EXARC Journal 2025/1
17 Articles | Open Access

Reviewed Article:

Simulating Organic Projectile Point Damage to Bison Pelves

Persistent Identifier: https://exarc.net/ark:/88735/10787

EXARC Journal Issue 2025/1 | **Publication Date:** 2025-03-25

Author(s): Charles A. Speer [1]

[1] Department of Anthropology, Idaho State University, Pocatello, Idaho, USA

A large *Bison sp.* pelvis was discovered eroding out of shoreline sediment at American Falls Reservoir in Bingham County, Idaho in 1953. The ischium section had a unique groove and perforation with a depth of 35 mm and 10 mm in diameter. The pelvis was X-rayed in 1961 for indicators of the origin of the damage, but it could not be ascertained, and human agency could not be ruled out. For the research presented here, the pelvis was CT scanned to look for any foreign material in the perforation and to determine the three-dimensional structure. A 3D model of the structure was constructed and did not reveal any particular or evident morphology to help explain the origin of the damage. An archaeological and taphonomic perspective were hypothesised and compared, suggesting that large carnivore predatory

behaviour could potentially be misinterpreted as damage from an atlatl-thrown dart fitted with an organic projectile point. An experiment was developed to determine whether a dart fitted with an organic projectile point could re-create the same damage and perforation morphology as observed in the bison pelvis. This research provides new data for taphonomic and archaeological interpretations of bison bone damage in southeastern Idaho.

> "The perforation in the bison ischium (IMNH-47001-1655) is unique in that it is fairly uniform in diameter and penetrates to a relatively significant depth of 35 mm. There is no evidence of the perforation healing and it is likely that the animal died shortly after receiving the injury.

Introduction

The purpose of this research was to explore whether an organic projectile point could experimentally produce damage morphology on a modern *Bison bison* ischium similar to that of a *Bison sp.* ischium fossil (IMNH-47001-1655) that was discovered in 1953 at American Falls Reservoir in Bingham County, Idaho. The damage was that of a single perforation oriented at a downward angle from the rear of the animal towards the front and into the centre of the animal (See Figure 1). The morphology of the damage suggests the possibility that the perforation could have been created by a dart thrown by an atlatl fitted with an organic projectile point. It is unknown, however, if this type of damage is possible with an organic projectile point. The American Falls Reservoir also has several Clovis period sites that also suggest the use of the area for hunting near the end of the Pleistocene. This question provided a unique opportunity to explore both archaeological and taphonomic perspectives such as whether the damage was made by humans or a large predator. To avoid confusion about the age and implications of the damage, the fossil will be referred to as *Bison sp.*. In this investigation, the archaeological potential of humans or a large predator hunting a large *Bison sp.* is investigated and information about the potential for such an event is collected.

The perforation is uniform in size, approximately 10 mm in diameter and 35 mm deep. There is also a small groove oriented down and towards the perforation. The goal of this research was to explore whether various organic projectile points made of antler, bone, ivory, or fire-hardened wood could possibly create similar morphological damage. If so, this could raise the possibility of human beings hunting large *Bison sp.* that may be a late remnant population of *Bison latifrons* according to past research. For example, in the original 1961 analysis of the fossil pelvis, the researchers studying the remains suggested that:

> "*consideration was given to the possibility of goring, slashing, and clawing by other animals and to 'accidental' breakage as plausible explanations of these artifacts. However, such explanations did not satisfactorily account for the relatively smooth, symmetrical appearance of the artifacts. As an alternative, the possibility of human association was suggested; this placed the problem within the purview of archaeology, and the artifacts*

will now be examined from that point of view"
(Hopkins and Butler, 1961, p.12)

The research presented in this current analysis suggests that it may be worth investigating fossil *Bison sp.* remains that have similar damage but may have been rejected in the past as evidence of human interaction due to the lack of stone tools and/or cut marks found with the remains. This research also seeks to better understand whether the types of damage from organic projectile points and carnivore attacks on bison can be distinguished from one another and especially in cases like American Falls where there are archaeological and paleontological assemblages that may be blended together (Speer et al., 2019; Stratton, et al., 2014; Villa, et al., 2004). There are multiple factors, therefore, that may adversely affect the recognition of human agency (positive or negative) upon fossil bone such as:

- lack of stone tools
- lack of cut marks
- questionable stratigraphic association
- the antiquity of species with unknown damage
- challenges to understanding the timing of when humans entered the Western Hemisphere

This is particularly evident where the damage as described in this research is present. Experimental archaeology can assist with developing a proxy measure of what kind of damage to bone various types of hunting weaponry may have been used on various species. This is important to assess because many cultures have used organic projectile points for hunting that have variable levels of preservation in the archaeological record (Langley, 2016; Langley, 2015; Ives, et al., 2014; Tejero, 2014; Waters, et al., 2011; Letourneux and Petillon, 2008).

Background

A significant collection of hundreds of *Bison sp.* remains have been found at American Falls Reservoir as well as a wide range of other Pleistocene fauna (Stratton, et al., 2014). There are also several Clovis sites that have been located in the American Falls Reservoir and other locations in the region (Speer et al., 2019). These factors make this research a useful tool for investigating any future anomalous bison bone with unknown damage vectors that may be recovered from the area. In previous research, it was concluded that the *Bison sp.* ischium found at American Falls was larger than modern *Bison bison* and fell within the range of *Bison latifrons* (Hopkins and Butler, 1961). This fossil was found in an area that has produced many *Bison latifrons* fossils to the exclusion of all other species of bison. Fossil *Bison latifrons* teeth were found approximately one meter away from the section of the ischium investigated here in Bed E (See Figure 2). The potentially associated tooth was found where naturally occurring charcoal had been radiocarbon dated and found to be more than 30,000 years old. The original radiocarbon dating techniques used at that time, however, can be questioned as to their accuracy. Regardless, the date returned would be very early for human interaction. In order to accurately assess the age of the bone, a 2g sample of interior bone was removed from the ischium for radiocarbon dating. This was to determine if the bone had a similar age to the charcoal dated in Bed E. Unfortunately, the sample did not produce enough collagen to provide a reliable date (Patrick, 2019).

The two scenarios assessed in this study are:

1. the perforation is the result of humans hunting the *Bison sp.* with an organic projectile point, or
2. the *Bison sp.* experiencing a bite during predation and/or scavenged by another animal.

