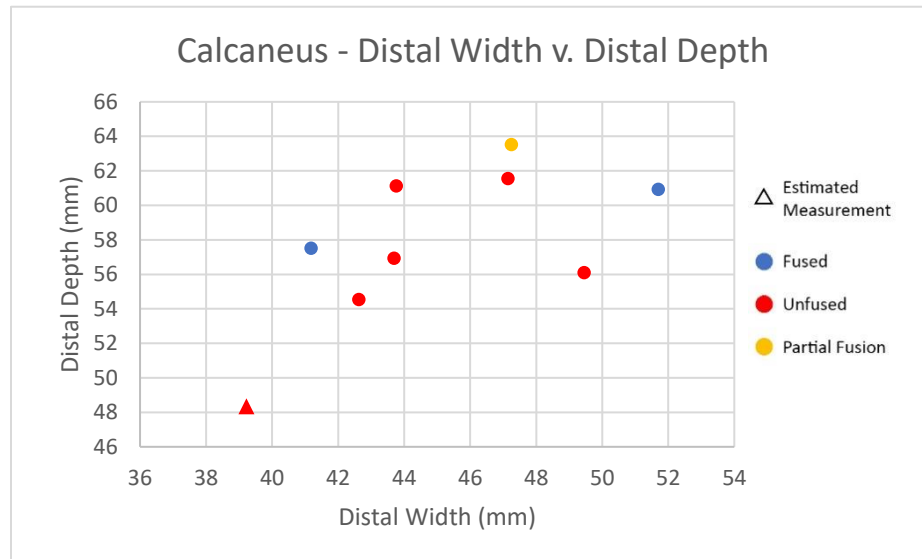


Figure 6.8. Calcaneus distal width versus distal depth measurements for specimens 0678a, 0898, 0996, 1555, 1570, 1637, 1648, 1742, and 1753a. Triangles indicate specimens for which one or both measurements are estimates. See Table A1.16 in Appendix I for additional information.

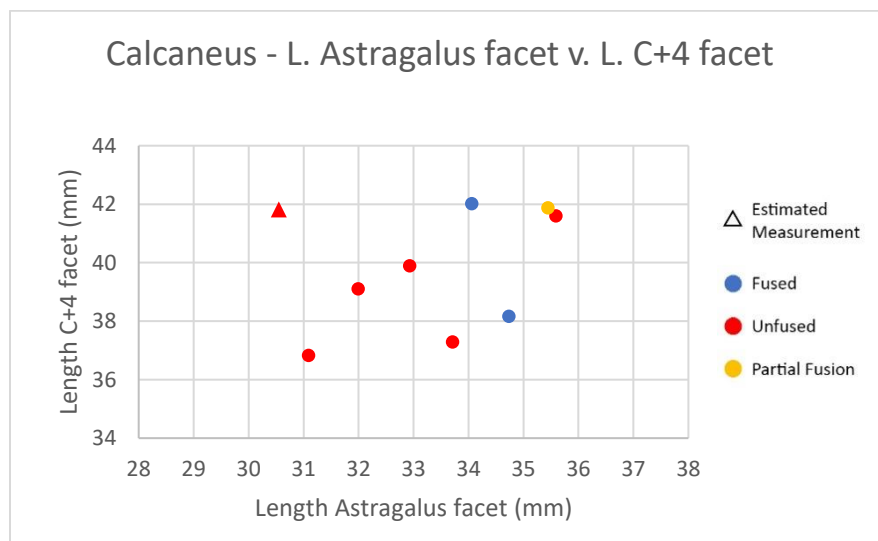


Figure 6.9. Calcaneus measurements, length of astragalus facet versus length of C+4 facet for specimens 0678a, 0898, 0996, 1155, 1570, 1637, 1648, 1742, and 1753a. Triangles indicate specimens for which one or both measurements are estimates. See Table A1.15 in Appendix I for additional information.

Several combinations of astragali measurements were plotted with mixed results (Figures 6.10-6.12). A plot of medial length versus distal width, which produced distinct clusters for Morlan (1991), did not produce clusters in the Licking Bison material (Figure 6.10). The plots of medial depth versus medial length (Figure 6.11) and medial depth versus distal width (Figure 6.12) form two, possibly even three, groupings.

If the plot of medial length versus medial depth (Figure 6.11) is interpreted as two clusters, five specimens fall into the ‘male’ group, with an MNI of three. This would be the largest number of males identified by any single plot. A second possible interpretation is that Figure 6.11 shows three clusters (two specimens in the highest size class, three in the middle, and seven in the lowest group), which could represent adult males, adult females, and juveniles.

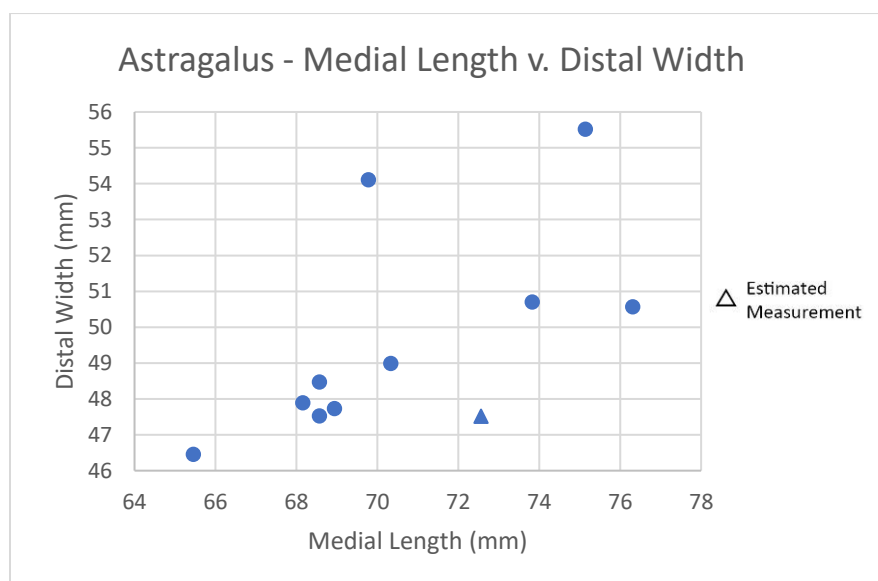


Figure 6.10. Astragalus medial length versus distal width measurements for specimens 0437, 0678b, 0697, 0775, 0883, 1264, 1557, 1672, 1724, 1753b, and 1788. Triangles indicate specimens for which one or both measurements are estimates. See Table A1.15 in Appendix I for additional information.

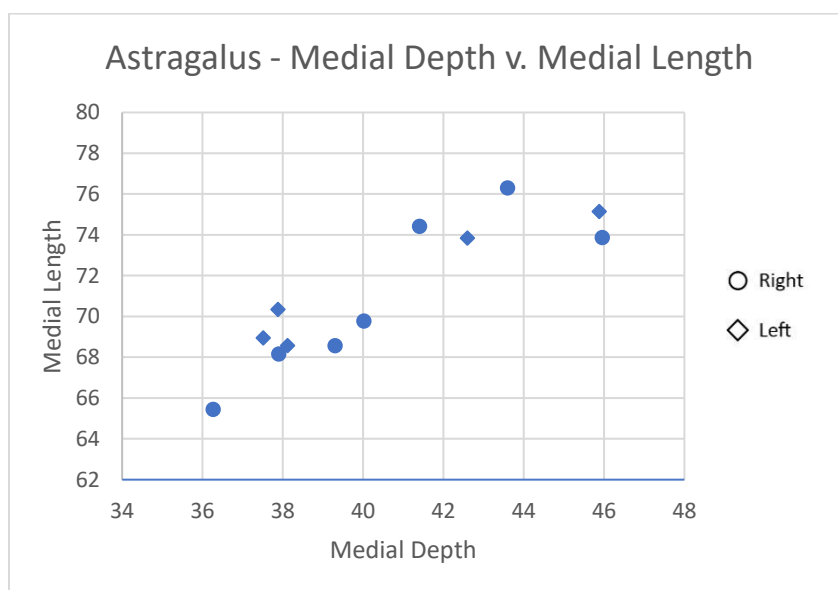


Figure 6.11. Astragalus medial depth versus medial length measurements for specimens 0437, 0678b, 0697, 0775, 0883, 1127, 1170h, 1557, 1672, 1724, 1753b, and 1788. See Table A1.15 in Appendix I for additional information.

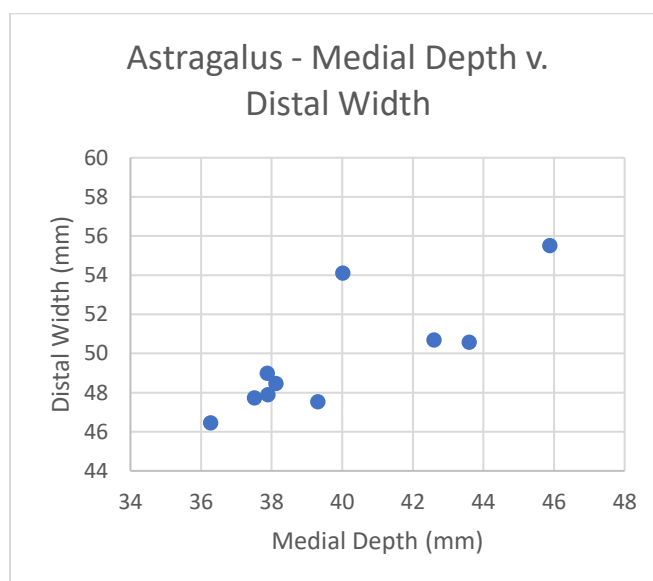


Figure 6.12. Astragalus medial depth versus distal width measurements for specimens 0437, 0678b, 0697, 0775, 0883, 1557, 1672, 1724, 1753b, and 1788. See Table A1.15 in Appendix I for additional information.

Plots for the intermediate carpal and radial carpal show a similar pattern to the astragalus medial depth versus medial length plot (Figure 6.11), with two or potentially three groupings (Figures 6.13 and 6.14). In both cases, the upper “male” cluster has an MNI of 2. The ulnar carpal plot shows two very distinct groupings (Figure 6.15). The upper cluster of four specimens is interpreted to represent males, and has an MNI of 2. Plots for the carpal 4 and carpal 2+3 both show one specimen plotting distinctly higher than the rest, and which are interpreted as male (Figures 6.16 and 6.17). Plots of measurements from the lateral malleolus, tarsal 2+3, and tarsal C+4 show a positive correlation between measurements, but lack clear clustering of groups (Figures 6.18, 6.19, and 6.20).

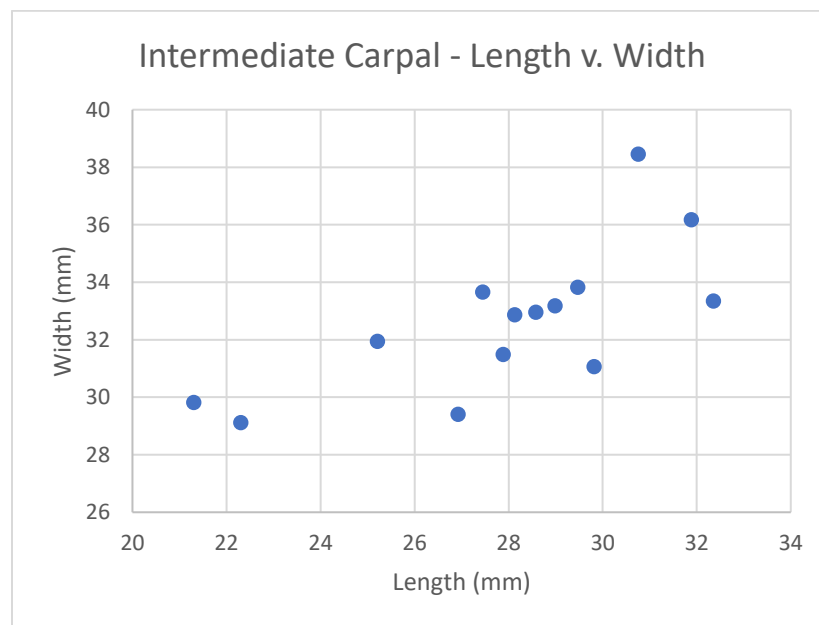


Figure 6.13. Intermediate carpal length versus width measurements for specimens 0007, 0205, 0719c, 0722e, 0772a, 0890, 1207, 1224b, 1322b, 1329, 1433, 1434c, 1592, and 1680b. See Table A1.9 in Appendix I for additional information.

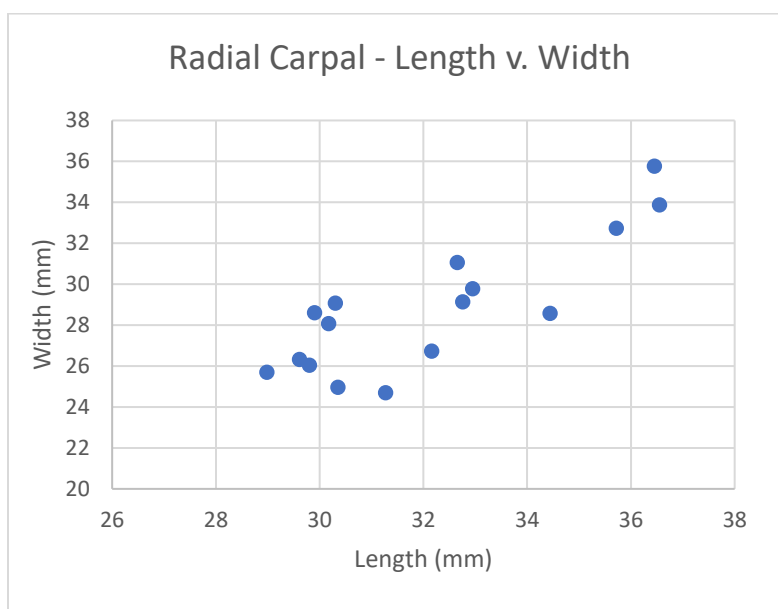


Figure 6.14. Radial carpal length versus width measurements for specimens 0128b, 0684b, 0722d, 0753a, 0895, 0949, 0964, 0981, 1042, 1170d, 1224a, 1326, 1434b, 1635, 1659, and 1680a. See Table A1.11 in Appendix I for additional information.

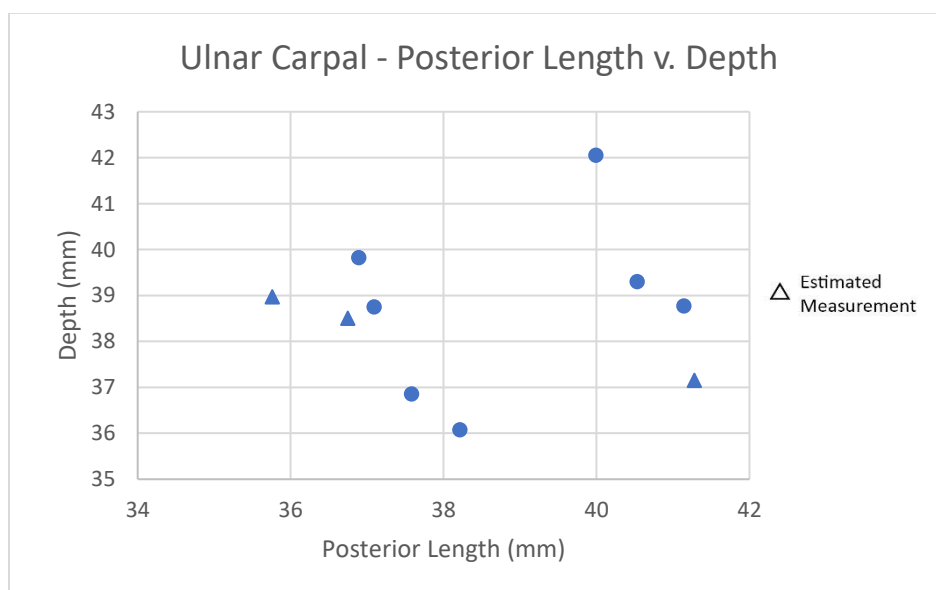


Figure 6.15. Ulnar carpal posterior length versus depth measurements for specimens 0293, 0719d, 0722f, 0772b, 1170e, 1224c, 1267, 1331, 1549, and 1652. Triangles indicate specimens for which one or both measurements are estimates. See Table A1.8 in Appendix I for additional information.

