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The members of the Committee approve the thesis of Morgan Robins presented on October 29, 2021.

Dr. Robert Kelly, Committee Head Chairperson

Janet Dewey, Outside Member

Dr. Todd Surovell, Co-Committee Chairperson

Dr. Richard Adams, Fourth Committee Member

Todd Guenther, Fifth Committee Member

APPROVED:

Dr. Todd Surovell, Department of Anthropology at the University of Wyoming

Camellia Moses Okpodu, College Dean of Arts and Sciences at the University of Wyoming

Abstract

Robins, Morgan, W, *The Use of Phosphorus to Determine Evidence of Bone on a Possible High Elevation Bison Jump*, Masters of the Arts, Anthropology, December 2021.

The Dinwoody Bison Jump (48FR7682) is located at 3,350m/11,000ft in the Wind River Mountains in the Greater Yellowstone Ecosystem of Wyoming. The site consists of an 8 km^2 grazing area, a 1.6 km long system of three converging drivelines comprised of stacked stone cairns and blinds with doglegs near the jump, an obscuring ridge, a scarp/kill site, a butchering area with thousands of pieces of debitage, and a shaman structure. Optically stimulated luminescence dating of built features in the drivelines indicates that the site was used between about A.D. 1310 - 1870. The jump is associated with a 5 km^2 complex of lodge pad villages and campsites. Diagnostic artifacts from Folsom through Late Prehistoric and into the Protohistoric have been documented in those sites. The jump complex has all the key characteristics of what Kornfeld et. al (2010), defined as a bison jump. Nevertheless, because the site is extraordinarily high and lacks a bone bed some have questioned its interpretation as a bison jump. Central Wyoming College (CWC) researchers documented the presence of prehistoric bison skeletal remains at multiple locations above 3,050 m/10,000 ft. over the entire length of the Wind River Mountains. Faunal remains are absent at the Dinwoody jump because only about 15 cm of acidic soil exists above bedrock in the butchering area at the foot of the jump, and the jump faces southwest toward the prevailing winds so is heavily impacted by weather. Consequently, there is no bone preservation. Soil analysis for the fungus sporormiella failed to produce evidence of herbivore decomposition (Petersen 2017). Phosphate analyses of soil samples collected from the butchering area produced results similar to soil analyses from the extensive bonebeds at the nearby Wiggins Fork Jump. Elevated calcium phosphate levels in soils from the suspected butchering areas compared to control samples from surrounding areas suggests decomposition of discarded bone in the Dinwoody jump butchering area.

The Use of Phosphorus to Determine Evidence of Bone on a Possible High Elevation Bison Jump

By

Morgan Wynne Robins

A thesis submitted to the Department of Anthropology

and the University of Wyoming

in partial fulfillment of the requirements

for the degree of **Master of Arts and Sciences**

in

Anthropology

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DEDICATION PAGE

"There may be no other type of archaeological site that can match the drama, can fire the imagination, and is as utterly compelling as that of a buffalo jump" (Brink 2008:2).

This thesis is dedicated to all my mentors and my family. For all who have pushed me, supported me and inspired me through my schooling and my life. Thank You.