Previous Studies

There are many studies that have investigated identifying the potential damage capability of stone projectile points on bone in the archaeological record (Dilley, 2021; Vieira, et al., 2021; Smith, et al., 2020; Duches, et al., 2020; Duches, et al., 2019; Kornfeld and Huckell, 2017; O'Driscoll and Thompson, 2014; Pargeter, 2007; Dockall, 1997). While fewer have focused experiments simulating the impact damage of organic projectile points on animal bone (Pfeifer, et al., 2019; Tapia, et al., 2018; Jordan, 2013; Letourneux and Petillon, 2008; Pokines, 1998; Bergman, 1987; Frison and Zeimens, 1980). Several of these studies vary in the type of methodological approach from using carcasses of various animals (goat, pig, deer, etc.) that have multiple shots creating damage, to the use of ballistics gel blocks looking only at wound path, cutting cross-section, etc. Additionally, these various experiments have wide variations in velocity, armature (bow, atlatl, length/weight of projectile), and user ability. This wide range of variability makes it difficult to tease out the specific damage morphology that a range of projectile point types might create on bison bone and even more difficult for highly specific areas with variable density. A commonly seen issue in several studies is the use of the same animal carcass (often suspended to simulate standing posture) which is used as a target to shoot projectile points at multiple times (O'Driscoll and Thompson, 2014; Letourneux and Petillon, 2008; Pargeter, 2007).

For this experiment, reusing the same carcass would create issues, with it being very difficult to single out which point created the specific damage on bones. Additionally, the multiple penetrations into the carcass allow for an overall decrease in resistance at the interface between skin, tissue, and internal organs before impacting bone. The ability to create actualistic studies is quite difficult when a live animal cannot be used for ethical reasons and the complexity and cost of using multiple animal carcasses for single data points are ever-increasing. Multiple shots of projectile points can weaken and decrease the impact resistance of various bones when struck multiple times. These factors combined make it very difficult to ascertain morphological characteristics of authentic damage on bone from organic projectile points.

Taphonomic Perspective

Frequently, as with the original article that prompted this study (Hopkins and Butler, 1961), archaeologists have worked from perspectives searching for or expecting archaeological signatures. The main problem lies in gaps in comprehension regarding the damage incurred on archaeological bones. These gaps are attributed to the limited exposure to various instances of carnivore predation, goring events, or distinctive post-mortem/post-depositional occurrences. The importance of encountering these examples is emphasised, as they serve as potential analogues for understanding the effects of human predation and scavenging on bones. This is also compounded by the fact that the diverse array of commonly found animal bones at paleontological or archaeological sites does not have a comparative database for study where it is clearly known how or what species of predator created the damage. As will be shown in this study, a perforation in a bison ischium could easily lead one to believe that such a uniform indicator of damage is not likely to have been the result of some natural process when it may specifically be an indicator of carnivore predation. This observation, however, does not preclude the fact that it is difficult to determine whether this damage is the result of human agency without an experimentally reproduced set of damage with which to compare to the paleontological material. This leads to the question: how often is archaeological material with signs of human modification misclassified as paleontological, especially when it lacks durable artefacts and clear indications of butchery or bone dispersal (Waters, et al., 2023)? There may be events in the past where organic projectile points were used, failed to bring an animal down, but still caused damage or injury enough to bone whereby the animal escapes and is not part of a traditionally observed kill site. Additionally, there may be kill sites that do not have clear indications of human agency where specific criteria are absent. In situations where damage is present but there is no artefact association, how likely could it be confirmed as archaeological in nature when organic tools are being used and may leave few or subtle traces of damage on bone? Perhaps, the best approach to solve this problem is through simulation in controlled settings followed by comparison. This topic is explored in this paper along with the most likely vector for the damage seen in this specimen.

Experiment Rationale

There are several archaeological correlations that prompted and guided the experiment discussed here that include data from the production of organic projectile points and subsequent bone damage found in archaeological contexts (Aleo, et al., 2023; LeFebvre, et al., 2023; Dilley, 2021; Horwitz, et al., 2021; Duches, et al., 2019; Pfeifer, et al., 2019; Tapia, et al., 2018; Langley, et al., 2016; Langley, 2016; Yeshurun and Yaroshevich, 2014; O'Driscoll and Thompson, 2014; Ives, et al., 2014; Letourneux and Pétillon, 2009; Moore and Schmidt, 2009; Villa and d'Errico, 2001; Bergman, 1987; Frison and Zeimens, 1980). One specific instance of important reference is the discovery of organic projectile point damage in the Manis Mastodon (Waters, et al., 2023; Waters, et al., 2011; Gustafson, et al., 1979).

The primary question for this experiment is: Could damage from organic projectile points such as antler, bone, ivory, or wood create similar patterns to carnivore damage? The human agency hypothesis is valid due to the area having several Clovis period sites (Speer, et al., 2019) and, as with other predators, may have served as a prime location for ambushing prey or purposefully driving animals to the edge of the water to be trapped and killed (Lupo and Schmitt, 2023; Montgomery, et al., 2022; Holliday, 1998). These scenarios may have all occurred at some point in the past and, possibly, within short spans of time, if not contemporaneously. In regards to the archaeological scenario, a comparative base of observation can be created experimentally to either confirm or reject that such a scenario is plausible.

Multiple artefacts from the Clovis period have been found in and around American Falls, illustrating that humans were present from earlier then expected. However, this does not establish a link to hunting activities before or after this period, especially if perishable materials no longer exist for study. The bones found in and around American Falls may contain evidence that can add more information to our understanding of human behaviour in this region. Early cultures in the Western Hemisphere may have favoured organic material technologies over lithic ones, resulting in inadequate data recoverable by traditional archaeological methods. Furthermore, early lithic artifacts might be mistaken for more generalised later stone artifacts (Wygal, et al., 2022; Davis, et al., 2019; Williams, et al., 2018; Redmond and Tankersley, 2005), particularly if they are mixed on the surface. Additionally, signs of human interaction with Pleistocene animals might be missed in faunal materials collected by researchers untrained in archaeology.