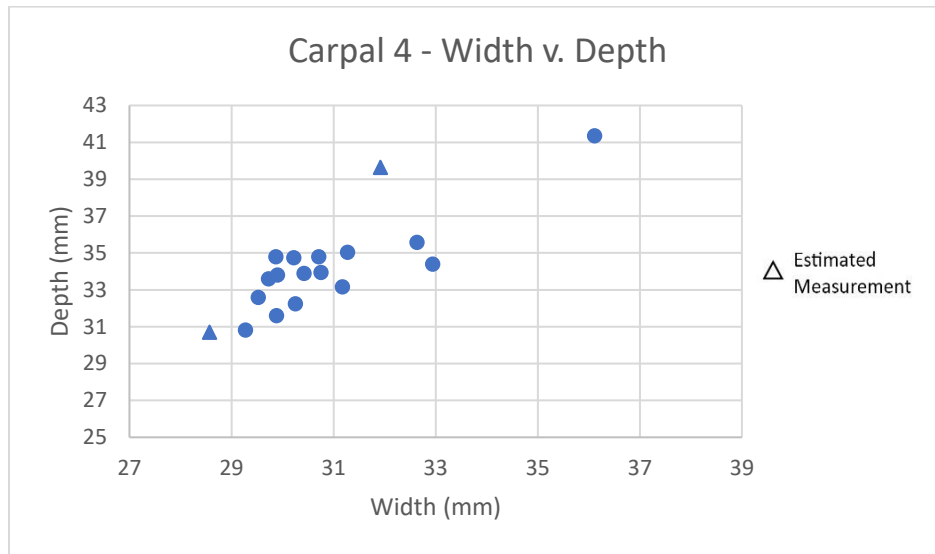


Figure 6.16. Carpal 4 width versus depth measurements for specimens 0017, 0046, 0054b, 0131d, 0219b, 0354b, 0626c, 0722c, 0772c, 1144, 1170c, 1193, 1322a, 1330, 1434a, 1520b, 1594, and 1654c. Triangles indicate specimens for which one or both measurements are estimates. See Table A1.7 in Appendix I for additional information.

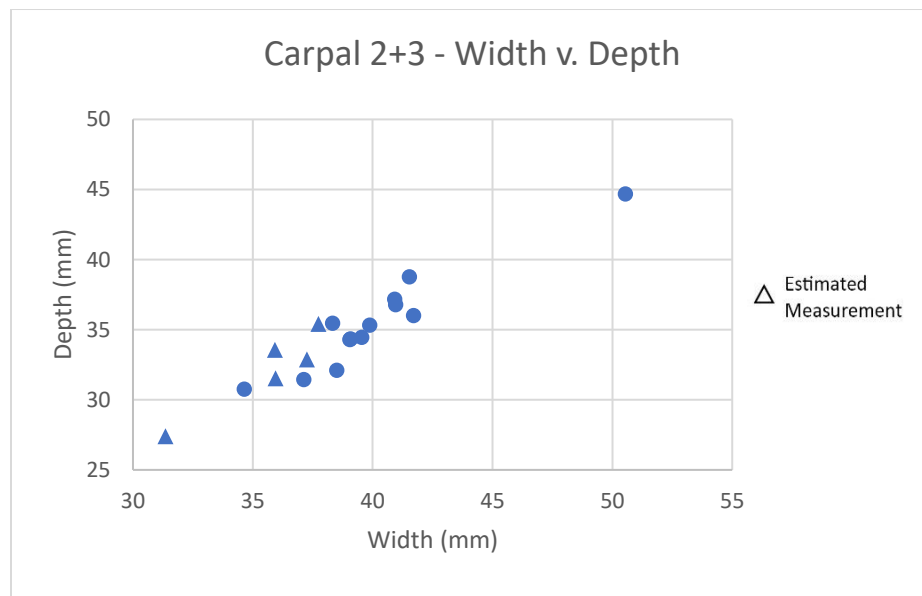


Figure 6.17. Carpal 2+3 width versus depth measurements for specimens 0132, 0182a, 0219a, 0238b, 0359b, 0626b, 0667a, 0720b, 0722b, 0953, 0965, 1170a, 1170b, 1327, 1434a, 1525, 1654b, and 1673. Triangles indicate specimens for which one or both measurements are estimates. See Table A1.10 in Appendix I for additional information.

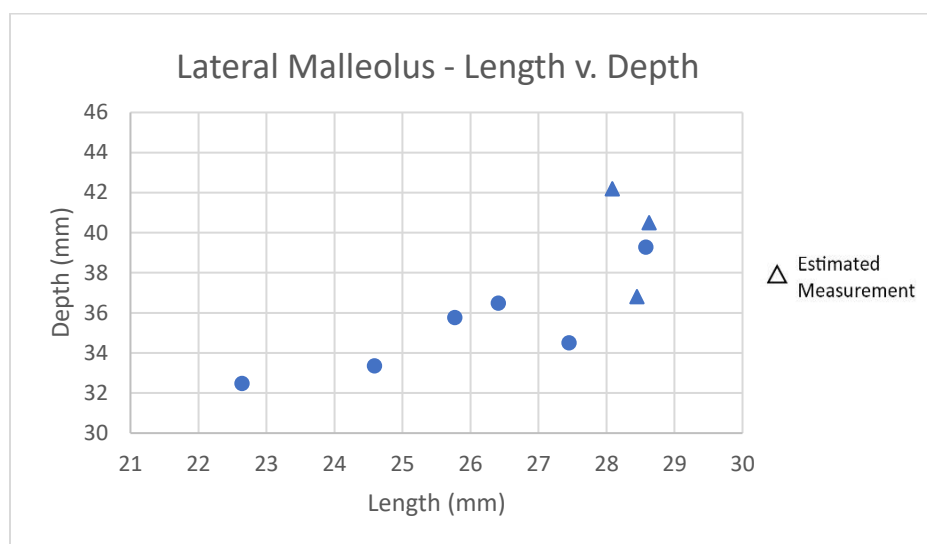


Figure 6.18. Lateral malleolus length versus depth measurements for specimens 0123e, 0238a, 0341b, 0438, 0678c, 0762b, 0896, 1753e, and 1774. Triangles indicate specimens for which one or both measurements are estimates. See Table A1.19 in Appendix I for additional information.

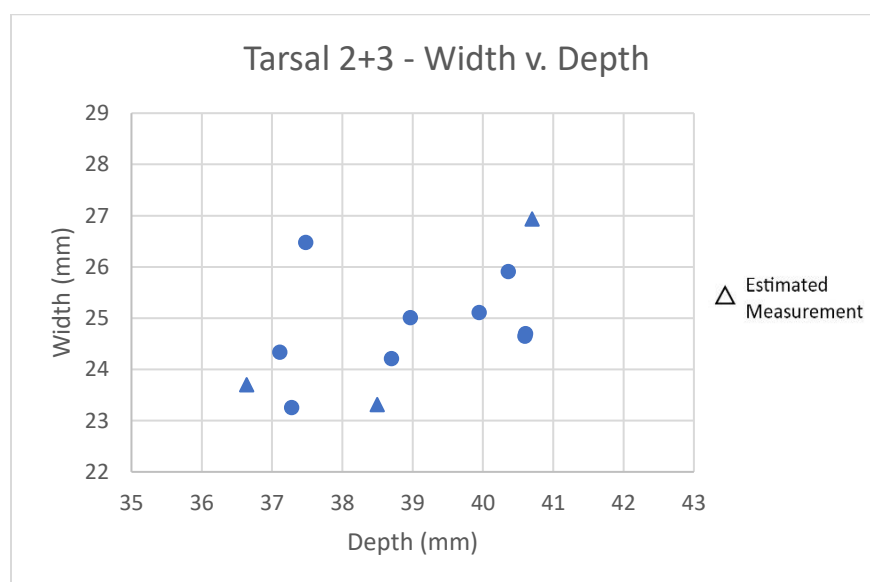


Figure 6.19. Tarsal 2+3 width versus depth measurements for specimens 0182b, 0219c, 0219d, 0861, 1069b, 1184, 1296b, 1318a, 1318b, 1556c, 1721, and 1753d. Triangles indicate specimens for which one or both measurements are estimates. See Table A1.19 in Appendix I for additional information.

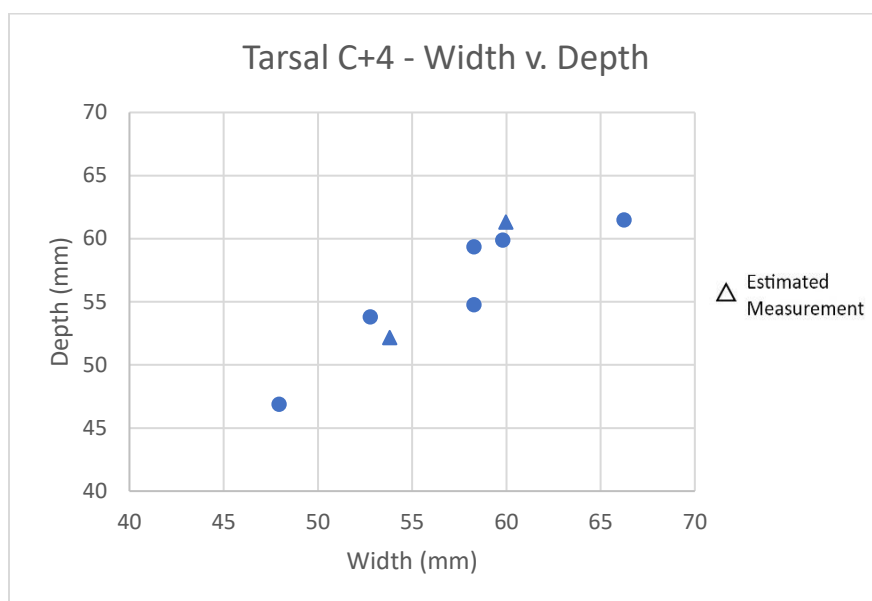


Figure 6.20. Tarsal C+4 width versus depth measurements for specimens 0426, 0753b, 1182, 1489, 1556b, 1601, 1689, and 1753c. Triangles indicate specimens for which one or both measurements are estimates. See Table A1.17 in Appendix I for additional information.

Morlan's (1991) plots from the Sjøvold site show clear separation between groups, even with small sample sizes. Licking Bison sample sizes are similar to Morlan's, but many plots do not show distinct clustering. This may be an indication that the Licking Bison assemblage represents a predominately calf/cow herd, and lacks enough male specimens to form clear groupings for plots of certain elements.

The metacarpals provide the most reliable data that at least one adult male and four adult females were present at the site. Evaluations of several other elements support the presence of at least one adult male in the herd, including one probable male skull, and plots of the carpal 4, carpal 2+3, and proximal radius, which all show one data point far larger than the rest.

Plots of the ulnar, radial, and intermediate carpals show groupings that suggest an MNI of two for the upper "male" clusters. One astragalus plot (Figure 6.11) suggests as many as three adult males in the herd, depending on how the clusters are interpreted. Because there is

substantial variation in clustering between carpal and tarsal plots, and multiple interpretations of clusters are possible, the higher MNI for adult males is considered not conclusive without further supporting evidence. Taking all plots together, the Licking Bison assemblage is interpreted to have at least four adult females and at least one, possibly up to three, adult males.

Only five of the 22 individuals present in the assemblage are definitely identified as male or female. However, based on dental ages distributions, the assemblage contains a high proportion of juveniles. Fifteen individuals are below 5.3 years old, the age at which the final longbone epiphyses fuse (Bement and Basmajian 1996). Ten individuals are 2.6 years old or younger, below the age at which metapodials fuse (Bement and Basmajian 1996).

The high proportion of adult females, juveniles, and calves to adult males would be consistent with a late fall death, when the majority of males are generally living singly or in small bachelor herds away from the matriarchal herd of adult females, juveniles, and calves (Olson 2005).

Chapter 7: Bison Species Identification

The bison from the Licking Bison site were not able to be identified to species. Bison species are largely distinguished on the basis of cranial characteristics, and the lack of complete skulls and the single partial horncore prevented identification of Licking Bison material. The few measurements that were obtained from partial skulls are reported in Appendix I (Table A1.2).

In the absence of meaningful skull data, measurements from mature Licking Bison metapodials, humeri, radii, and tibiae were compared to published ranges for *B. bison bison* and *B. antiquus occidentalis* from McDonald (1981). Sample sizes are small, and the femora did not provide any usable measurements. Astragali volumes were also compared to data from other Holocene bison populations.

Measurements generally fall within the published ranges of modern *B. bison bison*, but there is also significant overlap with the ranges of *B. antiquus occidentalis*. These comparisons show that the overall size of Licking Bison individuals may tend towards modern *B. bison bison*, however this determination is tentative and requires further research.

Longbones

There is a large degree of overlap between the ranges of males and females and between the species in McDonald's data (1981). Most measurements of Licking Bison specimens generally fall within the overlap of *B. bison bison* males, *B. bison bison* females, and *B. antiquus occidentalis* females (Tables 7.1-7.5). Few measurements are large enough to reach the lower end of the range of *B. antiquus occidentalis* males, and even when they do, they can still fit comfortably within the overlapping ranges of *B. antiquus occidentalis* females and *B. bison bison* males.

Female Licking Bison metacarpal measurements fit within the range of overlap for female *B. bison bison*, and female *B. antiquus occidentalis*. Measurement Mc3 from the single male metacarpal (0448a) exception is too large for the female range of both subspecies, but fits within the overlap of the males. The measurement is toward the upper end of the range for male *B. bison bison*. This is the same specimen identified as male in the bivariate plot in Chapter 6 (Figure 6.1).

The metatarsals are not helpful in determining species affinity. The female metatarsal (0016) fits within the wide overlap of female *B. bison bison* and *B. antiquus occidentalis*. The other two unsexed metatarsals sit at the upper end of the range for *B. bison bison* female and are within the ranges of male *B. bison bison* and male and female *B. antiquus occidentalis*.

Two radii, one identified as male, the other as possibly male in Chapter 6 (Figure 6.5) sit mostly within the overlap of male *B. bison bison* and *B. antiquus occidentalis*. Measurement Mc1 is on the cusp of the range for *B. antiquus occidentalis*, but the measurements for Mc2 and Mc3 are closer to the upper end of the ranges for *B. bison bison*.

Both humeri were too incomplete to measure rotational length. Measurement Mc2 and Mc3 both sit within the overlap between female *B. bison bison* and female *B. antiquus occidentalis*, and are too small to reach the lower end of the ranges for males of either subspecies.

Tibia measurements are larger than the female *B. bison bison* range and fit better with male *B. bison bison* or *B. antiquus occidentalis*. The three largest tibiae (0001, 0682, and 1838) correspond to the largest specimens on the bivariate tibia plot in Chapter 6 (Figure 6.7). While this plot did not form distinct clusters allowing for confident identification of these specimens as male, their positioning on the graph indicates it is likely. Assuming these specimens are males, they mostly fit more comfortably with male *B. bison bison*. Measurements for Mc1 are near the

high end of the range for *B. bison bison*, but a few Mc2 and Mc3 measurements are below the low end of the range for *B. antiquus occidentalis*.

Despite there being significant overlap in the ranges between *B. bison bison* and *B. antiquus occidentalis*, several specimens are closer to the upper end of the size range for *B. bison bison*, and at or near the lower end of the range of *B. antiquus occidentalis*. This suggests the Licking Bison individuals more closely match data from modern *B. bison bison*.

All measurements in Tables 7.1-7.5 are recorded in millimeters. The * denotes minimum measurements from specimens with minor bone loss; ** denotes specimens broken in two or more pieces, where measurements were taken while holding pieces together; *** denotes specimens that were glued together, usually in articulation. Measurements were taken as close to the appropriate positions as possible but should be considered estimates.

