

BONFIRE SHELTER: A ZOOARCHAEOLOGICAL  
REEVALUATION OF BONE BED 2

by

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## I. INTRODUCTION

A common form of large scale historic and late prehistoric megafauna hunting on the northern Plains utilizes what are known as “jump drives”. Hunting with a jump drive involves maneuvering or driving a herd of animals towards a steep cliff and then over the edge. Utilizing a jump drive requires cooperation between several groups and a deep understanding of animal behavior and terrain (Wyckoff and Dalquest 1997; Bement and Buehler 1994; Brooks and Flynn 1988; Drass and Flynn 1990; Harrison and Killen 1978; Johnson 1987; Johnson and Holliday 1986; Saunders and Penman 1979; Speer 1978; Carlson and Bement 2013a; Brink 2008; Frison and Reher 1970b; Frison 1991a; 2004; Zedeño et al. 2014). However, questions still remain of exactly when, how, and where hunting with jump drives developed.

One of the most iconic and potentially oldest bison jump drives in North America is Bonfire Shelter. Bonfire Shelter contains three bone bed deposits. A bone bed is an accumulation of bone that occurs in a defined geological stratum (“Bone Bed” 2020). The upper deposit, Bone Bed 3, is dated to 2,500-2,000 BP (Late Archaic) and is considered to conclusively represent a bison jump drive (Dibble and Lorrain 1968; Byerly et al. 2005:620; Kilby et al. 2020). The middle deposit, Bone Bed 2, is dated to 12,025 calBP (Paleoindian) but its formation has been heavily debated and it is unclear whether or not Bone Bed 2 is the result of a jump drive or if it represents a secondary butchering location for bison killed elsewhere (Dibble and Lorrain 1968; Dibble 1970; Bement 1986; 2007; Byerly et al. 2005; 2007a; Byerly et al. 2007b; Prewitt 2007; Kilby et al. 2020). The deepest deposit, Bone Bed 1, is dated to at least 14,600 BP (Late Pleistocene);

however, it contains no lithic artifacts and it is unclear whether it is the result of human activities (Dibble and Lorrain 1968; Bement 1986; Kilby et al. 2020).

The first excavations at Bonfire Shelter were carried out in 1963-64 under the direction of David S. Dibble (Dibble and Lorrain 1968). This investigation documented the presence of three individual bone beds and suggested that Bone Bed 3 and Bone Bed 2 were both the result of a bison jump drive. They also observed that Bone Bed 2 appears to be composed of at least three distinct strata and argue that these strata represent at least three distinct cultural events. Additional excavations in the interior portion of the site under the direction of Solveig Turpin were carried out in 1983-84 and uncovered more bison as well as bones belonging to at least one equus (Bement 1986). Although their research questions were more concerned with Bone Bed 1, they reiterated the argument that Bone Bed 2 was represented by at least three bison jump drives.

The current understanding of Paleoindian cultural patterns and subsistence strategies is heavily dependent on sites that were excavated during the mid to late 1900s, such as Bonfire Shelter. Incorporating these sites into current research presents a unique challenge due to the fact that the research took place decades earlier and the sites were often excavated with less than ideal documentation. Although far ahead of its time in terms of documentation and planning, the original excavation of Bonfire Shelter lacked detailed records of provenience and in situ faunal condition, in part, simply due to a lack of the technological means to do so. Similarly, the emerging field of zooarchaeology in North America then lacked an extensive research base and analytical methodology (Reitz and Wing 1999). The zooarchaeology of bison bone beds remained undeveloped until the 1980s with work conducted by researchers such as Larry Todd and George Frison.

Consequently, the zooarchaeological analysis of Bone Bed 2 carried out by Dessamae Lorrain (Lorrain 1968) was concerned with a description of the faunal assemblage geared towards determining the age and sex profiles as well as the size of the assemblage and lacks discussion of utility, bone modification, or site function.

A reanalysis of the curated fauna from Bone Bed 2 was conducted by Southern Methodist University (Byerly et al. 2005; 2007a; Byerly et al. 2007b) to update the understanding of the assemblage in light of modern methods. This analysis, among other research goals, reidentified the curated specimens from the original 1963-64 excavation and re-evaluated Lorrain's (1968) analyses of age and sex. The SMU researchers also incorporated utility analyses and inter-site comparison with the goal of determining whether or not Bone Bed 2 represents a primary kill or secondary processing locale. Although they ultimately argue that Bone Bed 2 represents a secondary processing locale, this interpretation has been subject to much debate (Byerly et al. 2005; 2007a; Byerly et al. 2007b; Bement 2007; Binford 1978a; Prewitt 2007).

Currently, the Ancient Southwest Texas Project (ASWT) of Texas State University has been conducting research at Bonfire Shelter beginning in 2017. The investigations carried out by ASWT are concerned with four major research goals: (1) establishing a detailed chronostratigraphic sequence for the site deposits; (2) determining the origin and number of events associated with Bone Bed 2, specifically regarding its original interpretation as resulting from one or more drives or jumps from the rim above; (3) determining the origins of Bone Bed 1, specifically regarding whether some part of it is the result of human activity; and (4) preserving the site by stabilizing the surface and



exposed deposits, including backfilling open excavation units and controlling surface runoff into and within the shelter (Kilby et al. 2020).

This thesis addresses the second ASWT research goal by thoroughly reviewing the previous Bone Bed 2 research and reanalyzing the assemblage with the inclusion of new data and analytical methods. This thesis integrates recently collected raw field faunal data integrated with existing data from existing sources (Dibble and Lorrain 1968; Bement 1986; Byerly et al. 2005; 2007a; Byerly et al. 2007b) through a discussion of the spatial patterning of the bones, patterns of fragmentation, and a comparison between Bone Bed 2 and other Folsom aged bison bone beds with regard to element frequency and age profiles.

## **II. ARCHAEOLOGICAL BACKGROUND**

The projectile points that have been recovered from Bone Bed 2 were identified as belonging to the Folsom and Plainview archaeological cultures (Dibble and Lorrain 1968). The Folsom cultural tradition on the Plains has been dated from ca. 12,900 to 12,000 calBP while the Plainview cultural tradition has been dated from ca. 12,100 to 11,300 calBP (Holliday 1997; Bousman, Baker, and Kerr 2004; Kornfeld, Frison, and Larson 2010; Holliday, Johnson, and Knudson 2017a; Surovell et al. 2016). The Folsom cultural tradition is an exclusively Plains hunter-gatherer adaptation with sites found from southern Canada into northern Mexico (Munson 1991; Sanchez 2001). Although it largely postdates Folsom, the Plainview cultural tradition is a similarly Plains adapted culture found only on the southern Plains (Holliday et al. 2017). The relationship between Plainview and other morphologically similar contemporary point types found across the Plains will also be discussed.

### **Material Culture**

In terms of lithic technology, the Folsom archaeological culture is best known for finely pressure-flaked fluted projectile points. These points have been argued to represent the pinnacle of bifacial lithic technology in the world at the time of their production (Frison 1991:51). In addition to lithic technology, the Folsom cultural complex also contains examples of bone and antler projectile points (Frison and Zeimens 1980), eyed bone needles (Frison and Craig 1982), and antler and bone punches that have been interpreted as being used to punch out the flute from Folsom points (Frison and Bradley 1980).

The Plainview projectile point is an unfluted lanceolate bifacial point that exhibits morphological similarities to Folsom points. Plainview points are highly variable but can be classified into one of three groups: Variety I (sudplano), II (traditional “Plainview”), and III (parallel collateral flaking) (Knudson 2017:35). Similarities have been noted between Plainview points and other point types across the Plains such as Folsom, Midland, Goshen, Agate Basin, Belen, and Milnesand points (Knudson 2017). Aside from Folsom and Midland which mostly predate Plainview, the similarity between point types has been argued to represent regional variations on a shared widespread technological form borne out of the high mobility that these people exhibited (Knudson 2017:75). For example, Belen points are considered to be the Southwest variant of the Plainview point while Goshen points appear to be the northern Plains equivalent (Knudson 2017).

Bifacial stone knives, utilized flakes, and end and side scrapers have been identified at Plainview and Folsom sites in addition to projectile points (Holliday, Johnson, and Speer 2017; Frison 1991b). While, these tool types often receive less attention than projectile points, they are the tool types that are most likely to be found at sites where butchering took place (Sivertsen 1980).

The relationship between Folsom and Plainview projectile technology is not fully understood; however, Plainview exhibits similar morphological traits and production steps as Folsom and Midland points suggesting that Folsom may have developed into Plainview with Midland as an intermediate stage (Holliday, Johnson, and Knudson 2017b:289). The concurrent points present across the Plains (Midland, Goshen, Agate Basin, Belen, and Milnesand) share morphological similarities with Plainview but are

distinct enough to be considered varieties of Plainview rather than additional labels for the same style (Knudson 2017:56). The similarity between Plains point styles is argued to represent widespread communication between individual Plains cultural groups rather than a singular culture (Knudson 2017:77).

The lithic assemblage of Bonfire Shelter has been employed to help interpret the function of the site (Byerly et al. 2007b). The relatively equal abundance of hunting tools (projectile points) and butchering tools (flake scrapers and bifaces) relative to the low abundance of resharpening flakes has been argued to suggest that extensive processing was not being conducted and that hunting and primary processing were the main activities that produced Bone Bed 2 (Dibble and Lorrain 1968). However, since the entire site has not been excavated, the addition of new, as-of-yet-unfound lithic evidence may change this interpretation.

### **Social Organization**

Paleoindian Plains cultures were inherently tied to the movement and behavior of bison (Amick 1996; Blackmar 2001; Bamforth 2011). In wetter environments where edible grasses were plentiful year-round, the movement of bison herds was less predictable. In more arid environments, bison were tethered to known water sources and moved between them during their yearly migration (Baker 2017:179; Kelly 2013). Hunters were able to exploit this predictability to follow the herds and, for mass kills, time their hunts for when the herds would be the largest. Studies show that hunter-gatherer band size varies primarily according to mobility and subsistence benefits (Amick 1996:421). Given the high mobility required of Paleoindian bison hunters, it is inferred that band sizes would have been relatively small. Furthermore, studies involving the

number of points, individuals, and structures at Folsom sites along the Rio Grande in Colorado indicate that the average Folsom band contained only two to three hunters (Jodry 1992; Jodry and Stanford 1992; Amick 1996).

Certain features of the Plainview archaeological culture such as the morphology of their projectile points, their location on the Plains, and the prevalence of bison remains at Plainview sites suggest that they too relied on bison as a primary means of subsistence (Holliday et al. 2017a). Bison remains have been recovered from the Plainview type site (Sellards et al. 1947), Bull Creek (Carlson and Bement 2017), Lubbock Lake (Eileen Johnson and Holliday 1980), and Perry Ranch (Saunders and Penman 1979) and potentially from the Reynolds-Truesdell site (Huckell and Merriman 2017). In addition to bison remains, the Bull Creek site contains the remains of deer, pronghorn, cottontail rabbit, jackrabbit, vole, kangaroo rat, badger, canid, small bird, rattlesnake, turtle, mussel, snail, and camel intermingled among the bison remains (Carlson and Bement 2017:136, Table 5.5). Although many of these faunal remains may be natural occurrences, their presence still suggests that Plainview peoples utilized other fauna in addition to bison potentially during seasons when bison were either less plentiful or nutritionally depleted such as has been proposed for the Folsom peoples (Greiser 1985; Amick 1996; Hill 2001; 2007; Carlson and Bement 2017).

The broad similarity between Plainview points and other point styles on the Great Plains has led some researchers to conclude that, though distantly separated, these various cultures were part of a larger meta-population that shared cultural ideas and styles (Knudson 2017:75). Since hunters were intimately familiar with the terrain and were able to predict the location of bison herds, communal hunting at large-scale hunting locals

may have been the mechanism by which the disparate Plains groups maintained social identity (Carlson and Bement 2013a).

### **Environment**

Bonfire Shelter is located in the Lower Pecos region of Texas at the margins of the Chihuahuan desert to the southwest and the Edwards Plateau to the northeast.

Palynological evidence from Bonfire Shelter indicates that during the late full-glacial period in which Bone Bed 2 was formed, the Lower Pecos region of Texas was covered by a mosaic of vegetation containing woodlands, pinyon parklands, and scrub grasslands with junipers also being likely (Bryant 1969).

Sedimentological and palynological research conducted by Robinson (1997) demonstrated that sediment from Bone Bed 1 dating to 12,430 RCYBP contained high amounts of sand relative to cobbles and pebbles. As Pleistocene temperatures decreased, freeze-thaw actions caused the rate of spalling in caves and rockshelters to increase. The lack of roofspall material in the Bone Bed 1 sample suggests less winter spalling and therefore relatively warmer temperatures. Robinson also noted the presence of pollen from pine and oak. Samples from Bone Bed 2 dated to  $10,230 \pm 160$  RCYBP exhibited a steady increase in sediment particle size up through the deposit suggesting that spalling was increasing and that temperatures were decreasing. Pollen data from the Bone Bed 2 samples also showed a decrease in pine and oak and an increase in grasses. The sample from Bone Bed 3 dated to sometime after 2,780 RCYBP was sedimentologically similar to the sample from Bone Bed 1 and suggests a return to warmer temperatures. Pine and oak pollen were also sparse from the Bone Bed 3 samples. Ultimately, Robinson (1997) argues that the hunting events at Bonfire Shelter correspond to warmer periods with

decreased forest elements. The thinning of forests likely allowed Plains bison to expand their grazing ranges and migration routes. He further argues that Paleoindian hunters followed the bison from the Plains and then settled in the Lower Pecos, continuing to hunt bison as the regional climate allowed for their reentry into the landscape.

Research conducted by Byerly et al. (2007b:134-135) demonstrated that the frequency of gastropod shells fluctuates throughout the Bonfire Shelter stratigraphy, with a paucity of shells in the Bone Bed 2 strata and the strata over- and underlying them. Byerly et al. argue that this indicates the environment surrounding Bonfire Shelter during the deposition of Bone Bed 2 was dryer relative to later Holocene times.

During the late glacial period from 14,000 to 10,500 years ago, temperature sensitive cave fauna from the Edwards Plateau, such as the masked shrew (*Sorex cinereus/haydeni*) and the cotton rat (*Sigmodon hispidus*), suggest that average summer temperatures on the Edwards Plateau were within 2-3°C of modern values (Toomey III 1992; Toomey III, Blum, and Valastro Jr. 1993). This result is similar to Bryant's (1969) research on the palynological record present in Bonfire Shelter which demonstrated that during full glacial conditions, the Lower Pecos region of Texas was on average 5°C cooler than modern temperatures.

### **Bison Physiology**

During the Middle to Late Paleoindian period, two proposed subspecies of bison were living on the Plains: *Bison antiquus* and *Bison occidentalis*. Although the exact nature and relationship between these subspecies has been debated (Hillerud 1966; Eileen Johnson 1974; Wilson 1974a; 1974b), it is clear that they represent the direct evolutionary ancestors to modern *Bison bison*. Because of this connection,

paleontologists and archaeologists assume that these prehistoric bison, apart from being up to two times larger, shared essentially the same physiology as modern bison (Borresen 2002:6; Byerly et al. 2005:607; Emerson 1993). Of particular relevance to archaeologists are tooth eruption rates, bone fusion rates, fat storage, and musculature. In regard to these factors, prehistoric bison are assumed to be similar enough to modern day bison that the use of data derived from modern bison to model prehistoric bison ecology is appropriate.

### **Bison Behavior**

Similar to physiology, *B. antiquus* are assumed to share similar herding behaviors with modern *B. bison* (Carlson and Bement 2013b; Reher 1974). For example, in modern bison herds, cows and bull bison converge into massive herds during the rutting season (July through early August) and split into herds comprised solely of either adult bulls (bachelor herds) or adult cows, juveniles, and calves (nursery herds) during the rest of year. Following Rosas et al. (2005), adults are defined as individuals older than three years old, juveniles are between one and three years old, and calves are less than one year old.

Research utilizing modern *B. bison* herds shows that the age composition of a herd varies widely depending on the year, season, and location of the herd. Depending on the herd being studied, herds were composed of between 31 to 50.7 calves per 100 cows and between 10 to 42 juveniles per 100 cows (Brodie 2008:10). Additionally, one bison herd in British Columbia documented in late winter contained 19 yearling bison per 100 cows (Rowe and Backmeyer 2006).

Despite these similarities, there are several characteristics that are argued to be uniquely modern adaptations. Guthrie (1980) argues that since the winter grasses that



bison rely on were not prevalent until the Holocene, *B. antiquus* herds that were present during the Late Pleistocene likely would have been composed of a much smaller number of individuals than modern herds, with particularly small herds during the winter. Landform-assisted Folsom bison kills have been reconstructed as containing an average of ~25 individual bison (Todd et al. 1992:137).

### **Bison Hunting**

Large-scale bison hunting developed in response to the consistent migratory patterns of bison. Optimal foraging theory indicates that, all things being equal, specializing in hunting megafauna is only advantageous when encounter rates are sufficiently high (Byers and Ugan 2005). Although *B. antiquus* herds were likely much smaller than their historic counterparts, the regularity of bison migration patterns would have allowed Folsom and Plainview hunters to predict where the bison would be during specific seasons and when their herds would be the largest (Bement 2003; Amick 1996).

Although bison hunting continued until historic times, the archaeological record shows that Late Paleoindian bison hunting differed in a few key ways from what is known from ethnographic and historic accounts (Bamforth 1988; Frison 1982; M. G. Hill 2001; Todd 1991). Primarily, Paleoindian bison hunters tended to hunt smaller groups of bison with evidence of hunting throughout the entire year. Although the intensity of hunting does appear to focus on the late fall and early winter, Archaic and Late Prehistoric groups have been argued to hunt bison almost exclusively during the early fall. Additionally, Paleoindians heavily utilized natural landscape features to either trap or disadvantage bison prior to their death. Later groups relied much more heavily on artificial constructions, such as corrals and drive lanes, to either trap the bison or lead

them into the kill locale. Although this could be partially a consequence of preservation bias, there is little to no evidence of Paleoindian hunters using stones and boulders to construct drive lanes; something that is done extensively in later times (Bamforth 1988).

Meat caching has often been suggested as a potential means by which Paleoindian hunters adapted to very cold winters during which bison display poor physiological health (Emerson 1993; Frison 1982b, 1988; Speth 1983; Speth and Spielmann 1983). Though hunting has been shown to occur throughout the entire year, mass kills that took place during fall and early winter allowed Paleoindians to store or freeze the meat and survive the winter. Although this would in theory be a suitable survival strategy, McCartney (1983, 1990) argues that there is little to no evidence of meat storage throughout the Post-Clovis Paleoindian era. Paleoindian hunters instead pursued the herds that would be in prime nutritional condition during specific times of the year with bulls pursued in the winter and spring and cows and calves during the summer and fall.

Recent evidence suggests that Folsom and later Paleoindian groups utilized additional faunal sources to offset seasonally variability in the amount and quality of nutrition provided by bison (Greiser 1985; Hill 2007). Furthermore, environmental data indicates that during the Late Pleistocene, seasonal environmental variability was much lower than it is in modern times (Guthrie 1984). This suggests that bison may have not have substantially varied in terms of nutritional content throughout the year, and thus Paleoindians hunters would have had no need to change their hunting strategies from season to season (Todd 1991). Seasonal strategies only developed much later in the Paleoindian period as extremes between seasons (warmer summers and colder winters) increased (Hill 2001).

## **Bison Hunting Strategies**

A summary of the hunting strategies utilized at well-documented Clovis, Folsom, and Plainview bison sites on the Great Plains is summarized in Table 1. Archaeological evidence indicates that Folsom and Plainview hunters conducted mass kills in two main ways: herding bison into natural obstacles and herding bison over natural obstacles (Frison 1991:162). There is also evidence that these Paleoindian hunters also engaged in “ambush hunting” in which individual bison were killed opportunistically when they were vulnerable, such as when drinking from a pond.

**Table 1.** Summary of well documented Clovis, Folsom, and Plainview bison kills sites on the Great Plains.

Culture	Site	Landform	Function	Season	MNI <sup>a</sup>	Number of events	Source(s)
Clovis	Jake Bluff	Arroyo	Arroyo Trap	Fall	22	1	Bement and Carter 2010
Folsom	Agate Basin	Arroyo	Arroyo Jump	Winter	9, 7	1	Frison and Stanford 1982
	Cooper	Arroyo	Arroyo Trap	Late summer/early fall	29, 29, 20	3	Bement 1999
	Lake Theo	Swale	Arroyo Trap	Fall	12	1	Harrison and Killen 1978
	Lipscomb	Arroyo	Arroyo Trap/Jump	Late summer/early fall	55	1	Schultz 1943; Todd et al. 1990
	Waugh	Arroyo	Arroyo Trap	-	3	1	Hili Jr and Hoffman 1997
	Lubbock Lake	Lake	Ambush	Fall/winter	3	1	Johnson 1997
	Folsom	Arroyo	Arroyo Trap	Fall	32	1	Meltzer 2006
	Linger	-		Late summer/early fall	5	1	Hurst 1943
	Stewart's Cattle Guard	Sand Dune	Sand Dune Trap	Late summer/early fall	49	1	Jodry 1987
	Blackwater Draw	Lake	Ambush	-	2-5	1	Bement 1999
Plainview	Plainview	Valley	Stampede	Fall, spring	84	>1	Sellards et al. 1947, Speer 1983; Hill 2010
	Bull Creek	Terrace	Campsite	Late winter	8	1	Carlson and Bement 2017
	Lubbock Lake	Lake	Ambush	Fall/spring	6	1	Johnson and Holliday 1980
	Rex Rodgers	Canyon	Arroyo trap	Late fall/Late winter	6	>2	Speer 1978
	Mill Iron <sup>b</sup>	-	Campsite, Jump	-	40	1	Frison 1996
	Perry Ranch	Arroyo	Arroyo Trap	Winter	2	1	Saunders and Penman 1979

<sup>a</sup> minimum number of individuals<sup>b</sup> Goshen

The use of natural obstacles, also known as landform-assisted hunting, is well documented across Paleoindian bison kill sites and appears to have been a favored kill method (Bement 1999; Frison 1991:158, 1984; Frison and Stanford 1982). These kills are often referred to as “arroyo traps” or “head cut traps” and involved maneuvering a herd of bison into an arroyo until they eventually reach the head-cut or “knick point”, where they were killed by hunters positioned along the rim of the arroyo. Some researchers argue that the entrance arroyo would then be blocked off by hides or branches and the bison killed while they were trapped (Bamforth 2011; Frison 2004). Others argue there is no solid evidence for true traps and that the bison were killed while they were disadvantaged trying to escape the arroyo (Bamforth 2011:27).

There are also several examples of Paleoindian hunters driving bison over natural obstacles. This method is less prevalent across Paleoindian sites, although this may be the result of equifinality. It is difficult to distinguish between bison remains that were driven into an arroyo versus bison that driven over the arroyo. This method has been proposed for the Lipscomb site (Todd et al. 1990) and the Plainview type site (Sellards et al. 1947). Although it is a Cody site and postdates Folsom and Plainview, the most notable example of this kill method comes from the Olsen-Chubbuck site in which ~200 *B. occidentalis* were driven across and into an arroyo where they were trampled by the rest of the oncoming herd (Wheat, Malde, and Leopold 1972). The method was determined based on the orientation of unprocessed bison carcasses. This kill method is very similar to the famous “jump drives” utilized from the Archaic period (Head-Smashed-In contains deposits dated to as old as ca. 5,800 cal BP (Brink 2008)) to historic times. The use of a jump drive involved stampeding a herd of bison off of a cliff where they would fall to

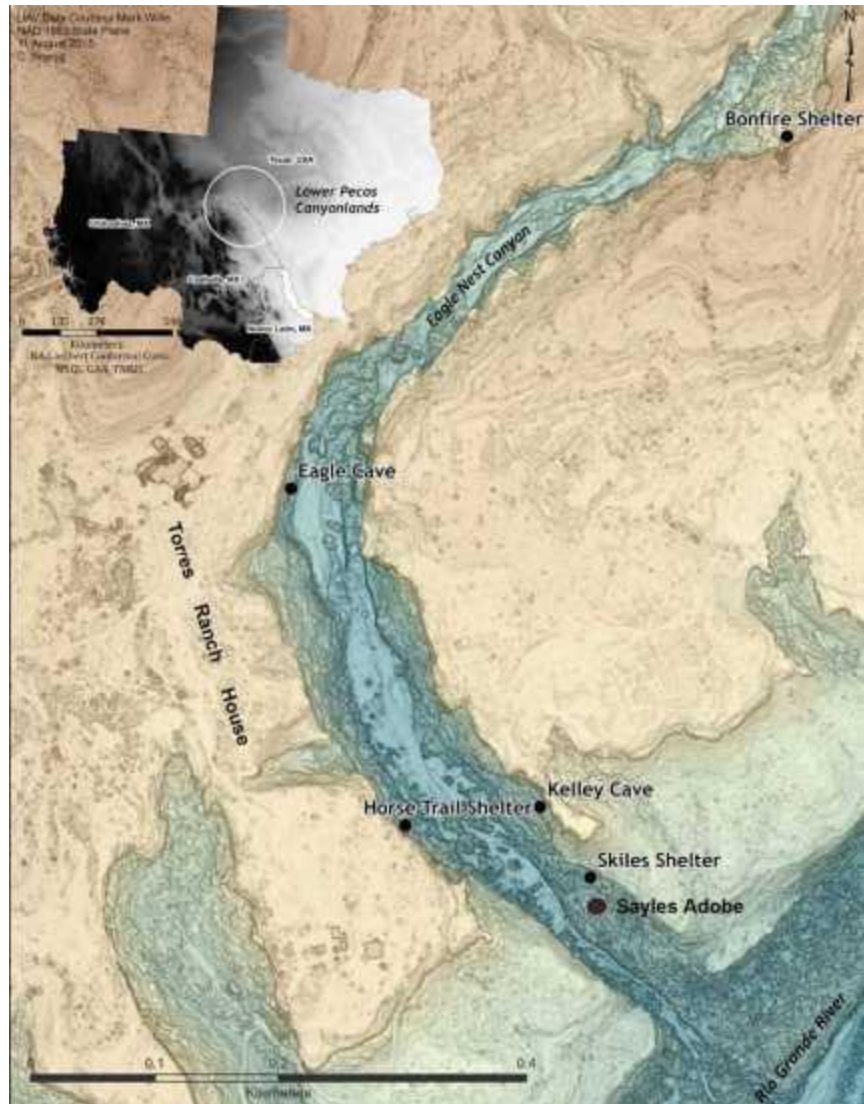
their deaths, or at least experience significant trauma allowing them to be easily killed afterwards. No uncontroversial example of a jump drive exists from the Paleoindian period, though it has been proposed for Bone Bed 2 at Bonfire Shelter and the Plainview type site (Sellards et al. 1947; Bement 2007).

Opportunistic or ambush hunting has also been documented at Folsom and Plainview bison kill sites. This type of hunting usually involves the killing of individual bison when they are isolated or vulnerable such as when drinking from a pond. A well-documented example of this style of hunting comes from Lubbock Lake with both Folsom and Plainview (or Plainview-esque) sites present (Eileen Johnson and Holliday 1980; Eileen Johnson 1987; Knudson 2017). Sites from Lubbock Lake contain one to two heavily processed bison each. They also contain well preserved examples of bone butchering tools created from the remains of the butchered carcasses. These bone tools have been argued to indicate that the hunters were not fully prepared to butcher bison thus reinforcing the opportunistic nature of these kills.

### **III. BONFIRE SHELTER**

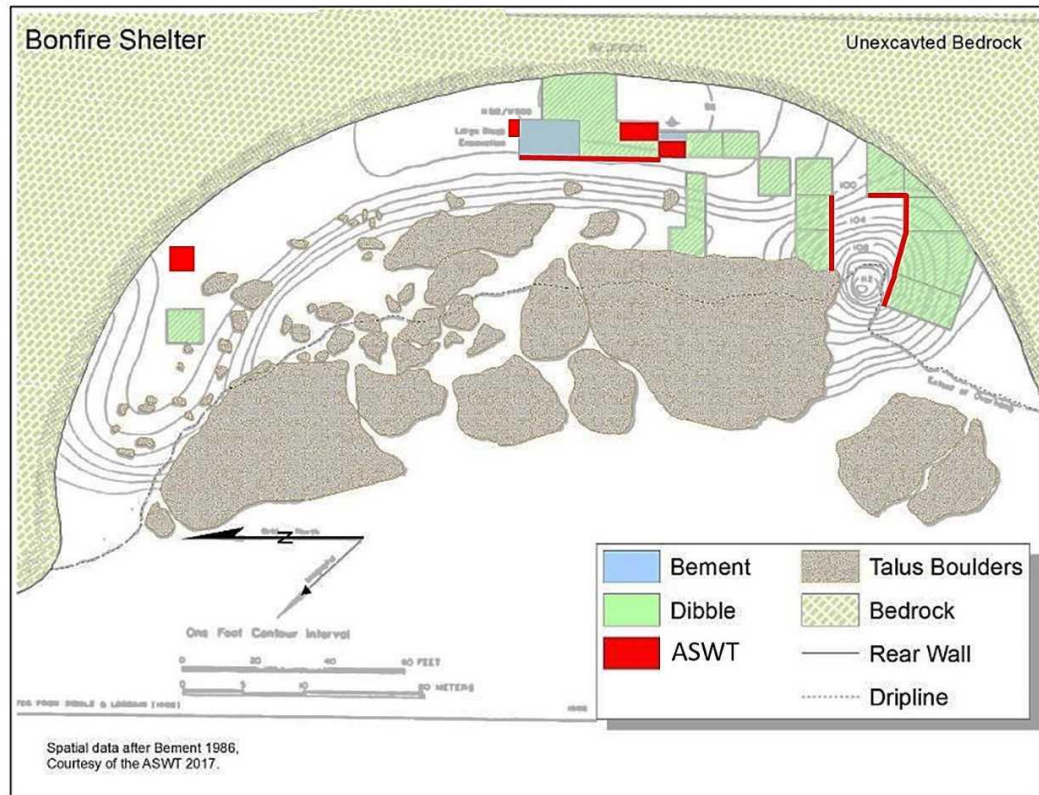
The following description of Bonfire Shelter is based on information found on Texas Beyond History (Black 2001a), personal communications, and the several key sources (Dibble and Lorrain 1968; Byerly et al. 2005; Skiles 1996). Bonfire Shelter is located in Eagle Nest Canyon (also known as Mile Canyon), a short tributary of the Rio Grande River (Figure 1). The shelter is roughly semicircular and occupies a space of ~120 square meters. The rim of the canyon is about 23 meters from the floor of the rockshelter which is about 20 meters above the floor of the canyon. Directly above the southern portion of the rockshelter is a large notch in the rim of the canyon. Below the notch is a large pile of debris and roof spall known as the talus cone. It is within this talus cone that the majority of the faunal remains have been found.

The locations of current and previous excavations are shown in Figure 2. The remains are concentrated within three major bone deposits known as Bone Bed 1, 2, and 3 (numbered from bottom to top). Only Bone Bed 2 and Bone Bed 3 are represented in the talus cone while Bone Bed 1 is only present in the shelter interior (Dibble and Lorrain 1968). The most recent Bone Bed, known as Bone Bed 3, is dated from 2,500 to 2,000 calBP and represents a Late Archaic deposit. It has been argued that this deposit was formed from the remains of a massive bison jump drive due to the amount of individual bison present in the assemblage (~800 individuals). Bone Bed 2 has been dated to 12,025 calBP making it a Paleoindian-age deposit. The third Bone Bed, Bone Bed 1, is dated to 14,600 calBP.

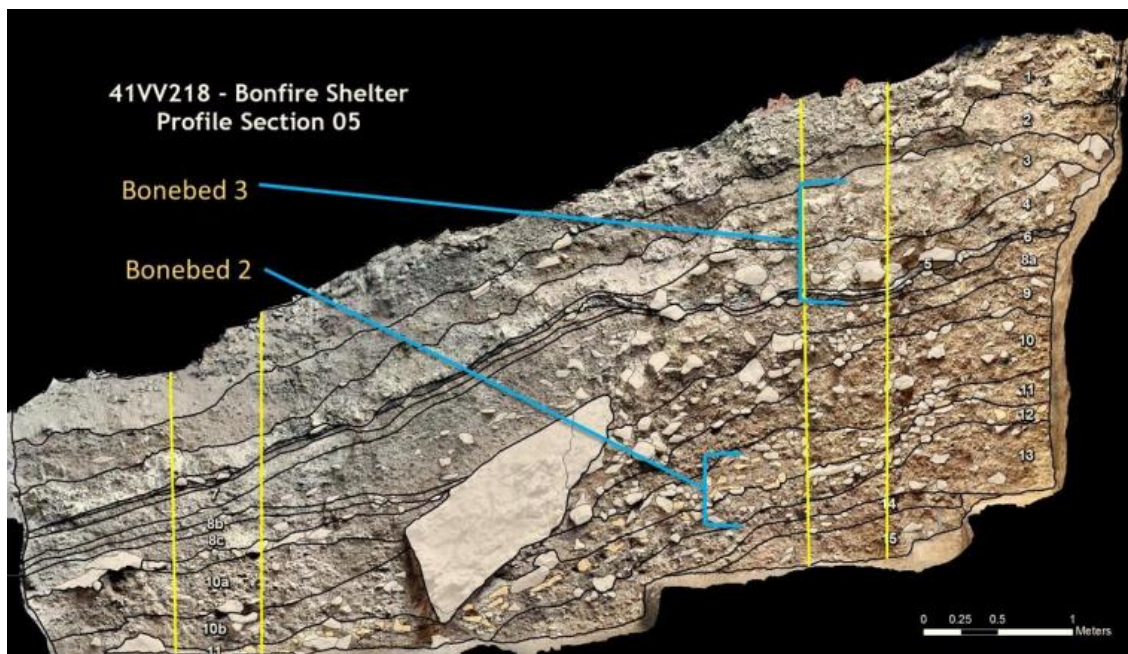


**Figure 1.** Map of Texas showing the location of Bonfire Shelter and details of Eagle Nest Canyon (from Koenig et al. 2017).