The possibility of human beings attacking a large *Bison sp.* with organic projectile points is tested here to determine if it is possible to recreate the damage seen on the bison ischium. Several examples of organic projectile points inflicting similar damage have been noted in other species of animals and other regions of the world (Pfeifer, et al., 2019; Tapia, et al., 2018; Letourneux and Petillon, 2008; Pokines, 1998; Knecht, 1993). Several things are necessary to validate whether the damage can be recreatedand can it be a reliable indicator of human activity. First, the artifacts created must be of similar attributes to those seen archaeologically. Second, the angle of impact must match the angle of impact determined from the original specimen *and* the force of impact must match the range of human ability to throw a dart with an atlatl (Denny, 2019; Whittaker, Pettigrew and Grohsmeyer, 2017; Pettigrew, et al., 2015; Pettigrew, 2015; Hunzicker, 2008; Whittaker and Kamp, 2007; Vanderhoek, 1998; Dockall, 1997). Lastly, the *Bison bison* ischia being tested here must have similar attributes to that of the original fossil specimen with an equivalent resistance to impact due to hide, musculature, and bone density (Huntington, 2018; Galbraith, et al., 2014; Breslawski and Byers, 2014, Niven, Egeland and Todd, 2004; Henrikson, 2003; Plew and Sundell, 2000; Hofman, Todd and Schtultz, 1989).

CT Scan morphology

A CT scan was performed at Bingham Memorial Hospital to ascertain if there were any foreign objects or debris inside the perforation as well as the angle of entry. It was determined there were no objects inside the perforation or lodged into the bone. The angle was noted and it was determined from what direction force was applied to the bone to create the perforation. The perforation size was recorded. For the organic projectile point damage to mimic the actual carnivore damage mentioned above, the puncture hole needed to be uniform in diameter and depth. In Figure 3 is a composite image of a *Bison latifrons* skeleton recovered from American Falls to assist with visualising where the damage is as well as the morphology of the hole and a reconstruction of the puncture hole from a positive inverse image.

Methodology

The experiment conducted here used several methods to approach as closely as possible the scenario of an atlatl dart impacting a bison ischium at the same point of damage as observed on the *Bison sp.* ischium observed from American Falls. In order to accomplish this, 20 fresh*Bison bison* ischium from the left side were encased in ballistics gelatin and oriented in such a manner that a simulated atlatl dart would impact at the correct location as seen on the fossil. The ballistics gelatin used for encasing and supporting every ischium was created using the typical FBI formula of 10% ballistic gelatin. The use of ballistics gelatin provided a standardized and replicable medium to approximate soft tissue resistance while eliminating the variability inherent in using actual bison carcasses, thereby ensuring controlled and consistent experimental conditions without the logistical and ethical complications of sourcing and preparing multiple animal specimens. This was created by mixing one part of 250 bloom type A gelatin with nine parts of warm water ~40°C (104°F)(by mass). The process involved stirring the water while adding powdered gelatin. The gelatin mixture was poured into a 269 mm x 193 mm x 160 mm mould with each bison ischium suspended in the centre. Each ischium was arranged to ensure the distance between the impact site and the surface of the ballistics gel was between 40-45 mm to simulate an average distance between exterior bison hide and the surface of the ischium. This distance is only an estimate from discussions with bison producers (Graese, 2021) as there is some variability in thickness between bison of different sexes and ages. The gelatin mixture was then chilled to ~4°C (39°F). Each block was then removed from chilling, mounted on a wooden clamp with a cinder block wall backing, and aligned with a laser pointer affixed to the compressed air launching mechanism to ensure accurate targeting.

A total of 20 darts were manufactured at a similar size and morphology. Five White Ash (*Fraxinus americana*) dart shafts were fire-hardened and sharpened; five projectile points were made from White-tailed Deer (*Odocoileus virginianus*) antler with a single bevel (See Figure 4); five projectile points were made from Mule Deer (*Odocoileus hemionus*) metatarsal bone with a single bevel (See Figure 4); and five projectile points were made from Common Warthog (*Phacochoerus africanus*) upper canines with four made with single-bevel (See Figure 4) and one with a split base. The projectile points were manufactured similarly to methods outlined by other experiments and by archaeological examples (Aleo, et al., 2023; Waters, et al., 2023; Pfeifer, et al., 2019; Tapia, et al., 2018; Langley, Pétillon and Christensen, 2016; Langley, 2016; Langley, 2015; Tejero, 2014; Frison and Zeimens, 1980). The projectile points were mounted on

1.20 m shafts of 15 mm diameter White Ash (*Fraxinus americana*) weighing between 83-107 grams. They were lashed to the dart shafts with White-tailed Deer (*Odocoileus virginianus*) back sinew and hide glue. Table 1 includes the physical characteristics of each dart and projectile point. None of the darts were fletched.

Dart Number	Projectile Point Material	Point Weight (g)	Point Diameter (mm)	Tip Diameter (mm)	Bevel Length (mm)	Point Length (mm)	Dart Length (cm)	Dart Weight (g)
1	White Ash	n/a	11.5	2	n/a	50	120	99
2	White Ash	n/a	11.5	3	n/a	45	120	104
3	White Ash	n/a	11.5	2	n/a	47	120	99
4	White Ash	n/a	11.5	4	n/a	40	120	107
5	White Ash	n/a	11.5	2	n/a	38	120	104
6	White-tailed Deer, antler	7	11	5	28	73	121	92
7	White-tailed Deer, antler	19	18	7	37	121	122	92
8	White-tailed Deer, antler	12	14	4	41	88	122	96
9	White-tailed Deer, antler	9	12	5	32	82	121	97
10	White-tailed Deer, antler	11	13	5	37	89	122	97
11	Mule Deer, metacarpal	12	11	5	60	102	123	97
12	Mule Deer, metacarpal	9	13	6	45	78	123	92
13	Mule Deer, metacarpal	9	15	5	45	83	123	93
14	Mule Deer, metacarpal	17	17	6	53	108	123	84
15	Mule Deer, metacarpal	14	14	6	68	140	123	83
16	Common Warthog, upper canine	15	17	5	32	74	123	92
17	Common Warthog, upper canine	10	15	8	46	74	123	91
18	Common Warthog,	16	17	7	28	82	123	91

	upper canine							
19	Common Warthog, upper canine	14	18	8	72	93	122	95
20	Common Warthog, upper canine	17	16	6	25	81	119	93
Average		**12.733**	**13.925**	**5.050**	**43.267**	**79.400**	**121.650**	**94.900**

TABLE 1. PHYSICAL CHARACTERISTICS OF EXPERIMENTAL ATLATL DARTS AND ORGANIC PROJECTILE POINTS.