Table 7.1. *Humerus measurements from Licking Bison, compared to ranges for B. bison bison and B. antiquus occidentalis from McDonald (1981).*

Licking Bison Humeri					
Catalog #	Side	Sex	Mc1	Mc2	Mc3
0149	R	Unknown	-	52.76	42
1438	L	Unknown	-	53.03	41
Humerus ranges from McDonald (1981)					
			<i>B. bison bison</i>	<i>B. antiquus occidentalis</i>	
Male					
Mc1 – Approx. Rotational Length			295-345	326-402	
Mc2 – Antero-posterior diameter of diaphysis at right angle to Mc3			54-68	58-76	
Mc3 – Transverse min. of diaphysis			43-56	48-66	
Female					
Mc1 – Approx. Rotational Length			259-301	286-395	
Mc2 – Antero-posterior diameter of diaphysis at right angle to Mc3			46-54	44-67	
Mc3 – Transverse min. of diaphysis			37-44	35-44	

Table 7.2. *Radius measurements from Licking Bison, compared to ranges for B. bison bison and B. antiquus occidentalis from McDonald (1981).*

Licking Bison Radii						
Catalog #	Side	Sex	Mc1	Mc2	Mc3	
0585	L	Male	-	34.72	56.67	
0957	R	Poss. Male	305.78	35.43*	54.61*	
Radius ranges from McDonald (1981)						
				<i>B. bison bison</i>	<i>B. antiquus occidentalis</i>	
Male						
Mc1 – Approx. Rotational Length				302-343	306-381	
Mc2 – Antero-posterior min. of diaphysis				29-36	30-39	
Mc3 – Transverse min. of diaphysis				48-61	52-69	
Female						
Mc1 – Approx. Rotational Length				274-313	284-372	
Mc2 – Antero-posterior min. of diaphysis				22-30	25-37	
Mc3 – Transverse min. of diaphysis				38-50	37-57	

Table 7.3. *Tibia measurements from Licking Bison, compared to ranges for B. bison bison and B. antiquus occidentalis from McDonald (1981).*

Licking Bison Tibiae						
Catalog #	Side	Sex	Mc1	Mc2	Mc3	*Questionable provenience, may not be from Licking Bison site
0001	L	Poss. Male	391	35.24	51	
0682	R	Poss. Male	371	31.66	43	
1752	L	Unknown	365	31.3	43	
1838*	L	Poss. Male	373	36.25	47	
Tibia ranges from McDonald (1981)						
				<i>B. bison bison</i>	<i>B. antiquus occidentalis</i>	
Male						
Mc1 – Approx. Rotational Length				348-391	372-464	
Mc2 – Antero-posterior min. of diaphysis				30-38	34-45	
Mc3 – Transverse min. of diaphysis				45-54	49-61	
Female						
Mc1 – Approx. Rotational Length				313-352	311-419	
Mc2 – Antero-posterior min. of diaphysis				28-34	29-39	
Mc3 – Transverse min. of diaphysis				37-46	40-54	

Table 7.4. *Metacarpal measurements from Licking Bison, compared to ranges for B. bison bison and B. antiquus occidentalis from McDonald (1981).*

Licking Bison Metacarpals					
Catalog #	Side	Sex	Mc1	Mc2	Mc3
0245	R	Unknown	215	25.9	-
0448a	L	Male	212.17*	-	51.37*
0626a	R	Female	198	24.87	38
0722a/0723	L	Unknown	206**	-	-
1119	L	Unknown	191**	-	-
1335	R	Female	199	24.15	38
1434a	R	Female	204.57***	23.03	34
1639	R	Female	207	25.73	40
1654a	L	Female	204	25.98	39
Metacarpal ranges from McDonald (1981)					
			<i>B. bison bison</i>	<i>B. antiquus occidentalis</i>	
Male					
Mc1 – Total Length			192-227	199-240	
Mc2 – Antero-posterior min. of diaphysis			22-31	26-35	
Mc3 – Transverse min. of diaphysis			38-53	40-61	
Female					
Mc1 – Total Length			182-219	194-233	
Mc2 – Antero-posterior min. of diaphysis			19-28	22-32	
Mc3 – Transverse min. of diaphysis			36-44	32-49	

Table 7.5. *Metatarsal measurements from Licking Bison, compared to ranges for B. bison bison and B. antiquus occidentalis from McDonald (1981).*

Licking Bison Metatarsals					
Catalog #	Side	Sex	Mc1	Mc2	Mc3
0016	L	Female	247	28	31.09
0900	R	Unknown	258	31	35.57
1511	L	Unknown	254	31	35.91
Metatarsal ranges from McDonald (1981)					
			<i>B. bison bison</i>	<i>B. antiquus occidentalis</i>	
Male					
Mc1 – Total Length			232-276	248-300	
Mc2 – Antero-posterior min. of diaphysis			27-34	29-38	
Mc3 – Transverse min. of diaphysis			30-43	32-48	
Female					
Mc1 – Total Length			224-264	230-284	
Mc2 – Antero-posterior min. of diaphysis			23-31	25-35	
Mc3 – Transverse min. of diaphysis			25-36	25-39	

Astragali

Only five astragali were complete enough to measure volume (Table 7.6). Two of the specimens (1557 and 1788) exhibited some surface erosion which may have a minor deflating effect on volume measures. Additionally, astragalus 1788 has an expanding crack, which may have a minor impact on the measurement by artificially inflating the volume (Figure 7.1).

Table 7.6. *Volumes of complete astragali from the Licking Bison site.*

Catalog #	Unit	Shot #	Side	Volume (cm ³)
0678b	E	701	R	70.94
0883	G	43	L	98.73
1557	Y	977	R	91.62
1724	BB	1538	R	69.61
1788	BB	N/A	L	68.96
Average volume = 79.97cm ³ , Standard Deviation 14.12cm ³				

The ages and sexes of the astragali are unknown, which in addition to the small sample size, makes meaningful comparison with datasets from other sites difficult. Licking Bison astragali volumes do not differentiate between *B. antiquus occidentalis* and *B. bison bison* overlapping with ranges from the Hawken, Vore and Glenrock sites (Zeimens and Zeimens 1974).



Figure 7.1. Astragalus 1788, showing expanding crack and surface abrasion.

Chapter 8: Seasonality

A total of 18 partial or complete mandibular tooththrows (Figures 8.1-8.2; Table 8.1) and 22 maxillary tooththrows (Figures 8.4-8.5; Table 8.2) were assessed for eruption and wear patterns to determine season of death for the Licking Bison specimens. Isolated specimens were also included when complete enough to identify wear patterns. Based on comparison to published data from other bison kill sites, the age at death for the Licking Bison individuals is interpreted to be birth +0.6 years, or approximately 7.2 months after the birthing period. Assuming a peak birthing period of 4-6 weeks in late April through May (Kornfeld et al. 2010; Gogan et al. 2005), this indicates a late fall to earliest winter kill event for the Licking Bison herd.

Eruption and wear patterns on the Licking Bison mandibular dentitions compare most favorably to those from the Casper (N+0.6 years) and Horner (N+0.6 years) sites (Reher 1974; Todd 1987a; Todd and Hofman 1987). Licking Bison specimens also compare well with mandibular dentition from the Glenrock site, but show slightly more wear on the first molar in age Group 1 (0.5 years) (Frison and Reher 1970). Licking Bison mandibular wear is also similar to the Hawken (N+0.7 years) site, but in several instances the wear on Hawken specimens appears to be slightly more advanced (Frison et al. 1976; Todd et al. 1996). Mandibles from Licking Bison consistently show less wear than the Agate Basin component of the Agate Basin site which are aged at N+0.7-0.8 years old (Hill 2008).

Maxillary wear and eruption patterns offer a less precise estimate of age, because there are fewer published references of maxillary dentition available for comparison. Maxillary dentition from Licking Bison is similar to the Casper Site when comparison is possible (not all age groups are represented) (Wilson 1974). Licking Bison specimens generally show comparable

or more wear than maxillae from the Clary Ranch site (N+0.3-0.5 years) and always show less than the Agate Basin component of the Agate Basin site (N+0.7-0.8 years) (Hill 2008).

Mandibular Dentition

Dental Age Group 1 (0.6 years old): The dp2 is fully erupted but shows only very light wear with no exposed dentine. The dp3 and dp4 in are full wear. Light wear is visible on posterior exostylid of dp4, but it is not yet connected to the rest of the tooth. Anterior exostylid is at the level of occlusal surface, but not showing wear. The m1 is fully erupted and shows wear on facets I-IV. One specimen (1834, right) shows light wear on facet VI. The m2 is visible in crypt, but unerupted on 1834 (left).

The Licking Bison material compares well with specimens from Group 1 (0.6 years old) from the Casper and Horner sites, both interpreted to be 0.6 years old at death (Reher 1974; Todd 1987a). Licking Bison specimens show slightly less wear on the m1 than is described on Group 1 from Hawken which are aged at 0.7 years (Frison et al. 1976). Wear patterns are slightly more advanced than Glenrock specimens for Age Group 1 (0.5 years old) (Frison and Reher 1970).

Dental Age Group 2 (1.6 years old): The dp3 is heavily worn. The dp4 is in full wear with the posterior exostylid worn to the point of connecting with the rest of the tooth. The m1 shows moderate to light wear on all facets. The protoconid of the m2 is erupting but is largely obscured by dirt and glue on the only *in situ* tooth row in this age group (0745b).

The obscured m2 makes comparison difficult, but Licking Bison specimen 0745b closely resembles the dp3-m1 wear pattern on Clary Ranch Group 2 specimens (1.3-1.5 years old), as well as Horner Group 2 specimens (1.6 years old) (Hill 2008; Todd 1987a).

Table 8.1. *Licking Bison mandibular dentition specimens.*

DAG	Tooth	L	R	NISP	MNI/DAG	Specimens
1 (0.6 years)	dp2	1	1	2	2	L: 1834; R: 1834
	dp3	1	1	2		L: 1834 ; R: 1834
	dp4	1	2	3		L: 1834 ; R: 1834 , 0062
	m1	1	1	2		L: 1834 ; R: 1834
	m2	0	1	1		L: 1834 ; R: 1834
2 (1.6 years)	dp3	0	1	1	4	R: 0745b
	dp4	1	1	2		L: 0745b; R: 0745b
	m1	2	1	3		L: 0745b, 1210; R: 0745b
	m2	4	4	8		L: 0745b, 1210, 1210 (2), 1039; R: 0745b , 0062, 1210, 1169
	m3	0	2	2		R: 1210, 1210 (2)
3 (2.6 years)	dp2	0	1	1	3	R: 1532 ,
	dp3	0	1	1		R: 1532 ,
	dp4	0	2	2		R: 1532 , 1032
	m1	0	2	2		R: 1532 , 1032
	m2	0	2	2		R: 1532 , 1032
	m3	0	3	3		R: 1532 , 1032 , 1251
4 (3.6 years)	m1	1	1	2	3	L: 0214 ; R: 1219
	m2	3	2	5		L: 0214 , 1219 , 1039; R: 1219 , 1219 (2)
	m3	2	1	3		L: 0214 , 1219 ; R: 1251
5 (4.6 years)	p2	1	1	2	2	L: 0613 ; R: 0599
	p3	1	1	2		L: 0613 ; R: 0599
	p4	2	1	3		L: 0613 , 0914 ; R: 0599
	m1	2	1	3		L: 0613 , 0914 ; R: 0599
	m2	2	1	3		L: 0613 , 0914 ; R: 0599
	m3	2	1	3		L: 0613 , 0914 ; R: 0599
7-8 (6.6-7.6 years)	p2	1	1	2	3	L: 1835 ; R: 1835 ,
	p3	1	2	3		L: 1835 ; R: 1835 , 1730
	p4	1	2	3		L: 1835 ; R: 1835 , 1730
	m1	1	3	4		L: 1835 ; R: 1835 , 0961 , 1730
	m2	1	3	4		L: 1835 ; R: 1835 , 0961 , 1730
	m3	1	3	4		L: 1835 ; R: 1835 , 0961 , 1730
9+ (8.6+ years)	p2	2	1	3	3	L: 0236 , 0476 ; R: 0578
	p3	2	1	3		L: 0236 , 0476 ; R: 0578
	p4	2	1	3		L: 0236 , 0476 ; R: 0578
	m1	2	1	3		L: 0236 , 0476 ; R: 0578
	m2	3	1	4		L: 0236 , 0476 , 0049; R: 0578
	m3	3	2	5		L: 0236 , 0476 , 0049; R: 0578 , 0049
Maximum MNI by mandibular dentition: 20 individuals						

Note: Includes isolated specimens and tooththrows too damaged or obscured to depict in Figures 8.1 and 8.2. Specimens in bold illustrated in Figure 8.1 and 8.2.












	dp2/ p2	dp3/ p3	dp4/ p4	m1	m2	m3	
1834 R							DAG 1 (0.6 yrs)
1834 L							
0745b R							DAG 2 (1.6 yrs)
1532 R							DAG 3 (2.6 yrs)
1032 R							
1219 R							DAG 4 (3.6 yrs)
1219 L							
0214 L							
0914 L							DAG 5 (4.6 yrs)
0599 R							
0613 L							

Figure 8.1. Mandibular dentitions from the Licking Bison site, DAG 1-5.

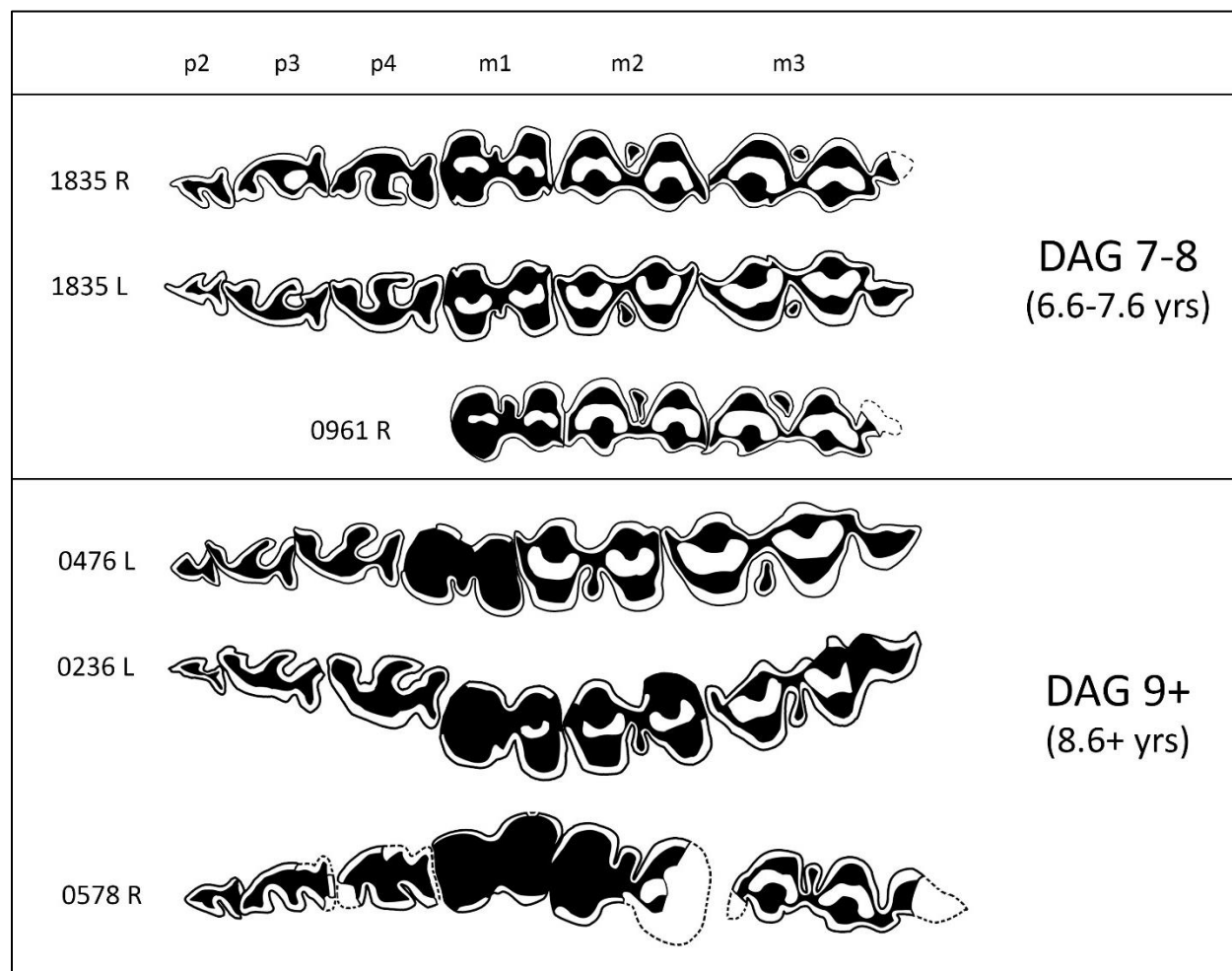


Figure 8.2. Mandibular dentitions from the Licking Bison site, DAG 7-8 and 9+.

Dental Age Group 3 (2.6 years old): dp2 is moderately worn. dp3 and dp4 are heavily worn. dp4 fossettes are reduced in one specimen (1532), and nearly absent in the other (1032). The m1 is in full wear, but the exostylid is only in wear on one of two specimens (1032). The m2 shows moderate wear. The hypoconid and entoconid are connected by a thin exposure of dentine on specimen 1532 but remain separated by enamel on specimen 1032. The first two cusps of m3 are erupting but unworn. The m3 hypoconulid is not yet visible.

The two Licking Bison mandibles compare well to Group 3 specimens (2.5 years) from the Glenrock site (Frison and Reher 1970). Wear on the Licking Bison specimens seems slightly

less advanced than Horner Group 3 (2.6 years) and Hawken Group 3 (2.7 years) both of which show light wear on facets I and II of the m3 (Todd 1987a; Frison et al. 1976). The p2 and p3 are also already erupted on Horner and Hawken mandibles, which is not the case on specimen 1532, the only Licking Bison specimen for which the p2 and p3 eruption can be assessed. However, Reher (1974) notes that premolar eruption in bison can be highly variable.