**Figure 2.** Site map of Bonfire Shelter showing the location of current and previous excavations (Kilby et al. 2020).



**Figure 3.** Profile Section 05 of Bonfire Shelter. Talus cone profile showing Bone Beds 3 and 2 (Kilby et al. 2020).

## **History of Investigations**

### **Discovery: 1958**

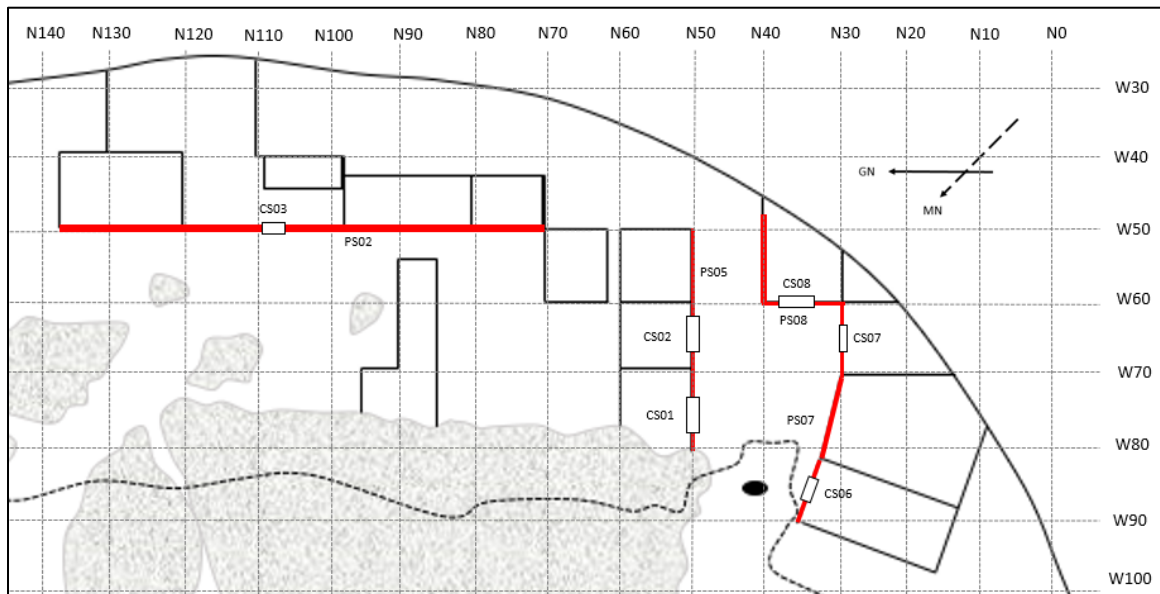
The intimate history of Bonfire Shelter has been documented on the public website Texas Beyond History (Black 2001b) and is summarized here. The scientific significance of Bonfire Shelter first became apparent in 1958 when a high school student named Michael Collins began exploring what was then known as Ice Box Cave with a shovel and a bucket. Not far below the surface, he uncovered large burned bones that seemed similar to cattle bones; however, he deemed this conclusion unlikely as the surrounding lands were not suited to raising cattle and he doubted any rancher would allow that many of his cattle to die in a rockshelter. To further investigate the matter, Collins removed a mandible which he took to a family friend named Glen Evans who worked as a geologist with the Louisiana Land and Exploration Company through Midland, Texas. Evans confirmed that the mandible belonged to a bison and was likely the result of a prehistoric bison kill.

During this time, the Texas Archeological Salvage Project (TASP, a former division of the Texas Archeological Research Laboratory) through the University of Texas at Austin was conducting salvage archaeology in the area prior to the creation of the Amistad International Dam and Reservoir. Jack Skiles, the former owner of the ranch, contacted the University of Texas and invited archaeologists to take a look at Ice Box Cave to ascertain its cultural and archaeological significance. In the fall of 1962, a survey team sent by the University of Texas and led by Mark L. Parsons visited Ice Box Cave. They briefly probed the uppermost layer of bones and recovered a projectile point and reported favorably on its potential as a worthwhile archaeological site. Subsequent visits

by TASP personnel ultimately led to the decision to excavate. This first excavation was led by David S. Dibble and began in the Fall of 1963 and continued to the winter of 1964 (Black 2001b).

### **The University of Texas at Austin: 1963-1964**

Systematic research at Bonfire Shelter began in 1963-1964 with excavations by David Dibble (Dibble and Lorrain 1968) and faunal analysis by Dessamae Lorrain (1968). Dibble created an arbitrary grid system that runs perpendicular to the longest point of the rockshelter (Figure 4). The majority of the excavation units were 10 by 10-foot squares with one, Pit C, being ~3 times larger. They opened nine excavation units around the talus cone and twelve excavation units in the shelter interior. They determined that there were three major bone deposits within the site. The two most recent deposits, Bone Bed 3 and Bone Bed 2, were both concluded to be the result of human activities due to bone alteration and the presence of lithic tools.



**Figure 4.** Map showing the grid system created by Dibble (Dibble and Lorrain 1968) and the location of column samples (abbreviated as CS) and profile sections (abbreviated as PS and colored in red) established by the present investigation. Measurements are in feet.

The latest deposit, Bone Bed 3, was interpreted as a bison jump drive. The skeletal assemblage contains ~800 individual bison and clusters around the talus cone. The skeletal assemblage contains a minimum number of ~200 individual bison; however, Lorrain (1968) arrived at ~800 individuals by observing that only half of the skeletal specimens were identifiable and only about half of the site had been excavated. To account these factors, the minimum number of individual bison calculated based on skeletal elements was multiplied by four to produce a minimum number of ~800 bison. Similarly, although a minimum number of 27 individual bison were identified in the Bone Bed 2 skeletal assemblage, Lorrain multiplied this number by four and reasoned that the site likely contains ~120 individual bison (Dibble and Lorrain 1968).

The causes of the accumulation of Bone Bed 2, however, were not immediately clear. Dibble and Lorrain originally argued that Bone Bed 2 represented at least three bison jump drives. Dibble observed that Bone Bed 2 was composed of two layers of unburnt bone with a layer of burnt bone in between them. They pointed to the concentration around the talus cone, the estimation of 120 individual bison, and the horizontal orientation of the bones as evidence that Bone Bed 2 was the result of a bison jump drive as well. They also discuss the difficulty one would encounter attempting to bring carcasses into the site from the outside as a way of ruling out the possibility that the bison were hunted elsewhere and carried into the site (Dibble and Lorrain 1968). For these and other reasons, Bonfire Shelter became notable for being the oldest and only Paleoindian bison jump drive in the Americas, as well as being the southernmost bison jump drive.

Lorrain's (1968:80) element frequencies are summarized in Table 2 in regard to the number of individual specimens (NISP), the minimum number of elements (MNE), the minimal animal unit (MAU), and the ratio minimal animal unit (%MAU). These terms are further discussed in Chapter V. Lorrain determined a minimum of 27 individual bison were present in the Bone Bed 2 fauna based on the frequency of right femurs. When including elements of unknown side as is common in recent zooarchaeological analyses, the minimum number of individual bison is increased slightly to 28.

**Table 2.** Bison skeletal element abundance collected by Dibble and Lorrain (1968), Bone Bed 2.

Element	NISP	Left	Right	n	MNE	MAU	%MAU
Horn core	9			9	9	4.5	16.4
Mandible	32	19	9	1	29	14.5	52.7
Skull - auditory bulla	3			3	3	-	-
Skull - misc.	6			6	6	-	-
Maxilla		11	4		15	7.5	27.3
Atlas	11			12	12	12	43.6
Axis	11			12	12	12	43.6
Vertebra <sup>a</sup>	90			19	19	0.8	2.9
Vertebra - sacral	13			12	12	2.4	8.7
Vertebra - caudal	22			4	4	0.3	1.2
Sternum	9			5	5	1.3	4.5
Scapula	32	14	13	1	28	14	50.9
Humerus	79	18	23	1	43	21.5	78.2
Radius	67	13	22	2	37	18.5	67.3
Ulna	23	13	11	1	25	12.5	45.5
Metacarpal	26	6	12	2	20	10	36.4
fifth metacarpal	3			3	3	1.5	5.5
Carpal	70			15	15	1.3	4.5
Innominate	39	13	20		23	11.5	41.8
Femur	126	26	27	2	55	27.5	100
Patella	11			7	7	3.5	12.7
Tibia	64	15	17	1	33	16.5	60
Metatarsal	30	6	16	2	24	12	43.6

<sup>a</sup> Includes cervical (CE3-7), thoracic, and lumbar vertebra

**Table 2. Continued.** Bison skeletal element abundance collected by Dibble and Lorrain (1968), Bone Bed 2.

Element	NISP	Left	Right	n	MNE	MAU	%MAU
Metapodial	74			16	16	4	14.5
Astragalus	43	18	26	1	45	22.5	81.8
Calcaneum	29	17	9	1	27	13.5	49.1
Naviculo- cuboid	26	15	10		25	22.5	81.8
Fused cuneiforms	3			3	3	1.5	5.5
Lateral malleolus	8			5	5	2.5	9.1
First phalanx	81			16	16	2	7.3
Second phalanx	76			19	19	2.4	8.6
Third phalanx	40	8	8	2	18	2.3	8.2

During the beginnings of the investigation, excavated specimens were recorded with sketches, photographs, and tallies of elements within several 10-x-10 foot excavation units. This level of detail was determined to be “returning little in archeologically useful information” (Dibble and Lorrain 1965:19) so, in the later portions of the excavation, specimens were excavated and recorded without photographs or sketches. This includes specimens from Pits A, B, C, and Square N20/W60. Similarly, sediments excavated during the later portions of excavation were not screened in order to save time; however, excavated sediments from the earlier portion of the excavation were screened with ½ and ¼ inch mesh screens. Specimens from Bone Bed 2 were described as being generally moist and pulpy. In order to extract the specimens intact, they were allowed to dry for some time upon exposure before being treated liberally with several applications of Alvar dissolved in acetone.

When they arrived in the laboratory for analysis by Lorrain (1968:80-81), specimens from Bone Bed 2 were sorted into right and left sides and proximal and distal

ends. Identification was facilitated with a comparative cow skeleton and drawings of prehistoric bison skeletons by Olsen (1960). The specimens were then cleaned and treated again with an unnamed commercial preservative. Many carpals, tarsals, and phalanges were coated with paraffin wax to prepare them to be submerged in water for measuring volume (Lorrain 1968:78; Byerly et al. 2005:613). All specimens were examined for butchery marks, evidence of unfused or partially fused epiphyses, and marks which might indicate the use of that specimen as a tool. Qualities such as weathering stages, carnivore activity, porosity, or fracture patterns were not recorded.

### **Nunamiut Ethnoarchaeology: 1978**

In the book “Nunamiut Ethnoarchaeology”, Lewis Binford argued that the frequencies of skeletal elements from Bone Bed 2 more closely matched a secondary processing site rather than a kill/primary processing site (Binford 1978a). He determined this by plotting the element frequencies published by Lorrain (1968) against the utility of their corresponding caribou skeletal element in order to determine whether a relationship existed between element frequency and utility. Although he argued the pattern was clear he also notes that caribou and bison likely exhibit different levels of utility for different skeletal elements. It was not until 1993 that Alice Emerson with her dissertation work created utility indices for bison skeletal elements which allowed for a reanalysis of bison skeletal assemblages (Emerson 1993).

### **The University of Texas at Austin: 1983-1984**

In 1983 and 1984, new excavations were carried out at the site by Solveig Turpin and Leland Bement to investigate the earliest deposits, Bone Bed 2 and 1 (Bement 1986). Although their main goal was to compare Bone Bed 2 to Bone Bed 1 in order to detect

patterns of human involvement, they argue that the bison remains they uncovered from Bone Bed 2 are consistent with a processing station near a primary kill. During the course of their excavation and analysis, Turpin and Bement uncovered more faunal material and performed sediment analysis that determined the interior of the site had largely been unaffected by alluvial actions.

The 1983-84 excavations were conducted stratigraphically. Sediment excavated from cultural layers (Bone Bed 3 and 2) and the previously unexplored layer (Bone Bed 1) were screened through ¼ inch mesh hardware cloth then separated by water in order to recover smaller floral and faunal remains. Each skeletal specimen was assigned a field number and photographed. Prior to their removal from the sediment, skeletal specimens were treated with acetone diluted PVA (polyvinylacetate) and jacketed in plaster-impregnated surgical gauze (Bement 1986).

A 4-x-3.4-meter unit was excavated just north of the northernmost units excavated by Dibble in the interior of the rockshelter (Figure 2). A rib and right tibia epiphysis were recovered from the upper most stratum of Bone Bed 2. The majority of the skeletal material was concentrated at the contact between the two lower layers of Bone Bed 2. Bement notes that the larger bone fragments were resting within the lower stratum and extended into the middle stratum while some smaller bone fragments were contained in the upper stratum. Fifty faunal specimens were identified as bison (minimum of three individual bison) and five specimens identified as *Equus sp.* (minimum of one individual equus) from the two deepest layers of Bone Bed 2 (Bement 1986).

Bement also recorded a spoke-like arrangement of long bones around a sizeable limestone cobble (Bement 1986:29) (Figure 5). He argues that this cobble was likely used



for butchering, but not for marrow extraction as only three (not identified) long bones displayed green breaks. Although the primary goal of this investigation was not to determine the origins of Bone Bed 2, Bement supported the conclusion put forward by Dibble and Lorrain that Bone Bed 2 represents a bison jump and argued that the skeletal elements that were excavated represented a processing station for a kill that happened at the talus cone.



**Figure 5.** "Spoke-like arrangement of bones around a limestone anvil or butcher block in Stratum C." (Bement 1986:31, Figure 13). Outline added around the limestone anvil or butcher block.

## **Southern Methodist University/Quest: 2005**

In 2003 and 2005, Bonfire Shelter was investigated by David Meltzer and Ryan Byerly with the explicit intent of testing Binford's hypothesis and reevaluating the origins of Bone Bed 2 (Byerly et al. 2005; 2007a; Byerly et al. 2007b). To test Binford's hypothesis that the skeletal component of Bone Bed 2 closely matches the skeletal profile of a secondary butchery site rather than a primary kill site, Byerly et al. conducted a GIS analysis on the upland region of the site and reanalyzed the bones from the original excavation. They did not reanalyze the skeletal elements from the 1983-84 investigation as they argue the exclusion of only fifty-two skeletal specimens would not significantly affect the results.

The results of Byerly's reidentification of the Bone Bed 2 fauna are summarized in Table 3 (Byerly et al. 2005). Rather than divide elements into sides, Byerly divided elements into proximal and distal portions. During the reanalysis of the Bone Bed 2 fauna, Byerly noted the specimens from Bone Bed 2 were in much poorer condition than originally described by Lorrain, though he notes that this is almost certainly due to the manner in which they were curated. This deterioration of the specimens resulted in Byerly recording much higher NISP and lower MNE values than Lorrain. Byerly reexamined all the specimens recovered from Bone Bed 2 and reidentified their element and element portion (left or right, proximal or distal). He also recorded weathering stages, evidence of butchery, evidence of carnivore activity, and fracture type (green or impact) for all specimens. Although Byerly's MNE counts for Bone Bed 2 were very similar to Lorrain's, there are some important differences. Primarily, Byerly records lower MNE values for all elements except sacra and patella. He also recorded significantly more

vertebra than Lorrain and was able to identify them to their body portion (cervical, thoracic, lumbar, or caudal).

**Table 3.** Bison skeletal element abundance reanalyzed by Byerly (Byerly et al. 2005), Bone Bed 2.

Element	NISP	Proximal	Distal	MNE	MAU	%MAU
cranium	102			5	5	30.3
mandible	122			26	14	78.8
hyoid	6			4	2	12.1
atlas	19			10	10	60.6
axis	24			10	10	60.6
cervical	117			37	8	44.8
thoracic	187			65	5	28.1
rib	117			43	2	9.3
costal cartilage	15			-	-	-
sternum	17			-	-	-
lumbar	103			42	9	50.9
sacrum	32			13	13	78.8
caudal	27			25	2	8.4
scapula	77			13	8	39.4
humerus	124	8	19	30	16	90.9
radius	107	26	22	26	16	78.8
ulna	42			18	11	54.5
carpal (all)	94			-	-	-
ulnar carpal	17			17	9	51.5
intermediate carpal	15			13	8	39.4
radial carpal	17			14	11	42.4
2nd and 3rd carpal	20			16	11	48.5
4th carpal	17			13	6	39.4
accessory carpal	8			8	4	24.2
metacarpal	30	18	13	18	12	54.5
5th metacarpal	2			2	1	6.1
innominate	74			16	11	48.5
Femur	180	33	33	33	17	100
patella	16			15	9	45.5
tibia	119	11	26	26	15	78.8
lateral malleolus	10			10	9	30.3
astragalus	51			33	24	100
Calcaneus	46			19	10	57.6

**Table 3. Continued.** Bison skeletal element abundance reanalyzed by Byerly (Byerly et al. 2005), Bone Bed 2

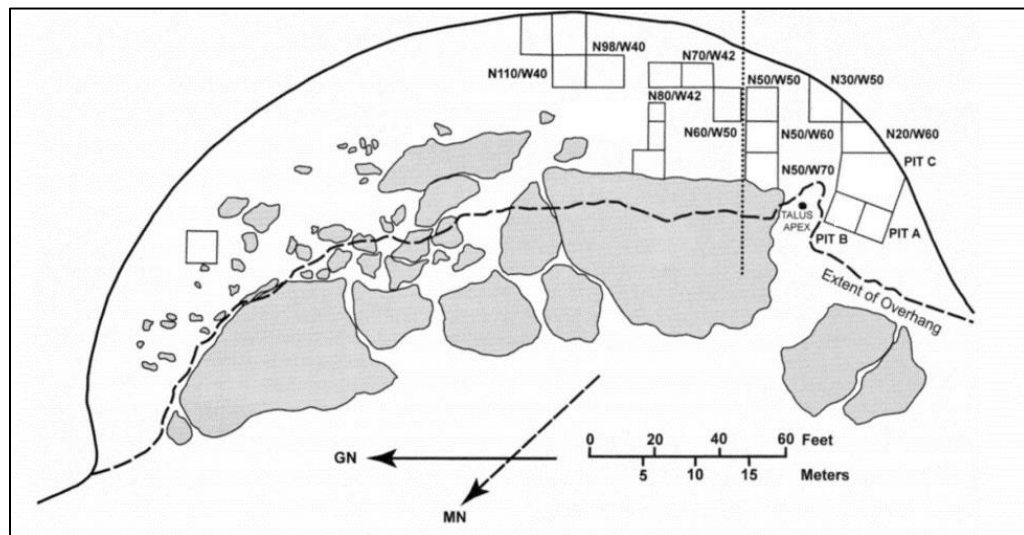
Element	NISP	Proximal	Distal	MNE	MAU	%MAU
central and 4th tarsal	34			18	11	54.5
2nd and 3rd tarsal	5			5	5	15.2
1st Tarsal	2			2	1	6.1
metatarsal	36	13	14	14	8	42.4
metapodial	60			-	-	-
1st phalanx	104			68	10	54.5
2nd phalanx	80			72	9	23.5
3rd phalanx	47			31	5	3.8
sesamoid (all)	30			-	-	-
proximal sesamoid	23			23	2	2.7
distal sesamoid	7			7	1	0.8
dew claw	1			1	1	-

Byerly et al. (2005) also argue that the Bone Bed 2 assemblage represents a single cultural event. This interpretation was based almost exclusively on the skeletal assemblage and does not take into account potential differences in the nature of the sediment between the sub-strata of Bone Bed 2. Their argument is based primarily on Dibble's observation that, aside from the burning of the bone the sub-strata of Bone Bed 2 "were sandwiched together to form essentially a single stratum" (Dibble and Lorrain 1965:29). Byerly also looked at molar wear from the Bone Bed 2 fauna and determined that the assemblage represents a single age cohort. He does note that a single age cohort can also represent multiple kills that took place at the same seasons over several years, but ultimately argues that a single age cohort is more consistent with a single kill.

#### **Texas State University/ASWT: 2017-Present**

Most recently, investigations have been carried out at Bonfire Shelter by David Kilby and Marcus Hamilton through the Ancient Southwest Texas Project (ASWT) at Texas State University with the intent of establishing a detailed chronostratigraphic

sequence for the site deposits, determining the origin and number of events associated with Bone Bed 2, specifically regarding it being a result of one or more drives or jumps from the rim above, determining the origins of Bone Bed 1, and preserving the site by stabilizing the surface and exposed deposits (Kilby et al. 2020). To this end, erosional material and debris was excavated from the interior of the shelter and backfill was removed from the 1964 excavation units exposing the north, east, and south side of the talus cone. In 2018, Dr. Kilby reprofiled the excavation units Pits A, B, C, and Squares N20/W60, N30/W50, N50/W50, N50/W60, and N50/W70 around the talus cone and Units B, C, D, and Squares N120/W50, N110/W40, N110/W30, N80/W42, and N70/W42 in the shelter interior (Figure 6). During the 2018 investigations, Square N20/W50 was excavated until the upper stratum of Bone Bed 2 was exposed.



**Figure 6.** Plan map of Bonfire Shelter showing units excavated into Bone Bed 2 (Byerly et al. 2005:Figure 2).

Bonfire Shelter is an incredibly valuable cultural resource that contains a wealth of data regarding some of North America's earliest inhabitants. Unfortunately, due to the size of the unit profiles and the long period of time which they have been exposed, the

site, and particularly the talus cone, is relatively unstable. To prevent disturbing or displacing the talus cone, Bone Bed 2 was investigated in a ‘high resolution, low impact’ method with only minimal excavation carried out in peripheral portions of the site (Koenig et al. 2017).

### **Interpretations**

The major published interpretations of Bone Bed 2 have been summarized in Table 4. Dibble and Lorrain originally argued Bone Bed 2 represented a series of jump drives based on the number of individual bison, the observed stratification in certain excavation units, and the fact that the majority of the assemblage is clustered in the talus cone under the notch in the canyon rim. This was first publicly refuted by Binford who argued the element profile was more consistent with a secondary processing site than a kill site. Although Turpin and Bement’s (1968) intent was not to determine the origins of Bone Bed 2, they argued in favor of Dibble and Lorrain’s original interpretation. Binford’s hypothesis was tested by Byerly et al. (2005) by reidentifying the curated skeletal assemblage and comparing the assemblage to measures of bison skeletal utility produced by Emerson (1993). In addition to element utility, Byerly et al. also looked at the frequency of green breaks, impact fractures, and cutmarks and compared them to other Folsom aged bison kill and butchery sites. Byerly et al. (2005; 2007a; Byerly et al. 2007b) ultimately argue in support of Binford’s hypothesis that Bone Bed 2 represents a secondary butchering site.

**Table 4.** Previous investigations and their interpretations of Bone Bed 2.

Investigation	Primary Investigator(s)	Year(s)	Interpretation of Bone Bed 2
University of Texas at Austin	David Dibble Dessamae Lorrain	1963- 1964	Jump drive
"Nunamiut Ethnoarchaeology"	Lewis Binford	1978	Secondary Butchering
University of Texas at Austin	Solveig Turpin Leland Bement	1983- 1984	Jump drive
Southern Methodist University/ QUEST	David Meltzer Ryan Byerly	2005	Secondary Butchering
Texas State University/ASWT	David Kilby	2017- Present	(Ongoing)

Bement quickly published a review of Byerly et al.'s (2005) work, critiquing Byerly's methods and arguing that they are conservative to the point of ignoring natural error in zooarchaeological estimation (Bement 2007). Bement claimed that Byerly et al. downplayed the minimum number of individual bison and only compared the skeletal element frequencies to specific sites that he knew would produce a certain result. Bement also argued that Byerly et al.'s interpretation was based on too few data and is overly reliant on element frequencies. He claimed that Dibble and Lorrain's (1968) interpretation was more holistic and, in addition to skeletal element frequencies, was based on the location of the elements within the site and the assertion that the assemblage represents three depositional events.

In turn, Byerly et al. published their own reply (Byerly et al. 2007a) supporting their own methods and interpretations. Byerly et al. argued that comparative sites were picked based on similarity between regional and functional contexts and not to

presuppose an outcome. In addition, they published their MNI as being smaller than Dibble and Lorrain's MNI because Bement assumed that the density of bison bones would be consistent throughout the site, as per the report by Dibble and Lorrain (Dibble and Lorrain 1968:84). Byerly et al. argue this would only be true if the Bone Bed 2 deposit represents a jump drive and, since this has not been proven, it cannot be used to estimate the MNI. With regard to their assertion that Bone Bed 2 represents a single event, Byerly et al. restate Dibble's observation that the separation of Bone Bed 2 into three distinct sub-strata is only based on a layer of burnt bone and is only observable on the southern side of the talus cone (Dibble and Lorrain 1968:29-30).

An additional article was published by Elton Prewitt (2007), a crew member of the 1963-64 investigations, in which he articulated a very similar argument as Bement. He reiterates the view that killing and processing are activities that do not necessarily need to take place at separate locations and are often carried out within the same site. He also asserts that this is Dibble and Lorrain's original hypothesis, not that Bone Bed 2 represents a kill site, but rather it represents the processed kill site. Byerly et al. did not publish a response to Prewitt's article.

### **Implications of Bone Bed 2 as a Bison Jump**

Large scale bison hunts are defined as hunts which involve killing between 50 and 100 animals (Frison 1991). Hunting such a large number of animals would require certain social and natural attributes in order to be performed successfully (Carlson and Bement 2013; Brink 2008; Frison and Reher 1970; Frison 1991; 2004; Zedeño et al. 2014). Large scale hunts are thought to typically require more than one band of hunter gatherers. Due to the number of people required, large scale hunts are often associated with seasonal



aggregations or other forms of cyclical nucleation. Aggregation also suggests the emergence of social hierarchies (Carlson and Bement 2013a). Furthermore, evidence from later jumps and historic accounts indicate that jumps typically involved extensive infrastructure such as drive lanes, cairns, walls, as well as the use of decoys and fire to further influence the direction of herd movement (Verbicky-Todd 1984; Barsh and Marlor 2003). Although these specific features have not been identified around Bonfire Shelter, the use of a jump drive would have required a fair amount of additional labor, coordination, and social organization than could be provided by a single, normal-sized band.

Although there are no other confirmed Folsom or Plainview bison jumps, the technique is similar to other landform assisted hunting techniques associated with other Paleoindian kills. Driving a herd off a cliff is potentially a logical extension of utilizing topographical features such as arroyo traps, dunes, and slopes (Bement and Carter 2016; Frison 1982; Meltzer 2006; Kerr and Dial 1998). Although jump drives are often seen as fundamentally different from a more traditional landform assisted kill, jump drives require similar amounts of cooperation and utilize similar principles to manipulate herd behavior. In fact, the uplands immediately surrounding the notch above Bonfire Shelter can be seen as an arroyo trap that ends in a drop rather than a headcut (Kilby et al. 2020). Many canyons in the Lower Pecos share similar morphological traits that would have made them suitable for a jump drive as well. This suggests that jump drives may have been much more prevalent in the Lower Pecos and Bonfire Shelter is simply the only documented site where evidence of this behavior has been preserved.

## **Lithic Material**

The lithic assemblage of Bone Bed 2 is composed of six mostly complete points (five Plainview and one Folsom), six fragmentary points (one identified by Cooper and Byerly (2005) as Folsom), two “crude” bifaces (Dibble and Lorrain 1968), one tip fragment of a biface, five flake scrapers, and three worked flakes. None have questioned the typological classification of the Folsom points; however, the Plainview points are more difficult to classify and have at times also been argued to be Midland, Milnesand, Lubbock, or Folsom points (Byerly et al. 2007b:139).

Seventeen unworked flakes were also recovered and were argued by Dibble to represent debitage from tool resharpening (Dibble and Lorrain 1968:37). Dibble remarks that this small total of resharpening flakes is surprising given the large amount of processing they believed was conducted at the site (Dibble and Lorrain 1965:40). Others have noted that this is not surprising at all and indicates that the majority of primary processing simply occurred outside of the rockshelter and on the floor of the canyon (Black 2001a). A second interpretation is that only minimal processing occurred within the shelter such as would be necessary to disarticulate the carcasses but not totally deflesh the bones. Five unworked flakes were recovered from backfill piles during the 2005 Southern Methodist University/QUEST investigation; however, the original provenience of these flakes was impossible to determine (Byerly et al. 2007b:129).

**Table 5.** Lithics recovered from Bone Bed 2, Bonfire Shelter (Dibble and Lorrain 1968; Cooper and Byerly 2005).

Classification	Type	Excavation Unit	Component (Dibble)	Stratum (ASWT)
Point	Plainview	N50/W70		
Point	Plainview	N50/W60		
Point	Plainview	Pit C		
Point	Plainview	N20/W60	C	(11)
Point	Plainview	CS02		11a
Point	Folsom	Pit A	A	(14)
Fragmentary Point		Pit B		
Fragmentary Point		Pit C	A	(14)
Fragmentary Point		Pit C		
Fragmentary Point		N50/W70		
Fragmentary Point		Pit C		
Fragmentary Point	Folsom	Backfill		
Biface		Pit C		
Biface		Pit C		
Fragmentary Biface		CS01		11
Flake Scraper		Pit C		
Flake Scraper		Pit B		
Flake Scraper		Pit B		
Flake Scraper		N50/W70		
Flake Scraper		Pit C		
Worked Flake		N30/W50		
Worked Flake		Pit C		
Worked Flake		Pit C		

### Stratigraphy

For the 1963-64 excavations, Dibble identified the three strata of Bone Bed 2 as Components A, B, and C with Component A being the deepest (Dibble and Lorrain 1968:29-30). During the 1983-84 excavations, Bement identified the three strata of Bone Bed 2 within the interior of Bonfire Shelter as strata A, B, and C with stratum A at the top (Bement 1986:6). In order to facilitate a detailed and unbiased understanding of the chronostratigraphic sequence of the Bonfire Shelter deposits and also to avoid confusion

between competing strata classifications, the Texas State University/ASWT investigation of Bonfire Shelter reanalyzed and renumbered the stratigraphy within Bonfire Shelter. Twenty-three discrete strata were identified in the exposed profiles (Kilby et al. 2020) with increasing value corresponding to increasing depth.

Within the talus cone, Bone Bed 2 is composed of up to four distinguishable strata designated strata 11, 12, 13, and 14 with increasing value corresponding to increasing depth. Stratum 11 is a massive colluvial deposit with abundant angular to subangular gravels and cobbles within a friable brown sandy loam matrix. This stratum is differentiated from the overlying stratum by the presence of bone and increased rock. It is up to 40 cm thick on the north side of the talus cone (Profile Section 5) and 20-30 cm thick on the south side of the talus cone (Profile Section 7). Bison bone is concentrated in the lower portion of this stratum.

Stratum 12 is a massive colluvial deposit with abundant rounded to angular gravels and cobbles within a friable gray silty matrix that is potentially ash. Stratum 12 contains the highest prevalence of burned bone and flecks of charcoal. Bison bone is concentrated in the upper portion of this stratum but only displays significant burning on the south side of the talus cone (Profile Section 7). The stratum is also jumbled on the south side of the talus cone. It is generally 15-20 cm thick but is not present on the east side of the talus cone (Profile Section 8).

Stratum 12b is a 5-10 cm thick discontinuous layer of heavily burned and calcine bone, along with burned rock and oxidized sediment. The matrix is a firm to friable ashy silt loam. This stratum is only present on the south side of the talus cone (Profile Section 7) where it likely represents a downslope facies of stratum 12 corresponding to higher

amounts of heat during the burning event. Portions of this stratum east of Column Sample 07 exhibit oxidation and blue-green reduction lenses.

Stratum 13 is a colluvial deposit composed of jumbled rocks in friable to firm grayish brown sandy silt matrix. It is massive in the north side of the talus cone (Profile Section 5) but thins to only 5-10 cm thick in the south side of the talus cone (Profile Section 7) and is totally absent in the east side of the talus cone (Profile Section 8). It is differentiated from stratum 12 mainly due to change in color and the absence of bison bones. Stratum 13 appears to represent a deposition of colluvium from the notch localized to the upslope portion of the talus cone.

Stratum 14 is a massive colluvial deposit composed of firm reddened sandy loam matrix and subangular gravels and cobbles. It has an increased clay content relative to the other strata of Bone Bed 2, possibly representing an increase in sediment being deposited from outside the shelter. Bison bone is only present in this stratum in the south (Profile Section 7) and east (Profile Section 8) sides of the talus cone. The bone is only occasionally burned.

Stratum 14b is a thick, variable layer of pebbles, cobbles, and dense bison bone. It is only present in the east side of the talus cone (Profile Section 8) It is thinner and contains a higher frequency of pebbles towards the southern portion of the profile and thickens towards the north. This stratum likely represents the downhill facies of stratum 14.

Stratum 15, the stratum onto which Bone Bed 2 (or the earliest event of Bone Bed 2) was originally deposited, is a massive colluvium with small rocks in a friable to firm

grayish brown sandy silt matrix. This stratum is similar to stratum 13 but contains finer gravels and less matrix.

In the interior of the rockshelter, Bone Bed 2 is composed of three distinguishable strata designated Strata 19, 20, and 21 with increasing value corresponding to increasing depth. Stratum 19 is a brown loam, Strata 20 is a pale clay silt, and Stratum 21 is composed of roof spalls in a gray silt matrix.

#### IV. RESEARCH QUESTIONS AND EXPECTATIONS

The purpose of this study is to utilize zooarchaeological methods to investigate three important issues regarding Bone Bed 2: (1) is Bone Bed 2 the result of more than one depositional event, (2) does Bone Bed 2 represent one or more jump drives, and (3) does Bone Bed 2 contain evidence representing butchering and processing, either instead of, or in addition to, primary kill deposits.

##### **Number of Events?**

In order to determine whether Bone Bed 2 represents more than one depositional event, the age profile and surface modification of the skeletal elements is examined (Table 6). Analyzing the age of skeletal elements helps determine if the skeletal assemblage represent a single age cohort with all ages being equally distant in time from the birthing season, or if there are multiple age profiles. If there are several age profiles, this would support the hypothesis that the deposit was created through several events occurring at several different times of the year. Other factors such as subaerial weathering and burning are also considered. If each stratum resulted from a cultural event, we would expect each stratum to display relatively consistent rates of weathering relative to the unit in which it is found. If each stratum resulted from a non-cultural redeposition of preexisting deposits, we would expect a higher degree of weathering relative to surrounding *in situ* cultural deposits resulting in inconsistent frequencies of weathered bones within individual units. Any data, however, must be examined dynamically and with relation to other non-faunal cultural context as certain cultural activities such as bone grease processing can result in mixed degrees of bone weathering within an individual unit (Jacobson in press; Jacobson et al. 2019). Differences in soil acidity, sun

exposure, and other natural processes could affect rates of bone weathering as well (Stiner et al. 1995; 2001; Stiner 2010).

If the layer of burned bone is present across the entire site, this would require multiple depositional events in order to deposit a layer of burnt bone above a layer of unburnt bone followed by a layer of unburnt bone.

**Table 6.** Expectations for whether Bone Bed 2 represents a single cultural event with several redepositional episodes or multiple cultural events.