These darts were launched via a piece of metal conduit using 30 psi of compressed air to between 25-30 m/s. The darts were loaded with a cotton wadding between them and the air outlet to maximise air pressure force. This speed was selected to closely mimic the average speed at which a human can throw an atlatl dart (Denny, 2019; Whittaker, Pettigrew and Grohsmeyer, 2017; Pettigrew, et al., 2015; Pettigrew, 2015; Tomka, 2013; Whittaker and Kamp, 2007; Vanderhoek, 1998; Dockall, 1997). The speed of each dart was recorded using a ballistics chronograph. The distance from the exit of the conduit to the edge of the ballistics gelatin was approximately two meters. Neither the wound path or the force of resistance from removing the dart from the ballistics gel were measured. The various patterns of damage to the bison ischium, projectile point, and dart shaft were assessed and compared.

Damage was recorded according to several criteria known to occur on bone with osseous projectile points both from experimentation and archaeological parallels (O'Driscoll and Thompson, 2014, Yeshurun and Yaroshevich, 2014; Letourneux and Petillon, 2008, Villa and d'Errico, 2001). For this experiment observations included: crack, notch, and puncture. No perforations or embedded points were observed. Perforations are when the complete thickness of the bone is traversed by the point (Smith, Brickley and Leach, 2007). Punctures are created when the tip of the point impacts the bone but does not penetrate through. Notches occur when a bone is grazed by a point, resulting in the tearing off of a small amount of material. The damage to the projectile points were also noted and those criteria observed were: blunted, broke hafting, notched, and saw-toothed fracture. Blunted is defined as the tip no longer being sharp (See Figure 5). Broke hafting is the hide glue and sinew coming loose and the dart point no longer adhered to the shaft (See Figure 6). Notched is defined as a small groove/scratch on the projectile point was created from impacting bone.Saw-toothed fracture is a complete failure of the point and a jagged edge on both segments of the broken point (See Figure 7). Penetration characteristics observed into the bone and ballistics gelatin were: complete rebound, glancing, impact, pass-through, slight rebound. Complete rebound is the dart impacting and falling out of the ballistics gelatin. Glancing is after impact the dart remains in the ballistics gelatin after impacting the bone. Impact is still seated against the bone but not embedded. Pass-through is after impact the dart continued completely through the ballistics gel.Slight rebound is after impact the dart remains in gelatin but does not remain seated against the bone or continued past nor fallen out of the gelatin. No damage to any of the dart shafts was observed.

Results

The table below shows each of the dart projectile point types with the various criteria that were recorded during the experiment. The overall weight of the dart as well as the kinetic energy was calculated (See Table 2). The average velocity of the darts was 27.4 m/s and the range of velocity was between 24.5-32 m/s. The results of this experiment showed a wide variation of dart point damage to bone: two fire-hardened wood points created two punctures with Dart #3 having a depth of 4.8 mm and a diameter of 3.6 mm and Dart #5 having a depth of 4.4 mm and a diameter of 6.5 mm (See Figure 8 for Dart #3 example); single-bevel antler points created one crack and one notch; single-bevel bone points created two notches and one puncture with Dart #13 having a depth of 1.5 mm and a diameter of 5.3 mm; and the ivory single-bevel points created one crack (See Figure 9), one notch, and one puncture with Dart #17 having a depth of 8.7 mm and a diameter of 5.6 mm (See Figure 10). There were no perforations recorded.

Dart Number	Projectile Point	Penetration Characterisitic	Bone Damage	Depth of Bone Puncture (mm)	Width of Bone Puncture (mm)	Point Damage	Velocity (m/s)	Total Weight (g)	Kinetic Energy (J)
1	Fire Hardened Ash	pass-through	none	N/A	N/A	notched	27	99	36
2	Fire Hardened Ash	glancing	none	N/A	N/A	blunted	26	104	35
3	Fire Hardened Ash	impact	puncture	4.8	3.6	blunted	30	99	45
4	Fire Hardened Ash	pass-through	none	N/A	N/A	blunted	30,5	107	50
5	Fire Hardened Ash	impact	puncture	4.4	6.5	blunted	27	104	38
6	Single Bevel Antler	pass-through	none	N/A	N/A	broke hafting	26	99	31
7	Single Bevel Antler	glancing	crack	N/A	N/A	none	30	111	41

8	Single Bevel Antler	slight rebound	notch	N/A	N/A	none	27	108	35
9	Single Bevel Antler	complete rebound	none	N/A	N/A	saw-toothed fracture	32	106	50
10	Single Bevel Antler	glancing	none	N/A	N/A	none	28.5	108	39
11	Single Bevel Bone	slight rebound	none	N/A	N/A	none	30	109	44
12	Single Bevel Bone	glancing	none	N/A	N/A	none	25	101	29
13	Single Bevel Bone	glancing	puncture	1.5	5.3	notched	26	102	31
14	Single Bevel Bone	glancing	notch	N/A	N/A	blunted	26	101	28
15	Single Bevel Bone	glancing	notch	N/A	N/A	blunted	26	97	28
16	Single Bevel Ivory	glancing	crack	N/A	N/A	none	26	107	31
17	Single Bevel Ivory	glancing	puncture	8,7	5,6	none	24.5	101	27
18	Single Bevel Ivory	glancing	notch	N/A	N/A	none	24.5	107	27
19	Single Bevel Ivory	glancing	none	N/A	N/A	none	29	109	40
20	Split-Based Ivory	complete rebound	none	N/A	N/A	notched	27	110	34
Average							**27.4**	**104.45**	**36**

TABLE 2. RESULTS OF ORGANIC PROJECTILE POINT DAMAGE ON *BISON BISON* ISCHIUM.

With regards to point damage created from impacting the bone: the fire-hardened ash points had four blunted (See Figure 5 above) and one notched; the single-bevel antler points had one broken hafting (See Figure 6 above) and one saw-toothed fracture (See Figure 7 above); the single-bevel bone points had one notched and two blunted; lastly, the single bevel ivory points had three that were notched including the split-based ivory point. The dominant penetration characteristic was the glancing blow, with 12 out of 20 points (~55%) impacting and continuing into the ballistics gelatin block while only the fire-hardened wood points (Dart #3 and Dart #5) had impacted and remained stuck in the bone. A single-bevel antler point and two of the fire-hardened wood points were the only points to completely pass through the gelatin block, while one single-bevel antler and one single-bevel bone point had partial rebounds after impacting the bone. One single-bevel antler point (with saw-toothed fracture) and the split-based ivory point were the only darts to completely rebound back out of the ballistics gelatin block after impact but, also, neither created any damage to the bone. No penetrations were recorded. The projectile points themselves did illustrate some damage notably with the fire-hardened tips and the antler experiencing the most damage.