ACKNOWLEDGMENTS

The field work and data collection for this project were authorized under permits issued by the United States Forest Service-Shoshone National Forest to Professor Todd Guenther and Central Wyoming College (CWC) Department of Anthropology/ Archaeological Field Schools (2015-2021). Data collection at the Wiggins Fork Bison Jump used here for the comparative purposes was permitted by the Wyoming Game and Fish Department. These high elevation archaeological projects were conducted as part of the CWC Alpine Science Institute's Interdisciplinary Climate Change Expeditions. The annual expeditions and laboratory costs were funded by Professor Guenther, Jacki Klancher and the Alpine Science Institute (supported by Wyoming NASA Space Grant Consortium, Wyoming EPSCoR, INBRE, CWC Foundation), CWC-Department of Anthropology, the Wyoming Cultural Trust Fund, the University of Wyoming Frison Institute, the Wyoming Archaeological Society, the Utah State University Luminescence Lab and US Forest Service. CWC Professor Guenther, Klancher, Darren Wells, and CWC crew leaders Mara Gans, Lucas Schwandt and Jessi Crawford taught me remote expedition logistics, field research methods, and back country and mountaineering skills in the Fitzpatrick Wilderness, including summiting Gannett Peak for the 2017 solar eclipse. Several University of Wyoming students and faculty, Janet Dewey, Dr. Zhang, Dr. Zhu and Sydney McKim, all of whom provided guidance and help with the methods for the different analyses that were used for this research project. I was fortunate to participate in both the various research analysis methods and in these expeditions as an undergraduate and graduate student and deeply appreciate the generosity of the project leaders, mentors, cheerleaders, and funders who provided me with the guidance, experience, information, and emotional and financial support to make this thesis possible.

Also, a huge thank you to all the ICCE archaeology field school crew members who helped collect the data and volunteer crew member Sig Schulz over the years of research. Carlie Ideker, former Utah State University Luminesces Senior Lab Manager. HEA mentors Del Nelson (CWC and USFS), Dr. Lawrence (Larry) Todd (Colorado State University), and Craig Lee (Colorado University/ INSTARR). My committee members Dr. Robert Kelly, Dr. Todd Surovell, Janet Dewey, Dr. Richard Adams, and Todd Guenther. Lasty, I want to give a big thank you to my family for the support and encouragement to follow my passions.

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Introduction

Indigenous peoples hunted modern and extinct species of bison continuously over the past 12,000 years on the Northwestern plains and Rocky Mountains (Kornfeld et al. 2016). Many prehistoric hunter-gatherer groups exhibited significant ingenuity in their communal hunting strategies that used the natural topography to drive these large mammals over high or rocky terrain, these sites known as bison jumps, are where animals were killed or crippled (and then dispatched) when they hit the ground or after the animals tripped over obstacles (Kornfeld et al. 2016; Grund et al. 2016). This communal procurement strategy reached its peak during the Late Prehistoric era (Kornfeld et al. 2016). In 2015, Central Wyoming College (CWC) archaeological field school discovered one such possible bison jump located approximately 609 m higher than any previously recorded bison jump site in North America. Central Wyoming College has returned to work on this site every year since its discovery.

The Dinwoody Site (48FR7682; hereafter referred to as Dinwoody) is in northwest Wyoming's Wind River Mountains and contains the distinct traits that archaeologists use to define a site as a bison jump. These traits are: 1) site contains a grazing area where the animals can be collected, 2) two or more lines of stacked stone cairns or alignments that converge to a point, 3) a jump off point either in the form of a short cliff or a steep scarp, 4) an area of 'deposition' below the slope that can contain faunal remains or stone artifacts from killing episodes, and 5) evidence of an occupation area near the jump (Malouf and Connors 1962: 2). However, there is no direct evidence that the Dinwoody site was used as a bison jump, or for hunting any type of animal. Most problematic is the lack of a bonebed. This paper will contribute toward answering the question of whether the Dinwoody site is a bison kill site by seeking evidence of bone decomposition through soil phosphorus analysis. Although no bone has survived, phosphorus analysis of sediment samples taken within and outside the postulated butchering area may provide evidence of a mass kill. The hypothesis tested here is that if a bison kill were present at the Dinwoody site, then soil samples within the postulated butchering area should have elevated phosphorus levels compared to those outside of it. The method is tested on samples taken from a bison kill site that contains a visible bonebed, the Wiggins Fork site (48FR7470).