Feature	Single	Multiple
Age Profile	One	One or more
Stratigraphic Separation	Localized	Across entire site
Burning	Localized	N/A
Orientation	Orientations that parallel the orientation of the talus cone in areas where multiple layers are visible (N20/W60, Pit C)	Random
Stratigraphic Boundaries	High frequency of bones that cross stratigraphic boundaries	Low frequency to no bones that cross stratigraphic boundaries

### **Kill/Primary Processing or Secondary Processing?**

To determine whether Bone Bed 2 contains evidence of secondary butchering and processing instead of solely kill/primary processing, the element frequency, the distribution of elements across the site, and evidence of cultural modification was examined (Table 7). Analyzing the distribution of elements across the site can show whether certain elements were being clustered in certain areas and whether these areas represent processing loci. The frequency and location of butchery marks indicate how and to what degree the carcasses were being processed. Additional cultural modification



such as impact and spiral fractures can give us information on possible marrow extraction. If Bone Bed 2 represents a kill/primary processing locale, we would expect the utility profile of the site to exhibit a high frequency of high utility elements where meat could easily be stripped for easier and lighter transport (such as long bones) and a low frequency of high utility elements that are difficult to process and strip of meat (such as ribs, vertebrae, and high marrow yielding bones) and would require more labor intensive processing. We would also expect a high frequency of low utility elements as they would be removed and left at the kill site for lighter transport. This pattern of abundance would produce a slight overall inverse correlation between utility and abundance. If Bone Bed 2 represents a secondary processing site only, we would expect a high frequency of high utility elements which were brought to the site for more intensive processing and a very low frequency of low utility elements which would have been left at the kill/primary processing site. This pattern of abundance would produce a positive correlation between utility and abundance. The inclusion of marrow as a factor influencing transport decisions requires an understanding of the season of the kill as bison catabolize marrow seasonally during times of nutritional stress typically in late winter (Brink 1997).

**Table 7.** Expectations for whether Bone Bed 2 represents a kill, secondary processing site, or a kill/primary processing site.

Feature	Kill/Primary Processing	Secondary Processing
Impact Fractures	Low relative to green breaks	High or equal to green breaks
High Utility Elements	High frequency of easy to process elements; Low frequency of difficult to process elements	High frequency
High Utility Element Distribution	Clustered	Clustered
Low Utility Elements	High frequency	Low to none
Low Utility Element Distribution	Periphery	Random
Correlation between Utility and Abundance	Slight Inverse	Positive

### **Does Bone Bed 2 Represent a Jump Drive?**

In order to determine whether Bone Bed 2 represents a jump drive as opposed to another method of kill, surface modification such as butcher marks and fractures and the morphology of the canyon relative to other arroyo traps will be examined (Table 8). The skeletal element abundance will allow us to see what elements are retained in the site and with what frequency. This will then be compared to experimental indices of utility to see whether a relationship exists between element abundance the relative usefulness of the elements. If Bone Bed 2 represents a jump drive, Bone Bed 2 would represent the remains of both the kill event and the subsequent primary processing activities and therefore would be expected to display the characteristics of a kill/primary processing locale. Additionally, if Bone Bed 2 represents a jump drive then we would expect there to

be evidence of fall trauma such as a relatively high frequency of greenstick fractures on the skeletal elements. Frison (1987:196) suggests that successful bison jump drives would have required a minimum of 50 to 100 individuals.

**Table 8.** Expectations for whether Bone Bed 2 represents a jump drive or an alternative kill method.

Feature	Jump Drive	Other Method
Green Breaks	High	Equal to Impact Fractures
Impact Fractures	Low	Equal to Green Breaks
Utility Profile	Kill/Primary Processing	Secondary Processing
Canyon	Deeper than other arroyo traps	Consistent with other arroyo traps
MNI	50-100	<50

## V. ZOOARCHAEOLOGICAL METHODS

In order to answer the research questions outlined in this thesis, new zooarchaeological data were collected from Bonfire Shelter and used in combination with previously published data. Element identification and modification such as butchering, burning, weathering, orientation and inclination, and breakage were documented for all specimens recorded during the present investigation. The Bone Bed 2 faunal assemblage from Bonfire Shelter is highly fragmentary. Since specimens were identified in the unit profiles and left *in situ*, complete specimens were often impossible to discern.

This thesis follows Lyman's (1994:100) classification where a "specimen" is defined as "an archaeologically discrete phenomenological unit, such as a complete humerus, a distal half of a tibia, or a mandible with teeth in it," while an "element" is defined as "a discrete, natural anatomical unit of a skeleton, such as a humerus, a tibia, or a tooth." In other words, a specimen represents a faunal artifact that can be assigned to an element.

Faunal specimens were recorded *in situ* in the profile walls from the previous excavations, from column sediment samples, and from excavations carried out in the periphery of the site near the base of the talus cone. The profiles were "cleaned" in order to expose the specimens which were then further cleaned to expose as much surface area of the specimen as possible without removing it from the profile.

### **Specimen Identification**

The faunal remains from Bone Bed 2 were identified in the field using comparative bison skeletons provided by the Texas State University Department of Anthropology in addition to osteological identification guides by Todd ("Bison

Osteological Identification Guide") and Balkwill and Cumbaa (1992). No faunal remains distinguishable as non-bison were identified in the unit profiles during this investigation. Following the system introduced by Gifford and Crader (1977) and enhanced by Todd (1987), Faunal remains were coded based on element, side, and portion (proximal, central, or distal with corresponding skeletal landmarks). When the element was unidentifiable, characteristics such as visible modification, burning, weathering, and provenience were recorded.

### **Bone Modification**

In addition to element, side, and portion, additional observations were documented, such as burning, subaerial weathering, orientation and inclination, and fracture type. Butchery marks and carnivore modification were not able to be identified in the field due to the inability to fully expose the surface of the specimens. However, the findings regarding butchery marks and carnivore modification from the previous investigations of Bone Bed 2 are discussed and incorporated into the analysis of the assemblage.

### **Burning**

Bonfire Shelter is notable for having a thick upper bonebed, Bone Bed 3, that is almost completely calcined. Though not as extensive or intense, the fauna of Bone Bed 2 displays a significant amount of burning as well. Although there are natural phenomena that can cause large scale burning of animal carcasses, the pattern and nature of burning can also potentially reveal human activities, such as cooking, ritual activity, or intentional site burning. For every specimen, the color and level of burning was recorded (Table 9).

**Table 9.** Level of burning and description (Lyman 1994b).

Level of Burning	Description
Unburnt	Brown or reddish brown
Partly Carbonized	Brown or reddish brown with portions of the surface blackened
Carbonized	Totally blackened
Partly Calcined	Totally blackened with portioned of the surface whitening
Calcined	Totally white and chalky

### **Subaerial weathering and Root Etching**

In order to better understand the depositional history of Bone Bed 2, both archaeologically and geologically, the weathering stage (Behrensmeyer 1978; E. Johnson 1985) was recorded for all specimens that retained any amount of cortical bone. Subaerial weathering is defined as the process by which the collagen and hydroxyapatite components of bones are separated from each other and destroyed by physical and chemical agents operating on the bone either on the surface or within the soil zone (Behrensmeyer 1978:153). Weathering most noticeably affects the surface condition of the bone, however, it does play a role in decreasing the tensile strength of bone and leads to splintering. Behrensmeyer (1978) identified five weathering stages representing specific periods of time in which the bone had been exposed (Table 10). These stages begin with the bone drying out leading to exfoliation of the outer surface and parallel cracking. As time progresses, the splinters fully separate from one another and develop rounded edges and rough surfaces.

**Table 10.** Bone weathering stages and descriptions (from Behrensmeyer 1978).

Weathering Stage	Description
0	Greasy; no cracking or flaking
1	Longitudinal cracking on diaphyses; mosaic cracking of articular surfaces
2	Flaking of outer surface (exfoliation); cracks are present; crack edges are angular
3	Compact bone has a fibrous texture; crack edges are rounded
4	Coarsely fibrous and rough surfaces; splinters of bone are loose on the surface; weathering penetrates inner cavities and open cracks
5	Bone falling apart <i>in situ</i> ; large splinters present; bone material very fragile

### **Orientation and inclination**

A recurring issue regarding the taphonomy of Bone Bed 2 concerns to what degree its deposition was affected by water and how the actions of water may have affected or produced the stratigraphy of Bone Bed 2 (Dibble and Lorrain 1968:27; Byerly et al. 2005:613; Bement 2007:370-371; Prewitt 2007:157). Although there are geoarchaeological methods for determining this, Byerly et al. (2005:613-614) suggested that future investigations should record the orientation and inclination of specimens from intact deposits to better understand the dynamics of water flow and detritus distribution throughout the site. If the three strata of Bone Bed 2 visible in Pit C and Square N20/W60 were caused by colluvial processes, the orientation and inclination of the skeletal elements is expected to parallel the orientation and inclination of the talus slope on which

those skeletal elements were deposited. To this end, orientation and inclination were measured for all specimens large enough to determine their shape.

### **Bone Breakage**

For any given faunal assemblage there are many potential sources for fragmentation including carnivore activity, human modification, trampling, sediment overburden, weathering, and human modification as well as perimortem fracturing (Lyman 1994a; Frison and Todd 1986; Haynes 1988). These different fracture agents often fragment the bones in unique ways. Thus, identifying patterns of fragmentation can help reconstruct the various taphonomic processes occurring at the site and the degree to which they affected the faunal assemblage.

The fracture categories and diagnostic features utilized in the current investigation are summarized in Table 11. In order to allow the current investigation to incorporate data from the previous investigations, breakage was documented using the same categories as Byerly et al. (2005): green breaks and impact fractures. Dry breaks were also recorded during the current investigation. Byerly et al. documented the presence of “green/fresh” breaks but did not explicitly define what constitutes a green or fresh break. They did, however, compare the green breakage data from Bone Bed 2 with green breakage data collected by Hill (2001) suggesting that they utilized the same criteria. Hill (2001:24-25) defined green breaks as exhibiting a fracture outline that is spiral or oblique relative to the long axis of the bone. He differentiated green breaks from impact fractures (such as hammerstone impacts or other forms of percussion) which he defined based on the presence of notches, inner-conchoidal flake scars, impact flakes, crescent shaped microcracks, crushing, percussion striae, or percussion pits. Since the specimens



identified during the present investigation were not removed from the profile, diagnostic features associated with impact fractures and anvil marks were not able to be identified. Following Hill (2001:25) dry breaks were identified based on the presence of a transverse or longitudinal fracture outline with a discolored fracture edge.

**Table 11.** Diagnostic features of fracture types (Hill 2001:24-25; Byerly et al. 2005).

Fracture Type	Diagnostic Features	Association
Green Break	Spiral or oblique fracture outline relative to the long axis of the bone	Fall; Marrow Processing; Carnivore Activity
Impact Fracture	Notches, inner-conchoidal flake scars, impact flakes, crescent shaped microcracks, crushing, percussion striae, or percussion pits	Marrow Processing, Roofspall
Dry Break	Transverse or longitudinal fracture outline; discolored fracture edge	Trampling; Sediment Overburden

### **Carnivore Activity**

Carnivores activity tends to focus on and significantly modify the diaphysis and epiphysis of long bones. The removal and chewing of the diaphysis cause them to fracture into long straight splinters that generally follow the longitudinal access of the bone (Johnson 1985:192). Additionally, gnawing creates marks such as furrows and punctures, or scoring and pitting, observed on the diaphysis. The types of fractures on the diaphysis generated by carnivore activity is highly dependent on the microstructural and macrostructural features of the bone in question and whether or not it was fresh or dry at the time of modification.

### **Marrow Processing**

Humans primarily fracture bones in order to gain access to the marrow and to produce bone tools. These activities virtually always involve dynamic loading through

direct percussion. Direct percussion often results in “point loading” (Johnson 1985:192), percussion pits (Blumenschine and Selvaggio 1988; 1991), and flake scars (Lyman 1987). The impact or loading point is a circular depressed area marked by incipient ring cracks or crushed bone. The static loading of the break causes spiral fractures to be the most common type of break caused by human activity. However, the presence of other diagnostic features, such as point loading and impact fractures, is crucial in connecting a break to an intentional activity (Agenbroad 1989; Fisher 1995; Haynes 1983; A. Hill 1989). Additionally, roof spalls, which are common in the strata of Bone Bed 2 (Dibble and Lorrain 1968:30), could produce green breaks on fresh bone.

### **Trampling**

Trampling is a common occurrence experienced by skeletal remains in an archaeological context, either through exposure to animals or by being left in living floors, and often destroys the features necessary to identify skeletal elements (S. L. Olsen and Shipman 1988). Green bones are often too flexible to break easily, thus trampling observed in the archaeological record often occurs after some degree of weathering has taken place (Lyman 1994c). Although human trampling may have played a part in the taphonomy of Bone Bed 2, limestone roof-spalls from the roof of the rockshelter could produce the same result. There is no consistent patterning of fractures created through trampling due to the fact that breakage from trampling tends to occur in the weakest parts of the bone (Olsen and Shipman 1988:537).

### **Sediment Overburden**

As skeletal specimens remain longer in an archaeological context, they often become more and more deeply buried by sediments. As sediment deposits increase, the

weight bearing on these skeletal remains increases and can lead to *in situ* fracturing. Often, the only means of determining bones fragmented through sediment overburden is through the observation of conjoining fragments lying near or in contact with one another (Villa and Mahieu 1991). The provenience of each element was carefully recorded through 3-Dimension plotting with a total data station and photography. Relationship between specimens of like elements was also recorded through careful in-field observation.

Research also indicates that the decreased presence of bone fragments that retain a full circumference may be indicative of post-depositional breakage due to sediment overburden (Villa and Mahieu 1991:41). Lyman and O'Brien (1987) suggest that as bone become more crushed under the weight of sediment they become less identifiable, therefore calculating the ratio between the number of (non-intentional) fragments and the estimated minimum number of individuals may be able to estimate the amount of fragmentation occurring in the assemblage and, therefore, the relative amount of time it has remained buried (Villa and Mahieu 1991; Klein and Cruz-Urbe 1984; Klein 1989; Marean 1991).

### **Falling**

While there can be many different causes for perimortem fracturing, the cause most relevant to the Bone Bed 2 faunal assemblage is falling. Falling as a fracture agent is unique in that it represents a situation in which the fractures occurred at or shortly before death. Perimortem fractures such as these that result from falling are often represented by a high frequency of compressive and greenstick fractures and show no signs of healing (Mays 1998). When an animal falls on impacts the ground with its legs,

fall damage often results in multiple greenstick and spiral fractures of the humerus (Isa et al. 2018).

### **Quantification**

Due to the highly fragmentary nature of the Bone Bed 2 specimens, several quantitative methods were used to reconstruct the nature of the faunal assemblage, including number of identified specimens (NISP), minimum number of elements (MNE), minimum number of animal units (MAU), and minimum number of individuals (MNI).

#### **Number of Identified Specimens (NISP)**

NISP is defined as the total amount of identified skeletal fragments, per species, per element (Lyman 1994c:100). Since only bison bones were identified in Bone Bed 2, NISP is primarily used to determine the degree of fragmentation across elements.

#### **Minimum Number of Elements (MNE)**

MNE is the minimum number of elements represented by its observed specimens (Lyman 1994c:102; Reitz and Wing 2008:215). When applicable, skeletal elements were divided into left, right, proximal, diaphyseal, and distal. The percentage of the whole element contained in the specimen was estimated and all identifiable skeletal landmarks were recorded. To produce the minimum number of elements, the number of whole specimens was added to the number of proximal or distal specimens, whichever was larger. This was done for each side and for specimens of unknown side. The minimum number of specimens for left, right, and unknown sides were then added to produce the minimum number of elements. When specimens were identified that were not “whole” proximal or distal portions, (such as diaphyses and fragments of proximal or distal portions) all identifiable skeletal landmarks were recorded. If the skeletal landmarks

overlapped with landmarks identified from other specimens of the same element, side, and portion, then the specimen was treated as an additional element.

### **Minimum Number of Animal Units (MAU)**

MAU is defined as the minimum number of individual animals required to produce the number of elements observed in an assemblage (Lyman 1994c:105; Binford 1978a:70). This value was produced by dividing the MNE of a specific skeletal element by the amount a single bison possesses of that specific element and then rounding up to a whole number. For example, an MNE of 4 femurs translates to a MAU of 2.

Standardized MAU (%MAU) was produced by dividing each MAU value by the largest MAU value in the assemblage and expressed as a percentage. %MAU is used to approximate what percentage of skeletal elements are present in the assemblage and is primarily used in reconstructing the function of the site.

### **Minimum Number of Individuals (MNI)**

MNI is defined as the minimum number of individuals required to account for all the specimens within a given assemblage (White 1953). It is calculated by finding the largest MAU value for all skeletal elements within an assemblage. This value is used to approximate the number of animals within an assemblage.

### **Intrasite Distribution**

It is possible that Bone Bed 2 represents both a kill and butchering deposit, and that these activities are spatially or temporally discrete. Cluster analysis of element utility distribution across the site was conducted to test for nonrandom spatial distributions and to potentially reveal the function of specific portions of the site. Since previous investigations did not record the provenience of faunal remains beyond unit and bonebed,

attempting to identify a change in the function of the site across several strata utilized a much less robust dataset.

### **Sex and Age Determination**

Estimations of sex and age were recorded in order to reconstruct the composition of the herd from which the faunal assemblage was derived. Since bison herds change in regard to sex and age throughout the year as herds separate and regroup, reconstructing the sex and age structure of the herd can be used to determine the seasonal of mortality.

#### **Sex Determination**

Typically, the sex of bison skeletons is estimated through the size of specific sexually dimorphic bones, such as the skull (Krysiak and Swiezynski 1967; Shackleton, Hills, and Hutton 1975; Skinner and Kaisen 1947; Speth and Parry 1980; Wilson 1974b), long bones (Smiley 1978; Speth 1983; Todd 1986; 1987b; Zeimens 1982), and carpals and tarsals (M. G. Hill 1996; Kooyman and Sandgathe 2001; Morlan 1991; 1992; Zeimens 1982) among others (Duffield 1974). This method of sex estimation was not possible given that the bones were identified *in situ* in the unit profiles making whole elements impossible to reconstruct. In previous excavations, specimens were recovered in good enough condition to estimate sex and produce a potential herd sex composition. Lorrain (1968:51) utilized metapodial osteometric data to reconstruct the sex composition of the Bone Bed 2 fauna while Byerly et al. (2005:610) used radii measurements. These findings are discussed later.

#### **Age Determination**

Age was estimated based on the eruption and wear of mandibular molars and the presence of epiphysial fusions (Duffield 1974). When determining the age of a specimen,

careful attention was also given to identifying and documenting the strata from which it came. This was done in order to determine whether the age composition of the assemblage changes in different strata. For example, if the age profile of the assemblage changes drastically between strata, this would indicate that Bone Bed 2 is composed of multiple kill events that occurred at different times during the year.

### **Utility**

Lewis Binford (1978b) argued that, under certain circumstances, specific human behaviors produce patterns within sites and that these patterns can be statistically quantified. His research showed that, for mass kills, hunter-gatherers tend to conduct primary processing at the kill site where they generally remove the most useful and nutritious portions of the carcass, then take these portions to a secondary location for secondary butchering where the meat will be totally stripped from the carcass and the bones processed. Through his work with the Nunamiut, he demonstrated that the frequency with which specific carcass portions (and their associated bones) are represented at an animal processing site tend to correlate with utility (Binford 1978b). Binford observed that Nunamiut kill-butchery sites displayed a positive correlation between element abundance (as expressed through %MAU) while secondary butchering sites displayed an inverse correlation between element abundance and utility.

The utility of body portions vary between species therefore a detailed description of the utility profile of a faunal assemblage requires utility indices made for individual species. Additionally, there are several resources available for a given carcass portion, thus, utility indices have been created to reflect both gross utility and the utility of specific carcass resources (Binford 1978b; Emerson 1993). Standardized MAUs

(%MAUs) were tested for correlation with several utility indices: The Standardized Modified Average Total Products index [(S)MAVGTP], the Standardized Modified Average Protein index [(S)MAVGPRO], and the Standardized Average Marrow index [(S)AVGMAR]. All descriptions of these utility models below are from Emerson (1993).

It is important to keep in mind that ‘correlation does not equal causation’ and that, in the case of utility indices, correlation does not equal motivation. A correlation between element abundance and a utility model must be interpreted to ensure that a third factor is not influencing both variables.

#### **(S)MAVGTP**

The standardized modified average total products [(S)MAVGTP] utility index takes into account the total utility of a given skeletal element and its surrounding tissue. This includes protein, marrow, intramuscular fat, and bone grease (Emerson 1993).

#### **(S)AVGPRO**

The standardized average protein [(S)AVGPRO] utility index takes into account just the muscle protein that surrounds and is associated with a given skeletal element. This utility index was used to determine whether protein was the primary resource affecting carcass utilization (Emerson 1993).

#### **(S)AVGMAR**

The standardized average marrow [(S)AVGMAR] utility index takes into account just the marrow content of specific marrow producing skeletal elements. This utility index was used to determine whether marrow was the primary resource affecting carcass utilization. It is important to note that, for male bison, marrow production changes throughout the year so the seasonality of the kill must be considered when determining



whether a specific skeletal element would be considered ‘high utility’ with regards to marrow (Emerson 1993).

### **Prior Research**

For the purposes of this thesis, Lorrain’s (1968) element counts were considered sufficiently accurate; however, Lorrain did not differentiate vertebra, tarsals, or carpals into specific element categories. In order to account for this, Byerly’s (2005) element counts were used for vertebra, tarsals, and carpals since he identified them to specific elements. Bement’s (1986) element frequencies and the element frequencies from the current investigation were then added to this updated dataset and converted into MAU and %MAU values. When determining the distribution and condition of elements between individual strata, MNE, MAU, and %MAU values based solely on specimens collected from this current investigation were utilized since the provenience of these elements was more precisely recorded.

## VI. RESULTS

The Bone Bed 2 fauna is highly fragmentary and consists of 8,105 specimens (7,736 from the original excavation (Lorrain 1968), 52 from the 1983-84 investigation (Bement 1986), and 317 from the present investigation). Of these specimens, 31.7% were identifiable to taxon and element (2,261 from the original excavation, 52 from the 1983-84 investigation, and 257 from the present investigation). With regard to the bison remains, a minimum number of 32 individuals was determined based on femurs. All identifiable specimens were *Bison* save for five elements identified during the 1983-84 investigation which were *Equus* (MNI = 1).

This chapter provides the results of the faunal analysis of the Bone Bed 2 bison fauna. Taxonomy, site distribution, herd structure, skeletal element abundance, site seasonality, and bone modification are discussed.

### Taxonomy

The majority of identified specimens (99.8%) were assigned to *B. antiquus*. This determination was made primarily on the size and morphology of the bones as well as the age of the deposit (Lorrain 1968:109-130). All specimens identified in the present investigation were determined to be *Bison* and interpreted as *B. antiquus* in keeping with previous analyses (Lorrain 1968:109-130; Byerly et al. 2005).

During the 1983-84 investigation through the University of Texas at Austin, Bement (1986) identified five *Equus sp.* specimens. These specimens include a mandibular tooth fragment, a left mandible, a left radius shaft, a maxillary tooth fragment, and a left maxillary fragment. These equus remains were found in the interior of the rockshelter in the uppermost layers of Bone Bed 2. Dibble and Lorrain also noted

the presence of a single prehistoric equus specimen in the Bone Bed 2 strata but did not record its element or location and argued that it represented an intrusion from Bone Bed 1 (Dibble and Lorrain 1968:30). Bement (1986) suggested that the presence of equus remains in the Bone Bed 2 strata could be explained by the use of a jump drive with wild horses becoming caught up in the bison stampede. Since equus remains are sparse and were not identified during the present investigation, only bison remains are considered in this research.

### **Skeletal Element Abundance**

Table 12 provides skeletal element abundance information for the Bone Bed 2 bison fauna (Lorrain's (1968) and Bement's (1986) data combined with the data from the current investigation with vertebrae, carpal, and tarsal counts from Byerly et al. (2005)). The largest MNE values for the crania were derived from maxilla. There is a marked difference in the frequency between crania (MNE = 20) and mandibles (MNE = 39). However, this patterning is not unusual and is exhibited at several other Paleoindian kill sites such as the Folsom site (Meltzer et al. 2002) and the Agate Basin site (M. G. Hill 2001). It has been proposed that the greater surface area and fragmentary nature of the cranium relative to the mandible may cause crania to appear underrepresented when compared with the frequency of mandibles. Additionally, mandibles may be buried quicker than the larger, blockier crania which may allow them to be more protected (Borresen 2002:50). Due to this difference in the rate of representation, the MNI of skulls has been based on mandible fragments.

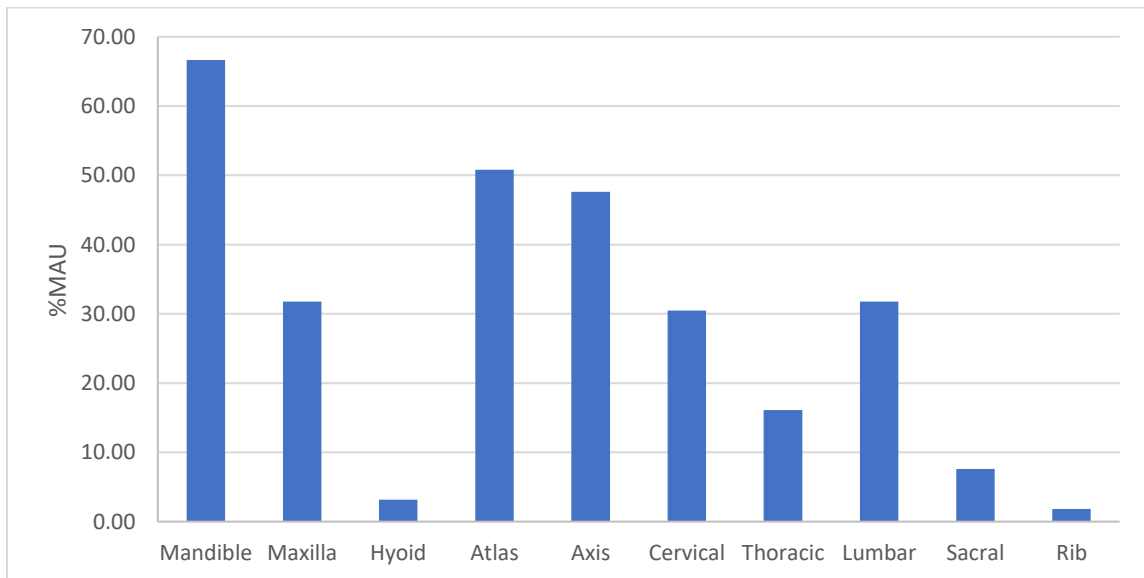
**Table 12.** Bison skeletal element abundance with data from Lorrain (1968), Bement (1986) and Byerly et al. (2005), Bone Bed 2.

Element	Code	NISP	Left	Right	n	MNE	MAU	%MAU
Horn core	HC	9			9	9	4.5	14.29
Mandible	MR	42	21	11	10	42	21	66.67
Maxilla	MX		11	4	5	20	10	31.75
Hyoid	HY	5			2	2	1	3.17
Atlas	AT	14			16	16	16	50.79
Axis	AX	13			15	15	15	47.62
Cervical (3-7) vertebra	CE	128			48	48	9.6	30.48
Thoracic (1-14) vertebra	TH	213			71	71	5.07	16.10
Lumbar (1-5) vertebra	LM	110			50	50	10	31.75
Sacral (1-5) vertebra	SA	13			12	12	2.4	7.62
Caudal (1-5) vertebra	CA	23			5	5	1.00	3.17
Rib	RB	149			16	16	0.57	1.81
Sternum	ST	9			4	4	1	3.17
Scapula	SC	34	15	13	2	30	15	47.62
Humerus	HM	86	21	25	6	52	26	82.54
Radius	RD	73	15	25	8	48	24	76.19
Ulna	UL	23	14	5	1	20	10	31.75
Metacarpal	MC	27	7	12	3	22	11	34.92
Fifth metacarpal	MC5	3			3	3	1.5	4.76
Ulnar carpal	CPU	17			17	17	8.5	26.98
Intermediate Carpal	CPI	16			14	14	7	22.22
Radial Carpal	CPR	17			14	14	7	22.22
2nd and 3rd carpal	CPS	20			16	16	8	25.40
4th Carpal	CPF	19			15	15	7.5	23.81
Accessory carpal	CPA	8			8	8	4	12.70
Innominate	IM	41	13	21	1	35	17.5	55.56
Femur	FM	129	26	26	11	63	31.5	100.00
Patella	PT	13			9	9	4.5	14.29
Tibia	TA	71	18	17	3	38	19	60.32
Metatarsal	MT	34	6	16	5	27	13.5	42.86

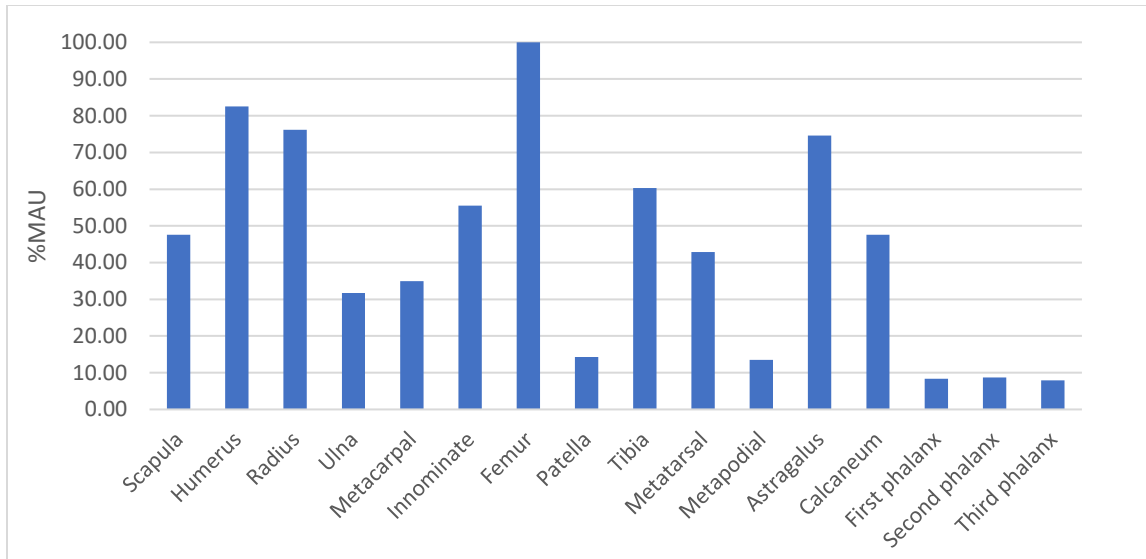
**Table 12. Continued.** Bison skeletal element abundance with data from Lorrain (1968), Bement (1986), and Byerly et al. (2005), Bone Bed 2.

Element	Code	NISP	Left	Right	N	MNE	MAU	%MAU
Metapodial	MP	79			17	17	4.25	13.49
Astragalus	AS	45	18	28	1	47	23.5	74.60
Calcaneum	CL	32	17	11	2	30	15	47.62
Central and 4th tarsal	TRC	30	16	11	2	29	14.5	46.03
2nd and 3rd tarsal	TRS	3			8	8	4	12.70
Sesamoid (all)	SM	41			3	3	0.13	0.40
Lateral malleolus	LTM	8			5	5	2.5	7.94
First phalanx	PHF	83			21	21	2.63	8.33
Second phalanx	PHS	78			22	22	2.75	8.73
Third phalanx	PHT	44	8	7	5	20	2.5	7.94

The postcranial axial skeleton is poorly represented, as are a number of smaller elements such as carpals, tarsals, and phalanges (Figures 7 and 8). Byerly et al. (2005), argued that this underrepresentation likely resulted from the discard of elements in the field during the 1963-64 excavations. Indeed, Dibble notes that due to budget and time constraints, only the most readily identifiable elements were collected from Pit C (Dibble and Lorrain 1968:29).



**Figure 7.** Bison axial skeletal element abundance profile for Bone Bed 2.



**Figure 8.** Bison appendicular skeletal element abundance profile for Bone Bed 2.

To determine the degree to which collection bias may have affected the element counts from Pit C, Byerly conducted Freeman-Tukey deviates which revealed that, when compared to the rest of the site, thoracics, lumbar, sacra, and innominates were significantly underrepresented in Pit C, while mandibles, femora, patellae, astragali, first and second phalanges, and proximal sesamoids were significantly overrepresented. Byerly concluded that there was a significant collection bias against thoracics, lumbar, sacra, and innominates in Pit C and excludes these elements from the remainder of his analysis. Comparing the elements counts collected by Lorrain (1968) for thoracic, lumbar, and cervical vertebra and innominates to the counts for those elements collected during the current investigation reveals that these elements do indeed appear to be underrepresented (Table 13). It is unclear whether this underrepresentation is the result of field discard or the difficulty Lorrain (1968) experienced in identifying vertebra. To help account for this, Byerly's vertebra element counts are utilized instead of Lorrain's. For the purposes of this research, it was assumed that this updated element count is

representative, as opposed to significantly biased, in order to identify any emergent patterns in element abundance. All spatial analyses that include Pit C are evaluated with caution given to this potential bias.

**Table 13.** Comparison between selected skeletal elements from Lorrain (1968) and the present investigation, Bone Bed 2.

Element	Lorrain MNE	Current MNE
vertebra <sup>a</sup>	3	4
vertebra – sacral	1	0
Innominate	4	1

<sup>a</sup> Sum of cervical (CE3-7), thoracic, and lumbar vertebra

In addition to the axial elements, smaller elements such as the 4<sup>th</sup> carpal, intermediate carpal, fused 2<sup>nd</sup> and 3<sup>rd</sup> tarsals, lateral malleoli, sesamoids, and phalanges are all poorly represented in Bone Bed 2.

The most abundant forelimb element in the Bone Bed 2 fauna is the humerus (MNE = 47), while the least abundant elements are the 4<sup>th</sup> carpal (MNE = 2) and intermediate carpal (MNE = 1). In terms of the major limb elements, the metacarpal occurs least frequently (MNE = 20). The most abundant hind limb element is the femur (MNE = 60). The least abundant hind limb elements are the patella (MNE = 9), fused central & 4<sup>th</sup> tarsal (MNE = 19), and fused 2<sup>nd</sup> & 3<sup>rd</sup> tarsal (MNE = 3). Figure 8-9 presents the skeletal element abundance profile for the Bone Bed 2 bison remains. MNEs are converted into MAUs which are then standardized by dividing by the largest MAU in the assemblage (31.5 derived from femurs). The profile reveals that the axial skeleton is underrepresented in relation to other skeletal elements. Both forelimb and hind limb profiles show a sharp drop in frequencies between major limb elements and smaller limb elements. Additionally, there is a general decrease in element frequencies from the femur

to the tibia and metatarsal followed by a spike in frequency with astragali before decreasing again with calcaneum frequency. In summary, the forelimb element representation is fairly even. Hind limb representation, however, is significantly more varied. The discrepancy between calcaneum, fused central & 4<sup>th</sup> tarsals, and fused 2<sup>nd</sup> & 3<sup>rd</sup> tarsals is unexpected yet likely the result of random collection during excavation. Given their close association with one another, all of these elements are expected to occur in similar frequency to the astragalus.