Discussion

Two of the fire-hardened points and one of the single-bevel antler points had complete pass-through on the block after initial impact with the bone. This is interesting because from the perspective of prey damage, a smooth transition point could continue through the body cavity and inflict more damage to internal organs (Wood and Fitzhugh, 2018; Wilkins, Schoville and Brown, 2014; Hunzicker, 2008; Frison, 1989; Christenson, 1985; Frison and Zeimens, 1980). In contrast, those points that do not completely pass through the body cavity but create a larger hole might facilitate greater blood loss, as seen with the single-bevel ivory and single-bevel bone points which both had four out of five points glancing and not continuing through the ballistics gelatin block. The bone projectile points were remarkably durable and only one point showed a small notch. The ivory also was durable and two of the points show some minor notching.

Regarding damage to the bone, it was clear that none of the organic projectile points had a consistent pattern of damage. This could be due to the small sample size or the orientation of the hafting of the point. It is interesting to note that the fire-hardened points were capable of puncturing the bone and it is possible that such damage could be mistaken for that created by antler, bone, or ivory. Additionally, the two fire-hardened points were the only dart points to impact and remain stuck inside the bone. The damage created by the fire-hardened and single-bevel ivory projectile points was most like the damage seen on the fossil bison ischium. The single-bevel bone point (Dart #13) did not create similar damage with a type of glancing and gouging puncture of the bone surface and making a slightly wider puncture (5.3 mm) than that of the dart point tip diameter (~5 mm). The morphology overall, however, and the lack of penetration depth strongly suggests that the possibility of the hole being created by an organic projectile point is remote. The single-bevel ivory dart point #17 had the greatest depth of penetration at 8.7 mm but this falls very short of the 35 mm measured in the fossil *Bison sp.* ischium. Additionally, none of the darts were able to create a 10 mm diameter puncture as seen in the fossil ischium even with the glancing and gouging puncture of the single-bevel bone dart point #13.

Comparison of canine from Panthera atrox

The perforation in the bison ischium (IMNH-47001-1655) is unique in that it is fairly uniform in diameter and penetrates to a relatively significant depth of 35 mm. There is no evidence of the perforation healing and it is likely that the animal died shortly after receiving the injury. There are possible post-depositional causes that could also be explored but they are not relevant to this paper. The damage was located on the rear of the animal and it was hypothesised that a large felid, which also would have been present during the Pleistocene, may have engaged in similar behaviour to that seen of modern African lions (*Panthera leo*) that frequently jump on the backs of their prey, such as African buffalo (*Syncerus caffer*) to slow them down and allow other members of their pride to also engage (Schaller, 1972). Paleontological evidence is best displayed in this type of behaviour in the remains of the 36,000 year old "Blue Babe," the Steppe Bison (*Bison priscus*) found in Alaska in 1979, which displays claw marks and tooth punctures likely caused by an American lion (*Panthera atrox*)(Guthrie, 1989). In order to test this hypothesis several canine teeth of various large predators in the paleontological collections of the Idaho Museum of Natural History discovered at American Falls and the surrounding region were measured and tested for fit into the perforation on the bison ischium.

These included canines from different species such as: American Lion (*Panthera atrox*), Saber-Toothed Cats (*Smilodon fatalis, Homotherium crenatidens*, and *Homotherium sp.*), Dire Wolf (*Canis dirus*), Short-Faced Bear (*Arctodus simus*), and American Cheetah (*Miracinonyx trumani*). The closest fit was that of the American Lion (*Panthera atrox*). There was minimal clearance, 1/10 mm, with one tooth (IMNH-71008-5561) which size was closest to the perforation on the bison ischium (See Figure 11). Additionally, impressions were made of the teeth with minimal pressure and fully pressed into a block of plasticine clay, up to what appeared to be the gumline at 21.2 mm deep, and leaving a diameter hole of 13.5 mm. This data came close to the range of that measured on the bison ischium with a depth of 35 mm and diameter of 10 mm. It may be that some of the depth difference (21.2 mm versus 35 mm) is due to erosion of the interior (cancellous) bone. This comparison was done in order to observe any similarities with the damage on the bone. Following this, the inter-canine distance for several skulls of American Lion were measured. The average distance was then used to see if any other damage matched up with the orientation of the canine impression in the bone. Surprisingly, a small groove was observed that showed similarity to the groove which was connected to main perforation on the bone. Altogether, the overall fit of the tooth in the perforation and the inter-canine distance being very close to that of the second observed groove strongly suggests that a predation event by an American Lion (*Panthera atrox*) as being the most likely vector for the damage.

Conclusion

In this experiment, the damage recreated from the simulated atlatl darts fitted with organic projectile points on *Bison bison* ischia strongly suggests that the damage observed on the fossil *Bison sp.* ischium from American Falls Reservoir was unlikely to have been caused by humans. While the damage created by the organic projectile points did demonstrate the capability to produce some degree of damage to bone, none of the points replicated the precise morphology or depth of the perforation observed in the American Falls *Bison sp.* ischium. The American Lion (*Panthera atrox*) was identified as a potential candidate responsible for the damage. The American Lion tooth size and morphology closely matched the perforation on the fossil. As aforementioned, this finding is consistent with predatory behaviours observed in modern, large felids, such as lions, which employ a similar method of hind-quarter attack on large prey animals.

This experiment underscores the critical role of identifying the taphonomic processes and natural predation as a vector in the interpretation of bone damage within paleontological contexts as well as archaeological. The study also reveals an overall lack of data on organic projectile point damage on various bone elements of important prey species. These findings highlight the need for additional experimental studies to deepen our understanding of bone damage patterns. Lastly, this study offers important insights into the strengths and limitations of organic projectile points on bison bone, thereby enhancing our knowledge of the potential overlap and avoidance of conflating human hunting strategies and natural predation events during the Late Pleistocene. Future research will aim to increase sample sizes, vary bone elements, and examine additional factors to better differentiate between human-induced and naturally occurring damage on faunal remains.

Declaration of Competing Interest

The author declares that they have no known competing financial interests or personal relationships that have influenced the work reported in this paper.