Dental Age Group 4 (3.6 years old): The m1 is in full wear with the exostylid worn and connected to the rest of the tooth. The m2 is in full wear, but the exostylid is not yet worn. The m3 shows light wear on facets I and II on specimen 0214, while specimen 1219 (left) shows moderate wear on facets I and II and light wear on facets III-VI. The hypoconulid is visible but unworn.

Licking Bison Group 4 specimens compare well with specimens from Group 4 (3.6 years) from the Casper site (Reher 1974). Licking Bison specimens also match well with Horner Group 4 (3.6 years) but show more wear on m1 exostylids, which are connected on Licking Bison specimens but remain separated on Horner specimens (Todd and Hofman 1987). Wear on Licking Bison m3s is slightly less advanced than seen in Group 3 (3.7 years) from the Hawken site, which in some cases show wear on m3 facets I-VIII (Frison et al. 1976).

Dental Age Group 5 (4.6 years old): p2-p4 is erupted and in full wear. The m1 is in full wear with the exostylid worn and connected to the rest of the tooth. The m2 is in full wear, and the exostylid is just beginning to wear in one specimen (0599), but not yet worn in the other two (0613 and 0914). The m3 is in full wear with the hypoconulid showing moderate wear and just barely connected to the rest of the tooth by a thin band of exposed dentine.

The Licking Bison mandibles compare well with specimens from Group 5 (4.6 years) from the Casper site (Reher 1974). Licking Bison specimens show slightly more wear on the m3

hypoconulid than Group 4 (4.6) specimens from Horner, where the hypoconulid remains separated from the second cusp of the m3 (Todd and Hofman 1987).

Beyond Dental Age Group 5 all permanent teeth are erupted and in wear, making it difficult to separate specimens into yearly age groups. Additionally, individual variation in wear patterns and the small sample size from the Licking Bison assemblage make age assignment less certain. The remaining six tooththrows were able to be separated into two distinct age groups based on differential wear patterns. The age group assignments (DAG 7-8 and DAG 9+) are based on comparison with materials described from other sites, but should be considered tentative.

Dental Age Group 6: no specimens in this age group.

Dental Age Group 7-8 (6.6-7.6 years old): p2-p4 are in full wear. The m1 shows heavy wear, with the exostylids connected to the body of the tooth. The m1 prefossettes are significantly reduced and the enamel is worn away on the anterior border of the m1. The m2 is in full wear, with the exostylid worn, but not connected to the body of the tooth. The m3 is in full wear, including the hypocondulid, which is connected to the posterior cusp by a thin exposure of dentine. The m3 exostylid is worn, but not connected to the body of the tooth.

The m3 exostylid wear pattern on the Licking Bison specimens is similar to wear on Hawken specimens in Group 7 (6.7 years) in which the m3 exostylid is usually worn (Frison et al. 1976). The m3 exostylid begins to wear in Horner/Finley Group 6C (7.6 years), by which time the m2 exostylid is connected to the main occlusal surface of the tooth (Todd and Hofman 1987). The Licking Bison m2 exostylids remain separated from the rest of the tooth, a condition which more closely matches Horner/Finley through Group 6B (6.6 years).

Dental Age Group 9+: The p2-p4 are in full wear. The m1 is heavily worn. Prefossettes and postfossettes are completely obliterated in two specimens (0476 and 0578), while the third

specimen (0236) retains a reduced postfossette. m1 exostylids are reduced or obliterated. Enamel is worn away on the anterior and posterior borders of the m1. The m2 exhibits heavy wear, with the exostylids connected to the body of the tooth. The m2 prefossette is obliterated on one specimen (0578). The m3 is in full wear, including the exostylid, which is connected to the main occlusal surface in two specimens (0236 and 0578), but remains separated on the third specimen (0476).

The three specimens in this group exhibit advanced wear typical of mature-old age individuals, but they cannot confidently be assigned an age at death. The following comparisons provide a guide, but are not conclusive.

Specimen 0476 closely matches the description of Group 6D (8.6 years) of the Horner/Finley specimens, with obliterated m1 fossettes, the m2 exostylid connected to the body of the tooth, and m3 exostylid remaining separate from the main occlusal surface of the tooth (Todd and Hofman 1987). Four loose, heavily worn incisors are also associated with this mandible.

The occlusal surfaces of the m2-m3 of specimen 0236 are partially obscured by dirt and glue, making it difficult to assess the wear pattern, but this mandible best matches Group 6E (9.6 years) from the Horner/Finley specimens, which exhibit a worn m3 exostylid connected to the main occlusal surface, and a heavily worn m1 with some fossettes obliterated (Todd and Hofman 1987).

Specimen 0578 most closely matches Group 6F (10.6 years) from the Horner/Finley specimens (Todd and Hofman 1987). The m1 fossettes and exostylid are obliterated, and the m2 has lost the prefossette.

Several other isolated specimens support the presence of at least one old age individual in the assemblage, including two heavily worn incisors (1176). Two additional molar specimens (0750 and 1089a) exhibit wear so advanced that all the enamel and most of the dentine has been worn away, leaving only polished single roots (Figure 8.3a and 8.3b). The m1 in bison infrequently becomes significantly more worn than the adjacent teeth, forming a pronounced dip in the occlusal surface of the toothrow when viewed from the side. A modern specimen from the Mammoth Site of Hot Springs, SD comparative collection exhibits this morphology (Figure 8.3c-8.3e), and an archaeological example can be seen in the Glenrock assemblage (Frison and Reher 1970, Fig. 3a). A similar wear pattern is visible on the m1-m2 of an old age animal from the Horner II bonebed (Todd 1987, Fig 5.10b), and the p3 and m1 of a mandible from the Hell Gap component of the Agate Basin site (Frison 1982, Fig. 4.30).

The two heavily worn specimens (0750 and 1089a) were initially identified by the author as potential elk ivories (maxillary canines) until comparison with the modern bison mandible. The high polish on the dentine and the lack of enamel can superficially resemble elk ivories, but the root morphology is distinct (Greer and Yeager 1967; Giering 2018). The wide, flat root on 1089a suggests it may have worn from a molar (probably m1), while the thinner root of 0750 may indicate it is a severely worn premolar root.

If elk ivories had been found in the absence of other elk skeletal material (as is the case at the Licking Bison site), it could have been culturally significant because elk canine teeth were used for decoration in Northern Plains cultures dating at least back to the Late Archaic (Giering 2018). Extra care should be taken to avoid misidentification of extremely worn teeth and elk ivories.

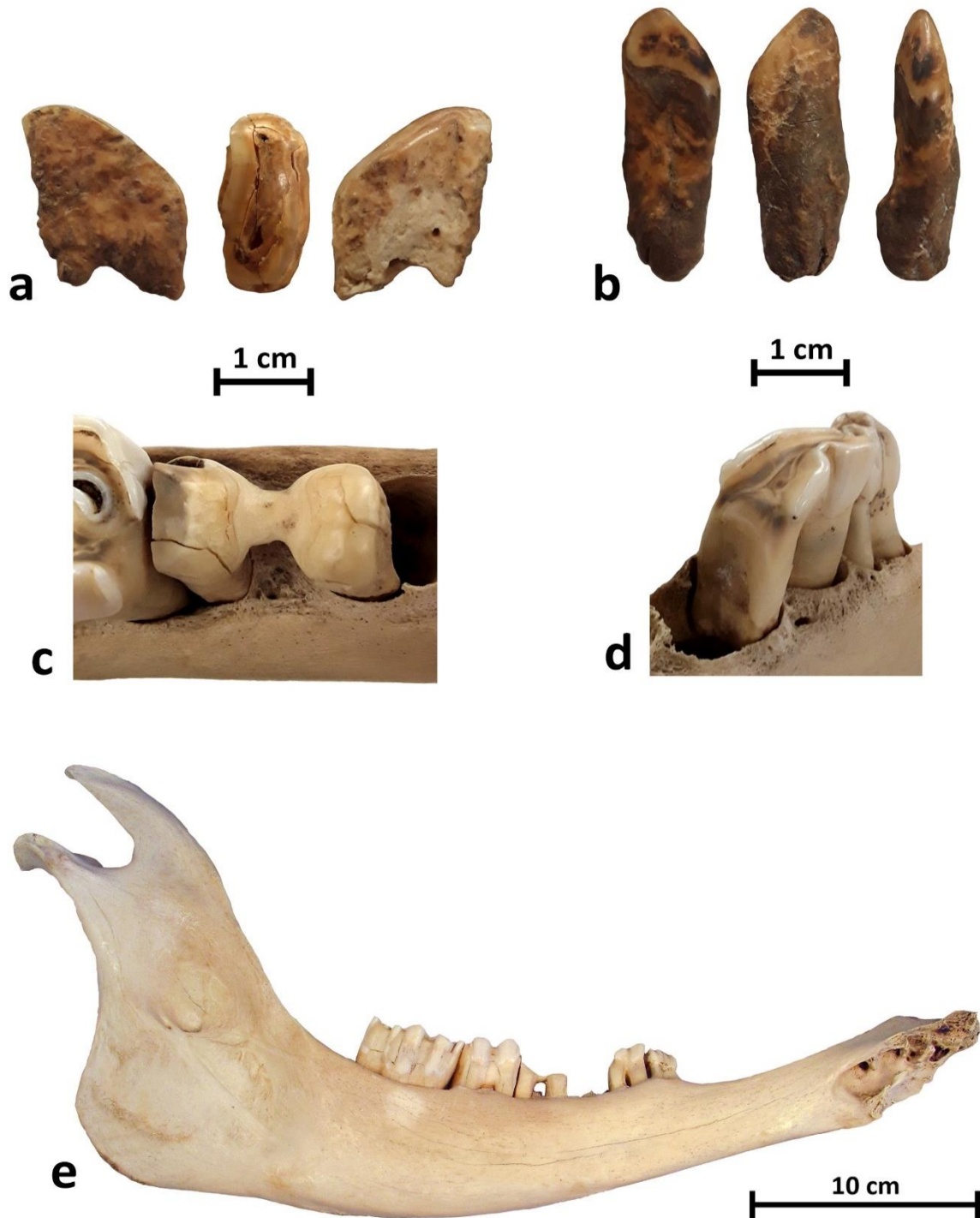


Figure 8.3. Worn bison teeth and modern comparisons from the Mammoth Site of Hot Springs, SD; a) Licking Bison specimen 1089; b) Licking Bison specimen 0750; c) modern heavily worn m1; d) heavily worn posterior of p3; e) modern left mandible, missing p4, showing heavy wear on the m1 and p3.

Maxillary Dentition

Dental Age Group 1 (0.6 years old): dP2-dP4 in full wear. Light wear is present on the dP4 endostyle, but it remains separated from the main occlusal surface. M1 is erupted, with only very light wear on facets I and II.

The single Licking Bison specimen in this age group (1834) compares well with Group II (0.6 years) specimens from the Casper site (Wilson 1974). Wear patterns on the Licking Bison specimen is bracketed between Clary Ranch Group 1 specimens (0.3-0.5 years) which show less advanced wear on the dP4, and Agate Basin Group 1 (0.7-0.8 years) specimens which exhibit heavier wear on the M1 (Hill 2008).

Dental Age Group 2 (1.6 years old): dP2-M1 in wear. dP2 and dP3 heavily worn. The dP3 prefossette is worn down to two small ovals. The dP4 is in full wear with the endostyle worn and connected to the rest of the tooth by a continuous loop of enamel. The interfossette is visible adjacent to the endostyle on three specimens (0745b, 0455, and 1456 [right side]). The M1 shows moderate wear on the first cusp and moderate to light wear on second cusp. Facets VII-VIII show lighter wear and remain separated by enamel. Both cusps of the M2 are erupting and show no visible wear. However, the M2 is largely obscured by dirt and glue on 0745b, and the protocone is damaged on both 1456 L and 1456 R.

The Licking Bison material compares well with Group 2 specimens (1.3-1.5 years) from the Clary Ranch site (Hill 2008). No specimens were reported from comparable age groups from the Casper or Agate Basin sites (Wilson 1974; Hill 2008).

Table 8.2. *Licking Bison maxillary dentition specimens.*

DAG	Tooth	L	R	NISP	MNI/DAG	Specimens
1 (0.6 years)	dP2	1	0	1	1	L: 1834
	dP3	1	0	1		L: 1834
	dP4	1	0	1		L: 1834
	M1	1	0	1		L: 1834
	M2	1	0	1		L: 1834
2 (1.6 years)	dP2	1	1	2	5	L: 0745b ; R: 1456 ,
	dP3	2	2	2		L: 0745b , 0455 ; R: 1456 , 0745b
	dP4	3	2	3		L: 0745b , 1456 , 0455 ; R: 1456 , 0745b
	M1	3	2	3		L: 0745b , 1456 , 0455 ; R: 1456 , 0745b
	M2	5	3	3		L: 0745b ; 1456 , 1210, 1156, 1039; R: 1456 , 0062, 1210
	M3	1	0	1		L: 1156
3 (2.6 years)	M1	1	1	2	1	L: 0214 ; R: 0214
	M2	1	1	2		L: 0214 ; R: 1251
	M3	1	1	2		L: 0214 ; R: 1251
4 (3.6 years)	P2	1	1	2	1	L: 0214; R: 0214
	P3	0	1	1		R: 0214
	P4	1	1	2		L: 0214; R: 0214
	M1	1	1	2		L: 0214 ; R: 0214
	M2	1	1	2		L: 0214 ; R: 0214
	M3	1	1	2		L: 0214 ; R: 0214
7-8 (6.6-7.6 years)	P2	4	3	7	5	L: 1835 , 1715 , 0614 , 0236; R: 0614 , 1835
	P3	3	3	6		L: 1835 , 1715 , 0614 ; R: 0614 , 1835 , 1736
	P4	4	3	7		L: 1835 , 1715 , 0614 , 0273 ; R: 0614 , 1835 , 1736
	M1	5	3	8		L: 1835 , 1715 , 0614 , 0273 , 1306 ; R: 0614 , 1735, 1715
	M2	3	5	8		L: 1715 , 0664 , 1306 , 0383; R: 0614 , 1835 , 1735, 1715
	M3	3	4	7		L: 1835 , 1715 , 0664 ; R: 0614 , 1835 , 1735, 1715
9+ (8.6+ years)	P2	1	0	1	2	L: 1306 ; R: 0049
	P3	1	0	1		L: 1306
	P4	1	0	1		L: 0049
	M1	2	1	3		L: 1306 , 0049; R: 1076
	M2	2	2	4		L: 1306 , 0049; R: 1076 ; 1306
	M3	2	2	4		L: 1306 , 0049; R: 1306 , 0049
Maximum MNI by maxillary dentition: 15 individuals						

Note: Includes isolated specimens and tooth rows too damaged or obscured to depict in Figures 8.4 and 8.5. Specimens in bold illustrated in Figure 8.4 and 8.5.









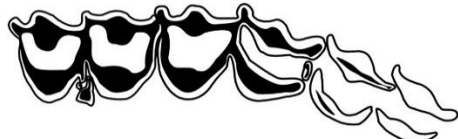
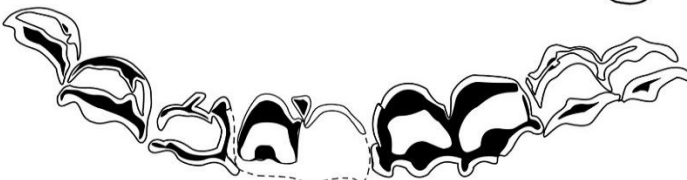
	dP2/ P2	dP3/ P3	dP4/ P4	M1	M2	M3	
1834 L							DAG 1 (0.6 yrs)
0745b L							DAG 2 (1.6 yrs)
0455 L							
1456 L							
1456 R							
0214 L							DAG 3 (2.6 yrs)
0214 R							
1251 R							
0214 L							DAG 4 (3.6 yrs)
0214 R							

Figure 8.4. Maxillary dentitions from the Licking Bison site, DAG 1-4.