### **Density-Mediated Attrition**

Although skeletal element frequencies are studied with an eye towards determining the cultural factors that affected or originated their deposition, natural formation processes also significantly affect the survivorship of skeletal elements and must be taken into account. An important factor determining the survivability of a skeletal element is its structural density ( $\text{g/cm}^3$ ). If density-mediated attrition was a significant agent in the survivorship of elements across Bone Bed 2, we would expect a correlation between element frequency and density.

The structural density of bison skeletal elements has been determined by measuring the mineral density at particular locations, or “scan sites” along the bone (Kreutzer 1992) (Table 14). A Pearson’s correlation was run to determine whether structural density affected skeletal frequency within Bone Bed 2. The test showed no correlation between ratio MAU and structural density ( $r = 0.148$ ,  $p = 0.426$ ). A Spearman’s correlation was also run but this test also revealed no correlation between ratio MAU and structural density ( $r_s = 0.219$ ,  $p = 0.237$ ).



**Table 14.** Bone Bed 2 skeletal element abundance and corresponding volume density values (Kreutzer 1992).

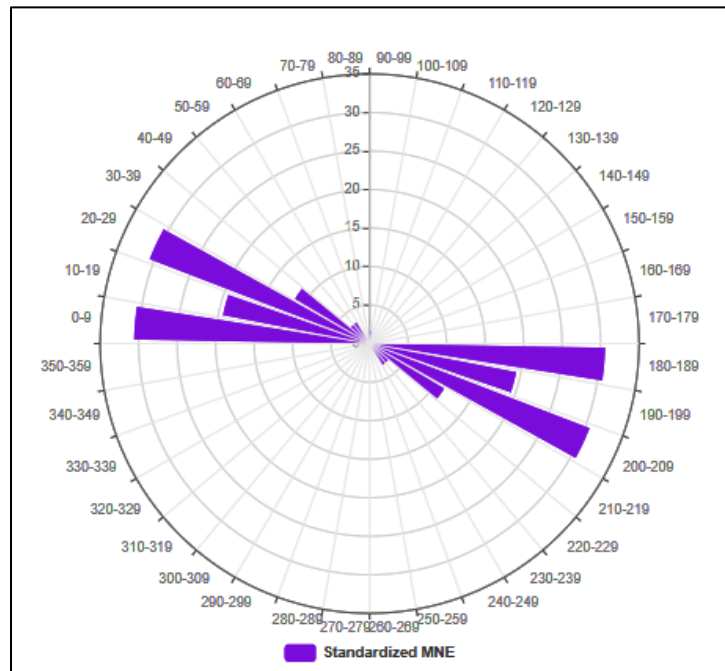
Element	MNE	MAU	%MAU	Rank	Volume Density	Rank
Cervical	79	11.3	37.7	12.0	0.62	2
Thoracic	71	5.1	17.0	19.0	0.42	12
Lumbar	50	10	33.3	14.5	0.21	24
Sacral	12	2.4	8.0	23.0	0.27	21.5
Rib	16	0.6	2.0	24.0	0.31	19.5
Scapula	30	15	50.0	10.0	0.5	6
Proximal Humerus	37	18.5	61.7	5.0	0.24	23
Distal Humerus	48	24	80.0	3.0	0.38	15
Proximal Radius	35	17.5	58.3	7.5	0.45	8
Distal Radius	47	23.5	78.3	4.0	0.35	16
Proximal Metacarpal	20	10	33.3	14.5	0.59	3
Distal Metacarpal	16	8	26.7	17.0	0.53	4
Carpals	84	7	23.3	18.0	0.44	10
Innominate	35	17.5	58.3	7.5	0.27	21.5
Proximal Femur	60	30	100.0	1.0	0.33	17
Distal Femur	49	24.5	81.7	2.0	0.31	19.5
Proximal Tibia	35	17.5	58.3	7.5	0.41	13.5
Distal Tibia	35	17.5	58.3	7.5	0.41	13.5
Proximal Metatarsal	17	8.5	28.3	16.0	0.52	5
Distal Metatarsal	25	12.5	41.7	11.0	0.44	10
Tarsals	41	10.3	34.3	13.0	0.72	1
first phalanx	21	2.6	8.7	21.0	0.47	7
second phalanx	22	2.8	9.3	20.0	0.44	10
Third Phalanx	20	2.5	8.3	22.0	0.32	18

### Orientation and Inclination

In order to test whether alluvial action was a significant agent in the distribution of elements within Bone Bed 2, orientation and inclination was recorded with a compass and inclinometer for all specimens whenever the specimen was sufficiently intact.

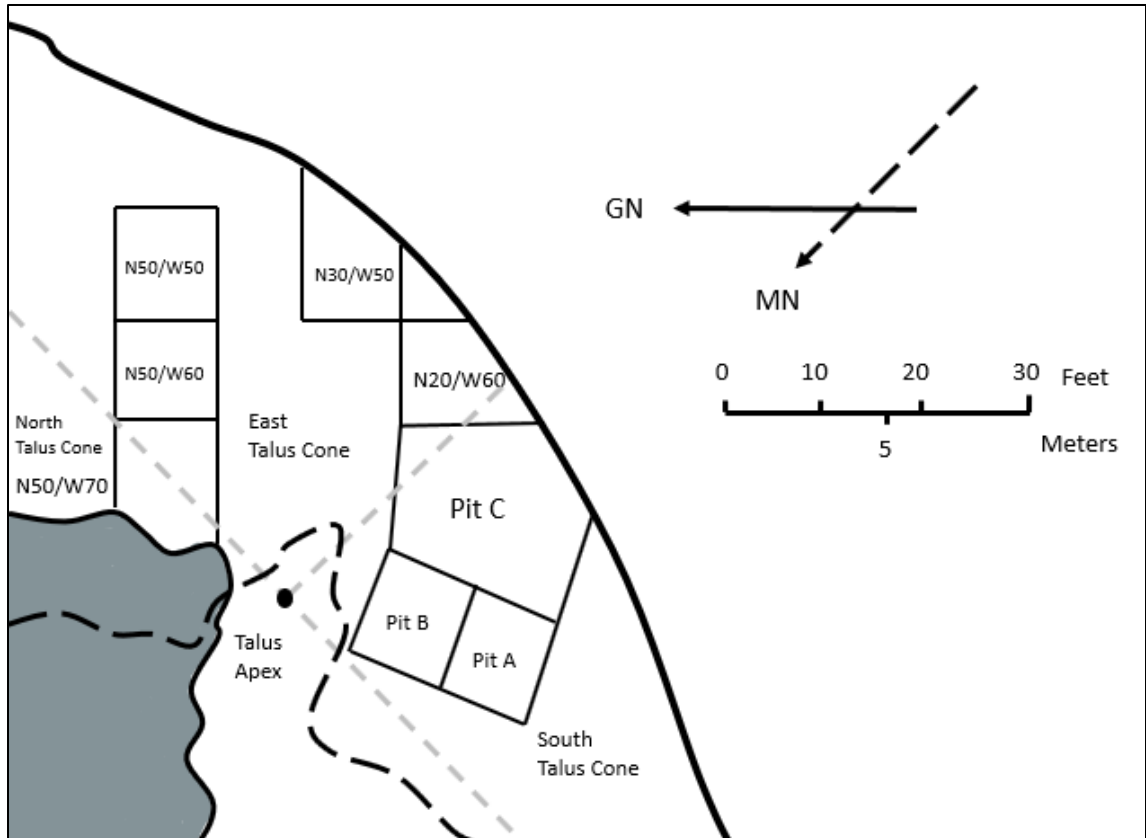
Orientation was recorded for 59 specimens and inclination was recorded for 62 specimens. Orientation was recorded with regard to magnetic north.

Data regarding the inclination of specimen is summarized in Figure 9. 80.65% (NISP = 50) of the specimens recorded for inclination had an inclination between 0 and 29 degrees. This range of degrees is consistent with the slope of the talus cone and the relatively flat interior of the rockshelter (Dibble and Lorrain 1968:23; Kilby et al. 2020).



**Figure 9.** Rose Diagram showing the standardized frequency of specimens with inclinations within discrete degree ranges.

The talus cone was divided into three sections: the north talus cone (Square N50/W70), east talus cone (Squares N50/W60, N50/W50, N30/W50, and N20/W60), and south talus cone (Pits B and C) (Figure 10). This delineation is based on the grid north instated by Dibble (Dibble and Lorrain 1968). Magnetic north is ~45 degrees to the west of grid north.

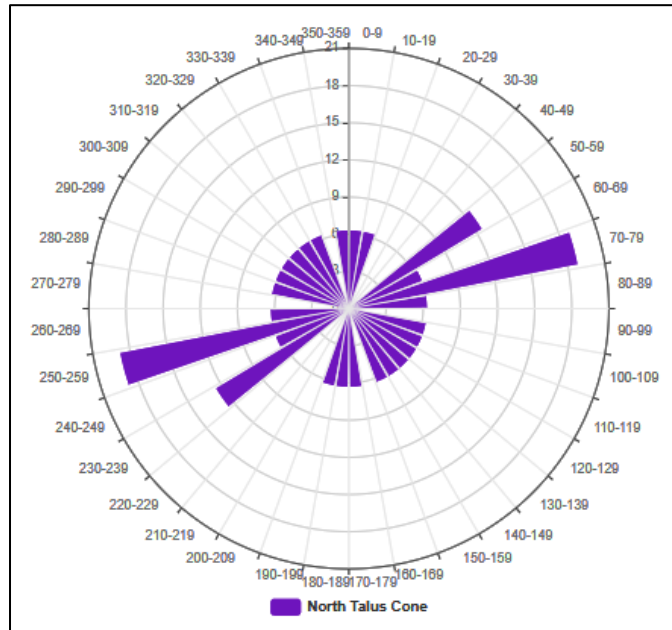


**Figure 10.** Map of the talus cone showing the locations of the north, east, and south excavation units.

If alluvial forces were affecting all elements on the talus cone equally, we would expect elements from the north side of the talus cone to have orientations of between 0 and 45 degrees (45 and 90 degrees based on magnetic north). We would expect elements from the east side of the talus cone to have orientations of between 45 and 135 degrees (90 and 180 degrees based on magnetic north). Lastly, we would expect elements from the south side of the talus cone to have orientations between 135 and 225 degrees (180 and 270 degrees based on magnetic north).

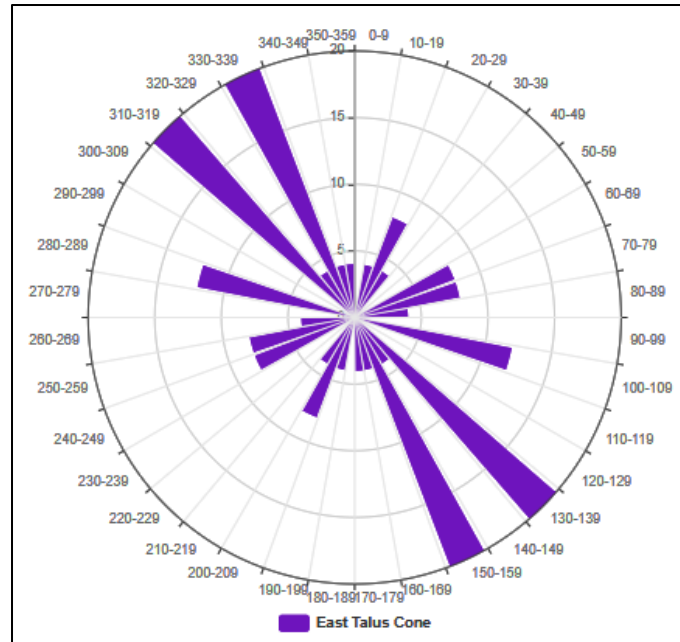
The majority of specimens recorded from the north side of the talus cone have orientations of between 50 to 80 degrees (Figure 11). This meets the expectations that

elements would display orientations of between 45 and 90 suggesting that elements from the north side of the talus cone experienced a fair amount of alluvial action.



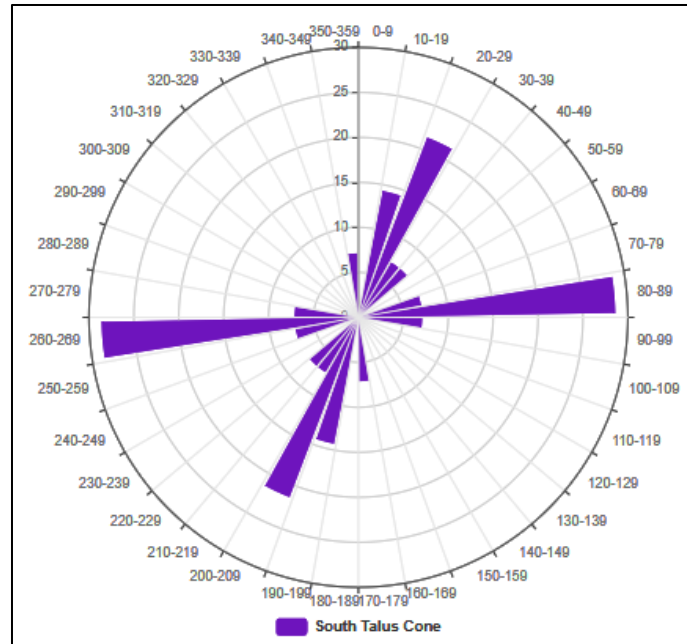
**Figure 11.** Rose diagram showing the standardized frequency of specimens with orientations within discrete degree ranges for the north side of the talus cone.

The majority of specimens recorded from the east side of the talus cone have an orientation of between 130 and 159 degrees (Figure 12). We would expect orientations of between 90 and 180 degrees based on magnetic north. This falls within expectations but suggests that alluvial action was more prevalent on the southeast side of the talus cone affecting Square N20/W60.



**Figure 12.** Rose diagram showing the standardized frequency of specimens with orientations within discrete degree ranges for the east side of the talus cone.

The distribution of elements from the south side of the talus cone is bimodal falling between 190 and 209 degrees and 260 and 269 degrees (Figure 13). We would expect elements from the south side of the talus cone to have orientations of between 180 and 270 degrees based on magnetic north. This suggests that alluvial action was a factor in the distribution of elements in Pits A, B, and C. The fact that elements are clustered towards the extremes of the expected range of degrees could suggest that alluvial action was most prevalent in the east side of Pit C and the west side of Pit B.



**Figure 13.** Rose diagram showing the standardized frequency of specimens with orientations within discrete degree ranges for the south side of the talus cone.

### Settling Velocity

To further explore the part that alluvial action played in the taphonomic history of Bone Bed 2, skeletal element frequencies (MNE) were compared to measurements of settling velocity collected by Todd (2003:244) (Table 15). Measurements of settling velocity show how quickly a given skeletal element sinks and, by extension, how easily it can resist the effects of water movement. Both Pearson's and Spearman's correlations showed no significant relationship between element frequency (NISP and MNE) and settling velocity (Table 16). This indicates that alluvial action was not a significant factor in the survivorship of skeletal elements within Bone Bed 2.

**Table 15.** Bone Bed 2 skeletal element abundance (NISP and MNE) and corresponding settling velocities (STD Vs) and rank values (Lorrain 1968; Todd 2003:244).

Element	NISP <sup>a</sup>	Rank	MNE	Rank	STD Vs	Rank
mandible	42	8	42	12	78.7	13
atlas	14	2	16	2.5	57.1	6
thoracic	69	12	71	18	44.6	3
lumbar	31	4	50	15	52.3	5
sacral	13	1	12	1	33.5	1
rib	149	18	16	2.5	38.3	2
scapula	34	6.5	30	9.5	46.8	4
humerus	86	16	52	16	72.3	11
radius	73	14	48	14	64.6	8
ulna	43	9	20	4.5	68	10
metacarpal	27	3	22	7	80.9	15
femur	129	17	63	17	65.9	9
tibia	71	13	38	11	80.6	14
metatarsal	45	11	27	8	100	18
astragalus	32	5	47	13	94	17
calcaneum	34	6.5	30	9.5	84.6	16
first phalanx	83	15	21	6	74.5	12
third phalanx	44	10	20	4.5	57.9	7

<sup>a</sup> Combination of Lorrain's (1968), and Bement's (1986) NISP values and the NISP values collected during the present investigation

**Table 16.** Pearson's and Spearman's correlations between MNE and NISP values and standardized settling velocities (Todd 2003:244), Bone Bed 2.

Values	Statistical Test	R	P
MNE	Pearson's correlation	0.096	0.704
	Spearman's correlation	0.176	0.489
NISP	Pearson's correlation	-0.144	0.568
	Spearman's correlation	0.011	0.964

### Weathering

To test the hypothesis that the observed stratification of Bone Bed 2 is the result of non-cultural redepositional events, weathering stages were recorded for all bones with exposed cortical surfaces. If the stratification of Bone Bed 2 is the result of noncultural

taphonomic processes, we would expect higher rates of weathering in the strata of Pit C and Squares N20/W60 than the rest of the talus cone. An alluvial event would likely re-expose the bone and subject it to more weathering. We would also expect larger amounts of variation in the stages of weathering in Pit C and Squares N20/W60 compared to the rest of the talus cone or the interior of the shelter. This is suggestive of redeposition where bones at various stages of weathering were redeposited at the base of the talus cone experiencing mixing and more weathering during the process.

Weathering stages (0-5) were recorded using the criteria set out by Behrensmeyer (1978) for all specimens with observable cortex. The weathering stages 0 through 5 produced by Behrensmeyer are equivalent to the weathering stages 1 through 6 produced by David Rapson (1991:370) and used by Byerly et al. (2005) and therefore allow data regarding the currently documented specimens to be incorporated with the data produced by Byerly et al. (2005:613).

A total of 2,241 identifiable specimens (2,009 from Byerly et al. (2005) and 232 from the current investigation) had sufficient cortical surface to be assigned to a weathering stage (Table 17). The majority of these bones (NISP = 1,258; 56.1 percent) are lightly weathered (weathering stages 0-1 and 1-2). 37.5 percent (NISP = 841) are moderately weathered and 6.3 percent (NISP = 142) are highly weathered. Overall, the weathering data collected during the present investigation displays higher degrees of weathering relative to the data collected by Byerly et al. (2005). This is possibly due to the fact that the specimens examined during the present investigation had been largely exposed in the unit profiles of Bonfire Shelter since the original excavation in 1963



whereas the specimens examined by Byerly et al. (2005) had been excavated during the 1963-64 investigation and immediately curated.

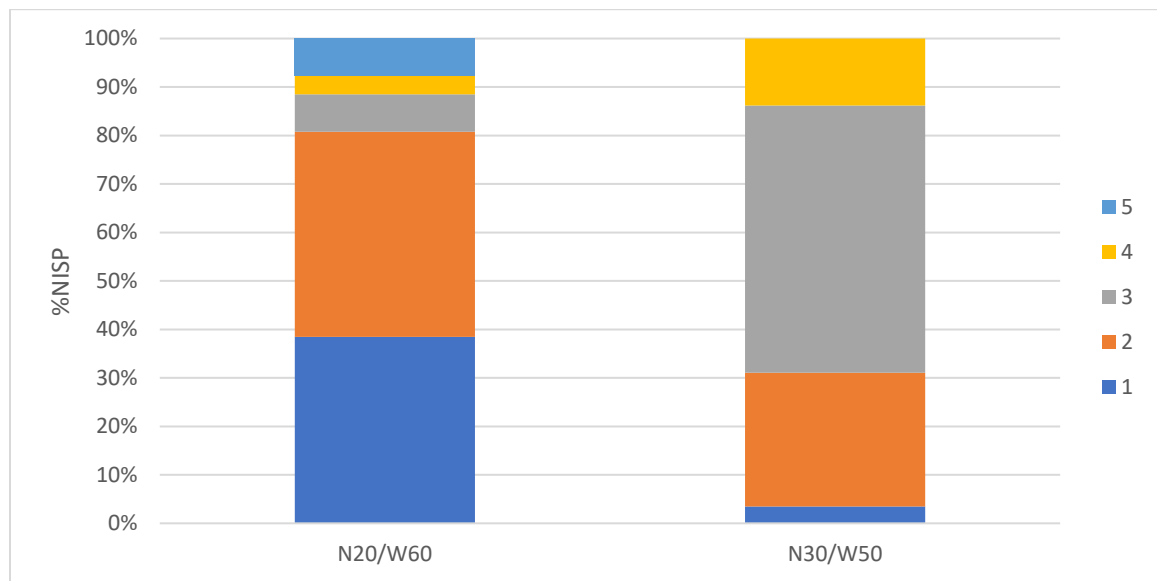
**Table 17.** Frequency of specimens displaying weathering recorded during the present investigation and by Byerly et al. (2005).

Byerly et al.			Current Investigation		
Weathering Stages (Rapson 1991)	NISP	%NISP	Weathering Stages (Behrensmeyer 1978)	NISP	%NISP
1-2	1198	58.8%	0-1	60	25.9%
3-4	697	34.2%	2-3	144	62.1%
5-6	114	7.1%	4-5	28	12.1%

Although the specimens were highly fragmentary, this data indicates that the cortical surface was in generally good condition suggesting that the majority of the bones likely did not spend a significant amount of time exposed on the surface. This also suggests that a factor other than subaerial weathering was responsible for the fragmentary nature of the fauna. Given what we know about events that transpired at Bonfire Shelter in later periods, it is likely that the extensive sediment overburden and the events that produced Bone Bed 3 are responsible for the fragmentation of Bone Bed 2.

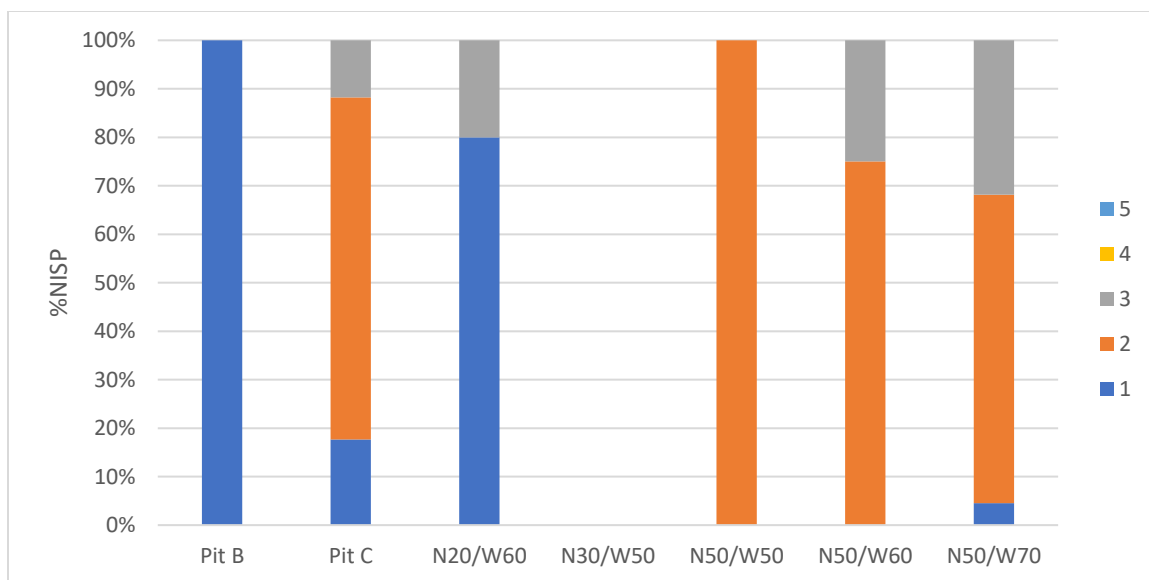
The weathering data collected during this investigation was then analyzed to determine whether individual units displayed unique weathering patterns across specific strata. Stratum 14 only contained bone in Squares N20/W60 and N30/W50 (Figure 14). Square N20/W60 is composed primarily of bone assigned to weathering stage 1 and 2 although it contains a few elements assigned to stages 3, 4, and 5. Square N30/W50 was dominated by weathering stage 2 and 3 bone with a few elements assigned to stage 4. This suggests that at the time of the deposition of stratum 14, Square N20/W60 was

exposed for slightly longer than Square N30/W50. It also suggests that Squares N20/W60 and N30/W50 were subject to quite a bit of mixing.



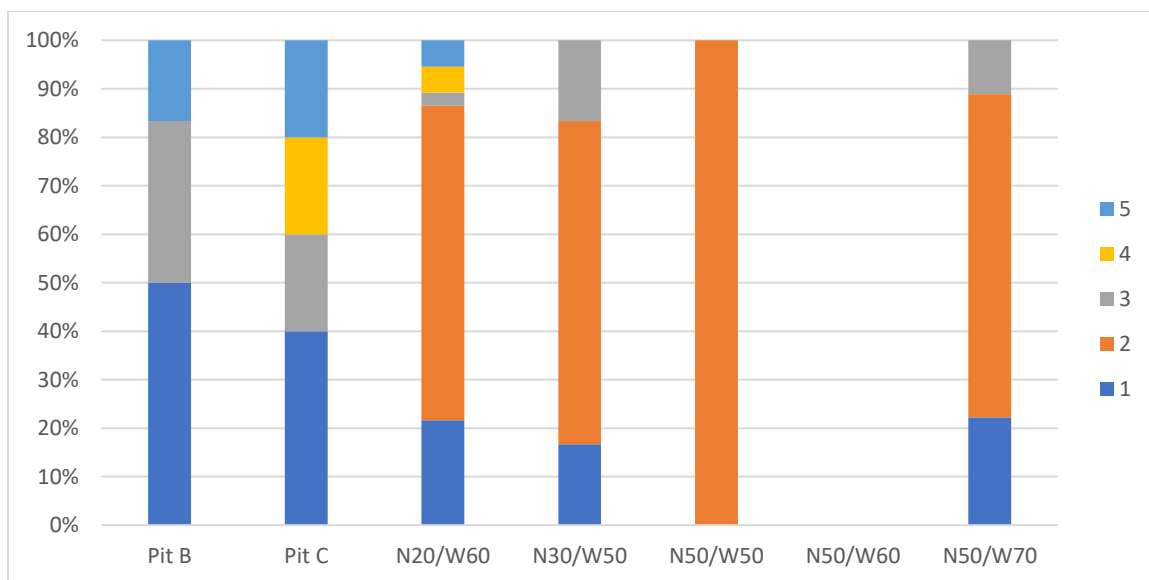
**Figure 14.** The relative frequency of specimens (Standardized NISP) displaying specific stages of weathering across stratum 14 in the units surrounding the talus cone of Bonfire Shelter.

Stratum 12 was composed almost entirely of bone assigned to weathering stage 2 and, to a lesser degree, 3 (Figure 15). The exception to this is Pit B and Square N20/W60 which were composed almost entirely of stage 1 bone. This suggests that Pit B and Square N20/W60 were covered by stratum 11 much quicker than the other units surrounding the talus cone. Square N20/W60 only contains bone assigned to weathering stages 1 and 3 suggesting some slight mixing.



**Figure 15.** The relative frequency of specimens (Standardized NISP) displaying specific stages of weathering across stratum 12 in the units surrounding the talus cone of Bonfire Shelter.

Stratum 11 (Figure 16) follows much the same pattern as stratum 12 with the majority of bone assigned to weathering stage 2; however, Pit B and Pit C are dominated by weathering stage 1 bone. Pit B, Pit C, and Square N20/W60 also contain several elements assigned to weathering stages 3 and 4. This mix of stage 1, 3, and 4 bone suggests that stratum 11 was either subject to some mixing or variable rates of deposition during its formation.



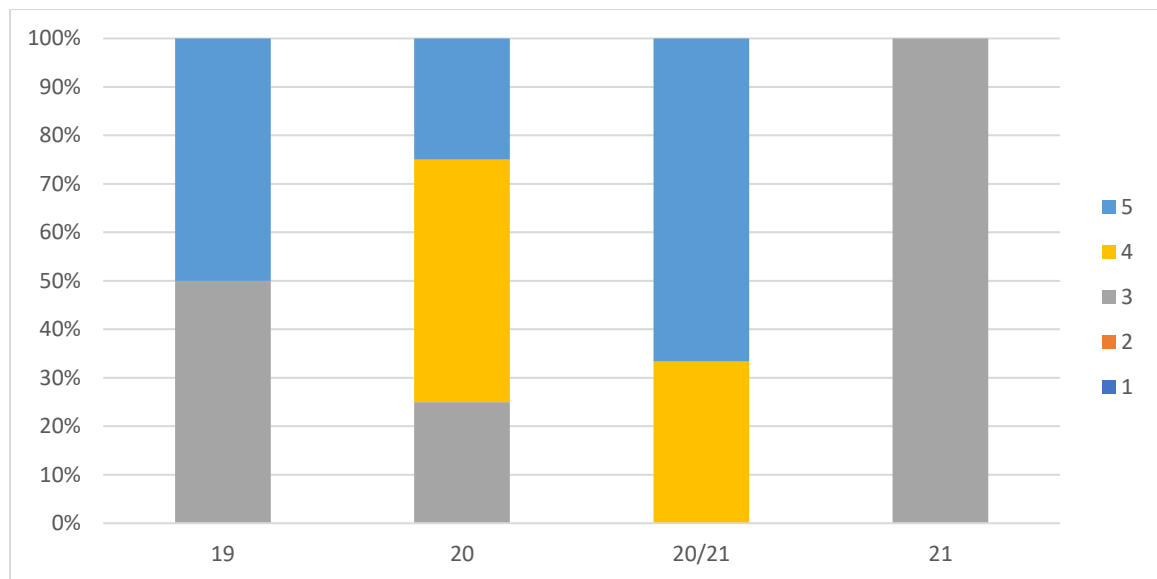
**Figure 16.** The relative frequency of specimens (Standardized NISP) displaying specific stages of weathering across stratum 11 in the units surrounding the talus cone of Bonfire Shelter.

Of particular note is the fact that Stratum 11 in Pit C is composed of bone assigned to weathering stages 1, 3, 4, and 5 but lacks any bone from weathering stage 2. Boiling bone can cause bone to weather at a slower rate than non-boiled bone and serves as a potential explanation for this lack of continuity (Jacobson In Press).

Ethnoarchaeological data suggests that boiling bone was required in order to render bone grease (Vehik 1977). Although the extent to which Folsom and Plainview peoples utilized bone grease is not fully understood, specific elements and the weathering stages were documented in order to determine if there was a relationship between low rates of weathering and bone grease utility. Bone grease was processed from long bones, ribs, and vertebrae (Vehik 1977:170). Within Stratum 11 of Pit C, a rib and talus fragment were assigned to weathering stage 1 while a 3<sup>rd</sup> phalanx was assigned to weathering stage 2. All other specimens were assigned to weathering stages 4 and 5. Although the sample

size is small, the differential rates of weathering combined with the fragmentary nature of the assemblage could indicate that bone grease processing was occurring. Further research with Bone Bed 2 and other Paleoindian bison assemblages will be required to fully determine whether bone grease processing was a common activity.

Strata 19, 20, and 21 from the interior of the shelter are slightly more weathered than the specimens from the talus cone but do not display the same amount of variation of weathering stages (Figure 17). Stratum 19 contains bones assigned to weathering stages 3 and 5 and lacks bones assigned to weathering stage 4. Only two specimens were recorded in Stratum 19 so this lack of continuity is likely the result of a small sample size. Most elements were documented at the boundary between strata 20 and 21 with very few elements falling above or below the stratigraphic boundary. Very few elements were documented from stratum 19 as well.



**Figure 17.** The relative frequency of specimens (%NISP) displaying specific stages of weathering across strata 19, 20, the contact between 20 and 21, and 21 in the Interior of Bonfire Shelter.

### **Rodent and Carnivore Modification**

The current investigation did not identify any specimens that displayed rodent or other nonhuman carnivore activity. There is no evidence of rodent or nonhuman carnivore activity on any of the specimens recovered from the 1964 excavation with the exception of a single proximal humerus that shows signs of gnawing or cracking (Byerly et al. 2005:614).

### **Sex and Age Composition**

Modern bison herds display certain sex and age compositions at different times of the year. Bison herds aggregate during the rutting season (July through early August) and split into “bachelor herds” and “nursery herds” during the rest of the year. The sex and age composition of the Bone Bed 2 fauna was estimated in order to reconstruct the nature of the herd and potentially the season during which the herd died. If the Bone Bed 2 bison herd displays the characteristics of a nursery herd (primarily female) or a bachelor herd (primarily male), we would expect the kill to have happened sometime other than July or August when the herds are dispersed. If the Bone Bed 2 bison herd displays equal amounts of male and female bison, we would expect the kill to have happened sometime during July or August when nursery and bachelor herds aggregate. Lastly, if the Bone Bed 2 bison herd displays the characteristics of a nursery herd (mostly adult females with calves and juveniles of both sexes), we would expect the kill to have happened sometime between the rutting season (July through August) and the calving season (April through May). The presence of calves and fetal bison can also be instructive in determining seasonality. A nursery herd that lacks fetal remains suggests a kill that happened before

the fetus skeletons were developed enough to preserve indicating a season of death sometime before the calving season.