Site Setting

The Dinwoody site is located in the Wind River Mountains approximately 32 km southeast of Dubois, Wyoming. The Wind River Mountains contain several peaks that exceed 13,700 feet (4,200 m) above sea level (Adams 2010), and its upper elevations are a forest-alpine tundra ecotone (Adams 2010; Hansen-Bristow et al. 1988). The alpine ecotone occurs between 10,200 and 10,800 feet (3,109 to 3292 m). At this altitude, the local weather pattern restricts or prohibits access into this region, even during summer months (Adams 2010). The site sits on bedrock consisting of granitic gneiss and local masses of quartzite, metagraywacke, iron-formation, and other metasedimentary rocks as well as amphibolite and felsic gneiss thought to be volcanic (Love and Christiansen 1985). The soils of the site consist of 304L-Agneston-McCall-families, Rubble land complex, and a 302L-Moos River-Elvick families complex (http://websoilsurvey.nrcs.usda.gov). The vegetation of Dinwoody consists of native bunch grasses, a variety of wildflowers, and low shrubs that appear around springs that lie along the mountain side (Guenther 2016). No invasive species were noted on the site. At one time the mountainside was forested, based on stumps and logs found around the site (Guenther 2016) (Figure 1). Evidence also comes from research conducted at the High-Rise village site and on Union Pass, where studies suggest that the tree line was higher around 1800 to 800 cal. yr. BP than present tree line (Morgan et al. 2014).

Figure 1. Example of one of the remnant trees stumps/logs that have been documented below the jump complex that indicate tree line was once higher and might have been used to bolster the drivelines. Photo credit: Todd Guenther.

The Central Wyoming College field school crew discovered the Dinwoody site in August 2015. The field school was part of the CWC Interdisciplinary Climate Change Expedition (ICCE), which aimed to document past human activity in the Dinwoody area, the status of the Dinwoody Glacier, snow fields, ice patches, water quality, and other ecological data (Guenther 2016). While recording a stone circle site located just below Arrow Pass, one of the students scouted the hill to the east and found several small anthropogenic rock piles, or cairns, which prompted investigation. At first thought to be trail markers, they took on new meaning when the southern end of the cairn line ended at an apparent jump and processing area. The northernmost cairns were in a cluster overlooking Arrow Pass and the Williamson Corrals meadow (Figure 2) (Guenther 2016). The quick 2015 survey also located possible shaman structures near the north end of the cairn line and at the jump site (Figure 3).

Figure 2. The northernmost part of the cairn line complex that extended up to the top of Arrow pass looking back to the suspected gathering area of Williamson Corrals. Photo credit: Todd Guenther.

Figure 3. Possible shaman structure that was recorded on Arrow pass at the northernmost point of the cairn line complex. Photo credit: Todd Guenther.

The Dinwoody site has several of the cultural and natural features that typify other, demonstrable bison jumps, including a herd gathering area, several drivelines, hunting blinds, shaman structure/sighting cairns, and associated campsites located in the valley below the jump. The

Dinwoody site is part of a complex that covers the Burro Flat area located just below the jump. Richard Adams and the CWC field school documented parts of this complex, which is located on Burro Flats below Arrow Mountain on USFS land (Shoshone National Forest; Guenther 2016) (Figure 4).