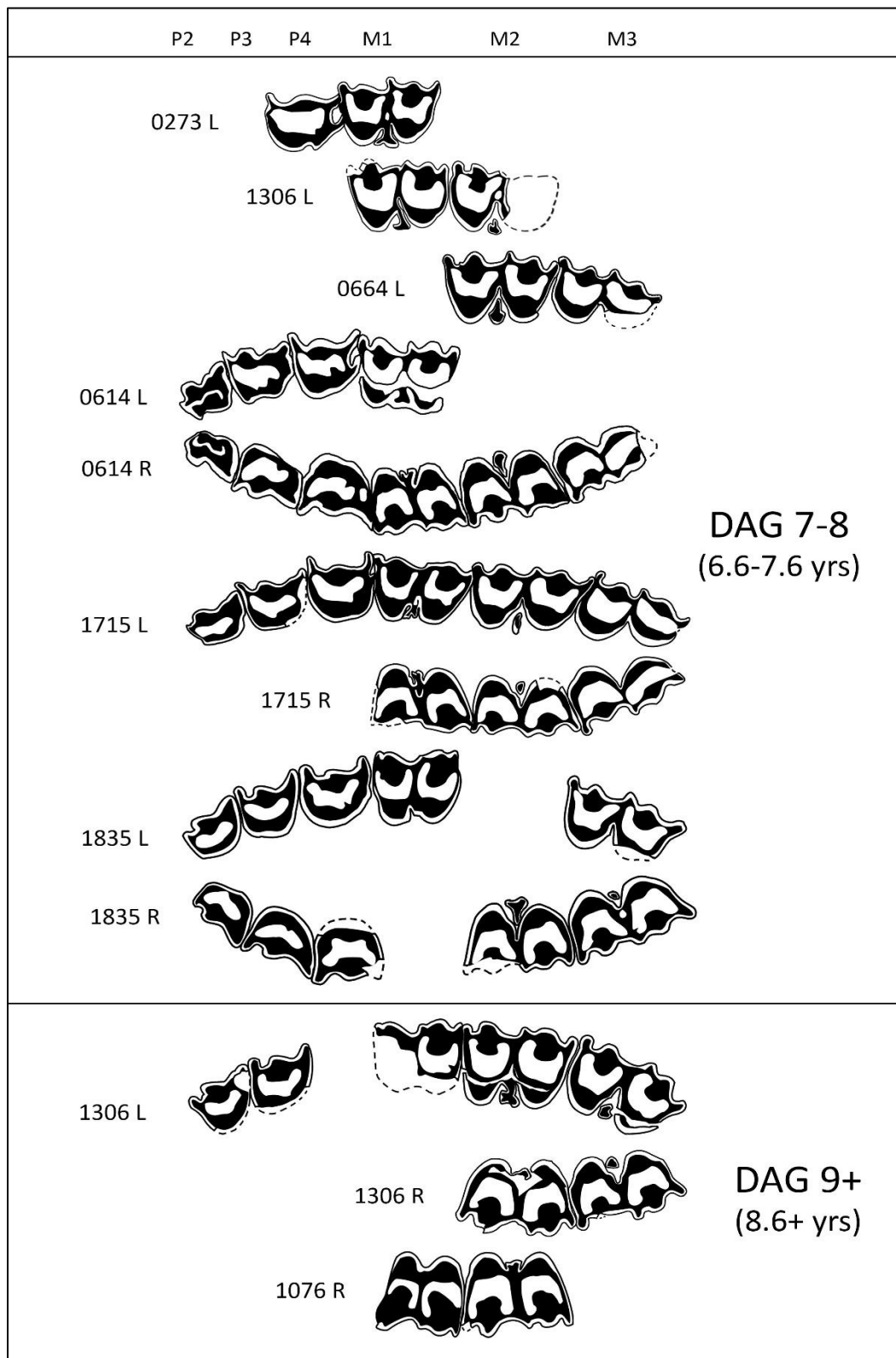


Figure 8.5. Maxillary dentitions from the Licking Bison site, DAG 7-8 and DAG 9+.

Dental Age Group 3 (2.6 years old): No premolars from this DAG were identified. M1 and M2 are in wear, with M3 erupting. The M1 is in full wear, with the endostyle exhibiting very slight wear on one specimen (0214 R), but only polish on the other (0214 L). The M2s show wear on all facets, very similar to DAG 4. Anterior and posterior cusps are connected by a band of dentine between the fossettes. Facets VII and VIII remain separated by enamel on the distal side of the posterior cusp. The crests of the cusps on the M3s show light polish, but they are not yet in wear.

Wear on the Licking Bison M2s in DAG 3 is nearly identical to M2 specimens placed in DAG 4. However, the lighter wear patterns on the M1 and M3 from the same tooth rows closely match Casper Age Group IV (2.6 years) and Clary Ranch Age Group 3 (2.3-2.5 years) (Hill 2008; Wilson 1974).

Dental Age Group 4 (3.6 years old): P2-M3 in wear. All permanent premolars are in place and exhibit moderate wear. The M1 is in full wear, with the endostyles worn down to a loop connecting to the body of the tooth. The M2 shows moderate to full wear. Anterior and posterior cusps are connected by a band of dentine between the fossettes. Facets VII and VIII remain separated by enamel on the distal side of the posterior cusp. Both cusps of M3 exhibit light wear. Specimen 0214 shows slight differential wear between left and right sides on the M3, with the posterior cusp unworn on the left side, but facets V and VI showing light wear on the right M3.

Licking Bison Group 4 is largely comparable to Age Group 4 (3.3-3.5 years) specimens from Clary Ranch, as well as Group V (3.6 years) specimens from the Casper Site (Hill 2008; Wilson 1974). Licking Bison M3s show less wear than on specimens from Group 4 (3.7-3.8

years) from the Agate Basin component of the Agate Basin site, where facets I-VIII all show moderate wear (Hill 2008).

Exact ages for the Licking Bison specimens beyond DAG 4 cannot be established, because the permanent teeth are all erupted and can no longer be used to assess age. Wear patterns on the remaining specimens fall into two distinct levels of wear. Based on comparison to maxillary wear patterns from the Casper site, the Licking Bison specimens are interpreted as DAG 7-8 (6.6-7.6 years) and DAG 9+ (8.6+ years) (Wilson 1974). However, due to limited sample size, Wilson (1974) considered the ages assigned to the Casper groupings to be tentative.

Dental Age Groups 5 and 6: No maxillary specimens in these age groups.

Dental Age Group 7-8 (6.6-7.6 years): P2-M3 in full wear. The M1 endostyle is worn to the point of connecting the main occlusal surface of the M1. An interfossette is present on the M1 for one specimen (0273). The M2 endostyle is worn, but not connected to the rest of the tooth. The M3 endostyle is not yet in wear, except for one specimen, 1835 (right), which exhibits light wear on the endostyle.

The Licking Bison specimens are interpreted to be at least 6.6 years old, because the M2 endostyle is worn to the point of connection with the larger occlusal surface, which is first seen in age Group VI-c (6.6 years old) at the Casper site (Wilson 1974). They are likely less than 8.6 years, at which point the M3 endostyle is in wear in Casper Group VI-e, which is not the case on the Licking Bison specimens in DAG 7-8 (Wilson 1974).

Maxillary tooththrows 1835 (left) and 1835 (right) exhibit characteristics of both DAG 7-8 and DAG 9+. The maxillary teeth and teeth from one left and one right tooththrow were all loose from the alveoli, but cataloged together under the same number (1835) along with numerous skull fragments. The four tooththrows are interpreted to be from the same individual.

Despite the obliterated left M1 endostyle and lightly worn right M3 endostyle, which are more representative of DAG 9+ (Wilson 1974), the maxillary tooththrows are placed in DAG 7-8. The right M2 endostyle is worn, but not yet connected to the main occlusal surface, and the left M3 endostyle is unworn, both of which are more consistent with DAG 7-8. Additionally, both of the associated mandibular tooththrows are unambiguously assigned to DAG 7-8.

Dental Age Group 9+ (8.6+ years): P2-M3 in full wear. The M1 is complete on only one specimen (1076), which shows the endostyle has been completely obliterated. The M2 endostyle has been worn to a continuous loop connecting with the body of the tooth. The endostyle on the M3 is worn, but not yet connected to the rest of the tooth.

The M1 and M3 wear patterns on DAG 9+ Licking Bison specimens match with Casper Group VI-e (8.6 years old), when the M3 endostyle first begins to wear and the M1 endostyle is mostly worn away (Wilson 1974).

Absence of fetal remains

Some specimens in the collection were initially identified as potential fetal bone, which has a distinctive appearance because of the porous surface texture (Wilson 1974). These specimens were reassessed by the author and identified as partially ossified costal cartilage through comparison with modern *B. bison* skeletal material (an adult male collected from Wind Cave National Park and housed at the Mammoth Site of Hot Springs, SD) (Figures 8.6-8.8). Ossified costal cartilage specimens are generally lightweight and have a porous texture similar to fetal bone. They form from the usually cartilaginous connection between the distal end of the ribs and the sternum, which can become partially ossified, but not as densely as normal bone (Sjøvold and Hufthammer 2008; Barone 1999). The absence of fetal bone in the assemblage is consistent with a late fall season of death.

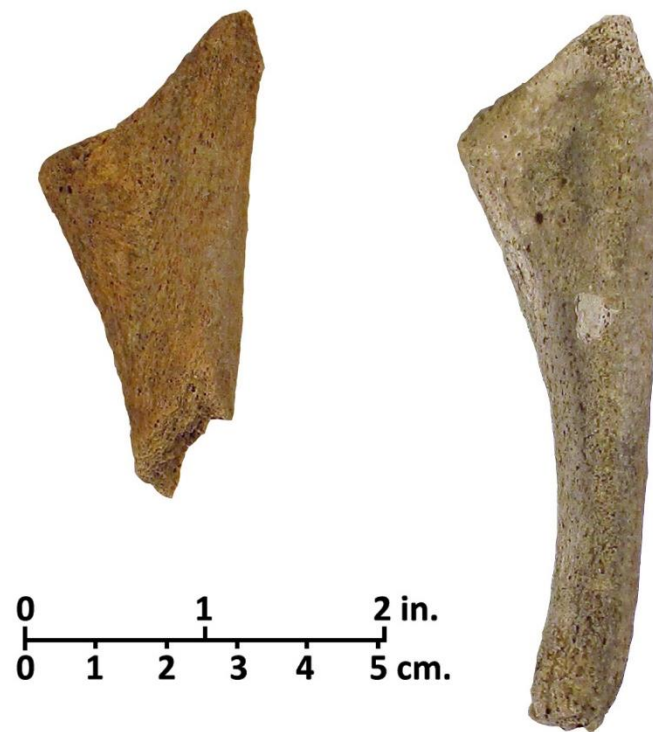


Figure 8.6. Ossified costal cartilage 0188 (left) with modern comparative specimen (right) from the Mammoth Site of Hot Springs, SD.

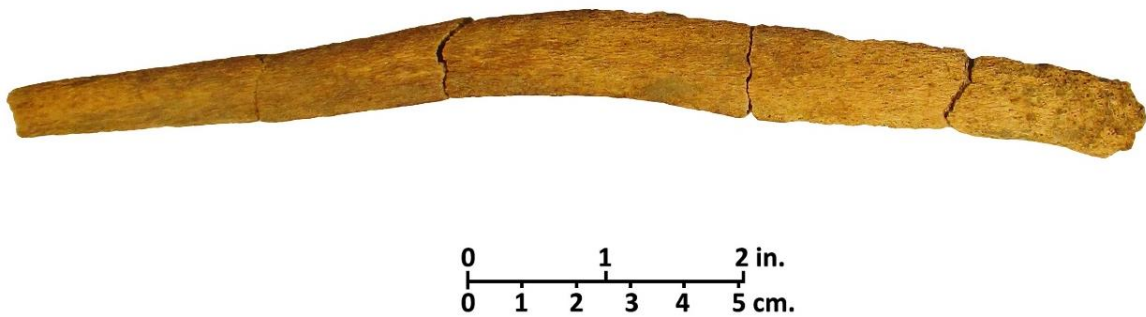


Figure 8.7. Ossified costal cartilage 0005.



Figure 8.8. Ossified costal cartilage 0632 (left) with modern comparative specimen (right) from the Mammoth Site of Hot Springs, SD.

Chapter 9: Conclusions and Future Research

The Licking Bison site provides valuable data to interpret life on the Northern Plains during the Early Archaic period. This analysis has identified that at least 22 bison were present in the excavated units, though additional individuals remain unexcavated at the site (Fosha 2001). Dental wear and eruption patterns indicate these bison were killed in the late fall to earliest winter. The herd was predominately made of calves, juveniles, and adult females. Four adult females and at least one, and possibly up to three adult males were identified in the assemblage. The species of bison remains unknown, but postcranial metrics suggest a slight lean towards *B. bison* sized-individuals.

Climate proxy data from numerous lake and wetland sites across the northern and eastern Plains identify a period of increased temperature and aridity, sometimes referred to as the Altithermal, which roughly corresponds to the Early Archaic period (Dean and Schwalb 2000; Valero-Garcés et al. 1997; Yansa 2007). This time period was not uniform, but contained numerous fluctuations of temperature and aridity. Early Archaic inhabitants of the Plains had to contend with shifting resource distributions caused by these fluctuations. The Altithermal climate stress hypothesis predicts that during arid conditions on the North Plains, poor quality graze and limited supply of fresh water would lead to diminished bison populations. Human populations are hypothesized to respond to the depletion of their staple food source by expanding their diet breadth, and migrating to cooler, wetter areas.

The Licking Bison site is chronologically in the middle of a period of severe aridity on the Northern Plains identified by Yansa (2007) lasting from 6000 to 5000 ¹⁴C yr BP. However, somewhat conflicting data from Moon Lake suggest while the climate was arid, the formation of the Licking Bison site did not occur during a period of peak aridity (Valero-Garcés et al. 1997).

This analysis presents new data from the Licking Bison site to evaluate against the Altitheal climate stress hypothesis. The site provides evidence that around 5570 ± 30 ^{14}C yr BP the landscape of northwestern South Dakota was productive enough to support a herd of at least 22 bison, and the humans who hunted them. A minimum of 22 individual bison are present in the excavated assemblage, but the actual size of the herd killed at the site could be much higher. It is not known how much of the site was lost to erosion prior to excavation, or how much remains to be excavated. Additionally, heavily deteriorated bone was not collected from excavated areas, and so not included in MNI analysis. The true number of bison killed at the site was undoubtedly higher than 22, which could suggest a robust bison population inhabited the area.

The climate stress hypothesis suggests bison populations would be under stress during arid conditions. Drought conditions could change nutritional quality of grasses available to bison (Bamforth 1988; Hill 2013). Birthing schedules in modern bison can be affected by the physical condition of the mother, and the quality of available forage (Gogan et al. 2005). Assessing the physical condition of the Licking Bison herd was beyond the scope of this study. However, the age distribution of calves and juveniles in the assemblage could be an indication that the adult females were in good enough physical condition to successfully bear calves for at least four years preceding the kill event.

The Licking Bison site likely represents the aftermath of a planned cooperative event requiring groups to come together for the hunt (Hill 2013). This suggests a certain level of landscape and environmental stability. The bison resource would have to be predictable enough to warrant planning, especially if a corral, or some other structure was used to trap the bison. This in turn suggests predictable vegetation and water resources, at least for the length of time needed to plan and execute the kill.

Several bison in the southwest corner of the Licking Bison site were left fully or partially articulated. A cursory review of breakage patterns in the assemblage does not show extensive breakage of longbones as if to extract marrow, though some processing took place on site, as evidenced by burned bone recovered from the hearth in the northeast section of the site. The relative infrequency of breakage could suggest a significant amount of meat and high calorie fats were not utilized by Early Archaic people at the Licking Bison site. Other later sites like Graham Ranch and Cordero Mine show evidence of extensive processing for marrow and bone grease extraction (Smith et al. 2008; Niven and Hill 1998).

This could be an indication that the human population at Licking Bison was not food stressed, and that they could afford to not extensively process the kill because resources were abundant. Alternatively, the number of animals killed could have been more than the number of people present could process before it spoiled. The late fall-early winter timing of the event suggests rapid spoiling in excessive heat was less likely to be a factor. The degree of cultural bone modification and breakage at Licking Bison needs to be explored in a systematic way to help resolve these questions.

Assuming the kill event took place during a warm, arid period, as suggest by climate data, the Licking Bison assemblage generally does not provide support for the Altithermal climate stress hypothesis. The possibility also exists that the Licking Bison kill event took place during an interval of cooler, wetter climate, when the open plains would have been more hospitable and productive for bison herds.

The Licking Bison site shares some notable differences with Hawken, the only other Early Archaic bison kill site from the region. Hawken has a much higher MNI than Licking Bison, nearly 100 individuals. However, this represents a combined MNI because the Hawken

bonebed was formed from three closely spaced kill events. This makes the particulars of herd demographics (MNI per kill event, age and sex distributions) difficult, if not impossible to parse out (Cunnar 1997). Hawken individuals appear to be more disarticulated and heavily processed than those at the Licking Bison site (Cunnar 1997). The Hawken site is a natural arroyo trap, that unlike the Licking Bison site, was used in multiple events (Frison et al. 1976).

The method of entrapment used at Licking Bison is still unknown, but the potential for a corral trap has been suggested. The paleo-landscape was not conducive to a jump event or arroyo trap (Albanese 1997), but the relatively shallow cut of Graves Creek could have been used as an impediment in conjunction with a corral-type structure. The herd size was big enough to require some sort of impediment to their movement. Use of a corral trap at the Licking Bison site, would suggest a similar strategy to Middle Archaic people at the Scoggin site (Niven and Hill 1998).