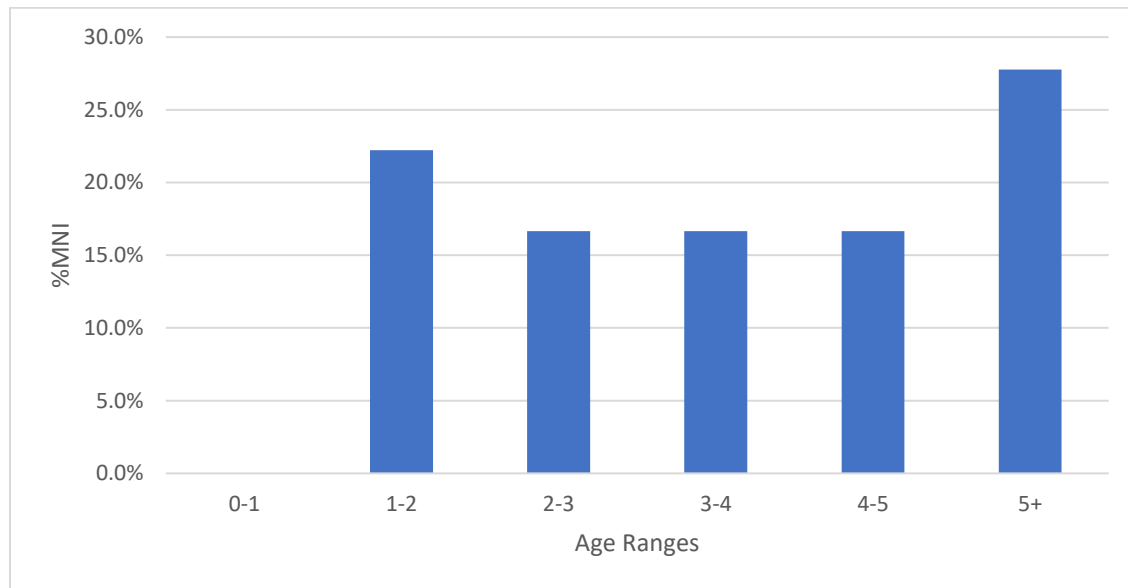
### **Sex Composition**

No data was able to be collected during the present investigation that would allow for sex estimation of skeletal elements. Although the exact ratio could not be calculated, Lorrain's faunal investigation reconstructed Bone Bed 2 as having a higher proportion of males to females based on metapodial osteometric data (Lorrain 1968:86-89). Byerly, however, concluded that the male to female ratio was more likely closer to 1:3 based on radii measurements (Byerly et al. 2005:611). Byerly also notes that the sample size for comparable specimens for other upper limbs elements was small and thus Lorrain's original sex estimate cannot be rejected. Lorrain's original sex estimation suggests a late summer kill at which time herds converge into male and female herds during the rutting season. Byerly's estimation, however, is more indicative of a nursery herd suggesting a kill that took place sometime other than late summer.

### **Age Composition**

All mandibles recorded during the current investigation (MNI = 4) were aged to 1-year increments based on eruption and wear. Calves (0 to 1 year of age) can be aged to the month; however, no calf mandibles were present in the Bone Bed 2 fauna. Although previous studies of prehistoric bison have aged mature bison dentition to age ranges of a few months using molar wear, numerous studies have shown that molar wear is highly dependent on the sex, general health of the individual, and type and quality of food they are consuming (Haynes 1984; Frison and Reher 1970a; Christianson et al. 2005). Since these factors cannot be satisfactorily reconstructed, age ranges of 1-year increments were

deemed more appropriate. These aged mandibles were then combined with the aged mandibles recorded by Byerly et al. (2005) (MNI = 14) and then standardized to create a sample age profile for the assemblage (Figure 18).



**Figure 18.** Age composition of Bone Bed 2 in ratio MNI

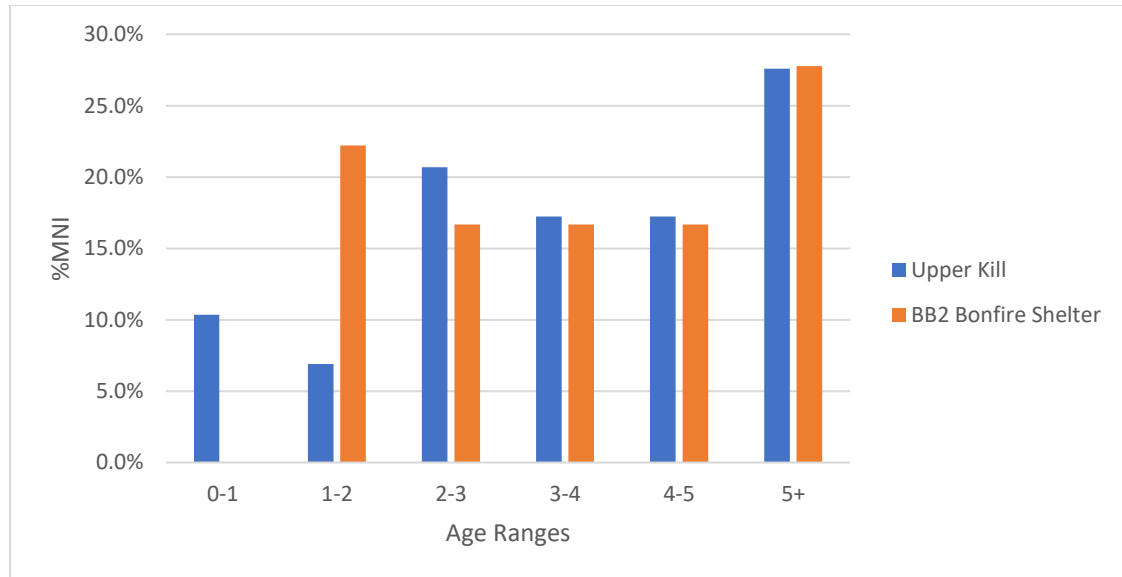
### Season of Death

Previous analyses of the season of death for the Bone Bed 2 bison have utilized molar eruptions and wear patterns. As previously discussed, molar eruptions are best suited for calves and the rate of molar wear is highly depended on factors such as the type and quality of available food and the overall health of the individual bison. It was decided to compare the Bone Bed 2 age profile to other documented bison herds killed during different seasons. Modern bison herds were deemed inappropriate as research shows that Pleistocene bison herds were likely smaller and may have behaved differently (Guthrie 1980b; Todd 1991; Carlson and Bement 2017). It was decided to compare the Bone Bed

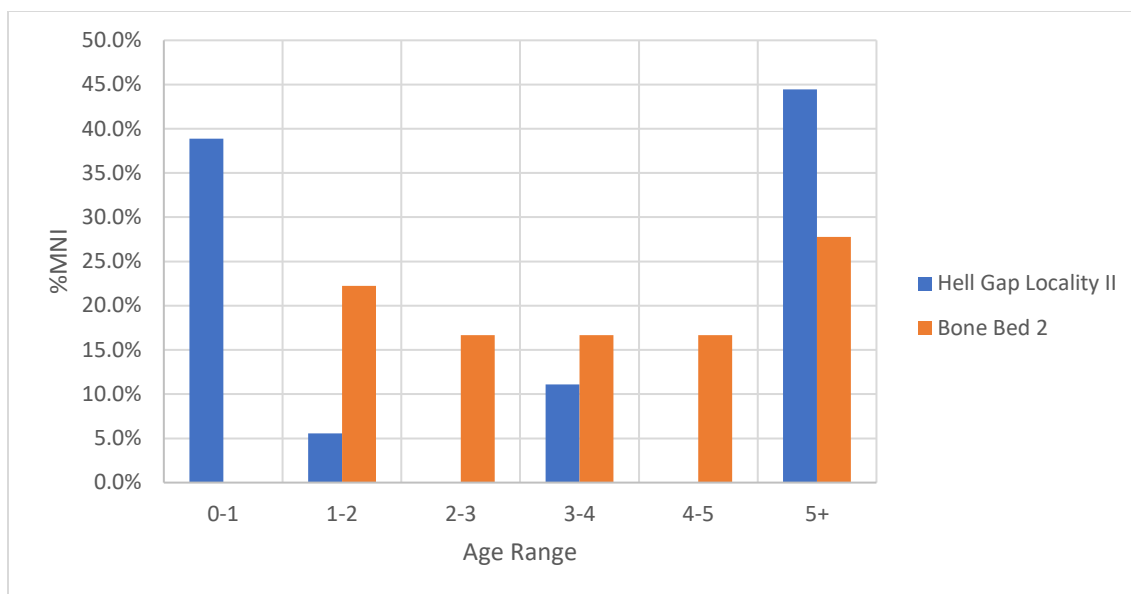


2 bison age profile with the bison age profiles from Paleoindian bison mass kills with documented seasons of death.

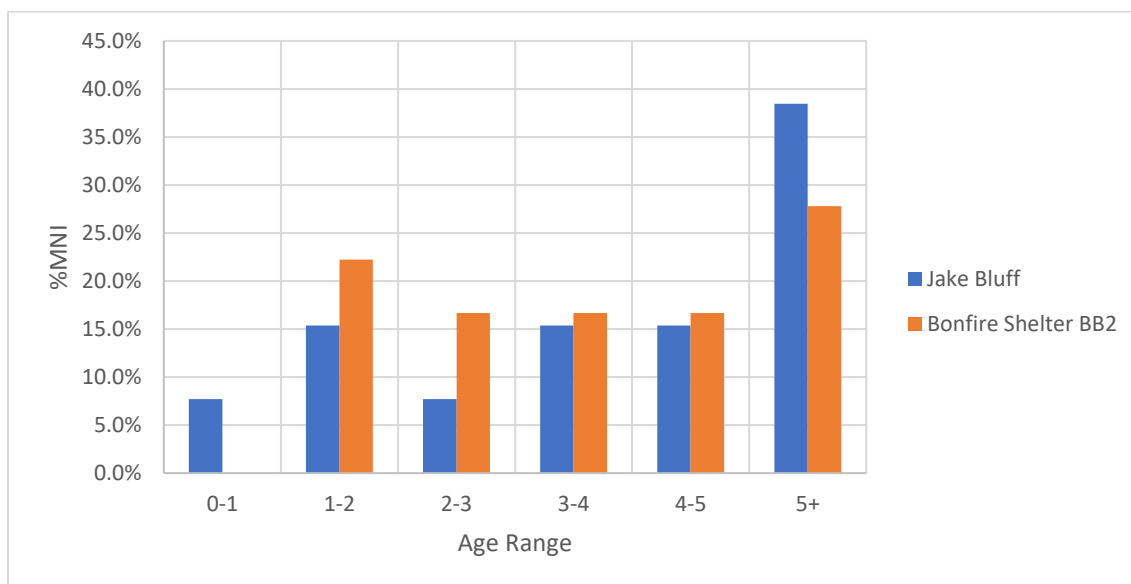
The Bone Bed 2 age profile was compared to the Cooper site Upper Kill (Bement and Carter 1999), Hell Gap Locality II (Byers 2002), Jake Bluff (Bement and Carter 2010), Hawken (Frison et al. 1976), and Wardell (Reher 1973) (Figures 19-23).



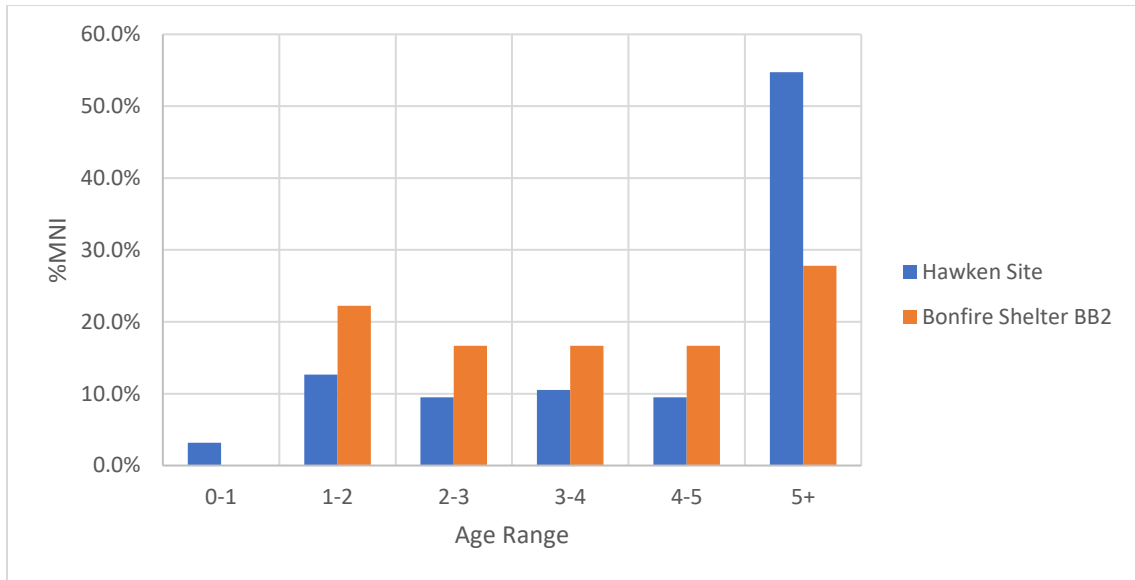
**Figure 19.** Comparison of the age composition of Bone Bed 2 with the Cooper Site Upper Kill composition (Bement and Carter 1999).



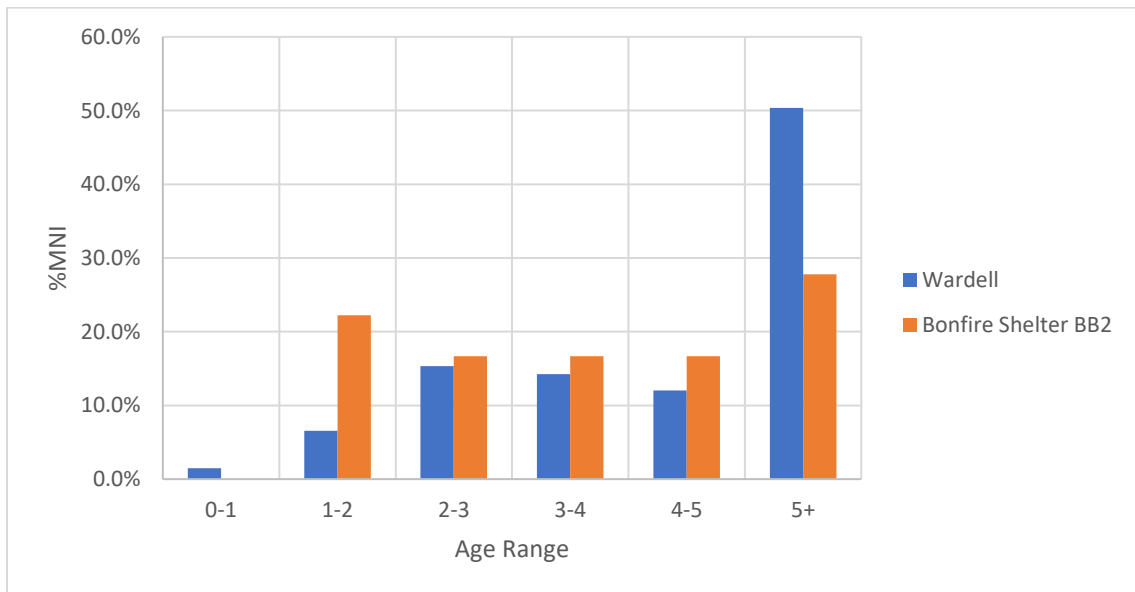
**Figure 20.** Comparison of the age ratio of Bone Bed 2 with the age composition of Hell Gap Locality II (Byers 2002).



**Figure 21.** Comparison of the age composition of Bone Bed 2 with the age composition of Jake Bluff (Bement and Carter 2010).



**Figure 22.** Comparison of the age composition of Bone Bed 2 with the age composition of the Hawken Site (Frison et al. 1976:39-41).



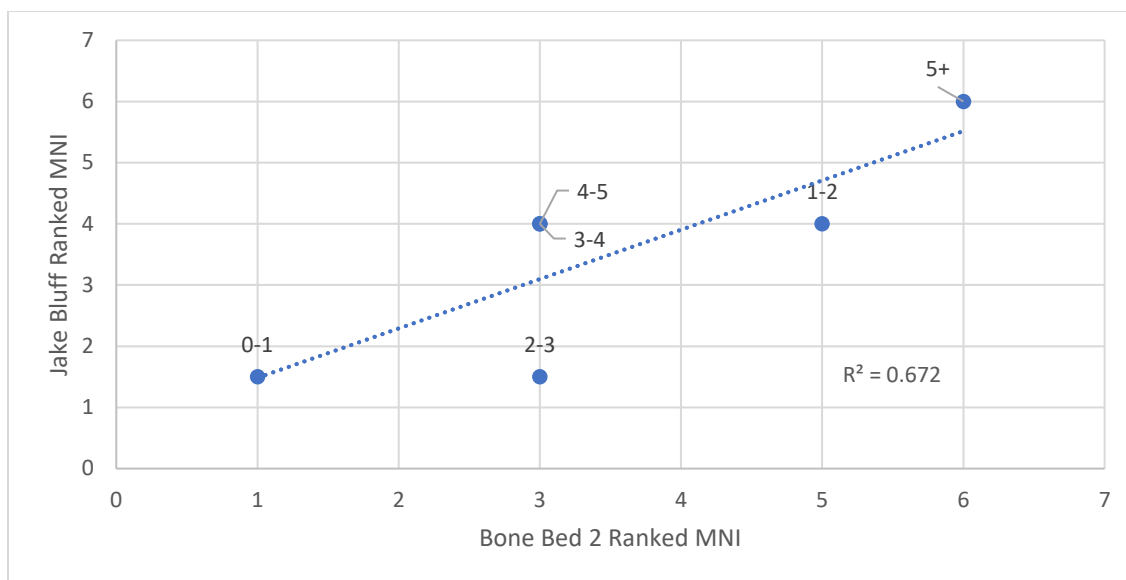
**Figure 23.** Comparison of the age composition of Bone Bed 2 with the age composition of the Wardell Site (Reher 1973).

Spearman's correlations were used to determine whether a relationship existed between the age profile of Bone Bed 2 and the age profile of these other Paleoindian bison kills (Table 18). There was no significant correlation between the Bone Bed 2 age

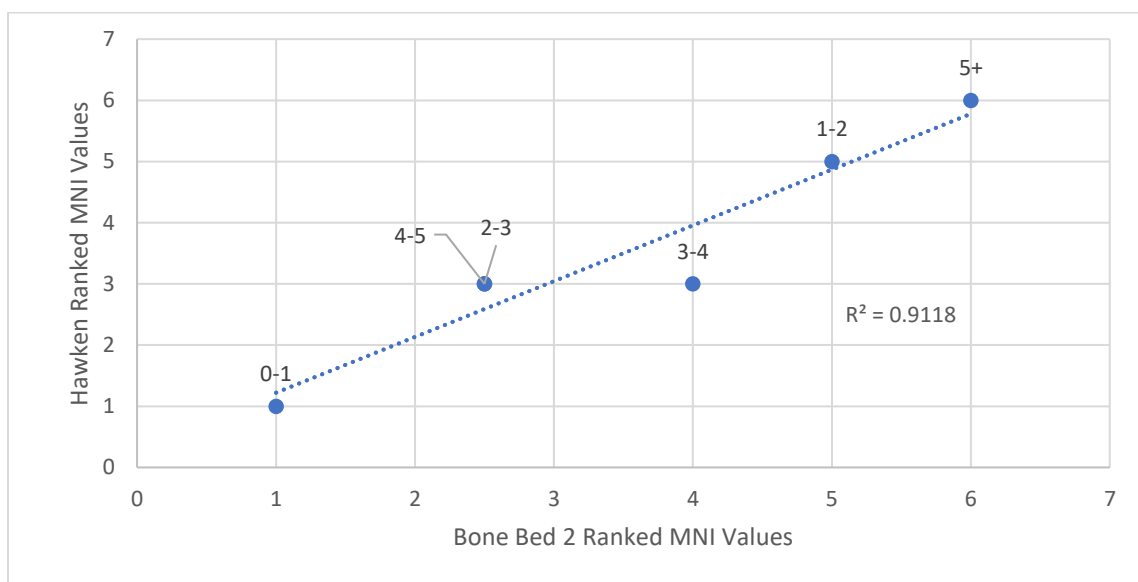
profile and the age profiles of the Cooper Site Upper Kill, Hell Gap Locality II, or the Wardell Site. The Bone Bed 2 age profile only significantly correlated with Jake Bluff and the Hawken Site (Figure 24 and 25). The Jake Bluff kill event has been interpreted as occurring during September/October while the Hawken Site kill event has been interpreted as occurring during December/January. Based solely on these two significant correlations, it is likely that the Bone Bed 2 kill event occurred between September to January. If the age ratio of a herd is directly related to the time of the year, then it is most likely that the Bone Bed 2 kill event occurred between December and January or, more generally, in late winter before the calving season (April to May). The total lack of calves in the Bone Bed 2 age profile further supports a late winter kill taking place before the calving season.

**Table 18.** Correlation between the age profile of Bone Bed 2 and other Paleoindian bison kills.

Site	$r_s$	P
Cooper (Upper Kill)	0.339	0.511
Hell Gap Locality II	0.216	0.682
Wardell	0.577	0.231
Jake Bluff	0.820	0.046
Hawken	0.955	0.003



**Figure 24.** Scatterplot showing the relationship between ranked MNI values for specific age ranges between Bone Bed 2 and Jake Bluff (Bement and Carter 2010).



**Figure 25.** Scatterplot showing the relationship between ranked MNI values for specific age ranges between Bone Bed 2 and the Hawken Site (Frison et al. 1976).

### Articulated Segments

In the 1963-64 investigation, Lorrain (1968) recorded only seven articulations in Bone Bed 2: one from Pit B, two from Square N50/W50, and four from Square N50/W50-N50/W60. She did not record which bones were articulated with one another,

but she did note that they usually consisted only of two bones. She notes that the true amount of articulations is probably much higher as articulations were likely missed in the field due to budget and time constraints.

Six obvious articulations were recorded in the profiles of the excavation units during the present investigation (Table 19). These include an articulated pelvis, femur, and tibia from profile section 7 (Figure 26), a sequence of three lumbar vertebra from column sample 6 (Figure 27), a vertebral column portion composed of CE6, CE7, TH1, and the head of a rib from profile section 7 at the northeast side of Square N20/W60, two articulated transverse processes from profile section 8 at the southwest corner of Square N30/W50, an articulation between the left and right first, second, and third phalanges (MNE = 6) from Column Sample 2, and an articulated Axis and Atlas from profile section 5 at Square N50/W70 (Figure 28).

**Table 19.** Articulations identified during the current investigation of Bone Bed 2.

Unit	Articulation
PS07	Pelvis, femur, tibia
CS06	Lumbar vertebra (n=3)
Square N20/W60	CE6, CE7, TH1, rib
Square N30/W50	Thoracic vertebra (n=2)
CS02	1st, 2nd, and 3rd phalanges (n=6)
Square N50/W70	Axis and Atlas (CE1 and CE2)

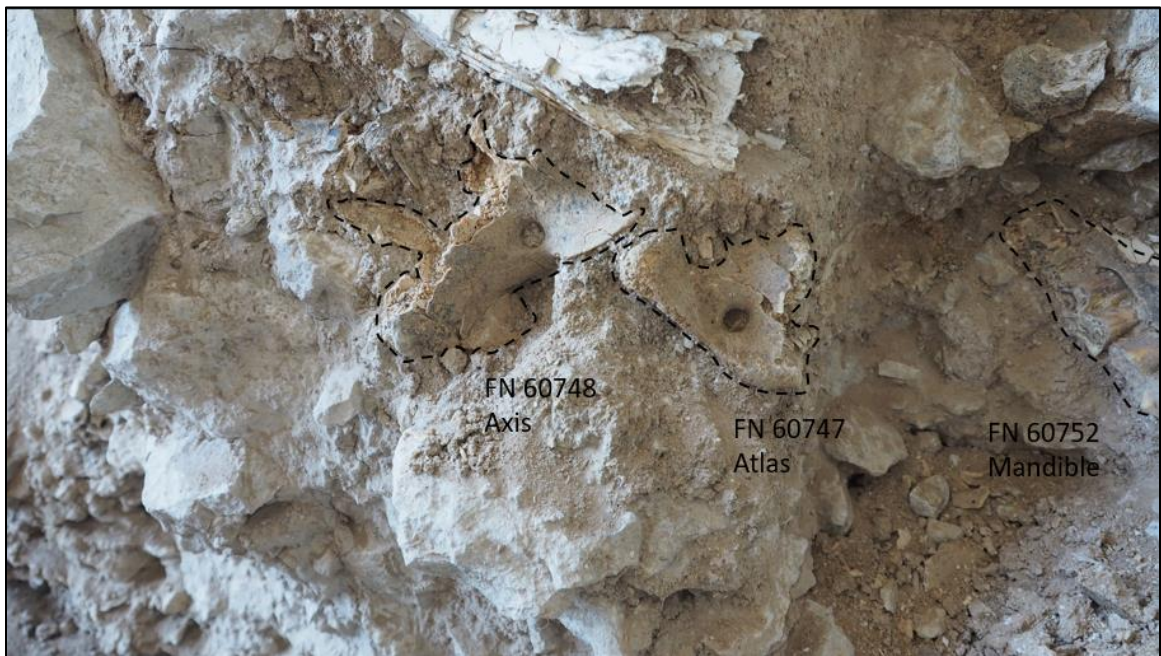


**Figure 26.** Articulated pelvis and femur, PS07.





**Figure 27.** Articulated lumbar vertebrae in CS06, PS07.



**Figure 28.** Articulated axis and atlas with an associated mandible from Square N50/W70.



In addition to these obvious articulations, four close associations between articulating bones were also noted (Table 20). These include a metatarsal, fused central and 4<sup>th</sup> tarsal, and proximal sesamoid from profile section 5 in Square N50/W70, a cluster of cranial bone fragments, an occipital condyle, maxillary fragments, and mandible from profile section 5 in Square N50/W70, and a right and left mandible from profile section 7 in Pit C, and a rib closely associated with a cervical vertebra from profile section 8 in Square N30/W50.

**Table 20.** Close associations between articulating bones identified during the current investigation of Bone Bed 2.

Unit	Association
Square N50/W70	Metatarsal, fused central and 4th tarsal, proximal sesamoid
Square N50/W70	Cranial fragments, occipital condyle, maxillary fragments, mandible
Pit C	Right and left mandible
Square N30/W50	Rib, cervical vertebra

If the frequency of articulated bones is consistent throughout Bone Bed 2 then the ratio of 10 articulations/associations for every 122 identifiable elements (1:12.2) should serve as a reasonable estimate of the true number of articulations across the entire assemblage. Given that 1,043 specimens were identifiable to element (Lorrain's (1968) total MNE combined with the total MNE from the current investigation), ~86 articulations/associations would be expected. This is very close to the 90 articulations identified in Bone Bed 3 (Lorrain 1968:93).

## **Bison Carcass Utility**

The relative utility of carcass portions and their associated skeletal elements is frequently employed to illustrate transport decisions made by hunters (Binford 1978a). This approach assumes that hunters will transport carcass portions away from kill sites in direct relationship to the utility associated with those carcass portions. If a skeletal assemblage displays a positive correlation between element frequency and utility with a low frequency of low utility elements and a high frequency of high utility elements, this is taken to indicate that the site represents a secondary butchering site in which high utility carcass portions were removed for storage or further processing. If a skeletal assemblage displays a negative correlation between element frequency and utility with a high frequency of low utility elements and a low frequency of high utility elements this is taken to indicate that the site represents a kill/primary processing site in which high utility carcass portion were removed from the site and the low utility portion were left in place. In other words, this approach is the means by which site function is determined with a positive correlation indicating a secondary processing site and a negative correlation indicating a kill site (Emerson 1993).

It is important to note that Binford based this approach on observations of historic Nunamiut hunters and the degree to which his observations match the activities and strategies carried out by Paleoindian hunters is unclear. Furthermore, the historical and archaeological records show that bison hunters often left large amounts of bone associated with high utility carcass portions at the kill site, particularly when the kill involved a large number of bison (Marcy 1866:305; Gregg 1958:374; Mackenzie 1960:360; Catlin 1926:289; Wissler 1910; Bement and Carter 1999, 2010; Sivertsen

1980; Borresen 2002; Wheat, Malde, and Leopold 1972; Meltzer 2002). Additional features such as surface modification, intrasite distribution, and the morphology of the site and surrounding area must be taken into account when determining site function.

Three modern bison utility models were utilized in this analysis: standardized average total food products [(S)AVGTP], standardized average protein [(S)AVGPRO], and standardized average marrow fats [(S)AVGMAR] (Emerson 1993) (Table 21). The (S)AVGTP model is used to determine whether transport decisions were made based on the total utility of the carcass portion. The (S)AVGPRO model is used to determine whether transport decisions were made based on protein alone. The (S)AVGTP model is used to determine whether transport decisions were made based on marrow utility alone.

**Table 21.** Bison skeletal element abundance, Bison carcass utility values (Emerson 1993), and value ranks, Bone Bed 2.

Element	(S)AVGTP	Rank	(S)AVGPRO	Rank	(S)AVGMAR	Rank
Horn core	14.2	21	10.9	20	-	-
Mandible	14.2	21	10.9	20	-	-
Maxilla	14.2	21	10.9	20	-	-
Atlas	6.4	15	6.6	15	-	-
Axis	7.8	17	8.1	18	-	-
Cervical (3-7) vertebra	56.6	28	59	28	-	-
Thoracic (1-14) vertebra	84.7	31	62.9	30	-	-
Lumbar (1-5) vertebra	82.9	30	60	29	-	-
Sacral (1-5) vertebra	54.7	26.5	51.3	26.5	6.7	5.5
Caudal (1-5) vertebra	1.5	12	0.9	14	-	-
Rib	100	32	100	32	-	-
Sternum	52.9	25	42.4	24	-	-
Scapula	31.6	24	43.7	25	2.2	1
Humerus	19.5	23	22.5	23	67.3	10
Radius	7.8	17	8	16.5	49.8	9
Ulna	7.8	17	8	16.5	-	-

**Table 21. Continued.** Bison skeletal element abundance, Bison carcass utility values (Emerson 1993), and value ranks, Bone Bed 2.

Element	(S)AVGTP	Rank	(S)AVGPRO	Rank	(S)AVGMAR	Rank
Metacarpal	1	7	0	7	14.4	7
Ulnar carpal	0.5	3.5	0	7	-	-
Intermediate Carpal	0.5	3.5	0	7	-	-
Radial Carpal	0.5	3.5	0	7	-	-
Fused 2nd and 3rd carpal	0.5	3.5	0	7	-	-
4th Carpal	0.5	3.5	0	7	-	-
Accessory carpal	0.5	3.5	0	7	-	-
Innominate	54.7	26.5	51.3	26.5	6.7	5.5
Femur	69.3	29	94.1	31	74.5	11
Tibia	11.2	19	11.3	22	84.5	12
Metatarsal	1.4	11	0	7	17.9	8
Fused central and 4th tarsal	1.6	13.5	0	7	-	-
Fused 2nd and 3rd tarsal	1.6	13.5	0	7	-	-
First phalanx	1.2	9	0	7	4.1	3
Second phalanx	1.2	9	0	7	4.1	3
Third phalanx	1.2	9	0	7	4.1	3

Hill (2001:73) argues that “analytical priority [should be] placed on those elements or element groupings most likely to reflect the primary reasons why a carcass unit was transported or ignored”. In other words, focusing on elements or element groupings that directly relate to transport decisions would likely provide a clearer picture of the activities carried out at the site. To this end, it was decided to run all utility analyses twice: once including all elements and a second time using a reduced element list. This reduced list contains only 17 elements and excludes the sternum, caudal vertebra, carpals, tarsals, patella, and phalanges. These elements were excluded because,

as previously discussed, they have a uniquely high chance of being underrepresented either due to documented collection bias or taphonomic processes.

Table 22 provides Pearson's correlation values between ratio MAUs and total food utility, meat utility, and marrow utility. There was no significant correlation between ratio MAU and total food products ( $r = 0.038$ ,  $p = 0.837$ ). There was also no correlation between ratio MAU and protein ( $r = 0.173$ ,  $p = 0.380$ ). The correlations were run again but this time restricted to the previously mentioned 17 elements. There was no significant correlation between element abundance and total food products ( $r = -0.404$ ,  $p = 0.108$ ) (Figure 29) or protein ( $r = -0.234$ ,  $p = 0.366$ ) (Figure 30). The correlation between total element abundance and marrow fats, however, was strong and significant ( $r = 0.683$ ,  $p = 0.000$ ,  $R^2 = 0.467$ ). Since the majority of skeletal elements have a marrow utility value of zero, marrow utility was also compared to just the twelve elements that contain marrow. There was a significant correlation between these twelve elements and marrow utility ( $r = 0.771$ ,  $p = 0.003$ ,  $R^2 = 0.595$ ) (Figure 31). The strong, positive correlation between ratio MAUs and marrow fats suggests there is a tendency for high utility marrow bones to occur in high frequency within Bone Bed 2. The correlation indicates that 46.7% of the variation observed in the element abundance of Bone Bed 2 can be explained by the variation in marrow utility. Although some slight marrow processing no doubt occurred at the site, the paucity of anvil marks on the bones indicates that marrow processing was not extensively conducted. An alternate interpretation of this result is that the Bone Bed 2 fauna contains a high proportion of proximal limb bones relative to distal limb bones and axial elements.

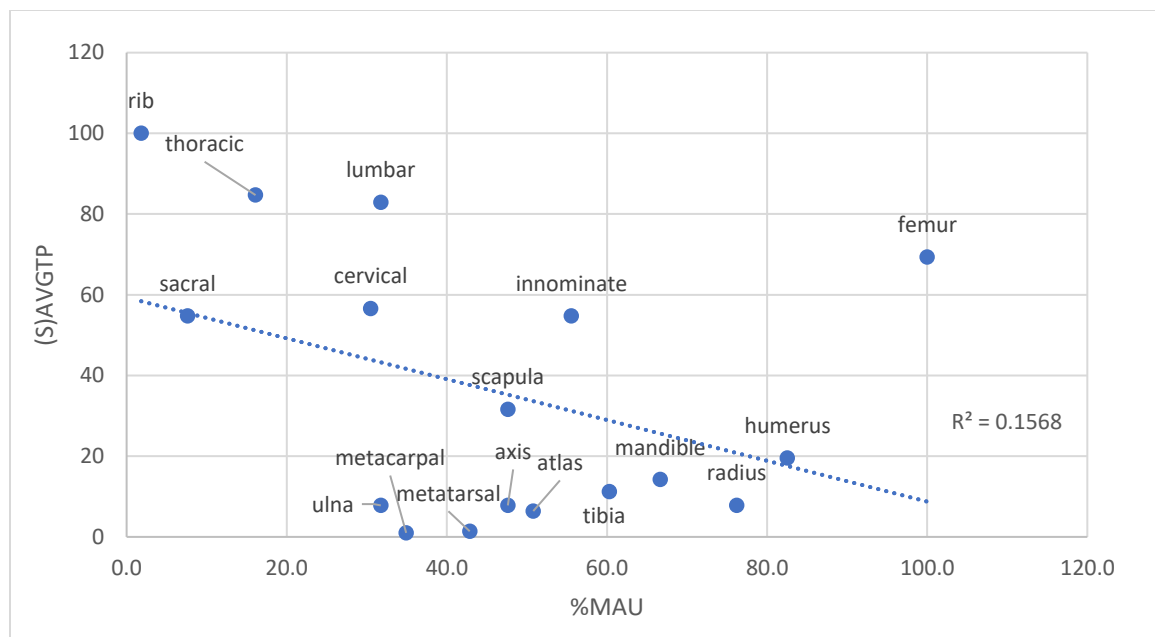
**Table 22.** Pearson correlations between bison %MAU and utility (Emerson 1993, 1996), Bone Bed 2.