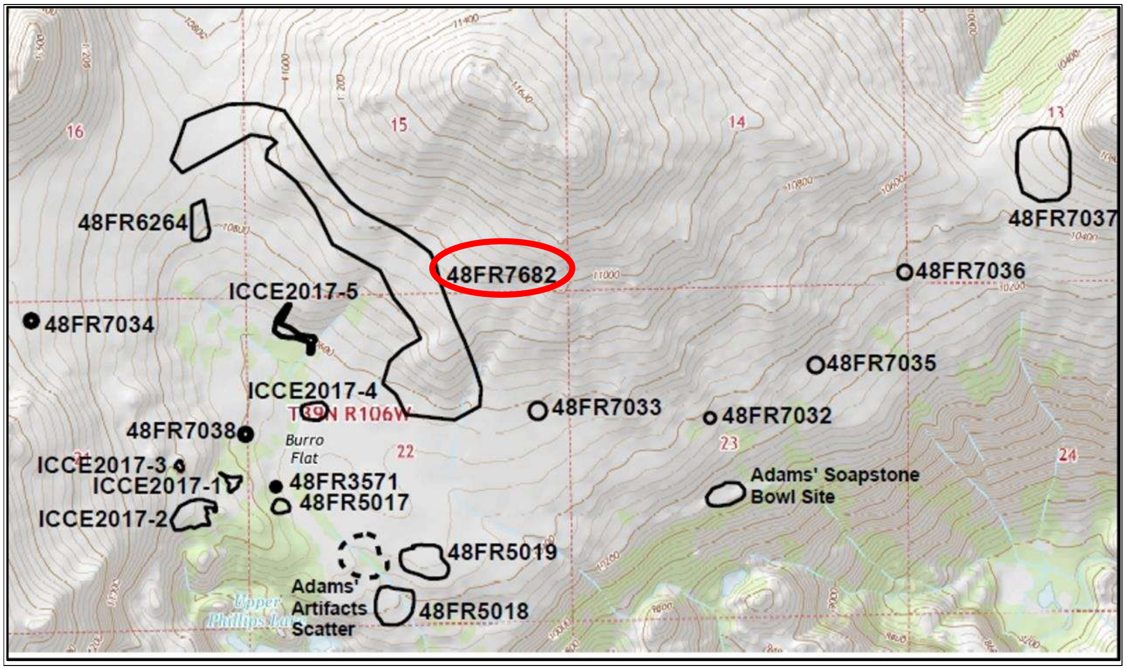

Figure 4. The entire Burro Flats Site Complex. Including sites that Adams recorded in the early 2000's and CWC Field School sites. Map Credit: Jordan Walter and Todd Guenther.

The north end of the Dinwoody site, where the driveline system begins, is in Arrow Pass, between Williamson Corrals Meadow and Burro Flats (Figures 5 and 6). The driveline component of the site extends southeast for approximately 0.9 miles (1.4 km) along the western-facing slope of an unnamed, barren rocky peak to the postulated jump and butchering area. The highest elevation of the site is just over 11,000 feet (3352 m) and the lowest point, a debitage concentration interpreted as the butchering/processing area immediately below the jump, is located between 10,800 and 10,840 feet (3,291 to 3,304 m; Figure 7). This driveline system is another example of how these extensive drive structures represent a significant expenditure of time and labor invested in a communal hunting strategy (Benedict 1975).

Figure 5. Arrow pass blinds that mark the beginning of the driveline complex looking towards the South. Photo credit: Todd Guenther.

Figure 6. Cairns that make up the driveline complex heading in the direction of the jump, looking to the southeast. Photo credit: Todd Guenther.

Figure 7. Top of the jump looking down on to the rocky scarp and into the suspected butchering area of the site. Students are used for scale to show the size of this steep and rocky scarp. Photo credit: Todd Guenther.

Survey

Several CWC archaeological surveys documented the full extent of the site. The entrance to the drive line lies at the south end of Williamson Corrals meadow, a large (>1,000 acre), well-watered grassy meadow on the west slope of Arrow Mountain that served as a grazing/gathering area (Figure 8; Guenther 2016). Prehistoric hunters could have slowly driven bison, consolidating them into a herd of sufficient number for a drive (Kornfeld et al. 2016), and then directed the animals through Arrow Pass into the driveline and south toward the jump (Guenther 2016).

Figure 8. Williamson Corrals looking toward the top of Arrow pass. This well-watered grassy area is believed to be the grazing area for this jump complex. Photo credit: Todd Guenther

The north end of the drive line in Arrow Pass is marked by a cluster of cairns and blinds on a small finger ridge at the southeast extremity of this gathering area and extends generally southeast along the contour of the slope but slightly downhill for 1,585 m (0.98 mile; Figure 9) (Guenther 2016). The cairns that make up the three distinct drive lines vary greatly in size, number of stones, design/construction, shape, and spacing (Guenther 2016). Some cairns consist of one stone placed conspicuously on top of a boulder or bedrock outcrop, piles of five or ten stones on a boulder or bedrock, piles of five to twenty stones on the ground, flat stones that are propped up vertically like historic gravestones, and piles of stones sandwiched between natural bedrock or regolith (Figure 10) (2016). The spacing between the cairns in the three lines varies from 10 to 50 m. The variable spacing might suggest the cairns were built at different times, added to the drive line as it was reused over time (2016). Logs may have been placed between the cairns. But there is a clear, overall pattern of an organized, intentionally constructed line of cairns, which ends at a feature that could have served as a kill area (2016).