The one significant similarity between Hawken and Licking Bison is that the kill events at both sites happened in the late fall to early winter, when bison would have been in good physical condition (Hill 2013). The late fall/early winter timing of the kill means the bison would have had their thick winter coats. The bison at both sites could have been targeted for their hides in addition to their meat. Some metapodials from the Hawken site show evidence of skinning (Cunnar 1997), though this has not been investigated at Licking Bison. Hawken mandibular dentitions show slightly more wear than Licking Bison, and so may have been killed slightly later in the season (assuming a similar rate of wear, and similar peak birthing season).

Cunnar (1997) and Frison et al. (1976) interpret Hawken as a continuation of Paleoindian hunting strategies, with the large number of bison, the late fall/early winter death, communal hunting, and use of a natural feature as a trap all aligning with Paleoindian practices. Licking Bison may have a higher number of bison present and the season of death matches with Hawken,

but if a corral trap was used, it would perhaps link Licking Bison more closely with Middle Archaic peoples, than Paleoindian.

Comparisons between Hawken and Licking Bison can begin to demonstrate variation in Early Archaic bison hunting strategies. However, without finer scale environmental data it is difficult to assess whether or not the kill events occurred under similar climatic conditions. Do these differences represent differing cultural preferences, or are they adaptive responses to differing climate conditions?

This analysis was intended to provide a baseline of data about the Licking Bison site bison assemblage which can be built on by further research. Careful evaluation of Early Archaic sites like Licking Bison is required to determine how bison populations shifted through time, and how humans responded to those changes. Excepting the geological investigations by Albanese (1997), the taphonomy of the site has yet to be addressed in a systematic way. Additional study of natural and cultural modifications to the bones and their distributions is necessary to fully interpret human use of the site.

Identification of species in the non-bison faunal assemblage would provide a more robust picture of the local environment around the time of the kill event. Further analysis of bison remains could also provide a better picture of the health of the herd by looking for signs of stress like dental enamel hypoplasia (Niven et al. 2004). Dietary stress within the bison population could be a reflection of the climate conditions at the time of the kill and oxygen and carbon isotope analyses may shed light on this. Two teeth from the Licking Bison assemblage were sampled by Widga for stable isotope analysis (0914 - left m3 and 1835 - right m3), but the results are currently unpublished (Widga, personal communication).

Widga's (2007) dissertation included the Licking Bison site in a regional scale study to identify patterns in bison biogeography on the Eastern Plains during the Middle Holocene. His results suggested that bison populations on the eastern Great Plains had fairly restricted home ranges and likely would have followed predictable annual cycles. However, the Licking Bison site was at the geographic periphery of his study area, and thus may have been subject to different environmental influences.

The current study aimed to create a more detailed base of knowledge about the bison present at the Licking Bison site, which can be used for better comparison with other sites in the region. Results of the present study have increased the MNI reported by Widga (2007) from 8 to 22 individuals and modified the season of death from fall to late fall-early winter (N+0.6 years).

The Licking Bison site was only partially excavated to salvage specimens at risk of erosion. The potential presence of a corral may be investigated by continued excavations in the near future (Mike Fosha, personal communication). Continued excavations may also help to better understand patterns of site use, butchering activities, and herd demographics. Any specimens recovered from renewed excavations could provide additional material to bolster sample sizes for analysis of sex distribution and species identification. Additional skulls could provide the diagnostic morphology needed to identify species. Genetic study could also be undertaken attempt to identify species affinity. Direct comparison of Hawken and Licking Bison specimens would help to assess the similarity between Licking Bison individuals and *B. antiquus occidentalis*.

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Appendix I. Measurements

The following abbreviations are used for measurements in Tables A1.2 – A1.19.

Source	Measurements:	Example
Skinner and Kaisen (1947)	Retain original numbers, but are preceded by ‘SK’	SK1
Todd (1987b)	Retain the original numbering system. Where there is overlap with McDonald (1981), Todd’s numbering system takes precedence.	TA1, HM1
McDonald (1981)	Retain the original numbers, but are preceded by and ‘Mc’	Mc1
Bedord (1974)	Retain the original numbers, but are preceded by ‘B’	B1
Lewis et al. (2005)	Retain the original numbers, but are preceded by ‘L’	L4
Morlan (1991)	Retain the original name	Width
Martin et al. (2018)	Retain the original name	DstL

Table A1.1. Measurement abbreviations for Appendix I by source.

All measurements are recorded in millimeters. Measurements obtained with an osteometric board are recorded to the nearest millimeter. Measurements obtained with a digital caliper are recorded to the nearest hundredth millimeter.

* denotes minimum measurements from specimens with minor bone loss

** denotes specimens broken in two or more pieces, where measurements were taken while holding pieces together

*** denotes specimens that were glued together, usually in articulation. Measurements taken as close to the appropriate positions as possible but should be considered estimates.

Catalog #	Shot #	Unit	Completeness	Age Group	Comments
0049	396	A	Missing anterior, and large parts of right side. Two bags of associated fragments. Adult teeth fully erupted, with partial left mandible in occlusion. Left orbit and horn core base present. Left P4-M3, and right M3 <i>in situ</i> . Left m2-m3 in mandible.	-	Jacketed and coated in unknown glue, probably Elmer's or another white glue. Unable to assess wear patterns due to the way the skull has been glued together.
0236	294?	A-B	Left side of skull and left mandible fairly well intact. Horn core missing. Left mandible glued in place.	DAG 9+ (8.8 yr)	Specimen is jacketed on its right side and treated with unknown glue. Maxillary dentition unable to be assessed for dental age.
0614	809	D	Missing most of base of cranium, and horncores. Right maxilla mostly intact, anterior section of left maxilla intact as well as left nasal and premaxilla. All permanent teeth erupted, missing left M2-M3.	DAG 7+ (6.6+ yr)	Partially jacketed sitting on left side with flange of jacket coming up the base of the cranium and over the right zygomatic/orbit area. Unknown glue.
0745b	1024	E	Severely distorted. Partial left maxilla and mandible, and partial right maxilla and mandible, but the skull is flattened, and the left and right halves are no longer in anatomical position.	DAG 2 (1.6 yr)	Skull glued into jacket with unknown glue.
1715	N/A	AA	Left partial maxilla with mostly complete tooththrow, associated fragments and teeth from right tooththrow.	DAG 7+ (6.6+ yr)	-

Table A1.2. Skull measurements after Skinner and Kaisen (1947) and McDonald (1981).

Catalog #	SK6	SK7	SK12	SK14	SK15	SK17	SK19	SK20	Mc20a
0049	55.51*	281*	62.96*	235.30*	293.60*	-	-	96.76*	-
0236	-	-	-	-	-	-	142.29*	-	-
0614	-	-	-	-	-	164.78*	153.86*	95.63	19.4
0745b	-	-	-	-	-	-	-	88.05	-
1715	-	-	-	-	-	-	149.04*	94.6	18.58

Table A1.2 (continued). Skull measurements after Skinner and Kaisen (1947) and McDonald (1981).

Catalog #	Shot #	Unit	Side	Completeness	Proximal Fusion	Distal Fusion	Comments
0036a	360	A	L	Complete	fused	fused	Partially jacketed, with an associated bag of fragments. May be missing some of distal end, some deformation of proximal end, some measurements approximate.
0149	961	A	R	Proximal and distal end, missing part of shaft	fused	fused	-
0382e	N/A	B	R	Distal end, broken in three pieces	-	fused	-
0562	571	D	R	Shaft only	-	-	Surface bone loss, may affect measurements slightly.
0962	9	J	R	Distal end and partial shaft	-	fused	-
1120	414	L	L	Proximal end, surfaces eroded in places on posterior edge of articular surface and posterior of the major tubercle	fused	-	-
1438	714	W	L	Mostly complete, missing part of posterior of distal end, and most of distal end	fused	fused	Some spall on shaft, circumference is a minimum measurement.
1725	1539	BB	R	Most of shaft, partial distal end (antero-medial section), and small part of cancellous of proximal end	-	fused	Bone in poor condition, cracking and spalling, measurements are estimates.
1787	N/A	BB	R	Shaft only	unfused	-	-

Table A1.3. Humerus Measurements after Todd (1987b) and McDonald (1981). No measurements obtained for Mc1; Mc2 is the same as HM10; Mc3 is the same as HM5.

Catalog #	HM1	HM2	HM3	HM4	HM5	HM6	HM7	HM8	HM9	HM10	HM11	HM12	HM13	HM14	HM15	HM16
0036a	351*	312*	319*	94*	-	-	-	-	119	-	-	81.65*	78.7	-	-	-
0149	-	-	-	-	41.84	84	83.66	28.01	-	52.76	96.58	70.26*	-	42.01	35.22	146
0382e	-	-	-	-	-	-	-	27.03**	-	-	-	-	-	39.19	37.62**	-
0562	-	-	-	-	28.24*	-	-	-	-	34.16	-	-	-	-	-	95
0962	-	-	-	-	-	77	76.83	27.32	-	-	86.93	-	-	38.5	30.18	-
1120	-	-	-	121*	-	-	-	-	135	-	-	88.29*	90.51	-	-	-
1438	316*	312*	-	-	41.25	86	86.21	-	-	53.03	95.06*	-	-	42.58	-	150*
1725	-	-	-	-	38.09*	-	-	-	-	52.59*	-	-	-	-	-	151
1787	-	-	-	-	39.58	-	-	-	-	44.38	-	-	-	-	-	143

Table A1.3 (continued). Humerus Measurements after Todd (1987b) and McDonald (1981). No measurements obtained for Mc1; Mc2 is the same as HM10; Mc3 is the same as HM5.

Catalog #	Shot #	Unit	Side	Completeness	Proximal Fusion	Distal Fusion	Comments
0093	550	A	L	Fragments of distal end and shaft, including radial carpal facet	-	-	-
0101a	697	A	R	Distal end	-	fused	Just articular surfaces
0128a	909	A	R	Proximal end	fused	-	Broken in three pieces
0142a	951	A	R	Distal end	-	fused	-
0459	311	C	R	Proximal end	fused	-	Articulates with ulna 0460
0585	594	D	L	Shaft and most of proximal end	fused	fused	-
0684a	747	E	L	Distal end, separated near line of fusion	-	fused	-
0688b	751	E	L	Most of proximal end, shaft missing some surface bone	fused	-	-
0719a	972	E	R	Most of shaft and proximal end, distal part of shaft missing, but most of the unfused distal epiphysis is present.	fused	unfused	Surface of bone is eroded on medial side of shaft
0957	85	I-J	R	Complete	fused	fused	Medial side weathered, some surface bone loss; unknown glue
0963	10	J	R	Complete, distal epiphysis unfused but present	fused	unfused	Unknown glue
1441a	717	W	L	Complete, but missing unfused distal epiphysis and small portion of proximal articular surface	fused	unfused	Articulates with ulna 1441b; unknown glue
1447	723	W	R	Proximal end	fused	-	-
1519	775	Y	R	Mostly complete, epiphyses unfused but present; missing fragments from lateral side of both proximal and distal epiphyses	unfused	unfused	-
1638	1570	AA	L	Complete, distal epiphysis unfused but present	fused	partial	Shaft measurements affected by surface bone loss and spreading cracks
1653	1616	AA	R	Distal end	-	fused	-
1701	1671	AA	R	Distal end	-	fused	-
1728	1542	BB	L	Mostly complete	-	partial?	Shaft measurements affected by surface bone loss and a large expanding crack; broken at fusion line, level of fusion unclear

Table A1.4. Radius Measurements after Todd (1987b) and McDonald (1981). No measurements were obtained for RD13, 14, or 15. Mc 1 is the same as RD1, and Mc3 is the same as RD5.

Catalog #	Mc2	RD1	RD2	RD3	RD4	RD5	RD6	RD7	RD8	RD9	RD10	RD11	RD12
0093	-	-	-	-	-	-	-	-	-	-	-	-	37.55**
0101a	-	-	-	-	-	-	-	101**	93.23**	-	-	-	33.04
0128a	-	-	-	91	86.56**	-	-	-	-	48.03	28.94	-	-
0142a	-	-	-	-	-	-	-	82*	74.63*	-	-	51	28.5*
0459	-	-	-	81	79.01	-	-	-	-	44.54	30.28	-	-
0585	34.72	-	-	-	97.89	56.67	38.01	-	-	50.51	36.32*	-	-
0684a	-	-	-	-	-	-	-	-	77.7	-	-	-	30.95
0688b	24.73	-	-	-	-	37.58	24.79	-	-	-	-	-	-
0719a	26.98	-	-	81*	-	41.95*	27.2	-	-	-	-	-	-
0957	35.43*	305.78	334	96*	87.79*	54.61*	35.88*	82*	82.04*	51.72*	38.1	64*	36.95*
0963	21.42	263.12	284**	78	75.67	37.26	22.52	71	65.43	41.63	29.46	52	29.77
1441a	24.77	-	-	78*	74.96*	37.2	25	-	-	42.87	26.99	-	-
1447	-	-	-	81	76.88	-	-	-	-	42.08	25.76	-	-
1519	23.32	253.10**	269**	77*	-	39.26	24.33	72*	74.03*	44.5	-	48*	29.49
1638	28.18	286.37**	308**	90	-	42.92*	30.31*	82	74.61	44.7	29.58	53	32.48
1653	-	-	-	-	-	-	-	76	70.89	-	-	51	29.54
1701	-	-	-	-	-	-	-	98	87.39	-	-	62	35.26
1728	27.63*	281.82**	299**	88	82.99	41.23*	27.78*	75	70.07	43.48	27.56	51	29.55

Table A1.4 (continued). Radius Measurements after Todd (1987b) and McDonald (1981). No measurements were obtained for RD13, 14, or 15. Mc1 is the same as RD1, and Mc3 is the same as RD5.

Catalog #	Shot #	Unit	Side	Completeness	Olecranon Fusion	Comments
0124b	905	A	R	Olecranon tuber	fused	-
0229a	N/A	A	R	Olecranon tuber and styloid process	fused	-
0246	252	B	L	Proximal end and partial shaft	fused	-
0290	611	B	R	Olecranon	fused	May be associated with ulna shaft 0289
0460	312	C	R	Proximal end, broken beneath articulation with radius, with unfused olecranon epiphysis	unfused	Articulates with radius 0459
0819b	229	F	R	Olecranon tuber	unfused	-
0957	85	I-J	R	Complete	-	Unknown glue
1441b	717	W	L	Mostly complete, missing distal end. Olecranon epiphysis unfused by present.	unfused	Articulates with radius 1441a. Unknown glue.
1449	724	W	R	Complete, missing only tip of distal end	fused	-

Table A1.5. Ulna Measurements after Todd (1987b). No measurements were obtained for UL10.

Catalog #	UL1	UL2	UL3	UL4	UL5	UL6	UL7	UL8	UL9	RDUL1
0124b	-	-	-	36	-	75*	-	-	-	-
0229a	-	-	-	26*	-	65	-	-	-	-
0246	-	50.6	126	29	52.94	75	67.53	89.43	11.99	-
0290	-	-	-	27	-	64	-	-	-	-
0460	-	42.6	108**	25	48.57	53*	-	-	9.24	-
0819b	-	-	-	35	-	66*	-	-	-	-
0957	419**	48.9	130	31	52.72	75*	66.93	94.41	10.88	435**
1441b	332*	42.1	106**	25	47.84	55*	51.51	72.57	10.09	-
1449	-	46.1	100	26	49.34	70*	59.35	79.27	11.08	-

Table A1.5 (continued). Ulna Measurements after Todd (1987b). No measurements were obtained for UL10.

Catalog #	Shot #	Unit	Side	Completeness	Distal Fusion	Comments
0094	668	A	R	Distal end	fused	-
0121	902	A	L	Proximal end	-	-
0245	251	B	R	Mostly complete, some damage to proximal end	fused	-
0448a	175	C	L	Complete, some bone loss on lateral side of proximal end	fused	Specimen is glued into its plaster jacket; all measurement taken with calipers, unable to use osteometric board
0572	581	D	L	Specimen damaged, but most of proximal end, shaft, and distal end present	partial	-
0576	585	D	R	Mostly complete, missing distal end	-	-
0626a	822	D	R	Complete, missing only small fragment from lateral proximal end	-	-
0720a	973	E	R	Postero-medial side weathered and missing bone, with bone loss increase towards the distal end. Distal epiphyses unfused, but present.	unfused	B8 taken on unfused epiphysis with eroded surfaces
0722a/0723	988	E	L	Proximal end, shaft broken	fused	Large crack on proximal articular surfaces may slightly inflate measurements. This specimen has two catalog numbers.
0953	678	I	R	Proximal end	-	Glued to carpal 2+3 with unknown glue
1005	82	J	R	Complete, unfused distal epiphyses glued in place	unfused	Unknown glue
1119	413	L	L	Mostly complete, but proximal end badly fragmented	fused	-
1223	N/A	L	-	Distal end, missing unfused epiphyses	unfused	††Measurements B4 and B8 taken for diaphysis, not including missing epiphyses
1335	442	P	R	Complete	fused	-
1434a	710	W	R	Complete	-	Metacarpal, Carpal 4, and Carpal 2+3 glued together with unknown glue.
1520a	776	Y	R	Complete, distal epiphyses unfused but present	unfused	Unknown glue
1589	866	Z	L	Proximal end, with splintered shaft	-	-
1626	1558	AA	L	Missing distal end	unfused	Spreading cracks in shaft and across proximal articular surface, may slightly inflate measurements
1639	1571	AA	R	Complete	fused	-
1654a	1617	AA	L	Complete	fused	-
1768	1599	BB	L	Mostly complete shaft, missing unfused distal epiphyses; posterior surface in poor condition	unfused	†B9 estimated due to dirt on posterior surface

Table A1.6. Metacarpal Measurements after Bedord (1974) and Lewis (2005).