Correlation	n elements	r	P
%MAU vs. Total Products Utility	32	0.038	0.837
%MAU vs. Total Products Utility <sup>a</sup>	17	-0.404	0.108
%MAU vs. Total Products Utility <sup>b</sup>	16	-0.649	0.007
%MAU vs. Protein Model	32	0.173	0.380
%MAU vs. Protein Model <sup>a</sup>	17	-0.234	0.366
%MAU vs. Protein Model <sup>b</sup>	16	-0.627	0.009
%MAU vs. Marrow Fat Model	27	0.683	0.000
%MAU vs. Marrow Fat Model <sup>c</sup>	12	0.771	0.003

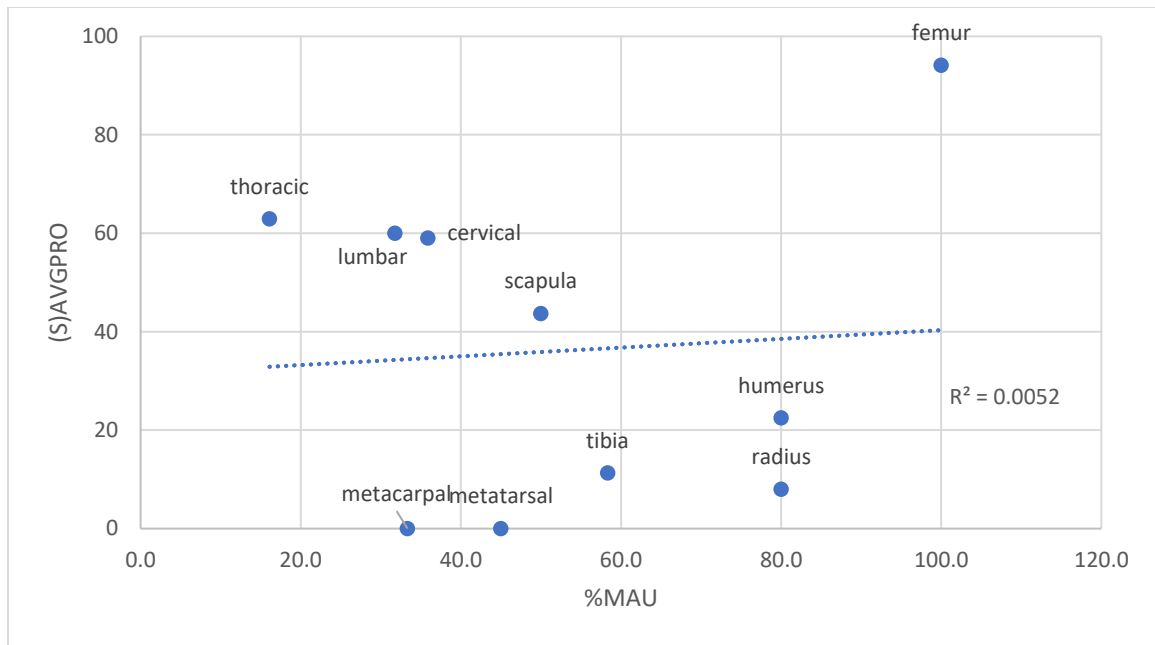
<sup>a</sup> only major limb elements

<sup>b</sup> only major limb elements excluding femurs

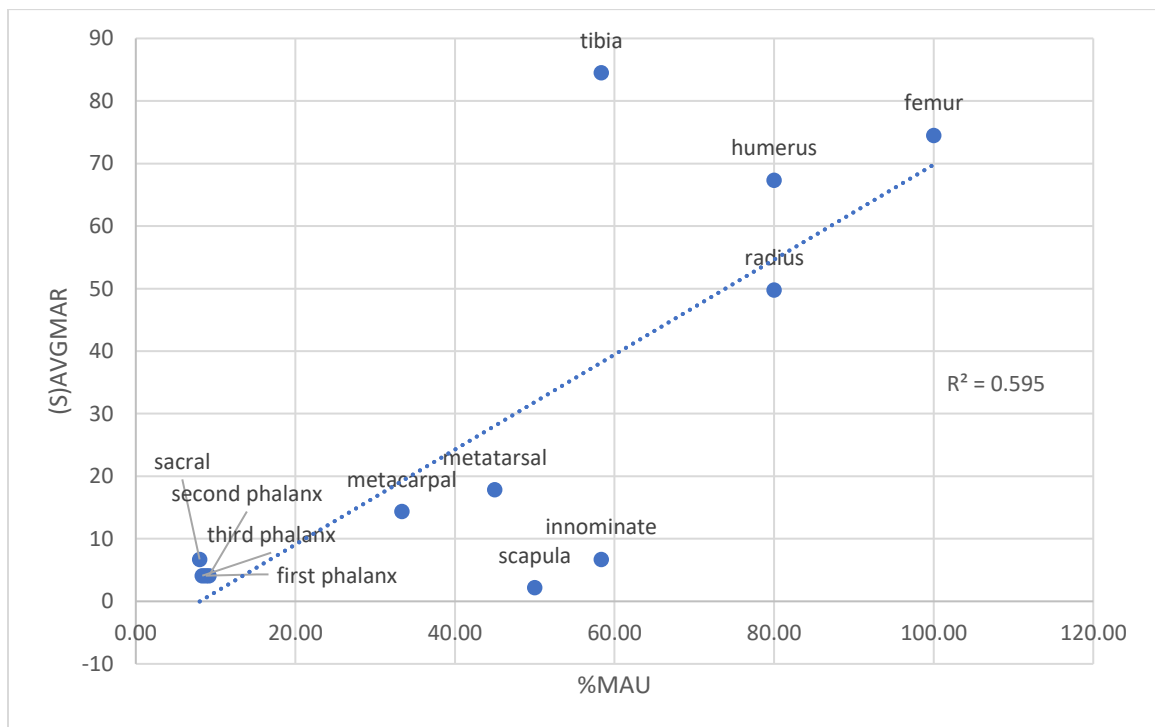
<sup>c</sup> only elements with marrow utility values greater than 0



**Figure 29.** Scatterplot of %MAU of bison skeletal elements (n = 17) against (S)AVGTP (Emerson 1993).



**Figure 30.** Scatterplot of %MAU of bison skeletal elements (n = 17) against (S)AVGPRO (Emerson 1993).



**Figure 31.** Scatterplot of %MAU of bison skeletal elements with marrow utility values greater than 0 against (S)AVGMAR (Emerson 1993).

The scatterplots of the correlations were then inspected in order to reveal any trends in the data that may have been missed. Inspection of both the Reduced Total Products scatterplot and the Reduced Protein Scatterplot revealed what appears to be a strong inverse correlation with a single outlier. For both of these scatterplots the outlier was the femur. In order to determine how strong these trends were, Pearson's correlations were run again but without the femur. The correlation between the reduced element abundance and Total Products was strong and significant ( $r = -0.649$ ,  $p = 0.007$ ,  $R^2 = .421$ ). The correlation between the reduced element abundance and Protein was also strong and significant ( $r = -0.627$ ,  $p = 0.009$ ,  $R^2 = 0.394$ ). This indicates that femurs occur within the site more than would be expected if the two previous correlations are valid. This could indicate that femurs were being brought into the site from outside the dripline.

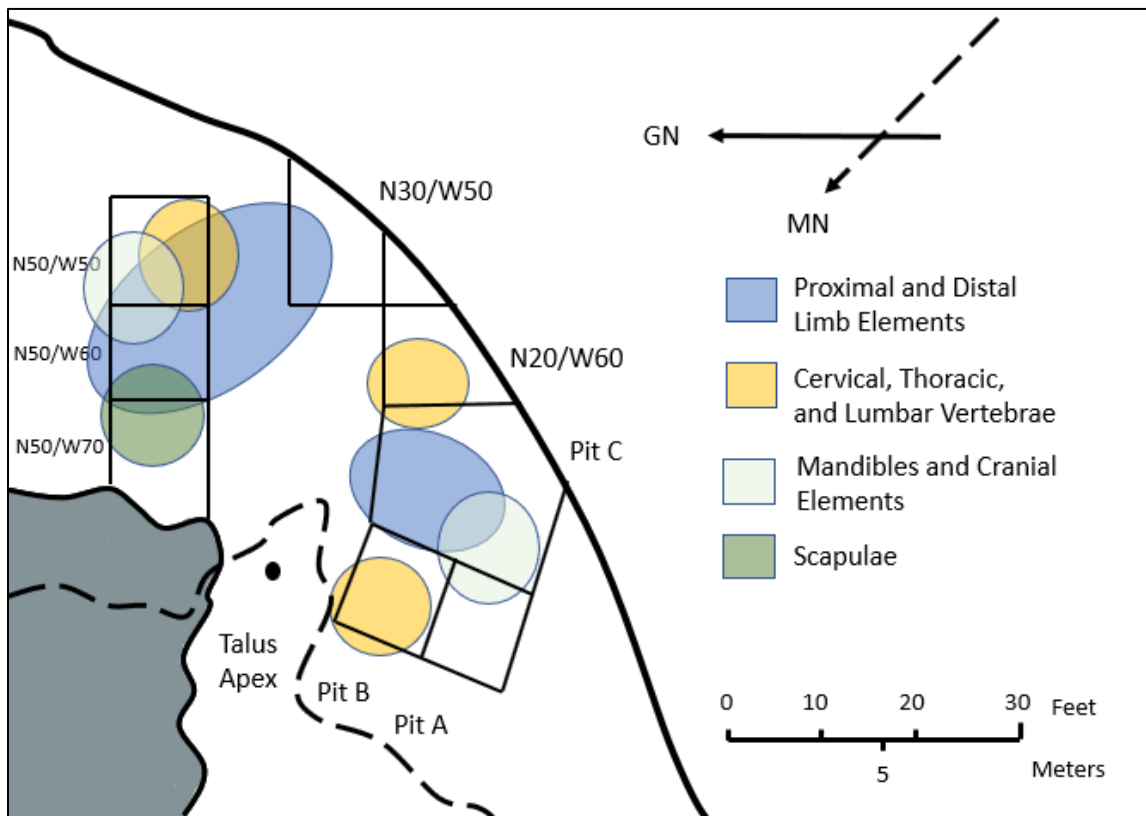
### **Intrasite Distribution**

To test the hypothesis that Bone Bed 2 represents a processing locus in addition to a kill locus, the distribution of elements was mapped throughout the site to determine whether these activities were spatially distinct. Processing loci should contain a greater abundance of meat-bearing elements (Sivertsen 1980) such as limb bones and cervical, thoracic, and lumbar vertebrae (Emerson 1993). Kill loci should contain a greater abundance of elements that contain little value as meat-yielding bones (Sivertsen 1980) such as crania, mandibles, and scapulae (Emerson 1993).

During the 1963-94 faunal analysis of Bone Bed 2, Lorrain (1968) noted that the bones within the assemblage appeared to be sorted in piles containing specific quarters and specific elements. She recorded that a concentration of partial skulls (identifiable by



the maxilla), mandibles, and atlas and axis vertebrae were uncovered near the rear of the shelter in Squares N50/W50 and N50/W60. A concentration containing the upper portion of the cranium and horn cores (MNE=4) was found in Pit C. A stack of scapula (MNE=7) was found in Square N60/W50 and likely represent a discard pile. Innominates and sacral vertebrae appear to concentrate in Squares N30/W50, N50/W50, and N50/W60. Lorrain argued that the distribution of skeletal units throughout the rockshelter represented a two-step butchering process in which primary disarticulation and secondary fileting occurred simultaneously in an assembly line fashion. The element frequencies from the present investigation were added to Lorrain's (1968) data and then the distribution of elements was remapped throughout the talus cone (Figure 32).



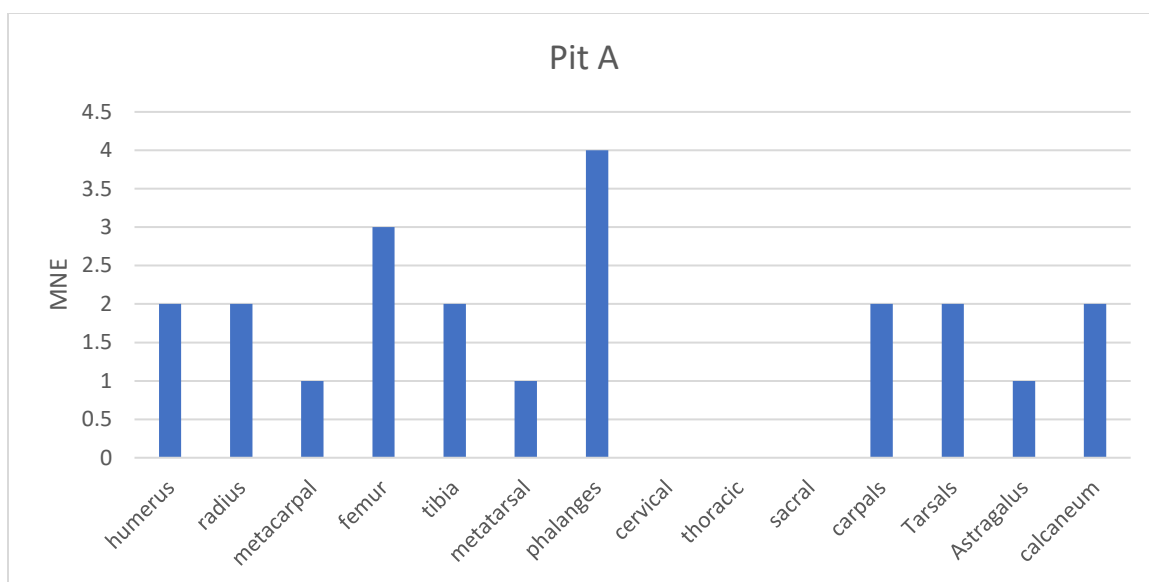
**Figure 32.** Map of element clusters identified in the units around the talus cone, Bone Bed 2, Bonfire Shelter.

Proximal and distal limb elements including carpals, tarsals, metapodials, and phalanges are concentrated in the same units (Squares N30/W50, N50/W50, N50/W60, and Pit C) suggesting that fore- and hind-limbs entered the rockshelter as fully articulated units. It is possible that the concentration of these elements in Pit C is a redeposition from the concentrations located in Squares N30/W50, N50/W50, and N50/W60. Cervical vertebrae are concentrated in the same units (Squares N50/W50 and N50/W60) in which Lorrain (1968) reported concentrations of mandibles and axis and atlas vertebrae. Thoracic vertebrae are concentrated in Square N20/W60 which is also where the highest concentration of rib fragments was found. Lumbar vertebrae are concentrated in Pit B. Innominates and sacral vertebrae are concentrated in Squares N30/W50 and N50/W50.

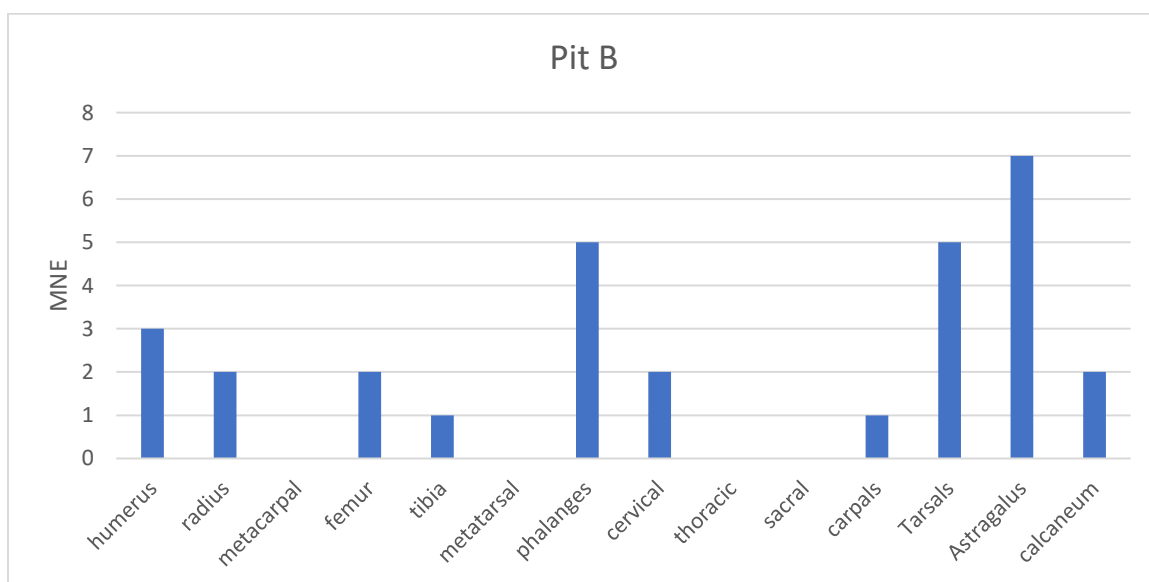
It is important to note that these concentrations of elements likely extend into the unexcavated portions of the talus cone. It is also possible that concentrations of other elements are located within the unexcavated portion of the talus cone. Although there is much overlap between concentrations of high utility and low utility elements, the concentrations are still relatively distinct and suggest that high utility elements such as limb bones and vertebrae were concentrated in the center of the talus cone while low utility elements were concentrated around the periphery of the talus cone. This could potentially represent unprocessed or lightly processed carcasses within the center of the talus cone and processed parts and discarded elements in the periphery. Other than the spoke-like distribution of long bones recorded by Bement (1986), no patterns of element distribution were discernable within the interior of the rockshelter.

The frequency of elements was recorded for each excavation unit around the talus cone (Figures 33-43). Within these units humeri and femurs are relatively equally

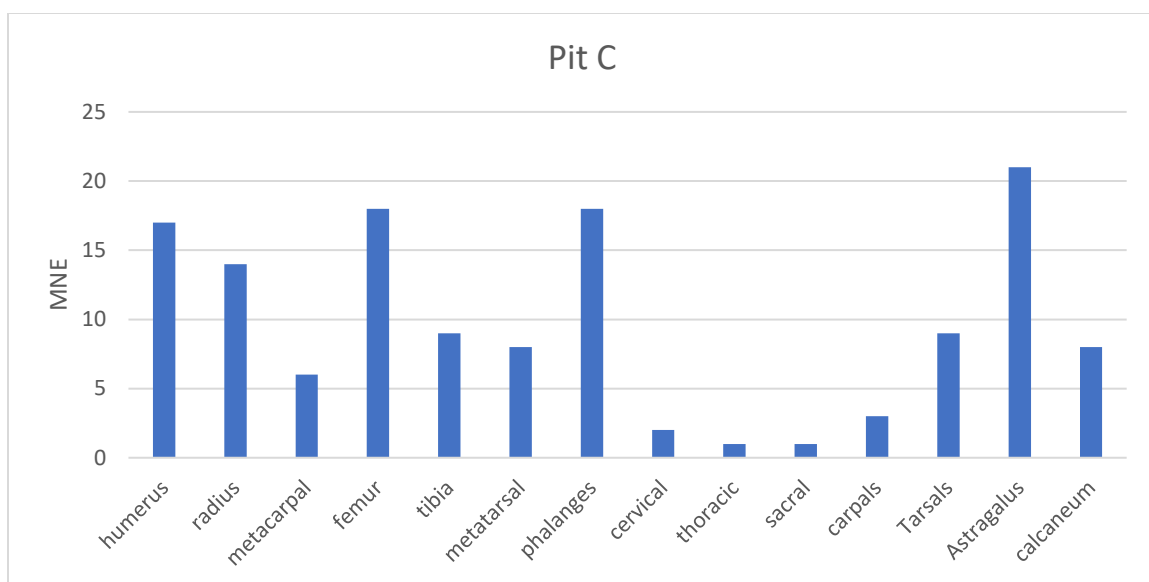
represented. (MNE = 55 and MNE = 58 respectively). Although they are less abundant than humeri and femurs, radii and tibias also occur with generally even frequency (MNE = 48 and MNE = 41 respectively). Humeri and fused radii/ulnae occurred with equal frequency and were concentrated in Pit C and Squares N30/W50, N50/W50, and N50/W60. Femurs and Tibias showed a similar distribution but did not occur with equal frequency. Of particular note is the fact that there were five fewer tibias than femurs in Square N20/W60 and seven fewer tibias than femurs in N30/W50. As expressed by Lorrain, this pattern of distribution could represent “the vagaries of preservation and random distribution” (Dibble and Lorrain 1964:96); however, it could also be the result of transport decisions. This distribution could indicate that more femurs than tibias were introduced into the rockshelter from outside the dripline and/or fewer femurs than tibias were removed from the site. Given the high amount of marrow housed in tibias, it is also possible that many tibias were destroyed to access the marrow cavity and were consequently harder to identify within the assemblage leading to an artificial underrepresentation. In times of nutritional deficiency, bison catabolize from proximal limb bones (humeri and femurs) before distal limb bones (tibias, radii/ulnas, and phalanges) (Brink 1997). If the Paleoindian hunters were removing/destroying tibias in higher frequency relative to proximal limb bones, this would suggest a late winter season of kill in which in body fat was largely depleted but still available in marrow. A late winter kill is also consistent with the lack of calves in the age profile.



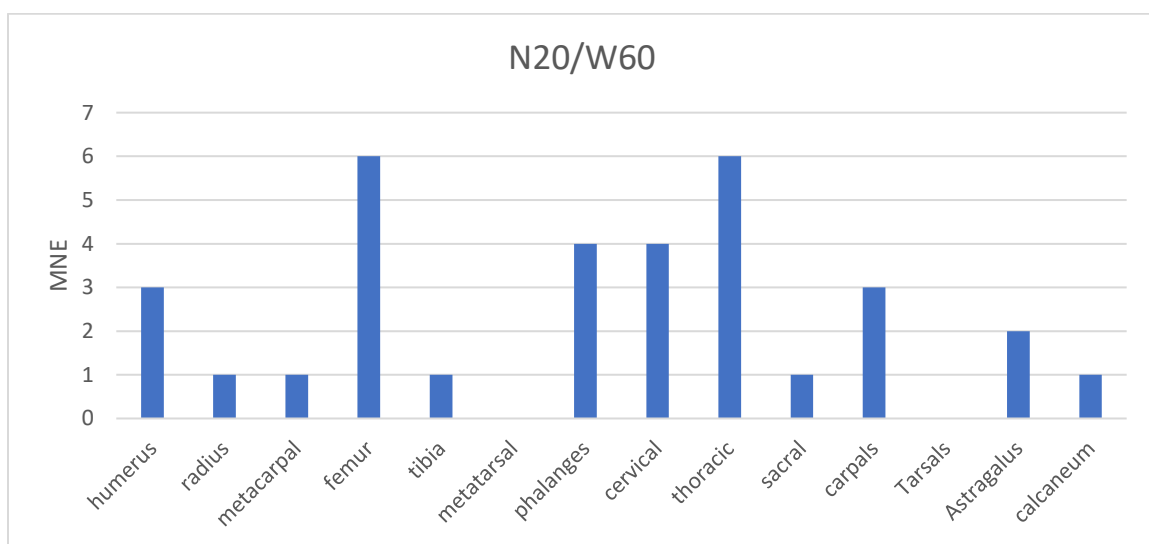
**Figure 33.** Skeletal element frequencies (MNE) for Pit A.



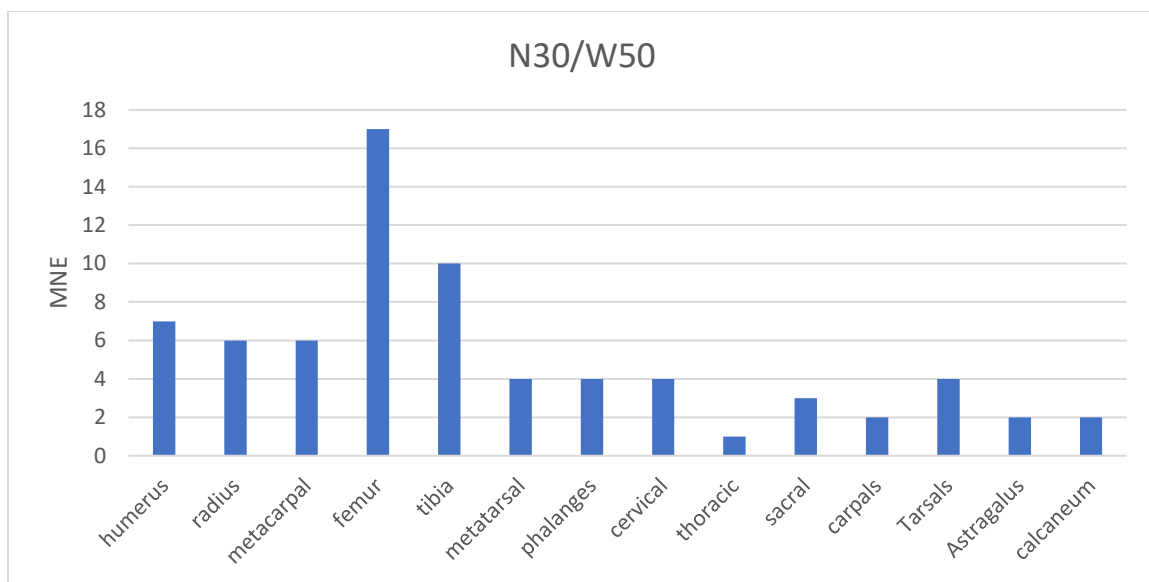
**Figure 34.** Skeletal element frequencies (MNE) for Pit B.



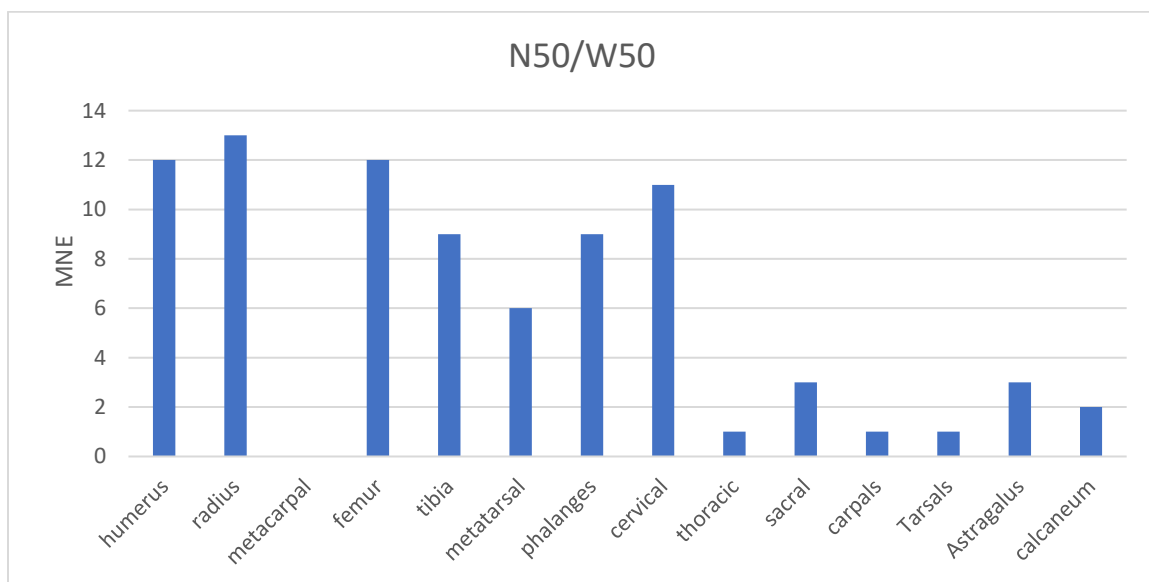
**Figure 35.** Skeletal element frequencies (MNE) for Pit C.



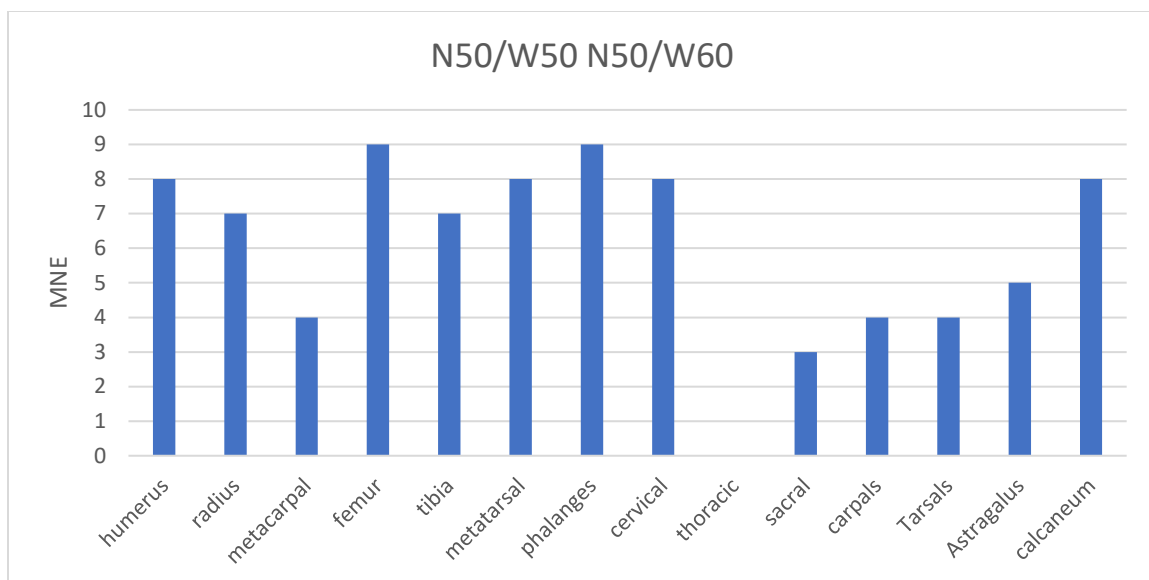
**Figure 36.** Skeletal element frequencies (MNE) for Square N20/W60.



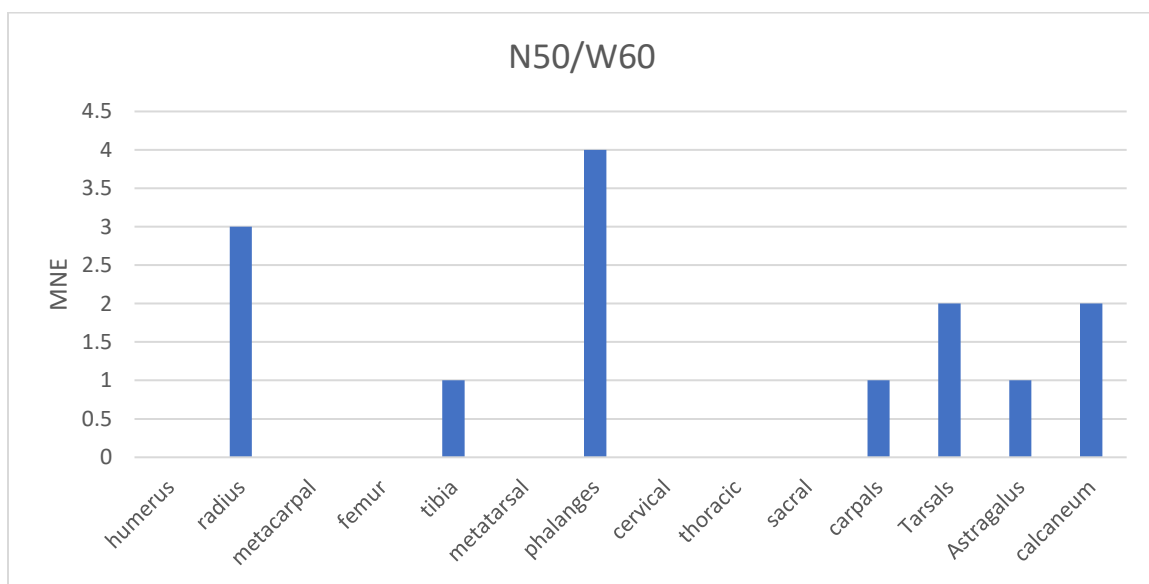
**Figure 37.** Skeletal element frequencies (MNE) for Square N30/W50.



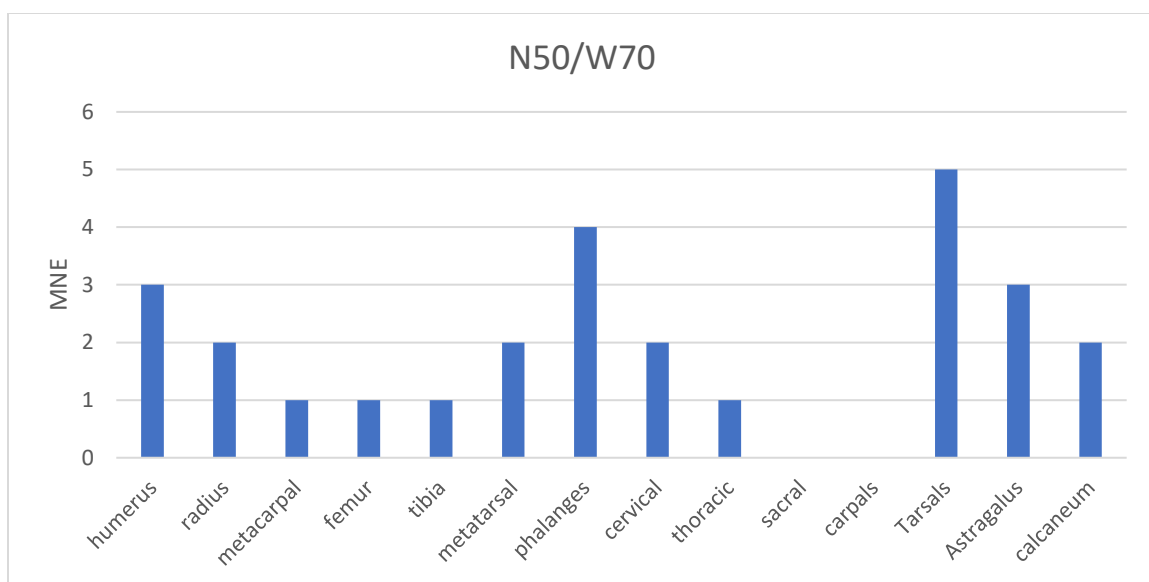
**Figure 38.** Skeletal element frequencies (MNE) for Square N50/W50.