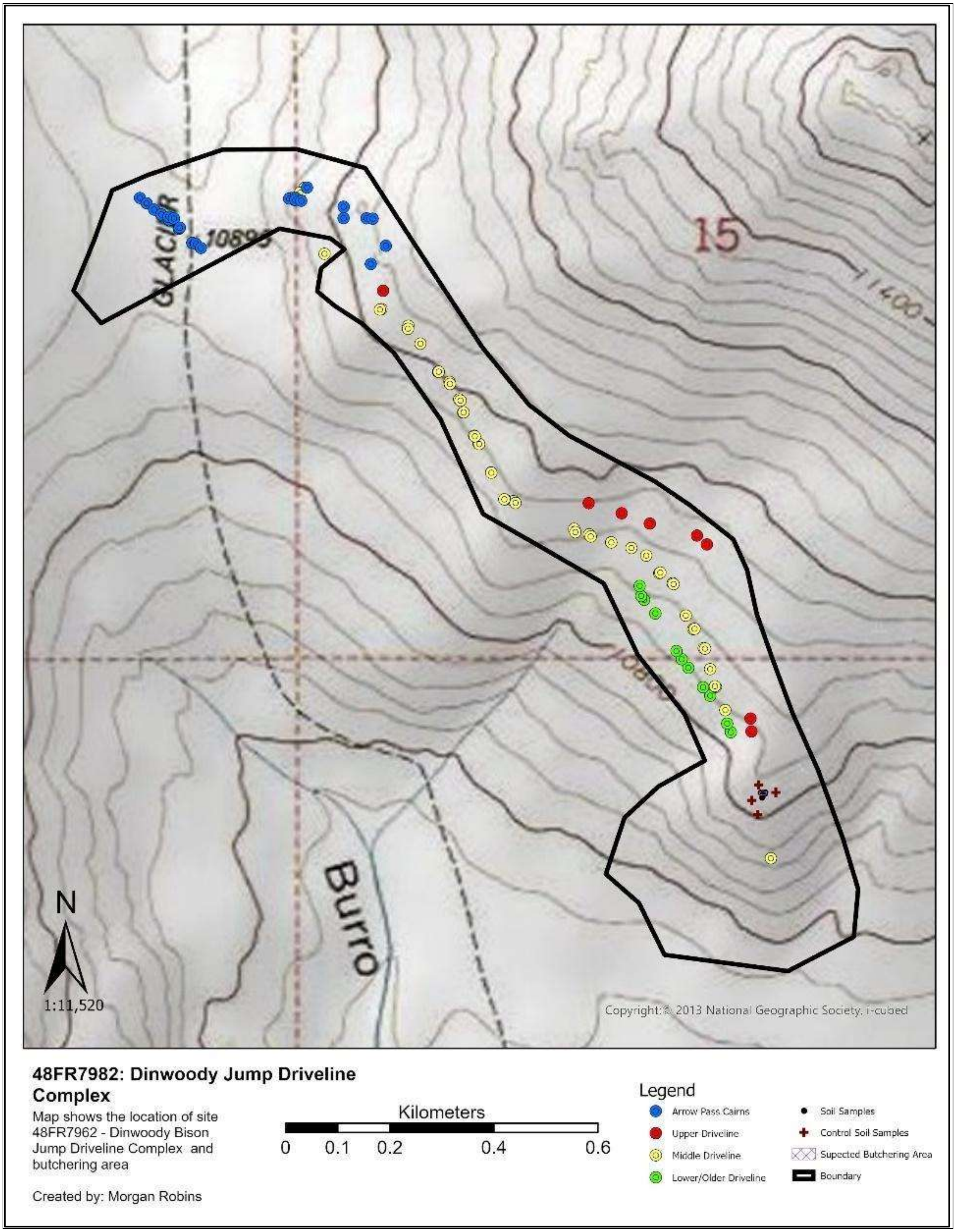

Figure 9. Map displaying the multiple cairn lines that were documented with this site. Created by Morgan Robins