Acknowledgments

I would like to thank Idaho State University (ISU), the Idaho Museum of Natural History, the ISU College of Arts and Letters, and the ISU Department of Anthropology for assisting me with this experiment. I would especially like to thank Dr. Amy Commendador for assisting me with inspection of the *Bison sp.* ischium fossil (IMNH-47001-1655) and looking through the many canine teeth from American Falls. Lastly, I would like to thank my wife, Adrienne, for helping me with all of the foul smelling bison pelves and mounting them in the ballistics gel.

Keywords hunting
weapon
spear

Country USA

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Corresponding Author

Charles A. Speer
Department of Anthropology
Idaho Museum of Natural History
Idaho State University
921 S 8th Ave
Pocatello, ID 83209
USA
E-mail Contact

Gallery Image

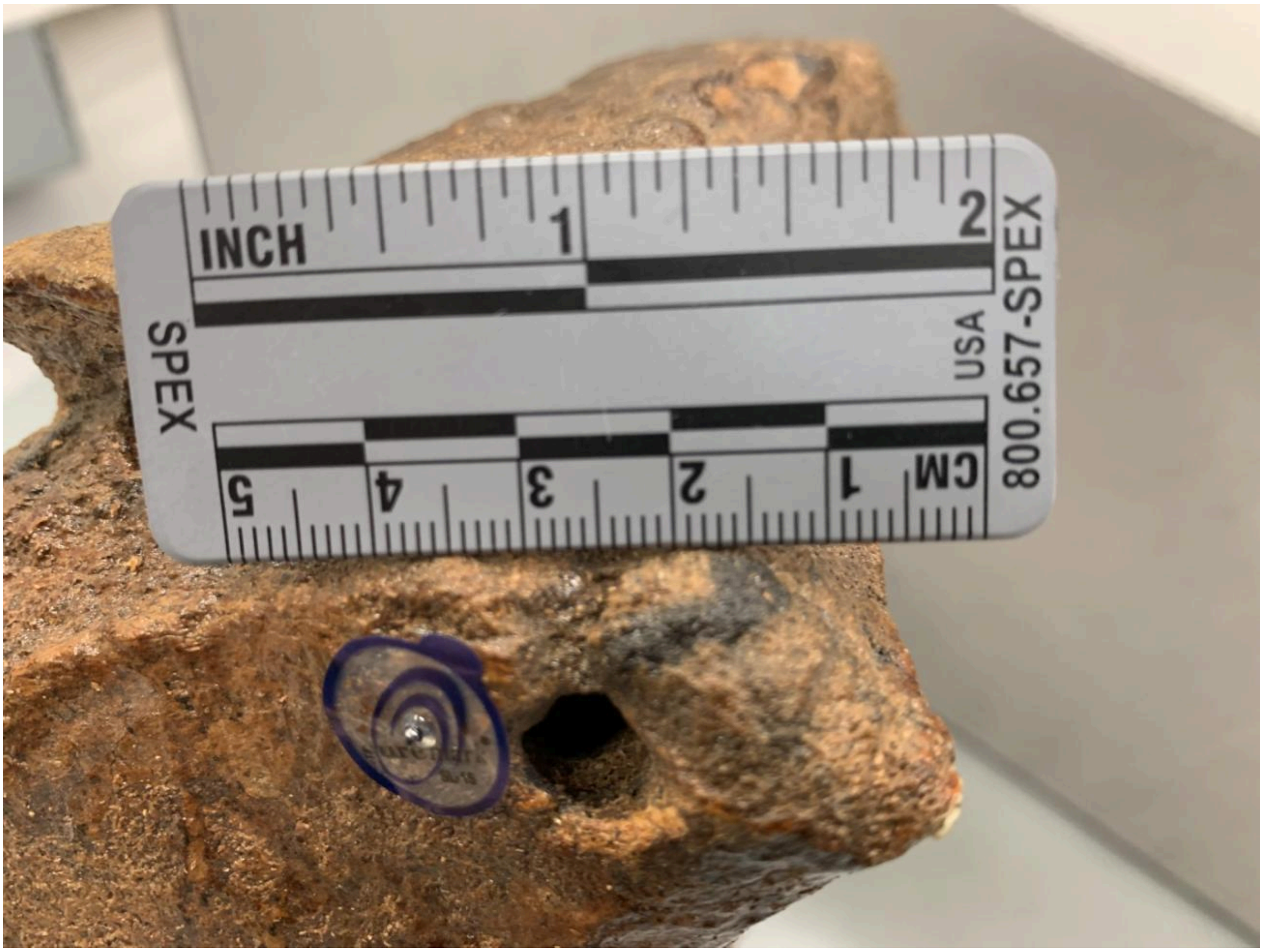

FIG 1. BISON SP. ISCHIUM WITH PERFORATION. PHOTO BY CHARLES A. SPEER.