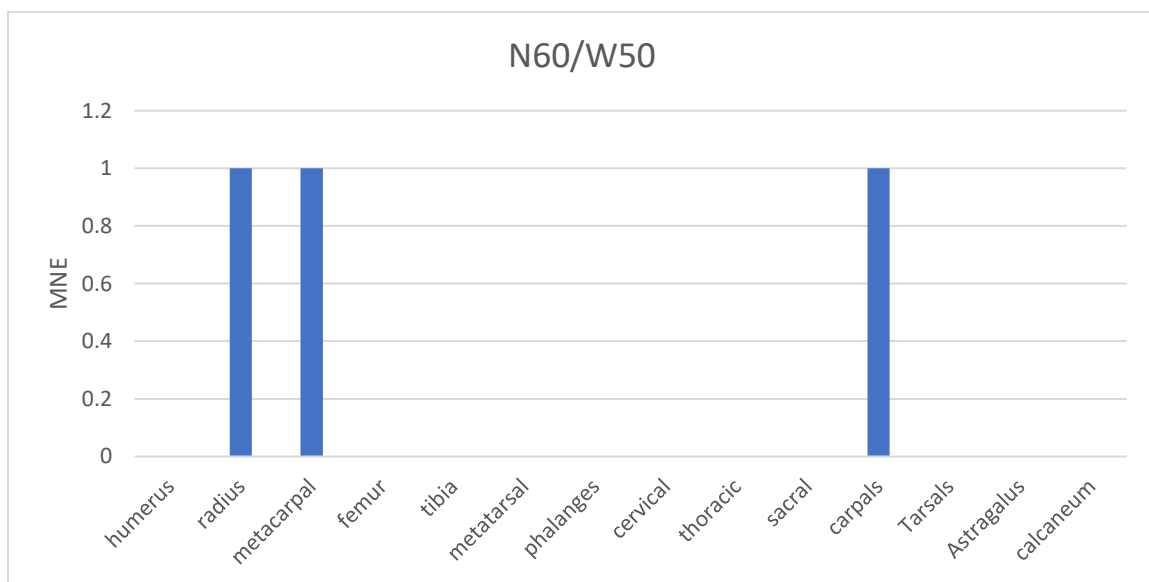
**Figure 39.** Skeletal element frequencies (MNE) for the combined Squares N50/W50 and N50/W60.



**Figure 40.** Skeletal element frequencies (MNE) for Square N50/W60.

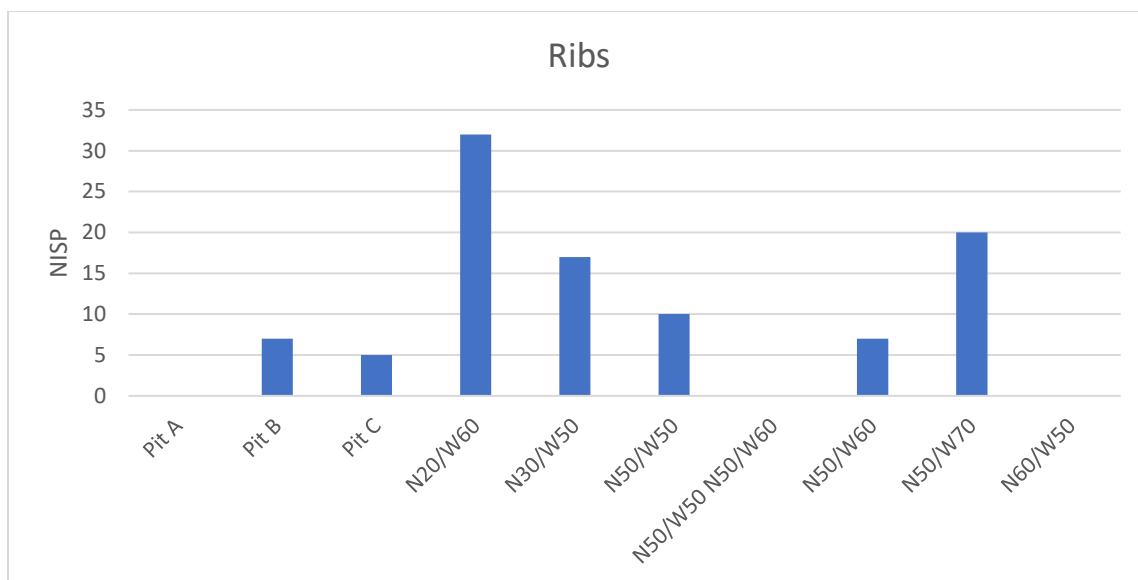


**Figure 41.** Skeletal element frequencies (MNE) for Square N50/W70.



**Figure 42.** Skeletal element frequencies (MNE) for Square N60/W50.





**Figure 43.** Specimen frequency of ribs (NISP) across the units surrounding the talus cone.

### Stratigraphic Boundaries

If Bone Bed 2 represents a single cultural event with three noncultural redepositions of bone evident in Pit C and Square N20/W60 then we would expect specimens to cross stratigraphic boundaries and be concentrated at the contact between strata for units other than Pit C and Square N20/W60.

Bement (1986:25) states that the majority of recorded bison specimens (92.2%, NISP = 47) were found in his strata B and C (equivalent to strata 20 and 21). Furthermore, he states that the specimens were concentrated at the contact between his strata B and C and that the larger bone fragments rested in the lower stratum and extended into the upper stratum (Bement 1986:25).

The data recorded during the present investigation mirrors Bement's (1986) observations. In the units where there were only two Bone Bed 2 strata present, the majority of elements were concentrated at the contact between strata. Similarly, for the interior only two specimens were recorded in stratum 19 (Bement's strata A) and the rest

(NISP = 14) were concentrated at the contact between strata 20 and 21 (Bement's strata B and C).

During the present investigation, fifty-eight specimens were recorded that crossed between stratigraphic boundaries from the interior and Squares N30/W50 and N50/W70 (Table 23). For the rest of the units around the talus cone, specimens that did not cross stratigraphic boundaries were concentrated at the contact between strata. The only units which showed clear separation between specimens were Pit C and Square N20/W60. This suggests that Bone Bed 2 represents a single cultural event that occurred after the formation of stratum 12 and before the deposition of stratum 11. This would indicate that stratum 14 remained exposed on the south side of the talus cone while strata 13 and 12 were formed on the north side of the talus cone. This also indicates that stratum 19, 20, and 21 in the interior are not equivalent to strata 11, 12, and 14 in the talus cone. Instead, strata 11 and 12 correspond to 20 and 21 with the few specimens from stratum 19 either representing slopewash from the talus cone or intrusions from strata 20 and 21.

**Table 23.** Number of specimens that overlap stratigraphic boundaries, Bone Bed 2.

Unit	Strata	Number of specimens that overlap strata
Interior	20/21	4
N30/W50	11/14	20
N50/W70	11/12	34

### Modification

Bone modification is an important factor in reconstructing the taphonomic history of a bonebed. In addition to weathering and carnivore modification which have already been discussed, taphonomic agents such as butchery, breakage, and burning were all recorded for the Bone Bed 2 fauna.

## Evidence for Butchery

If Bone Bed 2 represents solely a processing locale, we would expect a high frequency of butchering marks such as cutmarks and chopmarks. No specimens with cutmarks or chopmarks were identified during the current investigation. No extensive cleaning or handling of the specimens was possible during the current investigation suggesting that cutmarks and chopmarks may have been obscured by sediment or the surrounding profile. Six specimens from the original excavation were identified by Byerly et al. (2005) displaying cutmarks (Table 24). These specimens include two mandibles, a scapula, humerus, femur, and radius.

**Table 24.** Specimens displaying cutmarks identified by Byerly et al. (2005:615).

Element	NISP	MNE	BB2 MNE	%MNE
Mandible	2	2	42	4.8%
Scapula	1	1	30	3.3%
Humerus	1	1	52	1.9%
Radius	1	1	48	2.1%
Femur	1	1	63	1.6%

Several cutmarks (~14) were identified on the supraspinous fossa of the scapula near the glenoid fossa. The humerus displayed a cutmark on the lateral surface just above the olecranon fossa. The radius contained cutmarks at the neck near the proximal radioulnar joint. Cutmarks were also observed on the anterior portion of the head of the femur medial of the fossa. The mandibles were simply described as having “multiple cuts” (Byerly et al. 2005:616), the location of which were not published.

## Bone Breakage

Bone Breakage can reveal information about both cultural and non-cultural processes being carried out at the site (Lyman 1994a). Most commonly, green breakage is

used to determine whether intentional bone breakage was conducted at the site, such as marrow processing, meat removal, or if the bones experienced severe perimortem trauma. However, studies show that green breakage can also be produced by non-cultural means (Agenbroad 1989; Fisher 1995; Haynes 1983; A. Hill 1989). The presence of impact fractures in addition to green breaks is a much more accurate indicator of whether the breakage is related to cultural carcass processing activities. If Bone Bed 2 represents a jump drive, we would expect a high frequency of green breaks relative to percussion impact fractures. If Bone Bed 2 represents a different method of kill, we would expect green breaks to be largely cultural and therefore occur with relatively the same frequency as impact fractures.

Green bone breakage was relatively extensive across the site and occurred on axial elements, fore and hind long bones, and distal limb bones (Table 25). Seven specimens displaying green breaks were recorded in this present investigation: three ribs, one ulna, one innominate, and two tibias. All other breaks were dry breaks.

**Table 25.** Skeletal elements showing the number of individual specimens (NISP) and their respective reconstructed minimum number of elements (MNE) displaying green breaks (from Byerly et al. 2005:615, Table 4).

Element	NISP	MNE	BB2 MNE	%MNE
Mandible	3	2	26	7.70%
Thoracic	3	2	65	3.10%
Ribs	10	3	43	7.00%
Scapula	10	2	13	15.40%
Humerus	36	13	30	43.30%
Radius	28	9	26	34.60%
Ulna	5	2	18	11.10%
Radius/Ulna	33	11	44	25.00%
Metacarpal	7	3	18	16.70%
Innominate	4	4	16	25.00%
Femur	32	9	33	27.30%

**Table 25. Continued.** Skeletal elements showing the number of individual specimens (NISP) and their respective reconstructed minimum number of elements (MNE) displaying green breaks (from Byerly et al. 2005:615, Table 4).

Element	NISP	MNE	BB2 MNE	%MNE
Tibia	38	12	26	46.20%
Astragalus	4	3	33	9.10%
Calcaneum	1	1	19	5.30%
Metatarsal	13	5	14	35.70%
First Phalanx	1	1	68	1.50%
Second Phalanx	2	2	72	2.80%
Total	230	84	564	14.90%

Byerly et al. (2005) recorded the number of individual specimens displaying green breaks (n = 197) and the minimum number of elements represented by those specimens (MNE = 84). Byerly et al. did not record what portion of the bone these specimens came from therefore it was impossible to combine the NISP values from the current investigation with his and produce meaningful MNE values. Given the very low number of green breaks recorded relative to the previous investigations, this should not seriously affect the results or the interpretation of the site.

The element with the highest frequency of green breaks was the tibia with 46.2% of all tibias displaying green breaks. The next highest were the humerus (43.3%), metatarsal (35.7%), radius (34.6%), and femur (27.3%).

No specimens were recorded during the present investigation that displayed impact fractures. Byerly et al. (2005) recorded impact marks on humeri, radii, femurs, tibias, and metatarsals (Table 26). However, there were significantly fewer impact fractures relative to green breaks. In other words, direct impacts (either cultural or

natural) do not appear to be sufficient to explain the amount of green breaking exhibited by the fauna. It is probable that these green breaks were sustained through a fall.

**Table 26.** Skeletal elements showing the number of individual specimens (NISP) and their respective reconstructed minimum number of elements (MNE) displaying impact fractures (from Byerly et al. 2005).

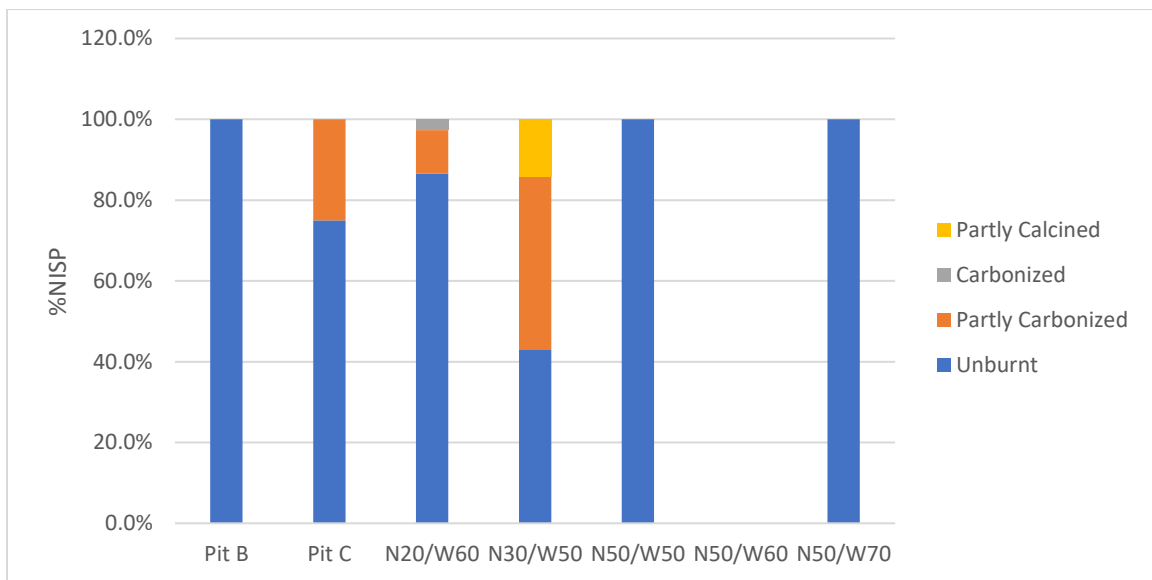
Element	NISP	MNE	BB 2 MNE	%MNE	BB 2 NISP	%NISP
Humerus	3	3	52	5.8%	131	2.3%
Radius	2	2	48	4.2%	112	1.8%
Femur	4	3	63	4.8%	183	2.2%
Tibia	5	3	38	7.9%	122	4.1%
Metatarsal	2	2	27	7.4%	40	5.0%

## Burning

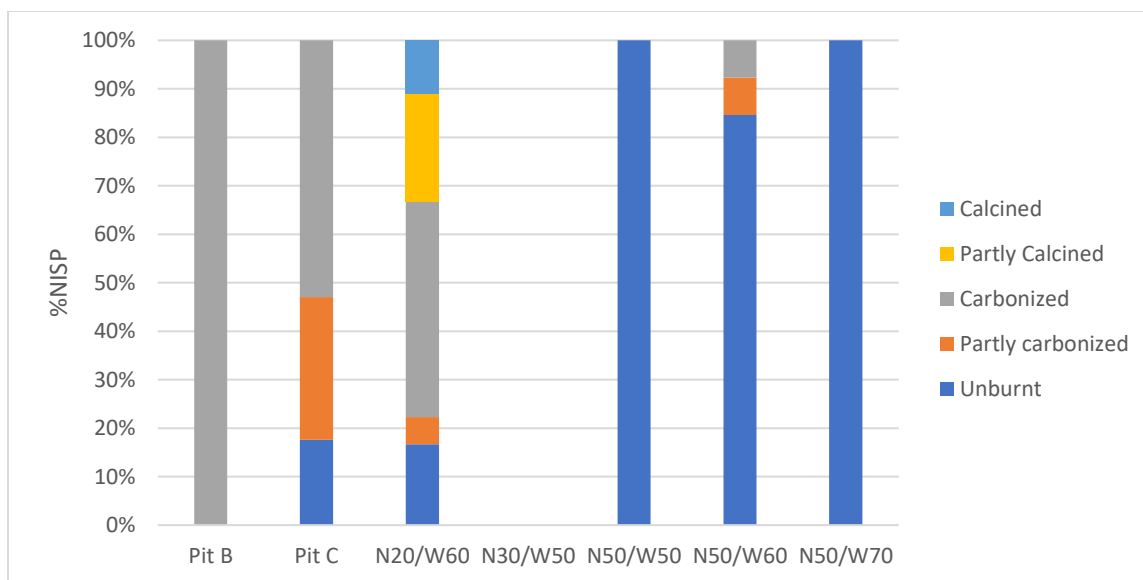
Bone Bed 2 has been observed to represent up to three layers of bones primarily distinguishable by the fact that the middle layer is burned. Three layers are discernable in the north wall of Square N20/W60 and parts of the north wall of Pit C; however, most units contain at most two layers of bone (Dibble and Lorrain 1968:29-30). Dibble notes that in sections of the site where burning was absent, the layers of Bone Bed 2 "were sandwiched together to form essentially a single stratum" (Dibble and Lorrain 1965:29). Byerly et al. (2005) argue that the perceived separation of Bone Bed 2 resulted from three pulses of slope-washed bone washing from the top of the talus cone down to the lower slopes with a burning event happening in between the last two pulses.

To further understand the nature of the burning event at Bonebed 2, all specimens were inspected for signs of burning (Figures 44-46). Burnt specimens appear to cluster near Squares N20/W60 and Pit B in Strata 12b and 12 respectively. There is a slightly lower concentration of burnt bone in the adjacent units, Square N30/W50 and Pit C.

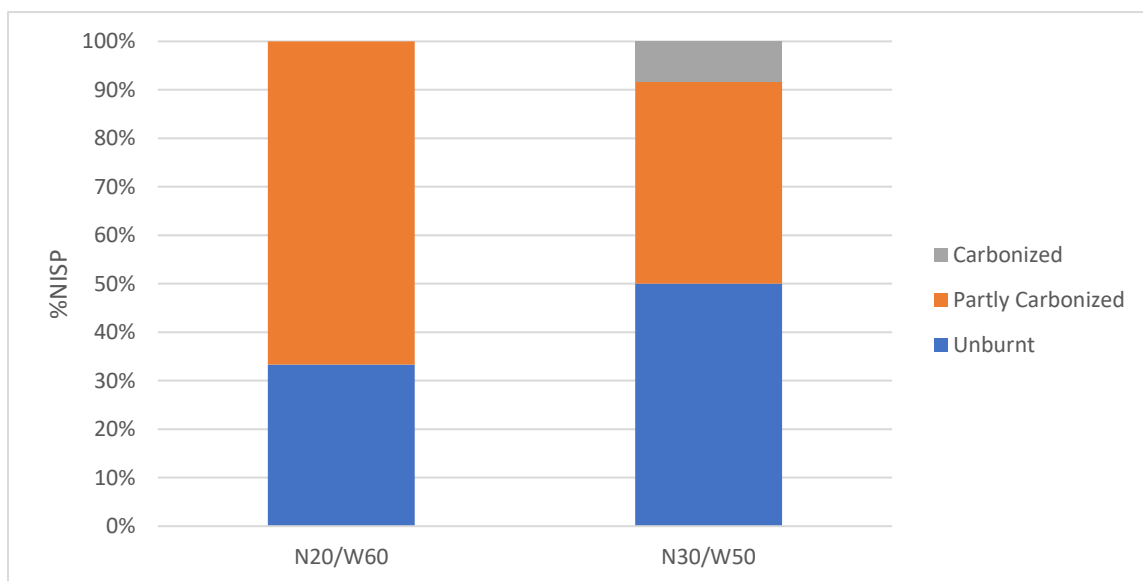
There was virtually no burnt bone in the units on the north side of the talus cone (Squares N50/W50, N50/W60, or N50/W70) with a single partly carbonized element and a single carbonized element found in Square N50/W60 from stratum 12. No burnt bones were identified in the interior of Bonfire Shelter. This data suggests that at least two burn events occurred at roughly the same time however they were not widespread and were localized in the rear and mouth of the rockshelter near Square N20/W60 and Pit B respectively.



**Figure 44.** Relative frequency of specimens (%NISP) from stratum 11 displaying evidence of burning.



**Figure 45.** Relative frequency of specimens (%NISP) from stratum 12 displaying evidence of burning.



**Figure 46.** Relative frequency of specimens (%NISP) from stratum 14 displaying evidence of burning.

Dibble and Lorrain (1968:30-33) recorded the presence of a hearth in the southwest quadrant of Square N20/W60. The hearth was located at the level of Component C (stratum 11) but also underneath the unburnt bones of Component C. The



hearth was described as an irregular circle with a diameter of 2 feet and a thickness of 2 centimeters. The hearth itself was unlined and composed of fire scorched earth, ash, and lump charcoal. No artifacts were associated with the hearth and no photographs or drawings were made of it. Even though it occurs in the same area as the proposed burning event, it is not likely that this hearth was responsible for the burning present in stratum 12 as the hearth was described as being stratigraphically distinct from stratum 12 (Dibble's Component B).

## VII. SUMMARY

The Bone Bed 2 bison remains excavated and recorded at Bonfire Shelter are consistent in size and morphology with the previous designation of *B. antiquus* (Lorrain 1968:109-130; Byerly et al. 2005) and reveal an age ratio suggestive of a nursery herd. The present analysis increased the minimum number of individuals from 27 (Lorrain) or 24 (Byerly et al.) to 32 based on femurs. Tentative seasonality data suggests the bison were most likely killed sometime in late winter before the calving season in spring.

The survivorship of the Bone Bed 2 faunal assemblage does not appear to have been significantly affected by bone density or alluvial action; however, the orientation of bones from around the talus cone suggest that water was at least partly responsible for redistributing skeletal elements around Squares N50/W70, N20/W60, and Pit C. The underrepresentation of certain elements noted by Byerly was likely influenced by field discard (Byerly et al. 2005:613). The original excavation was reported to have at some point stopped screening and discarded difficult to identify elements (Dibble and Lorrain 1968:19).

The updated herd composition suggests that the herd represents a nursery herd with a predominance of adult cows of all ages and offspring under the age of 3. The overall ages profile indicates a total lack of calves or fetal bison, a predominance of 1 to 2-year-old bison, and a relatively even distribution of bison older than 2 years. Given the lack of calf or fetal bison remains, no determination of seasonality was able to be made based on tooth eruptions. Although previous investigations into Bone Bed 2 have attempted to determine seasonality based on tooth wear, studies have shown that tooth wear is highly variable depending on individual health and diet. A tentative late

winter/early spring season of death is proposed based on the age composition. A herd killed after the rutting season (July through August) but sometime before the calving season (April through May) would likely have a predominance of 1 to 2-year-olds as infant mortality continued to reduce the number of calves. Furthermore, calves would be morphologically very similar to yearlings. A later winter season of death would also explain the lack of fetal remains as fetal skeletal material would not be sufficiently developed at this time to preserve in the deposit. Comparisons with other Paleoindian bison kill sites with well documented age profiles also supports the likelihood of a late winter season of death. Though large-scale bison kills associated with Clovis and Folsom typically occurred during late summer/early fall (Bement 1999, 2003; Bement and Carter 2010; Carlson and Bement 2013), large-scale bison kills during the middle to late Paleoindian Period are dominated by late winter/spring kills (Carlson and Bement 2017:143).

The age profile is consistent with the expectations for a single herd and does not contradict the hypothesis that Bone Bed 2 represents a single kill event. Although no new data was collected that could contribute to the sex composition of the fauna, a nursery herd is consistent with the interpretation by Byerly et al. (2005) of a herd composed primarily of females. In addition to the age profile of the assemblage, the MNI estimate of the herd from which the Bone Bed 2 fauna is derived is consistent with other Paleoindian mass bison kills which took advantage of entire herds (Todd et al. 1992:137).

The MNI of 32 is a conservative estimate of a sample of the entire site, meaning the true number of bison represented in the assemblage is almost certainly higher. Binford (1983:124), in describing a Nunamiut caribou kill, claimed that although 111

caribou were killed, analysis of the butchered bones after the kill yielded an MNI of 54. Binford's calculation of MNI utilized all the bones from the butchering site and did not need to account for the effects of weathering or other time dependent agents that would cause significant skeletal element underrepresentation. The fauna from Bone Bed 2 represents a very old and fragmentary sample of an assemblage which almost certainly extended outside of the rockshelter past and below the dripline (Dibble and Lorrain 1968:29). Given these additional factors, it is likely that the true number of bison involved in the events that produced Bone Bed 2 is more than twice the calculated MNI. Although the original estimate proposed by Dibble of 120 seems overly liberal in light of the current understanding of the assemblage, a total assemblage composed of perhaps 60 to 90 individuals seems more appropriate. This number is similar to late Pleistocene/early Holocene bison herd estimates (Wheat et al. 1972; Wyckoff and Dalquest 1997; Guthrie 1980a) suggesting a large-scale kill method capable of dispatching an entire herd.

Byerly et al. (2005; 2007a; Byerly et al. 2007b) argued that Bone Bed 2 represents the remains of a single kill event with the observed stratification being the result of noncultural redeposition of bone-bearing sediment. No data from this present analysis contradicts this hypothesis. The burnt stratum (stratum 12) is only found on the south side of the talus cone. The overlying stratum (stratum 11) contains almost no burnt bone while the underlying stratum (stratum 14) contains bones burnt to a lesser degree than stratum 12. This stratigraphic pattern of burning could be produced by a small burning event localized to the south side of the talus cone that occurred before the formation of stratum 11, but after the formation of strata 12 and 14. The burning would have blackened and

carbonized the bones of stratum 12 and heated the underlying bones of Stratum 14. Stratum 11 would have been largely untouched by this event.

The three strata of Bone Bed 2 (strata 11, 12, and 14) in Square N20/W60 and Pit C display differential rates of weathering suggesting a high degree of mixing. Stratum 14 contains several specimens that are more weathered than specimens from strata 11 or 12 and appears to be highly mixed. Stratum 12 is more consistent across the site but is slightly less weathered in in Pit B and Square N20/W60. Stratum 11, similarly, is consistently weathered across the site except for Pits B and C and Square N20/W60, which appear to be mixed with highly weathered specimens. Although this mixing can be explained by differential rates of sediment deposition, the hypothesis by Byerly et al. (2005) that the multiple strata of Bone Bed 2 evident in Pit C and Square N20/W60 resulted from non-cultural taphonomic processes, cannot be rejected.

The three Bone Bed 2 strata in the interior of Bonfire Shelter (strata 19, 20, and 21) display individually unique weathering patterns with weathering decreasing in relationship to increasing depth. Although this is consistent with what would be expected in a single depositional event with a slow rate of sediment deposition, further geoarchaeological analysis of the individual Bone Bed 2 strata will be required to conclusively determine the nature of the depositional events.

Bone Bed 2 displays virtually no non-human carnivore activity of any kind. Lorraine documented no cases of carnivore activity and Byerly recorded a single potential tooth mark. Though less extensive, the data collected during this present investigation recorded no additional carnivore activity. Although it is not uncommon for faunal assemblages to lack evidence of larger carnivore activity, the total lack of any

rodent gnawing is unprecedented (Johnson 1985). In order to prevent rodents from modifying the bones in any way, the assemblage must have been quickly covered by sediment, no more than a few days or potentially weeks after the deposition of the bones. The notch of the talus cone has been observed to act as a funnel gathering runoff from the canyon the rim and channeling it directly above the talus cone. This phenomenon creates an increased sedimentation rate and is responsible for the creation of the talus cone. It is possible that a significant weather event occurred shortly after the deposition of Bone Bed 2 and funneled large amounts of sediment directly into the rockshelter. It is also possible that, if Bone Bed 2 was formed through a jump drive, the stampede destabilized the sediments on the rim, making them easily eroded and redeposited through the talus cone.

The element frequencies from Bone Bed 2 most closely match a processing locale at or near a kill locale. Research has shown that for Paleoindian kills that involve a large number of animals, individual processing locales will usually bud off from the center of the kill (Wheat, Malde, and Leopold 1972; Borresen 2002; Byers 2002; Bement and Carter 2010). Bone Bed 2 compares favorably with the “processing pile” documented at Jake Bluff (Bement and Carter 2010) where nearly equal amounts of front- and hind-limb elements were recorded with relatively few axial elements. The skeletal elements recorded from this processing pile also show only minimal amounts of processing. It is important to note that the majority of the talus cone remains unexcavated and that the sample from Bone Bed 2 is primarily from areas adjacent to the talus cone. If a primary kill occurred near the center of the talus cone or past the dripline, then the actual kill locus is mostly unexcavated.

With regard to all documented skeletal elements, Bone Bed 2 contains and abundance of both certain low utility elements that would be expected at a kill locale, as well as certain high utility elements that would be expected to be removed from a kill locale. Most notably, when elements that are likely to be misidentified or discarded in the field are excluded, the Bone Bed 2 faunal assemblage contains low frequencies of certain high utility elements and high frequencies of other specific high and low utility elements. This may be a result of only butchering a partial amount of the animals and removing certain choice parts.

Strong inverse correlations exist between ratio MAU and total product utility and meat utility only when femurs are excluded. This is interpreted to be a result of the use of Bonfire Shelter as both a kill and processing site. Additional high meat bearing elements such as femurs were likely brought into the shelter from the portion of the site that extended outside the dripline. The high frequency of both low utility and high utility elements (e.g., femurs) indicates that Bone Bed 2 represents the remains of a processing site at or very near the kill site. Although considered high utility, femurs are difficult to remove from the carcass and will often be depleted of marrow by late winter. For these reasons, the femurs were likely left at the site while other high utility elements such as ribs, cervical, and thoracic vertebra were removed from the site.

The Pearson's correlations show a strong correlation between element frequency and marrow utility. Historical accounts show marrow was often consumed as a snack during the butchering of bison (Dodge 1882:273). Although light processing for marrow was likely occurring at Bonfire Shelter, the scarcity of impact fractures indicates marrow processing was not extensive. Rather than representing marrow-based transport decisions,

the strong correlation between element frequency and marrow utility is interpreted as representing an abundance of proximal limb elements relative to distal limb and axial elements. This is likely a result of the butchering process, described by Lorrain (1968:108) as a two-part process, in which limb bones were disarticulated at a nearby kill locale then placed within the rockshelter to await further processing and ultimately transport to a camp or residential site.

No bone modification indicative of butchering activities (cutmarks, chopmarks, or impact fractures) were recorded in the unit profiles during this investigation; however, since the bones were left in the profiles and were not able to be thoroughly cleaned, marks associated with butchering activities may have been obscured. Very few butchering marks were recorded by Byerly et al. (2005). Cutmarks were only recorded on six specimens (MNE = 6) from five element groups and they were only recorded at or near joints. This is consistent with the interpretation that the bones were being disarticulated and stored within the rockshelter, but not extensively processed. Impact fractures were only recorded on sixteen specimens (MNE = 13) from five element groups. Again, this is consistent with non-intensive processing. Green breaks were recorded on 238 specimens (MNE = ~84) across sixteen element groups. There is a marked inconsistency between impact fractures and green breaks both in terms of frequency and number of affected element groups. Although green breaks are often interpreted as resulting from marrow processing, studies have shown that this is not always the case (Agenbroad 1989; Fisher 1995; Haynes 1983; A. Hill 1989). Impact fractures and anvil marks are a more conclusive sign of direct human modification. To complicate matters, evidence of butchery (specifically impact fractures and green breaks)



are often not recorded across Paleoindian assemblages (Todd 1987a; 1991; M. G. Hill 2001), making comparisons across sites challenging and difficult to interpret. In general, given the very low frequency of impact fractures relative to the frequency of green breaks, a different fracture agent is likely responsible for the high degree of green breakage. Here it is argued that fall damage is the most parsimonious explanation for the observed green breakage.

Though not morphologically identical, African wildebeest provide a useful proxy for comparison with prehistoric bison. When forced over steep, several-meter-high riverbanks during seasonal migration, wildebeest will contort their bodies and extend their legs in order to land on their feet either in the water or against the base of the riverbank (Preston 2014; Subalusky et al. 2017). This suggests that it is likely that bison falling from a great height also would land on their feet, thus explaining the prevalence of long bone and metapodial green breaks exhibited by the Bone Bed 2 fauna.

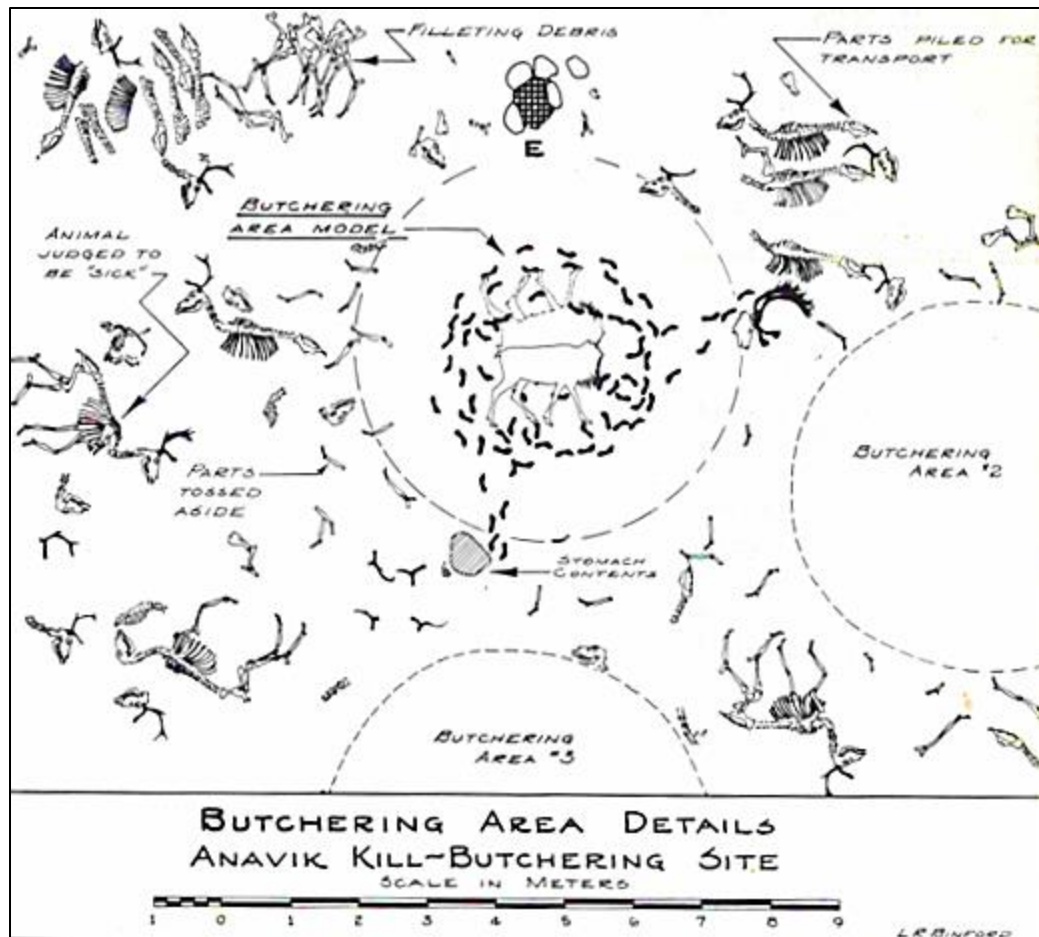
## VIII. DISCUSSION

Interpreting the nature of the events that deposited Bone Bed 2 at Bonfire Shelter is difficult due to the fact that the excavated remains were recovered from only a sample portion of what is interpreted as being a much more extensive site that would have potentially extended into the floor of the canyon (Black 2001c). Nonetheless, the skeletal element profile and utility profile indicate that Bone Bed 2 most closely resembles a processed kill site.