Catalog #	B1	B2	B3	B4	B5	B7	B8	B9	B10	B11	B12	B13	L4
0094	-	-	-	63	-	-	34	-	-	-	-	-	28.3
0099	-	-	-	47*	-	-	33*	-	-	-	-	-	-
0121	-	77.1	-	-	-	42.41	-	-	-	-	-	-	-
0245	215	62*	-	72	-	42.93*	38	25.9	-	188.86*	159.74*	158.72*	30.44
0448a	212.17*	71.75*	51.94*	83.33*	-	37.89*	-	-	51.37*	181.48	-	155.3	33.35
0572	-	68.73**	-	-	-	-	-	-	-	-	-	-	-
0576	-	74.7	47.07	-	31.47	41.22	-	29.66	47.11	-	159.56	155.53	-
0626a	198	60.38*	38.26	68	25.59	37.15	37	24.87	38.02	172.13	149.21	145.16	28.11
0720a	206**	65.39*	-	-	-	38.97	38.53*	-	-	-	156.24	153.98	-
0722a/0723	206**	66.3	-	68	-	40.16	36	-	-	181.76**	153.76**	148.97	28.67
0953	-	58.8	-	-	-	34.59	-	-	-	-	-	-	-
1005	194	57.1	29.95	62	21.79	34.3	35	21.75	29.92	166.69	144.75	142.9	26.56
1119	191**	59.57*	-	65	-	38.27**	35	-	-	166.47	144.51	139.17**	26.93
1223	-	-	-	69††	-	-	37††	-	-	-	-	-	-
1335	199	68.4	38.48	71	24.41	39.2	37	24.15	38.45	171.52	147.65	141.74	29.15
1434a	204.57***	60.6	34.15	65	23.47	36.42	36	23.03	34.09	177.81***	156.82	154.52***	27.52
1520a	199**	65.3	33.15	69**	24.62	36.28	35**	24.29	33.05	169.05	146.87	140.29	27.03
1589	-	66.7	-	-	-	38.51	-	-	-	-	-	-	-
1626	-	65.2	37.76	-	27.96	38.39	-	26.45	37.69	-	151.32	146.61	-
1639	207	67.8	40.19	71	27.23	38.64	35	25.73	39.95	180.68	159.48	153.74	28.74
1654a	204	68.6	39.15	71	26.6	40.61	39	25.98	38.92	173.72	154.32	148.1	30.64
1768	-	65.7	37.96	-	26.02	34.66	-	25.37†	37.87	-	157.05	154.62	-

Table A1.6 (continued). Metacarpal Measurements after Bedord (1974) and Lewis (2005).

Catalog #	Shot #	Unit	Side	Completeness	Length	Width	Depth
0017	290	A	R	Complete	27.11	32.63	35.57
0046	392	A	L	Complete	29.12	36.11	41.35
0054b	412?	A	R	Complete	25.09	29.88	31.61
0128c	909	A	R	Missing anterior	29.56	38.85*	-
0131d	915	A	R	Complete	25.28	30.25	32.24
0219b	N/A	A	R	Complete	24.62	29.27	30.82
0354b	N/A	B	R	Complete	25.41	30.75	33.94
0626c	822	D	R	Complete	24.98	29.52	32.60
0720c	973	E	R	Surfaces somewhat eroded, missing fragment on postero- lateral corner	26.25	-	34.53
0722c	988	E	L	Complete	25.36	31.27	35.04
0772c	N/A	E	L	Missing part of posterior	24.53	30.42	33.90
1144	517	L	L	Complete	24.28	29.72	33.60
1170c	1537	L	L	Complete	24.14	29.90	33.80
1193	N/A	L	L	Complete, but surfaces somewhat eroded	24.67	30.71	34.80
1322a	411	P	L	Missing part of posterior and dorsal surfaces	25.55*	31.92*	39.63
1330	437	P	R	Mostly complete	26.05	32.94	34.40
1434a	710	W	R	Complete	24.56***	28.57***	30.70***
1520b	776	Y	R	Complete	25.00	31.17	33.17
1594	874	Z	L	Complete, some surfaces eroded	24.59	30.22	34.74
1654c	1617	AA	L	Complete	27.54	29.87	34.80

Table A1.7. Carpal 4 Measurements after Morlan (1991).

Catalog #	Shot #	Unit	Side	Completeness	Anterior Length	Posterior Length	Depth
0293	626	B	R	Mostly complete, but missing a tiny bit along dorsal ridge, may affect Ant. Length	31.45*	41.14	38.77
0719d	972	E	R	Mostly complete, but some surface erosion	32.45	35.76*	38.97
0722f	988	E	L	Complete	32.05	39.99	42.05
0772b	N/A	E	L	Complete	28.10	36.89	39.82
1170e	1537	L	R	Complete	31.32	37.58	36.85
1224c	N/A	L	L	Complete	31.33	38.21	36.07
1267	462	N	R	Mostly complete	31.79	36.75*	38.50
1331	438	P	R	Mostly complete	35.49	41.28	37.15*
1549	947	Y	R	Complete	28.63	37.09	38.75
1652	1615	AA	L	Complete	33.63	40.53	39.30

Table A1.8. Ulnar Carpal Measurements after Morlan (1991).

Catalog #	Shot #	Unit	Side	Completeness	Length	Width	Depth
0007	276	A	R	Complete	28.13	32.87	46.40
0205	N/A	A	R	Missing ventral surface and medial-posterior projection	30.76	38.45	-
0719c	972	E	R	Mostly complete, but missing surface on medial side	28.99	33.18	-
0722e	988	E	L	Complete	28.58	32.95	43.68
0772a	N/A	E	L	Complete	29.47	33.82	44.70
0890	50	G	R	Complete	32.36	33.34	45.59
1207	N/A	L	R	Mostly complete, but missing part of projection	22.31	29.11	39.67*
1224b	N/A	L	L	Complete	21.31	29.82	41.05
1322b	411	P	L	Only anterior portion	31.89	36.17	-
1329	436	P	R	Complete	29.82	31.06	44.67
1433	710	W	R	Mostly complete	25.21	31.94	46.52
1434c	710	W	R	Complete	26.93	29.40	41.31
1592	869	Z	L	Complete, some surfaces eroded	27.89	31.49	48.07
1680b	1651	AA	L	Complete	27.45	33.65	48.49

Table A1.9. Intermediate Carpal Measurements after Morlan (1991).

Catalog #	Shot #	Unit	Side	Completeness	Width	Depth
0132	916	A	R	Complete	50.54	44.69
0182a	N/A	A	L	Mostly complete	31.36	27.4*
0219a	N/A	A	L	Mostly complete, but missing part of lateral aspect	37.26*	32.86
0238b	244	B	R	Complete	41.70	36.01
0359b	N/A	B	R	Mostly complete	41.53	38.77
0626b	822	D	R	Complete	38.33	35.45
0667a	N/A	D	L	Complete, surfaces eroded	39.05	34.30
0720b	973	E	R	Surfaces somewhat eroded, especially on medial side	37.74*	35.39
0722b	988	E	L	Complete	39.87	35.31
0953	678	I	R	Complete. Glued in articulation with metacarpal.	35.95	31.53***
0965	12	J	R	Complete	34.64	30.76
1170a	1537	L	R	Complete	37.12	31.45
1170b	1537	L	L	Complete	38.50	32.11
1327	435	P	R	Complete	40.91	37.16
1434a	710	W	R	Complete. Glued in articulation with Metacarpal and Carpal 4.	35.93***	33.55***
1525	781	Y	R	Complete	39.07	34.34
1654b	1617	AA	L	Complete	40.95	36.79
1673	1645	AA	L	Complete	39.54	34.45

Table A1.10. Carpal 2+3 Measurements after Morlan (1991).

Catalog #	Shot #	Unit	Side	Completeness	Length	Width	Depth
0128b	909	A	L	Missing posterior	36.45	35.77	-
0182c	N/A	A	R	Partial, measurements are minimums	-	36.55*	51.67*
0433	149	C	L	Missing lateral side	34.54*	-	52.54*
0684b	747	E	L	Complete, but surface bone eroded on posterior surfaces	34.44	28.58	46.65*
0722d	988	E	L	Complete	29.90	28.61	44.47
0753a	N/A	E	R	Complete	35.72	32.73	51.65
0895	55	G	R	Complete	30.17	28.08	44.97
0949	653	I	L	Complete, but surfaces eroded on dorsal, medial, and posterior surfaces	30.30	29.08	46.63
0964	11	J	R	Complete	30.35	24.96	39.18
0981	28	J	L	Complete	31.27	24.70	39.60
1042	160	K	L	Mostly complete, but missing surface of posterior surface	36.55	33.88	54.47*
1170d	1537	L	R	Complete	28.98	25.71	41.27
1224a	N/A	L	L	Complete	29.80	26.04	43.53
1326	434	P	R	Mostly complete, but missing posterior surface	32.95	29.78	44.25*
1434b	710	W	R	Complete	29.61	26.32	40.97
1635	1567	AA	L	Complete	32.76	29.14	46.56
1659	1624	AA	L	Mostly complete, but missing posterior projection	32.16	26.73	43.55
1680a	1651	AA	L	Complete	32.65	31.06	48.72

Table A1.11. Radial Carpal Measurements after Morlan (1991)

Catalog #	Shot #	Unit	Side	Completeness	Fused proximal	Fused distal	Comments
0042a	382	A	R	Femur head	fused	-	Unknown glue; refits with 0043a.
0043a	386	A	R	Proximal shaft and distal end	-	fused	Unknown glue; refits with 0042a
0043b	386	A	L	Mostly complete, missing head	-	fused	Specimen glued into a thin, flexible plaster jacket with unknown glue; significant offsets between glued fragments; measurements are estimates.
0213b	N/A	A	L	Proximal end, missing posterior surfaces	fused	-	-
0561	569	D	R	Proximal end and shaft fragments	fused	-	Bone loss on lateral surface of trochanter
0565	574	D	R	Shaft, and partial trochlea of unfused distal epiphysis	unfused	unfused	-
1051	174	K	L	Partial distal end	-	fused	Covered in unknown glue and glued to pieces of other bones; specimen loose in plaster jacket.
1259	N/A	M	L	Distal end	-	fused	-
1647	1611	AA	L	Proximal end	fused	-	-
1733	1547	BB	R	Distal end	-	fused	-
1750	1583	BB	L	Distal and shaft fragments	-	fused	Refits to 1748
1759	1590	BB	R	Shaft, missing both ends	-	unfused	-

Table A1.12. Femur Measurements after Todd (1987b) and McDonald (1981). No measurements obtained for FM3 or FM11. Mc2 the same as FM17, and Mc3 the same as FM10.

Catalog #	Mc1	FM1	FM2	FM4	FM5	FM6	FM7	FM8	FM9	FM10	FM12	FM13	FM14	FM15	FM16	FM17	FM18	FM19
0042a	-	-	-	-	-	-	-	57.87	-	-	-	-	-	-	-	-	-	-
0043a	-	-	-	-	69.34	71.18	-	-	-	-	121**	60.55**	40.60**	13.62**	-	-	-	-
0043b	417*	474*	466*	-	71.27*	73.14	-	-	-	-	-	61.38	37.62*	-	-	-	156*	117.18*
0213b	-	-	-	-	-	-	146**	52.5*	-	-	-	-	-	-	77*	-	-	-
0561	-	-	-	-	-	-	127.28**	51.77	-	-	-	-	-	-	-	-	-	-
0565	-	-	-	-	-	-	-	-	-	39.25	-	-	-	-	-	41.88	-	-
1051	-	-	-	-	-	63.21	-	-	-	-	-	-	-	-	-	-	-	-
1259	-	-	-	-	71.76	68.51*	-	-	-	-	120	64.77	39.95*	12.24	-	-	147	113.02
1647	-	-	-	-	-	-	127	51.7	-	-	-	-	-	-	60*	-	-	-
1733	-	-	-	-	54.31	61.56**	-	-	-	-	99	-	37.41*	15.38**	-	-	120*	-
1750	-	-	-	-	60.03	60.11	-	-	-	-	104	54.42	36.92	18.22	-	-	136	97.94
1759	-	-	-	239*	-	-	-	-	56*	30.77	-	-	-	-	-	36.91	-	-

Table A1.12 (continued). Femur Measurements after Todd (1987b) and McDonald (1981). No measurements obtained for FM3 or FM11. Mc2 the same as FM17, and Mc3 the same as FM10.

Catalog #	Shot #	Unit	Side	Completeness	Fused proximal	Fused Distal	Comments
0001	270	A	L	Complete	fused	fused	Some very minor distortion, possibly inflating Mc3 by a mm or two, missing small amount of bone from posterior and lateral surfaces of lateral condyle, may have some small effect on TA4 and TA15
0213a	N/A	A	L	Partial proximal end	fused	-	-
0567	576	D	R	Mostly complete, proximal epiphysis separated and missing most of medial and anterior portions.	unfused	fused	Medial aspect of bone weathered, surface bone loss.
0682	705	E	R	Mostly complete, but missing fragment of antero-lateral corner of distal articular surface, and the anterior aspect of proximal end.	fused	fused	-
0776	187	F	L	Partial, most of shaft, but missing ends, partial distal and proximal epiphyses.	unfused	unfused	Very poor condition. Surface of shaft somewhat eroded, may have minimal effect on measurements
0818	229	F	L	Mostly complete, missing proximal epiphysis, some fragmenting on proximal end	unfused	unfused/visible line	Jacketed in articulation preventing most measurements.
0826	334	F	R	Proximal epiphysis, missing anterior	unfused	-	-
0959	6	J	L	Distal end with partially unfused epiphysis glued in place	-	unfused	-
1627	1559	AA	R	Distal end	-	fused	-
1642	1606	AA	R	Distal end	-	unfused	-
1660	1626	AA	R	Mostly complete, but proximal end and unfused proximal epiphysis somewhat fragmented	unfused	fused	Some medio-lateral deformation apparent when holding proximal fragments in place.
1699	1669	AA	L	Proximal end	fused	-	-
1740	1573	BB	R	Distal end and partial shaft	-	fused	Refits with 1741
1752	1584	BB	L	Mostly complete, missing a few fragments from proximal end	fused	fused	Refits with 1751 (measurements taken with 1751 in place)
1838	N/A	N/A	L	Complete	fused	fused	Provenience in question, may not actually be from this site.

Table A1.13. Tibia Measurements after Todd (1987b) and McDonald (1981). No measurements obtained for TA5 or TA8.

Catalog #	Mc1	Mc2	Mc3	TA1	TA2	TA3	TA4	TA7	TA9	TA10	TA11	TA12	TA13	TA14	TA15
0001	391	35.2	50.98	416	397	-	113*	77	37.75	53	10.93	28.32	19.09	52.98	102*
0213a	-	-	-	-	-	-	-	-	-	-	10.48	32.83	18.99	-	-
0567	341**	29.5	39.54	362**	-	-	-	63	30.8	46	7.81	22.76	11.64	47.23	-
0682	371	31.7	43.14	393	374	-	108*	75	33.21	51	9.88	-	-	54.72	-
0776	-	28.5	38.09	-	-	-	-	-	28.7	-	11.91	-	-	-	-
0818	-	27.51*	-	-	-	298.41	-	-	-	49.35*	-	-	-	-	-
0826	-	-	-	-	-	-	-	-	-	-	10.75	-	-	-	-
0959	-	-	-	-	-	-	-	59	-	41	-	-	-	47.87	-
1627	-	-	-	-	-	-	-	71	-	52	-	-	-	51.35	-
1642	-	-	-	-	-	-	-	61*	-	46*	-	-	-	45.92*	-
1660	354**	32.1	44.35	369**	350**	-	113**	68	32.48	50	8.79	-	-	51.62	-
1699	-	-	-	-	-	-	113	-	-	-	9.56	24.13	16.88	-	100
1740	-	29.5	38.23**	-	-	-	-	63	32.38**	46	-	-	-	49.83	-
1752	365	31.3	43.17	379	367*	-	110	66	32.73	49	11.20*	25.4	15.27	48.62	95*
1838	373	36.3	47.31	396	380	-	120	70	40.06	54	8.72	24.76	17.93	53.85	99

Table A1.13 (continued). Tibia Measurements after Todd (1987b) and McDonald (1981). No measurements obtained for TA5 or TA8.