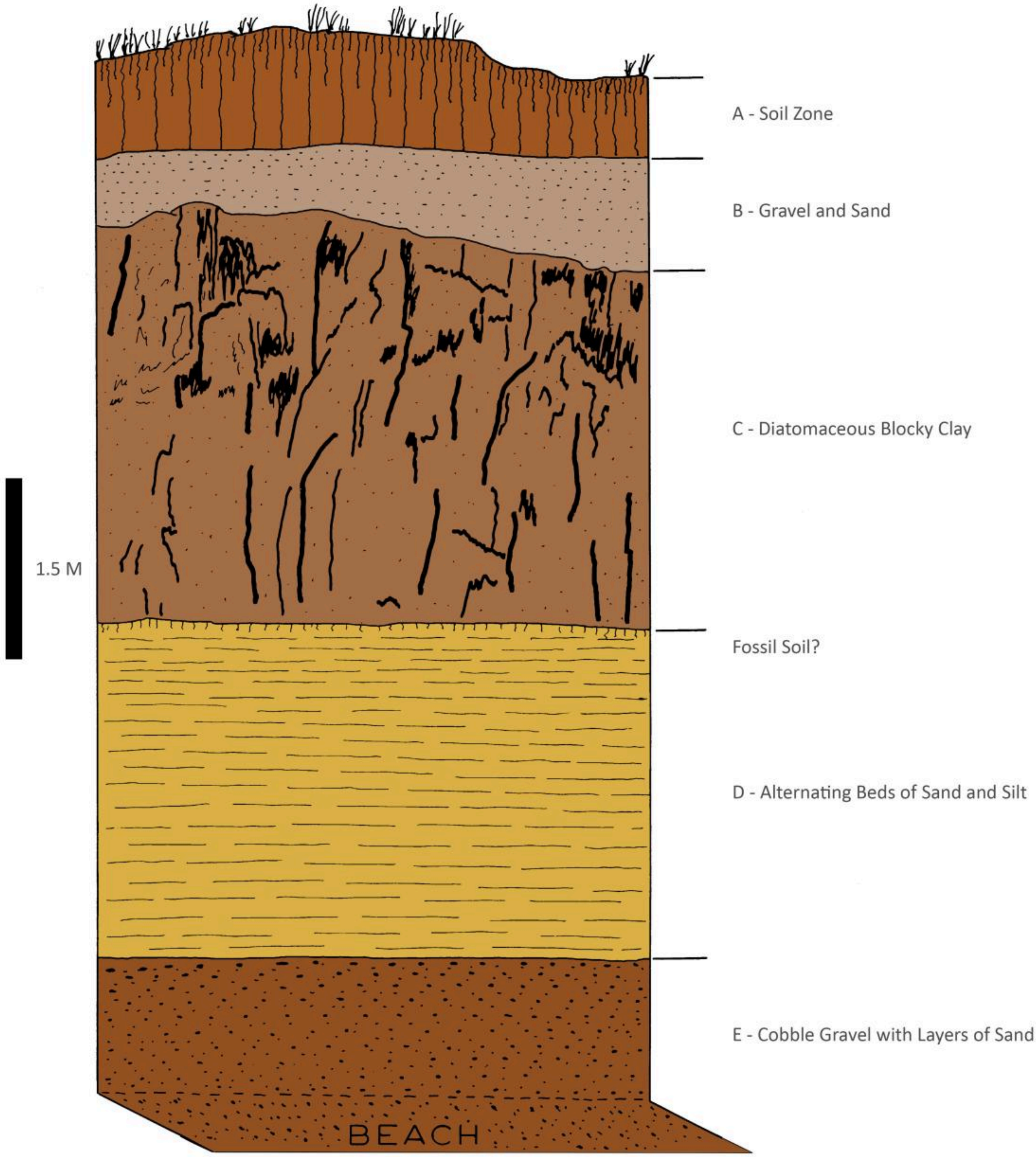

FIG 2. GENERALIZED STRATIGRAPHIC COLUMN OF AMERICAN FALLS RESERVOIR NEAR LOCATION WHERE BISON ISCHIUM WAS FOUND; ADAPTED FROM (HOPKINS AND BUTLER, 1961).

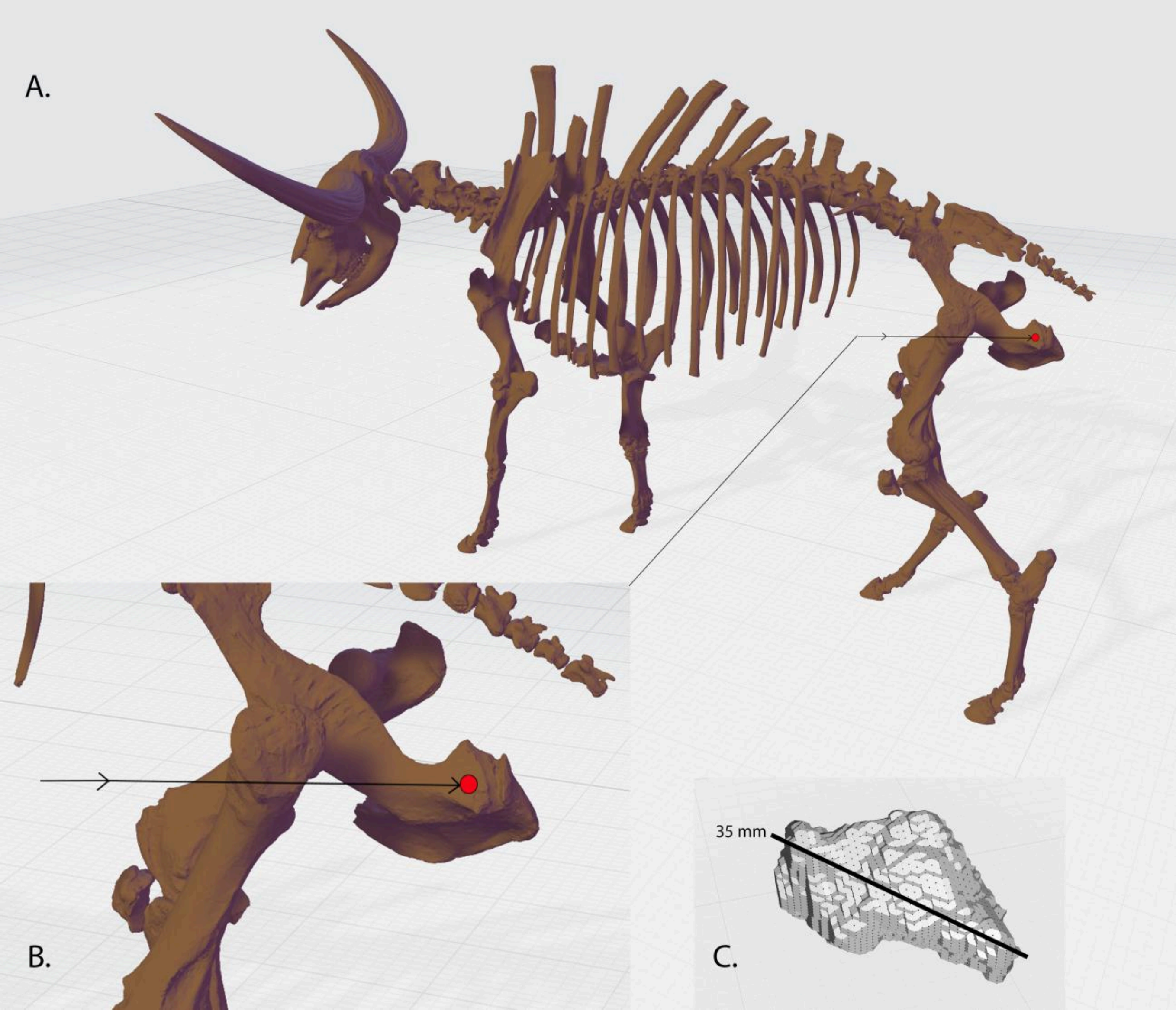

FIG 3. A. APPROXIMATE LOCATION OF DAMAGE AS ILLUSTRATED ON BISON LATIFRONS SKELETON RECOVERED FROM AMERICAN FALLS RESERVOIR IN SOUTHEASTERN IDAHO. B. DETAIL IMAGE SHOWING THE DIRECTION OF THE PUNCTURE HOLE IN THE ISCHIUM. C. RECONSTRUCTED POSITIVE INVERSE IMAGE OF PUNCTURE HOLE; THE IMAGE IS ORIENTED WITH THE SHARP END BEING AT THE BOTTOM OF THE PUNCTURE HOLE.