Ethnoarchaeological research carried about by Binford (1983) among the Nunamiut at Anavik Springs documented the manner in which hunters processed a caribou mass kill and how those remains were distributed across the immediate landscape. Although the Nunamiut being studied had been influenced by modern technology, Binford argues that the rich and detailed site data that can be collected from their activities serves as a useful proxy for interpreting prehistoric hunter-gatherer sites, especially ones in which large number of animals were killed. With regards to the kill-processing site, Binford noted that after the caribou were killed, the carcasses were dragged a short distance to be butchered. Binford referred to this as initial or primary field butchering which was conducted in order to break down the carcass into smaller units and facilitate transport away from the kill site (Binford 1978b:48). This is differentiated from secondary field butchering which took place at meat caches (Binford 1978b:48). The primary field butchering site at Anavik Springs included discrete piles composed of disarticulated fore- and hind-limbs for fileting, and other piles that contained large, difficult-to-process food packages such as ribs and vertebral sequences. Because the elements from the latter piles are difficult to process, they were stacked to be

prepared for transport to either a residential camp or a cache. Although it has been suggested as a survival strategy performed by Paleoindians (Frison 1982), no conclusive evidence for Folsom or Plainview meat caching has been identified.

The nature of the Nunamiut's initial field butchering process resulted in a site with large empty spaces where skinning, disemboweling, and disarticulation occurred surrounded by a ring of low utility elements discarded by the butchers (Figure 47). Surrounding this ring were discrete clusters of long bones and other high utility elements. Hearths were usually located at the boundaries between these butchering, fileting, and transport piles to maximize the amount of people who would benefit from the warmth. Although the finer details are missing from the Paleoindian archaeological record, this method of processing large numbers of animals is very similar to what has been interpreted as occurring at Paleoindian sites such as the Frazier site (Borresen 2002), the Olsen-Chubbuck site (Wheat et al. 1972), and Jake Bluff (Bement and Carter 2010). Specifically, since prehistoric bison carcasses would have been too massive to be dragged any significant distance, initial field processing must have occurred at the kill site itself with filet and transport piles located at the periphery.



**Figure 47.** "Close up of the butchering area at the Anavik Springs site [Alaska] showing the circular areas in which the caribou were dismembered and the location of the waste by-products" (Binford 1983: Figure 61).

In all regards, Bone Bed 2 most closely resembles a kill with onsite processing. This matches Binford's (1978b) description of a primary field butchering site in which animals were disarticulated and minimally processed at the kill to prepare them for transport. In terms of other site classification schemes, Bone Bed 2 resembles what Sivertsen (1980) referred to as a Class III Site (Butchery/Special Processing Locus), an argument she herself makes. To further classify the site, Bone Bed 2 most closely resembles what Binford (1978b:60-61) refers to as a piece-butchered kill in which, due to

certain constraints, the animals were butchered but not fully transported away. In the case of Bone Bed 2, the most likely constraint causing the under-utilization of the carcasses was simply the vast number of bison involved in the kill and the time needed to process the carcasses before they began to putrefy.

Determining the method of kill that produced the carcasses from Bone Bed 2 is a more challenging undertaking. As previously discussed, the bison from Bone Bed 2 were either killed by being driven into an arroyo in the canyon floor or by being driven over the edge of the canyon. There is no ‘smoking gun’ with regards to either of these forms of procurement. Bone breakage data is difficult to compare across sites and may be obscured by marrow utilization. Projectile points were recovered from amongst the bones; however, projectile points may have been used as butchering tools or to dispatch bison that were only wounded from the fall. The strongest indicator of procurement method is the morphology of Eagle Nest Canyon. Of particular note is the fact that Eagle Nest Canyon does not conform to the typical expression of an arroyo trap. Typically, arroyos used by Paleoindians for bison procurement have been reconstructed as simply slowing down the bison to allow hunters to spear them while they are panicked and disadvantaged (Frison 1991a). Although the dimensions of arroyos are not often recorded, Eagle Nest Canyon is much deeper than other documented arroyo traps (Table 27) such as the Cooper site (Bement and Carter 1999:48), Jake Bluff (Bement and Carter 2010:912), the Folsom site (Meltzer et al. 2002:13), Rex Rodgers (Speer 1978:Fig. 13.2), the Carter/Kerr-McGee site (Frison 1984:290), and the Agate Basin (Hill 2001:43). Even if the floor of Eagle Nest Canyon were at the level of Bonfire Shelter (see Dibble and Lorrain 1968:69; Bement 1986:2; Byerly et al. 2005:624; 2007a) the rim of the canyon

would still be ~26 meters above the base of the canyon (Byerly et al. 2005:598).

Additionally, at its narrowest, the rim-to-rim width of Eagle Nest around Bonfire Shelter is ~50 meters wide with the majority of the canyon rim being much wider (Byerly et al. 2005:598). This would put hunters at a significant distance from the bison and decrease the likelihood of making a kill by spear or dart. It is also considered unlikely that a group of hunters in this type of scenario would be able to kill a minimum of 32 bison when they themselves were so distant and disadvantaged. The alternative is that the bison were driven over the rim of canyon and died or became incapacitated upon impact. The presence of projectile points can be explained by hunters dispatching the incapacitated bison or using the projectile points as knives during butchering.

**Table 27.** Selected Paleoindian arroyo bison kills and the reconstructed maximum depth of the arroyos.

Site	Arroyo Depth (meters)
Jake Bluff	1.5
Rex Rodgers	2.5
Cooper	5
Agate Basin	7.6
Folsom	10
Carter/Kerr-McGee	12
Bonfire Shelter	26 <sup>a</sup>

<sup>a</sup> minimum

Although there are no widely accepted cases of Paleoindians utilizing this exact form of procurement, the strategy of herding bison over the edge of a natural landscape feature has been identified at Olsen-Chubbuck (Wheat et al. 1972) and has been suggested for Lipscomb (Hofman et al. 1989; Todd et al. 1992), the Plainview site (Sellards et al. 1947; Johnson and Holliday 1980), the Folsom component of Agate Basin (Frison and Stanford 1982), and the Mill Iron site (Frison 1996). Based on the extreme

depth of the canyon, the clustering of high utility elements with random distribution of low utility elements, the high frequency of green breaks, low frequency of impact fractures, and the high frequency of both high and low utility elements, the Bone Bed 2 assemblage is most consistent with the expectations for a bison jump drive.

### **Conclusion**

The Bonfire Shelter Bone Bed 2 fauna exhibits the characteristics that would be expected from a single cultural event with several episodes of local redeposition (Table 5). The age profile matches the expectations for a single bison herd. The separation of bones into more than one stratum is only strongly evident in two excavation units (Pit C and Square N20/W60) both of which had many specimens extending across multiple strata. The presence of a burnt stratum separating an upper and lower bone bearing stratum was only evident in Pit C and Square N20/W60. Weathering was relatively consistent across strata except for specimens recorded from units of the south side of the talus cone, which were generally more weathered and displayed an irregular range of weathering stages suggesting mixing. The orientation of bones around the talus cone largely matches the orientation of talus cone itself suggesting that water flowing down the talus cone at least partly redistributed bones. Overall, this supports the expectations for a single cultural event with three noncultural redepositional events.

Bone Bed 2 most closely matches the expectations for a kill/primary processing site (Table 7). Bone Bed 2 contains a relatively high frequency of certain high and low utility elements suggesting that the kill happened in the immediate vicinity. High utility elements such as proximal limb bones and vertebrae are clustered in the center of the talus cone. Low utility elements such as mandibles, crania, and scapulae are clustered in

the periphery of the talus cone. High utility limb bones (such as humeri, radii/ulnae, femurs, and tibiae) are clustered in the same units as low utility limb bones (such as carpals, tarsals, and phalanges) suggesting that limb bones entered the site as fully articulated units.

Cutmarks are relatively infrequent in the Bone Bed 2 fauna in spite of the generally low levels of weathering identified by Byerly et al. (2005) and the current investigation. The cutmarks are infrequent and clustered around joints which is consistent with primary disarticulation rather than intensive secondary meat removal.

Future studies regarding the relationship between cutmarks and utility should examine the location and frequency of cutmarks on previously excavated archaeological faunal assemblages with a large abundance of vertebrae (Jacobson personal communication). If cut marks on vertebrae are consistent with meat removal, this would suggest that the vertebrae were stripped of meat and discarded at the site to reduce weight. If cutmarks are absent on vertebrae, then that may indicate that certain vertebral portions were left at the site while more select vertebral sections from “higher grade” animals may have been removed from the carcasses transported off site for further processing.

Bone Bed 2 most closely matches a jump drive rather than any known alternative Paleoindian kill method (Tables 8 and 9). Green breaks occur with much higher frequency than impact fractures making fall damage a more likely fracture agent than impacts such as marrow processing or falling roof spall. Eagle Nest Canyon is significantly deeper than other documented arroyo traps, suggesting that an arroyo trap kill would be difficult if not impossible to undertake. Although, this method of kill would



be possible if a smaller arroyo existed within the floor of the existing canyon. Further research will be required to determine the likelihood of this combination of canyon and arroyo existing.

The Bone Bed 2 faunal assemblages is composed of an MNI of 32 bison. MNI does not represent the total number of animals that were involved in the formation of the site, but is rather a tool used for analyzing and interpreting the data. Given that much of the site remains unexcavated and potentially once extended past the dripline of the rockshelter, a much larger number of bison was likely involved in the formation of Bone Bed 2. The present investigation increased the MNI from Bone Bed 2 from 24/27 to 32 based primarily on elements identified from unit profiles. If the addition of 5-8 individuals was possible based on profiles, then a full excavation of the site would likely reveal significantly more bison. This suggests a catastrophic kill much larger than other documented arroyo traps which typically contain between 2 to 20 individuals and up to 38 (Table 9). A single bison jump drive is the most parsimonious explanation for the patterns exhibited by the Bone Bed 2 fauna.

These results support Dibble's (Dibble and Lorrain 1968) original interpretation of Bone Bed 2 resulting from a jump drive but support Byerly et al.'s (2005) interpretation of Bone Bed 2 as resulting from a single kill event. These results also support the argument that groups using Folsom technology and groups using Plainview technology not only overlapped but cooperated with one another in hunting activities. Since a large-scale kill would almost certainly have required more than one band of hunter-gatherers, Bone Bed 2 likely indicates that Plains groups using variable technology were aggregating (or aggregated at least once) in order to conduct a bison

jump drive. This cooperation would not have been a random occurrence but suggests that cooperation between multiple wide-ranging groups was becoming increasingly common in the Middle Paleoindian Period with planned aggregation events and emergent social hierarchies capable of planning and enforcing the aggregations. Bone Bed 2 at Bonfire Shelter also serves as a “missing link” documenting the development and transition from more traditional landform assisted Paleoindian kills to jump drives common in the Archaic period. Lastly, Bone Bed 2 demonstrates the transition from late fall/early winter kills dominating the Early Paleoindian period to late winter/early springs kills prominent in the Middle and Late Paleoindian period. This is likely the result of the increasing migratory habits of bison as increasing seasonal and resource variation caused bison herds to move between water and grass sources throughout the year. Increased migration allowed Paleoindian hunters to predict the location of herds at specific times of the year and plan their hunts for when the herds would be the largest and in a favorable location to dispatch.

## **APPENDIX SECTION**

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# APPENDIX A: COLLECTED DATA

Element	NISP	Left	Right	Unsid	MNE	MAU	%MAU
Mandible	10	1	1	8	10	5	100
Skull - Misc.	7			7	1	1	20
Maxilla	5			5	5	2.5	50
Hyoid	2			2	2	1	20
Atlas	3			3	3	3	60
Axis	2			2	2	2	40
cervical vertebra (5)	11			7	7	1.4	28
thoracic vertebra (14)	26			10	10	0.71	14.3
lumbar vertebra (5)	7			2	2	0.4	8
caudal vertebra (12)	1			1	1	0.2	4
unknown vertebra	10			3	3	0.13	2.5
rib (28)	107			15	15	0.54	10.7
Scapula	2	1		1	2	1	20
Humerus	7	2	1	3	6	3	60
Radius	6		3	3	6	3	60
Metacarpal	1			1	1	0.5	10
4th carpal	2	1	1		2	1	20
intermediate carpal	1		1		1	0.5	10
Pelvis	2	1	1		2	1	20
Femur	3	1		2	3	1.5	30
Patella	2			2	2	1	20
Tibia	7	1	2	3	6	3	60
Metatarsal	4		1	3	4	2	40
Metapodial	5			4	4	1	20
fused central and 4th tarsal	4	1	1	2	4	2	40
proximal sesamoid (16)	5			5	5	0.31	6.3
Astragalus	2		2		2	1	20
Calcaneum	3		2	1	3	1.5	30
first phalanx	2			2	2	0.25	5
second phalanx	2			2	2	0.25	5
third phalanx	4	1	1	2	4	0.8	16

# APPENDIX B: RAW DATA

Field Number	Profile	Unit	Stratum	Element	Side	Portion
FN60686	PS07	Pit B	11c	UID bone		Long Bone fragment
FN60687	PS07	Pit B	11c	Irregular Bone		
FN60688	PS07	Pit B	12	Innominate	Right	Acetabulum and small the ilium
FN60689	PS07	Pit B	12	P1 Molar	Left	Whole
FN60690	PS07	Pit B	12	Rib		Midshaft
FN60691	PS07	Pit B	11c	UID Bone		Flat Bone
FN60692	PS07	Pit B	11c	Metapodial		Distal end
FN60693	PS07	Pit B	11c	Rib		
FN60694	PS07	Pit B	11c	Rib		Body fragment
FN60695	PS07	Pit B	11c	Rib		Body fragment
FN60696	PS07	Pit B	11c	Rib		Body fragment
FN60697	PS07	Pit B	11c	Irregular Bone		
FN60698	PS07	Pit B	11c	Rib		Body fragment
FN60699	PS07	Pit B	11c	Rib		Body fragment
FN60700	PS07	Pit B	11c	Humerus		Proximal end
FN60701	PS07	Pit B	12	Irregular Bone		
FN60702	PS07	Pit B	12	Vertebra		
FN60703	PS07	Pit B	12	Lumbar Vertebra		Body
FN60703	PS07	Pit B	12	Lumbar Vertebra		Body
FN60704	PS07	Pit B	12	Lumbar Vertebra		Spinous Process
FN60705	PS07	Pit B	12	Lumbar Vertebra		Body
FN60706	PS07	Pit B	12	Lumbar Vertebra		Body
FN60708	PS07		14b	Thoracic Vertebra		Body and part of Spinous Process
FN60709	PS07		12	Cervical Vertebra		Whole
FN60710	PS07		14b	Thoracic Vertebra		Spinous Process
FN60711	PS07		14b	Rib	Right	Head
FN60712	PS07		14b	Rib		Midshaft

FN60713	PS07		14b	Rib		Midshaft
FN60714	PS07		14b	Rib		Head
FN60715	PS07		14b	Thoracic Vertebra		Spinous Process
FN60716	PS07		12b	Rib	Left	Neck
FN60717	PS07		12b	UID bone		Long Bone Midshaft fragment
FN60720	PS07		12b	UID bone		Long Bone Midshaft fragment
FN60721	PS07		12b	UID bone		Long Bone Midshaft fragment
FN60722	PS07		11	Thoracic Vertebra		Spinous Process
FN60723	PS07		11	Thoracic Vertebra		Centrum
FN60724	PS07		11	Patella		Whole
FN60725	PS07		11	Rib		Distal end
FN60726	PS07		11	Rib		Body fragment
FN60729	PS07		11	UID bone		Long Bone Midshaft fragment
FN60730	PS07		12b	UID bone		Long Bone Midshaft fragment
FN60731	PS07		12b	UID bone		Long Bone Midshaft fragment
FN60732	PS07		12b	UID bone		Long Bone Midshaft fragment
FN60733	PS07		12b	Rib		Midshaft
FN60734	PS07		12b	Rib		Midshaft
FN60735	PS07		12b	Rib		Midshaft
FN60736	PS07		14b	Rib		Midshaft
FN60737	PS07		14b	Rib		Midshaft
FN60738	PS07		14b	Thoracic Vertebra		Spinous Process
FN60739	PS07		14b	Thoracic Vertebra		Spinous Process
FN60740	PS07		14b	Thoracic Vertebra		Spinous Process
FN60741	PS07		14b	Thoracic Vertebra		Spinous Process
FN60742	PS07	Pit C	12/12b	Hyoid		"Head"
FN60747	PS07	Pit C	12/12b	Cervical Vertebra 1 (Atlas)		Whole

FN60748	PS07	Pit C	12/12b	Cervical Vertebra 2 (Axis)		Whole
FN60749	PS07	Pit C	12/12b	Humerus		Proximal Surface and Shaft
FN60750	PS07	Pit C	12/12b	Humerus		Distal Surface
FN60751	PS07	Pit C	12/12b	Tibia		Proximal end
FN60752	PS07	Pit C	12/12b	Mandible	Right	
FN60753	PS07	Pit C	12/12b	Mandible	Left	
FN60754	PS07	Pit C	12/12b	Rib		Midshaft
FN60756	PS07	Pit C	11	Talus	Right	Whole
FN60757	PS07	Pit C	11	3rd Phalanx	Left	Whole
FN60758	PS07	Pit C	12	Metatarsal		
FN60759	PS07	Pit C	12	Rib		Midshaft
FN60760	PS07	Pit C	12	UID bone		Long Bone Midshaft fragment
FN60761	PS07	Pit C	12	Tibia	Right	Distal end
FN60762	PS07	Pit C	12	Rib		Midshaft
FN60763	PS07	Pit C	12	Sesamoid		Whole
FN60766	PS07	Pit C	12	4th Carpal	Left	Whole
FN60771	PS07	Pit C	12	2nd Phalanx		Whole
FN60772	PS07	Pit C	11	Mandible		Partial alveolus and single molar
FN60773	PS07	Pit C	11	Talus	Right	Whole
FN60774	PS07	Pit C	12	Calcaneus	Right	Calcaneal tuber
FN60779	PS07	Pit C	11	3rd Phalanx		Whole
FN60780	PS07	Pit C	11	Thoracic Vertebra		Centrum
FN60783	PS07	Pit C	11	Rib		Body fragment (extends into profile)
FN60784	PS07	N20/W60	11	Rib		Head
FN60785	PS07	N20/W60	11	Rib		Distal End
FN60786	PS07	N20/W60	11	UID bone		
FN60801	PS07	N20/W60	14b	Hyoid		Distal End
FN60802	PS07	N20/W60	12b	Femur		Proximal end
FN60803	PS07	N20/W60	14b	Cervical Vertebra 6		Spinous Process
FN60804	PS07	N20/W60	14b	Cervical Vertebra 7		Spinous Process
FN60805	PS07	N20/W60	14b	Cervical Vertebra 7		Centrum
FN60806	PS07	N20/W61	12	Cervical Vertebra 6		Whole

FN60807	PS07	N20/W60	12b	TH1		Centrum
FN60808	PS07	N20/W60	12b	Caudal Vertebra		Whole
FN60809	PS07	N20/W60	14	Rib	Left	Neck
FN60810	PS07	N20/W60	14	Rib		Midshaft fragment
FN60811	PS07	N20/W60	14	Rib		Midshaft fragment
FN60814	PS07	N20/W60	12b	Thoracic Vertebra		Spinal Canal
FN60815	PS07	N20/W60	12b	Humerus	right	Proximal surface
FN60816	PS07	N20/W60	12b	UID bone		Cortical fragment cluster (n=5)
FN60817	PS07	N20/W60	12b	UID bone		Long Bone Midshaft fragment
FN60823	PS07	N20/W60	12b	UID bone		cortical and trabecular fragment cluster (n=8)
FN60824	PS07	N20/W60	11	3rd Phalanx		Hoof
FN60825	PS07	N20/W60	11	Rib		Head and neck
FN60826	PS07	N20/W60	11	Vertebra		Spinous process
FN60827	PS07	N20/W60	14b	Metapodial		Midshaft fragment
FN60828	PS07	N20/W60	14b	Rib/spinous process		distal end
FN60829	PS07	N20/W60	14b	Vertebra		Centrum
FN60830	PS07	N20/W60	11	Maxilla		alveolus and molar
FN60831	PS07	N20/W60	11	UID bone		Condyle
FN60832	PS07	N20/W60	14b	UID bone		trabecular mass
FN60833	PS07	N20/W60	11	Rib		Head and parts of body
FN60834	PS07	N20/W60	14b	UID bone		Long Bone Midshaft fragment
FN60835	PS07	N20/W60	11	Rib		Head and parts of body
FN60836	PS07	N20/W60	11	Rib		Head and parts of body
FN60837	PS07	N20/W60	14b	Mandible		Ramus and M3
FN60838	PS07	N20/W60	14b	Cranial bone		small fragment
FN60839	PS07	N20/W60	12b	UID bone		cortical fragment
FN60845	PS07	N20/W60	11	UID bone		Midshaft fragment
FN60846	PS07	N20/W60	11	Rib		body fragment
FN60847	PS07	N20/W60	11	Rib		body fragment
FN60866	PS08	N30/W50	11	Thoracic Vertebra		Centrum and Spine (whole)
FN60867	PS08	N30/W50	11	Pelvis		Ischiatic tuber
FN60868	PS08	N30/W50	14b	Maxilla		Two Molars



FN60869	PS08	N30/W50	14b	Mandible	with M1, M2, M3
FN60870	PS08	N30/W50	14b	Molar in alveolus	
FN60871	PS08	N30/W50	11	UID bone	Cortical Bone Frag
FN60874	PS08	N30/W50	14b	Radius	Proximal End fragment
FN60881	PS08	N30/W50	14b	Femur	Proximal end fragment
FN60882	PS08	N30/W50	11	Fused Central and 4th Tarsal	Whole
FN60883	PS08	N30/W50	14b	Rib	body fragment
FN60884	PS08	N30/W50	14b	UID bone	Cortical fragment
FN60885	PS08	N30/W50	11	Maxilla	Molar in alveolus
FN60886	PS08	N30/W50	14b	UID bone	Cortical and trabecular fragment
FN60887	PS08	N30/W50	14b	Rib	body fragment
FN60888	PS08	N30/W50	11	Articulated Thoracic Vertebra	Transverse Processes
FN60889	PS08	N30/W50	14b	UID bone	cortical fragment
FN60890	PS08	N30/W50	14b	UID bone	trabecular fragment
FN60891	PS08	N30/W50	14b	UID bone	Cortical and trabecular fragment
FN60892	PS08	N30/W50	11	Rib	body fragment
FN60893	PS08	N30/W50	11/14b	Rib	body fragment
FN60907	PS08	N30/W50	11/14b	Mandible	Molar in alveolus
FN60908	PS08	N30/W50	11/14b	Cervical Vertebra 7	Whole
FN60909	PS08	N30/W50	11/14b	Rib	body fragment
FN60910	PS08	N30/W50	11/14b	UID bone	trabecular fragment
FN60911	PS08	N30/W50	11/14b	Rib	body fragment
FN60912	PS08	N30/W50	11/14b	Rib	body fragment
FN60913	PS08	N30/W50	11/14b	Rib	body fragment
FN60914	PS08	N30/W50	11/14b	Rib	body fragment
FN60915	PS08	N30/W50	11/14b	Rib	body fragment
FN60916	PS08	N30/W50	11/14b	Rib	body fragment
FN60917	PS08	N30/W50	11/14b	Rib	body fragment
FN60918	PS08	N30/W50	11/14b	Rib	body fragment
FN60922	PS012	N30/W50	11/14b	Tibia	Lateral Condyle
FN60923	PS012	N30/W50	11/14b	Cervical Vertebra	Whole

FN60924	PS012	N30/W50	11/14b	Rib		Head
FN60925	PS08	N30/W50	11/14b	UID bone		cortical and trabecular fragment cluster (n=8)
FN60926	PS08	N30/W50	11/14b	Rib		body fragment
FN60927	PS08	N30/W50	11/14b	Rib		body fragment
FN60928	PS08	N30/W50	11/14b	Rib		body fragment
FN60946	PS05	N50/W70	11/14b	Rib		body fragment
FN60947	PS05	N50/W70	11/14b	Metatarsal		Whole
FN60948	PS05	N50/W70	11/14b	Cranial bone		Fragment
FN60949	PS05	N50/W70	11/14b	Fused Central and 4th Tarsal	Left	Whole
FN60950	PS05	N50/W70	11/14b	Fused Central and 4th Tarsal	Right	Whole
FN60951	PS05	N50/W70	11/14b	Rib		Head and Neck
FN60952	PS05	N50/W70	11/14b	Proximal Sesamoid		Whole
FN60953	PS05	N50/W70	11/14b	Calcaneus	right	Whole
FN60954	PS05	N50/W70	11/14b	Distal Sesamoid		Whole
FN60955	PS05	N50/W70	11/14b	Tibia	Right	Distal
FN60956	PS05	N50/W70	11/14b	Rib		Body and neck
FN60957	PS05	N50/W70	11/14b	Rib		body fragment
FN60958	PS05	N50/W70	11/14b	Maxilla		Fragment; two molars
FN60959	PS05	N50/W70		Rib		body fragment
FN60960	PS05	N50/W70		Metatarsal	Right	mishaft fragment
FN60967	ZZ	N20/W60	11	Rib		body fragment
FN60968	ZZ	N20/W60	11	Rib		body fragment
FN60969	ZZ	N20/W60	11	Humerus	Left	Proximal epiphysis
FN60970	ZZ	N20/W60	11	Scapula	Left	
FN60971	ZZ	N20/W60	11	Thoracic Vertebra		Centrum
FN60972	ZZ	N20/W60	11	Cervical Vertebra 1 (Atlas)		
FN60973	ZZ	N20/W60	11	Thoracic Vertebra		Centrum
FN60974	ZZ	N20/W60	11	Thoracic Vertebra		Spinous Process
FN60975	ZZ	N20/W60	11	Thoracic Vertebra		Costal Pit and Centrum
FN60976	ZZ	N20/W60	11	Thoracic Vertebra		Transverse Process

FN60977	ZZ	N20/W60	11	Thoracic Vertebra		Costal Pit
FN60978	ZZ	N20/W60	11	Cervical Vertebra		Centrum
FN60979	ZZ	N20/W60	11	Cervical Vertebra		Transverse Process
FN60980	ZZ	N20/W60	11	Cervical Vertebra		Transverse Process
FN60981	ZZ	N20/W60	11	Intermediate Carpal	Right	Whole
FN60982	ZZ	N20/W60	11	4th Carpal	Right	Whole
FN60983	PS05	N50/W60	11	Radius-Ulna		Proximal end
FN60983	ZZ	N20/W60	11	Radius-Ulna	right	
FN60985	PS05	N50/W60	11	Cervical Vertebra 3		
FN60986	PS05	N50/W60	11	Rib		Distal fragment
FN60987	PS05	N50/W60	11	Rib		Distal fragment
FN60988	PS05	N50/W60	11	Femur	Left	Distal End
FN60989	PS05	N50/W60	11	2nd Phalanx		
FN60990	PS05	N50/W60	11	Proximal Sesamoid		
FN60991	PS05	N50/W60	11	humerus	Left	proximal end fragment
FN60992	PS05	N50/W60	11	Vertebra		Centrum
FN60993	PS05	N50/W60	11	UID Bone		Long bone fragment
FN60994	PS05	N50/W60	11	Cranial Bone		
FN60995	PS05	N50/W60	12	Vertebra		Spinous process (n=7)
FN60996	PS05	N50/W60	11	rib		Body fragment
FN60997	PS05	N50/W60	11	Rib		Body fragment
FN61011	PS05	N50/W60	12	1st Phalanx		condyle fragment
FN61012	PS05	N50/W60	12	Metapodial (?)		Long bone fragment
FN61013	PS05	N50/W60	12	UID Bone		Trabecular bone fragment
FN61014	PS05	N50/W60	12	Vertebra		Costal pit fragment
FN61015	PS05	N50/W60	12	UID Bone		Trabecular bone fragment
FN61016	PS05	N50/W60	12	Lumbar Vertebra		Spinal canal fragment
FN61017	PS05	N50/W60	12	Radius	right	Distal end
FN61018	PS05	N50/W60	12	Radius	right	Distal end
FN61025	PS05	N50/W60	12	Rib		Head and body fragment

FN61026	PS05	N50/W60	12	Lumbar Vertebra		Spinal canal fragment
FN61028	PS05	N50/W60	12	Rib		Head, neck, and body
FN61029	PS05	N50/W60	12	Rib		body fragment
FN61030	PS05	N50/W60	12	Mandible		at least 1 molar
FN61031	PS05	N50/W60	12	Rib		Neck fragment
FN61037	PS05	N50/W70	12	Rib		Head and body fragment
FN61038	PS05	N50/W70	12	Humerus	right	Distal epiphysis
FN61039	PS05	N50/W70	11/12	Metacarpal		Distal epiphysis fragment
FN61040	PS05	N50/W70	11/12	3rd Phalanx		Whole
FN61041	PS05	N50/W70	12	Patella		Fragment
FN61042	PS05	N50/W70	11	Incisor		fragment of alveolus and incisor
FN61043	PS05	N50/W70	11/12	Cranial bone		Fragment
FN61044	PS05	N50/W70	11/12	Occipital condyle		Fragment
FN61045	PS05	N50/W70	11/12	Maxilla		fragment with heavily worn molars
FN61046	PS05	N50/W70	11/12	Fused Central and 4th Tarsal		Whole
FN61047	PS05	N50/W70	11/12	Mandible		
FN61048	PS05	N50/W70	11/12	UID Bone		Flat bone fragment
FN61049	PS05	N50/W70	11/12	UID Bone		Flat bone fragment
FN61050	PS05	N50/W70	11/12	Radius		Distal end
FN61051	PS05	N50/W70	12	Cranial bone		Fragment
FN61052	PS05	N50/W70	11/12	Rib		Head fragment
FN61053	PS05	N50/W70	11/12	Metapodial		midshaft fragment
FN61054	PS05	N50/W70	11/12	Rib		body fragment
FN61055	PS05	N50/W70	11/12	Rib		body fragment
FN61057	PS05	N50/W70	11	Rib		body fragment
FN61058	PS05	N50/W70	11	Rib		body fragment
FN61059	PS05	N50/W70	11	Rib		body fragment
FN61060	PS05	N50/W70	11	Rib		body fragment
FN61061	PS05	N50/W70	12	Rib		body fragment
FN61069	PS05	N50/W70	11/12	CE1 (Atlas)		Whole
FN61071	PS05	N50/W70	11/12	CE2 (Axis)		Whole
FN61072	PS05	N50/W70	11/12	Mandible		
FN61079	PS05	N50/W70	11	Rib		body fragment

FN61080	PS05	N50/W70	11	Thoracic Vertebra	Spinous process
FN61081	PS05	N50/W70	11	Metapodial	Long bone fragment
FN61082	PS05	N50/W70	11	UID Bone	Trabecular mass
FN61083	PS05	N50/W70	11/12	Sesamoid	Fragment
FN61084	PS05	N50/W70	11	UID Bone	Cortical Bone Frag
FN61085	PS05	N50/W70	11/12	Rib	body fragment
FN61086	PS05	N50/W70	11	Rib	body fragment
FN61088	Unit D (N)	Interior	20	UID Bone	Long bone fragment
FN61089	Unit D (N)	Interior	20	Rib	Distal end fragment
FN61090	Unit D (N)	Interior	20	UID Bone	Cortical Bone Frag
FN61091	Unit D (N)	Interior	20	UID Bone	Long bone fragment
FN61093	PS02	Interior	20	Scapula	Fragment
FN61094	PS02	Interior	20	Calcaneus	Whole
FN61096	PS02	Interior	21	UID Bone	Trabecular bone fragment
FN61097	PS02	Interior	21	Rib	Distal fragment
FN61098	PS02	Interior	20	Long Bone	Radius/Tibia?
FN61099	PS02	Interior	20	UID Bone	Cortical Bone Frag
FN61100	PS02	Interior	20	UID Bone	Bone frag
FN61101	PS02	Interior	20	Mandible	Fragment
FN61115	PS02	Interior	20/21	Rib	body fragment
FN61116	PS02	Interior	20/21	UID Bone	Cortical fragment
FN61117	PS02	Interior	20	Rib	body fragment
FN61118	PS02	Interior	19	UID Bone	Thoracic Vert?
FN61119	PS02	Interior	20	Rib	body fragment
FN61120	PS02	Interior	20	Rib	body fragment
FN61121	PS02	Interior	20	UID Bone	Cortical fragment
FN61122	N/A	Interior	19	Long Bone	Fragment
FN61123	N/A	Interior	20/21	UID Bone	Flat bone fragment
FN61124	N/A	Interior	20/21	Thoracic Vertebra	Spinal canal fragment
FN61125	PS05	N50/W50	11	Vertebra	spinous process
FN61126	PS05	N50/W50	11	Rib	Distal end
FN61127	PS05	N50/W50	11	Rib	Neck fragment
FN61128	PS05	N50/W50	11	Rib	Head, neck, and body
FN61129	PS05	N50/W50	12	Rib	Neck fragment
FN61130	PS05	N50/W50	11	Vertebra	

FN61131	PS05	N50/W50	11	Vertebra		
FN61132	PS05	N50/W50	11	Rib		body fragment
FN61133	PS05	N50/W50	11	Rib		Distal end
FN61134	PS05	N50/W50	11	Vertebra		unfused centrum
FN61135	PS05	N50/W50	11	Tibia	Left	proximal half
FN61136	PS05	N50/W50	11	Phalanx		unfused proximal
FN61137	PS05	N50/W50	11	Metatarsal		Distal
FN61138	PS05	N50/W50	11	UID Bone		Long bone fragment
FN61139	PS05	N50/W50	11	Tibia	Left	Distal half

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## VITA

James O. Ramsey was born April 9, 1997 in Arlington Texas. He was homeschooled and received much of his education through visiting historical sites across Texas. He graduated from SALT Educational Co-Op in 2014.

In the Fall of 2014, James began his undergraduate career at the University of Texas at Arlington. James earned a Bachelor of Arts degree in Anthropology (archaeology emphasis). He was the president of Lambda Alpha (Anthropology honors society) and graduated *summa cum laude* in December 2017. He was also an officer of the undergraduate Anthropology club.

During the summer of 2018, James was awarded the HOMER (Human Origins, Evolution, and Migration Research) Consortium Travel Fellowship through Arizona State University. This fellowship allowed to James to work at several Middle and Later Stone Age archaeological excavations in South Africa and Malawi.

James entered the Anthropology graduate program at Texas State University in the Fall of 2018, where he focused his studies on Paleoindian zooarchaeology. He was awarded a graduate teaching assistantship for the 2018-2019 and 2019-2020 academic years and a second additional assistantship for the 2019-2020 academic year.