Catalog #	Shot #	Unit	Side	Completeness	Dist. Fusion	Comments
0009	278	A	R	Mostly complete	fused	Proximal and distal ends jacketed together, but most of the shaft is missing. Length measurements based on assumption that jacketed length is representative of actual length. Most measurements unattainable.
0016	289	A	L	Complete	fused	Repaired with unknown glue.
0123b	904	A		Distal end	fused	Estimate
0784	195	F	R	Mostly complete, missing only unfused distal epiphyses.	unfused	Some surface exfoliation, on posterior surfaces. Could not measure B13, no visible foramen on posterior side.
0800	211	F	R	Mostly complete, distal end and unfused distal epiphyses partially fragmented	unfused	-
0818	229	F	L	Mostly complete, some fragmenting of proximal end	unfused	Articulated left hind limb, jacketed in two pieces: tibia through tarsals, and metatarsal to third phalanx. Jacketed medial side up. Jacket is thin, bones are all coated in an unknown glue, obscuring features, and preventing most measurements.
0900	60	G	R	Complete	-	Pathological lump on center midshaft on medial side
1296a	399	O	R	Partial proximal end and distal end with unfused distal epiphyses	unfused	-
1511	785	X-Y	L	Complete	fused	-
1556a	976	Y	R	Proximal end	-	-
1559	979	Y	L	Distal end, missing unfused epiphyses	unfused	Measurements for end of shaft, no epiphyses
1569	1019	Y	L	Proximal end	-	-
1754	1586	BB	L	Distal end partially fragmented, difficult to assess fusion	?	Large open split in shaft (~5mm) which will inflate shaft width and breadth measurements, as well as B6.

Table A1.14. Metatarsal Measurements after Bedord (1974) and Lewis et al. (2005).

Catalog #	B1	B2	B3	B4	B5	B6	B8	B9	B10	B11	B12	B13	L11
0009	263*	57.53*	-	67	-	-	37.5	-	-	227.89*	-	-	28.54
0016	247	53.6	31.88	61	33.09	49.83	36	28.21	31.09	214.29	190.03	190.45	26.25
0123b	-	-	-	-	-	-	40	-	-	-	-	-	-
0784	-	48.5	28.66	-	29.78	47.39	-	27.51	28.62	-	196.56	-	-
0800	240**	46.5	25.92	-	28.25	47.9	33.52*	27.55	25.28	-	173.14	180.42	-
0818	263*	50.44*	25.73	-	-	51.01	-	-	-	212.79*	182.34	-	28.16*
0900	258	58.1	36.82	67	37.37	54.5	40	31.34	35.57	218.77	197.14	195.81	29.66
1296a	-	47.83*	-	60**	-	48.83	-	-	-	-	-	-	27.1
1511	254	58.3	36.41	66	36.07	54.69	40	30.88	35.91	216.47	197.36	194.51	30.01
1556a	-	50.3	-	-	-	53.68	-	-	-	-	-	-	-
1559	-	-	-	50	-	-	31	-	-	-	-	-	-
1569	-	43.1	-	-	-	41.97	-	-	-	-	-	-	-
1754	-	54	34.24	-	34.57	54.05	-	31.28	32.92	-	196.09	196.27*	-

Table A1.14 (continued). Metatarsal Measurements after Bedord (1974) and Lewis et al. (2005).

Catalog #	Shot #	Unit	Side	Completeness	Comments
0123d	904	A	L	Partial	-
0437	153	C	R	Complete	Some deformation where cracks are splitting apart, may affect measurements (distal width, lateral length). Missing too much to measure volume.
0678b	701	E	R	Complete	
0697	760	E	R	Complete	Some cracking and deformation, not able to measure volume.
0775	187	F	L	Mostly complete, missing some bone from center of anterior, some surface bone eroded from anterior side.	Missing too much bone to measure volume.
0818	229	F	L	Mostly complete	Articulated left hind limb, jacketed in two pieces: tibia through tarsals, and metatarsal to third phalanx. Jacketed medial side up. Jacket is thin, bones are all coated in an unknown glue, obscuring features, and preventing most measurements.
0883	43	G	L	Complete	-
1127	421	L	R	Medial half	-
1170h	1537	L	R	Medial half	-
1264	459	N	R	Postero-medial section	-
1557	977	Y	R	Complete, some surfaces eroded	-
1672	1644	AA	L	Missing proximal part of lateral condyle	-
1724	1538	BB	R	Complete	-
1753b	1585	BB	L	Mostly complete, missing postero-lateral surface	-
1788	N/A	BB	L	Complete, but surfaces eroded, one spreading crack	-

Table A1.15. Astragalus Measurements after Morlan (1991).

Catalog #	Volume (mm³)	Medial Depth	Lateral Depth	Lateral Length	Medial Length	Proximal Width	Distal Width
0123d	-	-	-	-	-	-	53.06
0437	-	40.02	42.22	76.10	69.78	52.13	54.11
0678b	70939.77	39.31	39.29	73.87	68.57	47.70	47.53
0697	-	36.27	40.70	71.91	65.45	48.43	46.46
0775	-	37.52	39.76	73.59	68.94	49.88	47.73
0818	-	38.13*	-	-	-	-	-
0883	98731.35	45.88	43.53	78.27	75.14	55.62	55.52
1127	-	41.41	-	-	74.42	-	-
1170h	-	45.96	-	-	73.87	-	-
1264	-	-	-	-	72.57*	-	47.51*
1557	91622.66	43.6	44.22	81.02	76.31	51.37	50.57
1672	-	37.88	40.99	-	70.33	-	48.99
1724	69608.63	37.90	39.89	74.11	68.16	47.47	47.89
1753b	-	42.6	43.09**	76.60*	73.83	51.02**	50.70
1788	68956.20	38.12	38.31	71.55	68.57	48.43	48.47

Table A1.15 (continued). Astragalus Measurements after Morlan (1991).

Catalog #	Shot #	Unit	Side	Completeness	Comments	Fusion
0382d	N/A	B	R	Tuber calcis and part of sustentaculum	-	fused
0678a	701	E	R	Complete	Tuber calcis unfused, but intact	unfused
0898	58	G	R	Complete	Large crack runs longitudinally down sustentaculum, which is split open and may affect proximal width measurement	-
0996	73	J	R	Complete, unfused tuber epiphysis glued in place	-	unfused
1111a	262	L	L	Fragments lateral malleolus, tarsal C+4, and astragalus articulations	-	-
1132	422?	L	L	Fragments of tuber calcis, lateral malleolus and astragalus facets	-	fused
1155	617	L	R	Mostly complete, but missing part of tuber calcis, and astragalus facet	-	unfused
1168a	1537	L	L	Astragalus facet	-	-
1555	975	Y	L	Mostly complete, missing distal tip	-	unfused
1570	1020	Y	R	Complete	-	fused
1637	1569	AA	R	Mostly complete, with unfused tuber epiphysis present	-	partial
1648	1612	AA	R	Mostly complete, missing only unfused tuber epiphysis	-	unfused
1742	1575	BB	R	Complete, unfused tuber epiphysis glued in place	Length measurements may be slightly affected by the glue job.	unfused
1753a	1585	BB	L	Mostly complete, missing some fragments from tuber	-	unfused

Table A1.16. Calcaneus Measurements after Morlan (1991) and Martin et al. (2018).

Catalog #	Mt DstL	Length	Length A. facet	Length C+4 facet	Proximal width	Distal Width	Proximal Depth	Distal Depth
0382d	-	-	-	-	41.32	-	43.89	-
0678a	91.66	142.79	31.99	39.11	35.96	49.45	40.10	56.10
0898	99.60	158.51	34.06	42.01	43.02	51.70	43.07	60.92
0996	88.45	144.46	35.59	41.60	36.62	47.14	40.46	61.55
1111a	-	-	-	40.20	-	-	-	-
1132	-	-	-	-	37.88	-	36.69	-
1155	-	-	30.55*	41.82	-	-	-	61.58
1168a	-	-	36.67	-	-	-	-	-
1555	64.79**	-	28.85	-	28.92	39.23	32.37**	48.34*
1570	98.01	149.23	34.74	38.16	37.57	41.19	40.80	57.50
1637	93.6	149.95**	35.45	41.87	37.90*	47.25	40.68*	63.52
1648	-	-	31.09	36.83	27.94*	42.62	36.43*	54.54
1742	93.95	145.55	33.71	37.29	34.75	43.69	42.91	56.93
1753a	96.32	149.3	32.93	39.89	32.34*	43.76	42.40*	61.14

Table A1.16 (continued). Calcaneus Measurements after Morlan (1991) and Martin et al. (2018).

Catalog #	Shot #	Unit	Side	Completeness	Length	Width	Depth
0426	123	C	R	Mostly complete, missing mid-section	46.83	59.81	59.90
0753b	N/A	E	R	Complete, surface eroded on medial side	46.03	53.81*	52.15
1182	N/A	L	L	Complete, but surfaces eroded and missing part of posterior-medial process	38.58*	58.27	54.78
1489	785	X	L	Complete, ventral surfaces somewhat eroded	50.47	66.24	61.48
1556b	976	Y	R	Complete	47.43	58.28	59.35
1601	885	Z	L	Complete	37.16	47.94	46.9
1689	1659	AA	L	Mostly complete	41.87	52.78	53.8
1753c	1585	BB	L	Mostly complete, missing fragments from center	45.54**	59.98**	61.31**

Table A1.17. Tarsal C+4 Measurements after Morlan (1991).

Catalog #	Shot #	Unit	Side	Completeness	Depth	Width
0182b	N/A	A	L	Complete	39.95	25.11
0219c	N/A	A	R	Complete	38.97	25.01
0219d	N/A	A	L	Complete	38.70	24.21
0861	N/A	F	L	Complete, dorsal surfaces eroded	37.28	23.26
1069b	N/A	K	L	Mostly complete, missing surfaces along postero-medial aspect and antero-lateral aspects	40.70*	26.93*
1184	N/A	L	L	Complete, but ventral and medial surfaces eroded	38.50	23.31*
1296b	399	O	R	Mostly complete	37.48	26.48
1318a	N/A	O	R	Mostly complete, ventral surface eroded	40.60	24.65
1318b	N/A	O	L	Mostly complete, dorsal surface eroded	36.64*	23.70
1556c	976	Y	R	Complete	40.36	25.91
1721	N/A	AA	R	Mostly complete	37.11	24.34
1753d	1585	BB	L	Complete	40.61	24.70

Table A1.18. Tarsal 2+3 Measurements after Morlan (1991).

Catalog #	Shot #	Unit	Side	Completeness	Length	Width	Depth
0123e	904	A	L	Complete, some surface abrasion, measurements are minimums	28.09*	22.28*	42.18*
0238a	244	B	R	Complete	27.45	17.57	34.51
0341b	N/A	B	L	Mostly complete	28.63*	19.55*	40.49
0438	154	C	R	Missing medial surfaces and posterior edge	28.45	16.61*	36.80*
0678c	701	E	R	Complete	25.77	17.79	35.78
0762b	N/A	E	L	Mostly complete, lateral surfaces eroded	22.64	14.30	32.48
0896	56	G	R	Complete	28.58	19.01	39.29
1753e	1585	BB	L	Complete	26.41	17.05	36.49
1774	1628	BB	L	Complete	24.59	15.29	33.36

Table A1.19. Lateral Malleolus Measurements after Morlan (1991).

Appendix II. Radiocarbon Date (Beta-527954)



Beta Analytic
TESTING LABORATORY

Beta Analytic Inc
4985 SW 74 Court
Miami, Florida 33155
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Fax: 305-663-0964
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ISO/IEC 17025:2005-Accredited Testing Laboratory

REPORT OF RADIOCARBON DATING ANALYSES

Michael Fosha

Report Date: June 25, 2019

State Archaeological Research Center

Material Received: June 11, 2019

Laboratory Number	Sample Code Number	Conventional Radiocarbon Age (BP) or Percent Modern Carbon (pMC) & Stable Isotopes	
		Calendar Calibrated Results: 95.4 % Probability High Probability Density Range Method (HPD)	
Beta - 527954	39HN570 sample 2019	5570 +/- 30 BP	IRMS $\delta^{13}\text{C}$: -16.8 o/oo
			IRMS $\delta^{15}\text{N}$: +9.2 o/oo
	(95.4%) 4457 - 4352 cal BC	(6406 - 6301 cal BP)	
	Submitter Material: Bone (Non-heated)		
	Pretreatment: (bone collagen) collagen extraction; with alkali		
	Analyzed Material: Bone collagen		
	Analysis Service: AMS-Standard delivery		
	Percent Modern Carbon: 49.99 +/- 0.19 pMC		
	Fraction Modern Carbon: 0.4999 +/- 0.0019		
	D14C: -500.12 +/- 1.87 o/oo		
	$\Delta^{14}\text{C}$: -504.28 +/- 1.87 o/oo(1950:2,019.00)		
	Measured Radiocarbon Age: (without $\delta^{13}\text{C}$ correction): 5440 +/- 30 BP		
	Calibration: BetaCal3.21: HPD method: INTCAL13		
	Carbon/Nitrogen: CN : 3.3 %C: 42.21 %N: 15.08		

Results are ISO/IEC-17025:2005 accredited. No sub-contracting or student labor was used in the analyses. All work was done at Beta in 4 in-house NEC accelerator mass spectrometers and 4 Thermo IRMSs. The "Conventional Radiocarbon Age" was calculated using the Libby half-life (5568 years), is corrected for total isotopic fraction and was used for calendar calibration where applicable. The Age is rounded to the nearest 10 years and is reported as radiocarbon years before present (BP), "present" = AD 1950. Results greater than the modern reference are reported as percent modern carbon (pMC). The modern reference standard was 95% the ^{14}C signature of NIST SRM-4990C (oxalic acid). Quoted errors are 1 sigma counting statistics. Calculated sigmas less than 30 BP on the Conventional Radiocarbon Age are conservatively rounded up to 30. $\delta^{13}\text{C}$ values are on the material itself (not the AMS $\delta^{13}\text{C}$). $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values are relative to VPDB-1. References for calendar calibrations are cited at the bottom of calibration graph pages.

BetaCal 3.21

Calibration of Radiocarbon Age to Calendar Years

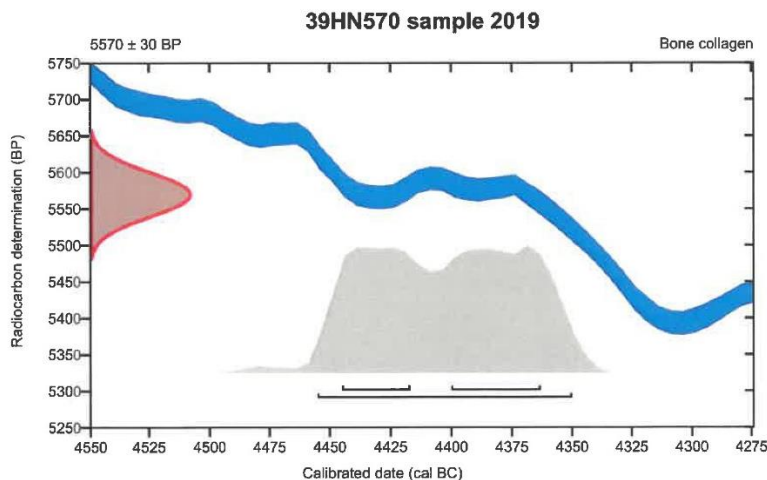
(High Probability Density Range Method (HPD): INTCAL13)

(Variables: $\delta^{13}\text{C} = -16.8$ o/oo)**Laboratory number Beta-527954****Conventional radiocarbon age 5570 \pm 30 BP**

95.4% probability

(95.4%) 4457 - 4352 cal BC (6406 - 6301 cal BP)

68.2% probability

(38.6%) 4402 - 4365 cal BC (6351 - 6314 cal BP)
(29.6%) 4447 - 4419 cal BC (6396 - 6368 cal BP)**Database used**
INTCAL13**References****References to Probability Method**Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. *Radiocarbon*, 51(1), 337-360.**References to Database INTCAL13**Reimer, et.al., 2013, *Radiocarbon* 55(4).**Beta Analytic Radiocarbon Dating Laboratory**4985 S.W. 74th Court, Miami, Florida 33155 • Tel: (305)667-5167 • Fax: (305)663-0964 • Email: beta@radiocarbon.com