FIG 4. A. SINGLE-BEVEL COMMON WARTHOG (PHACOCHOERUS AFRICANUS) UPPER CANINE POINT; B. SINGLE-BEVEL MULE DEER (ODOCOILEUS HEMIONUS) METATARSAL BONE POINT; AND C. SINGLE-BEVEL WHITE-TAILED DEER (ODOCOILEUS VIRGINIANUS) ANTLER POINT. PHOTO BY CHARLES A. SPEER.

FIG 5. BLUNTED TIP OF FIRE-HARDENED DART POINT (DART #7). PHOTO BY CHARLES A. SPEER.

FIG 6. FIGURE 6. BROKEN HAFTING OF DART POINT (DART #6). PHOTO BY CHARLES A. SPEER.

FIG 7. SAW-TOOTHED FRACTURE OF SINGLE-BEVEL ANTLER DART POINT (DART #9). PHOTO BY CHARLES A. SPEER.

FIG 8. A. PUNCTURE DAMAGE FROM FIRE-HARDENED WOOD POINT (DART #3) ON RAW BONE. B. INSET, PUNCTURE DAMAGE FROM FIRE-HARDENED WOOD POINT (DART #3) ON DRIED & DEFLESHED BONE. PHOTO BY CHARLES A. SPEER.

FIG 9. A. CRACK DAMAGE FROM SINGLE-BEVEL IVORY POINT (DART #16) ON RAW BONE. B. INSET, CRACK DAMAGE FROM SINGLE-BEVEL IVORY POINT (DART #16) ON DRIED & DEFLESHED BONE. PHOTO BY CHARLES A. SPEER.

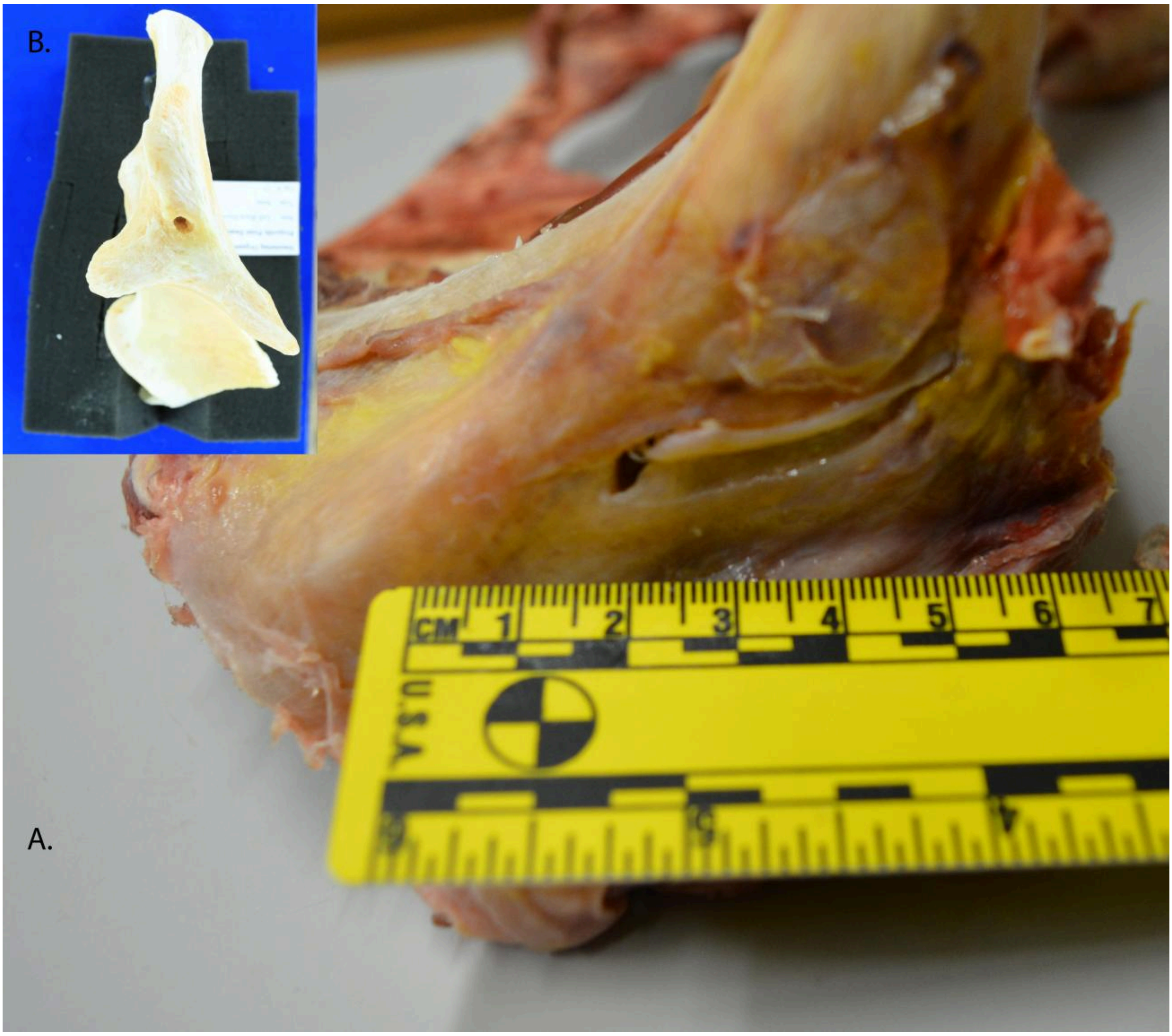

FIG 10. A. PUNCTURE DAMAGE FROM SINGLE-BEVEL IVORY POINT (DART #17) ON RAW BONE. B. INSET, PUNCTURE DAMAGE FROM SINGLE-BEVEL IVORY POINT (DART #17) ON DRIED & DEFLESHED BONE. PHOTO BY CHARLES A. SPEER.

FIG 11. AMERICAN LION (PANTHERA ATROX) CANINE FITTING INTO HOLE MORPHOLOGY. PHOTO BY CHARLES A. SPEER.