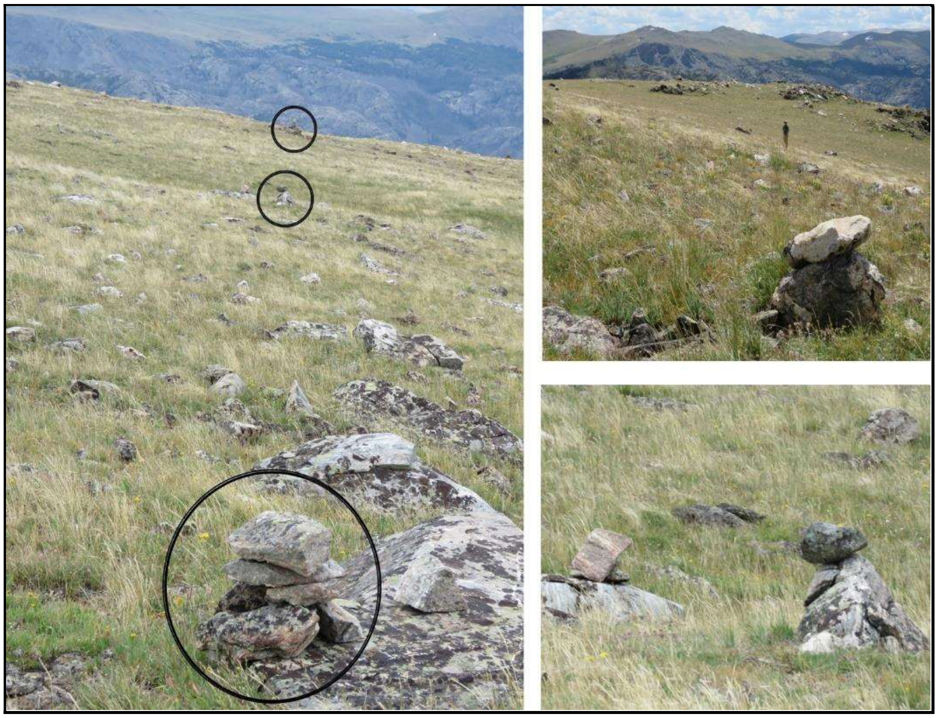

Figure 10. Example of the variety of cairn structures that have been documented in all drivelines on this site complex. Photo credit: Todd Guenther.

There are also two stacked stone walls located about 50-60 m uphill from the middle cairn line that can be seen in figure 9(Guenther 2016). The northernmost blind is the larger of the two and incorporates a naturally occurring boulder with other rocks stacked around it in a semicircle 4-5 m long (Figure 11). The space behind this blind has been excavated to make a better hiding place so hunters would not be prematurely exposed. The south blind is about 80 cm high, 3 to 4 m long, and built in a straight line (Figure 12). It is located at a point in the driveline where the bison would have encountered a small finger ridge that would have encouraged them to break uphill and escape. Both blinds are placed at locations crucial to keeping bison from breaking away too early, and to help turn the bison downhill to the southwest toward the base of the next finger ridge that hid the jump from view. Several other blinds are located at weak points in the drivelines where bison might have tried to escape. In conjunction with survey, several small excavations were made in several of the upper driveline blinds to search for temporally diagnostic artifacts. Unfortunately, this effort was not rewarded.

Figure 11. Northern blind looking down towards the southwest down into Burros Flats. Photo Credit: Todd Guenther

Figure 12. South blind looking towards the southeast back towards the jump off. Photo credit: Todd Guenther

Along with the drivelines and hunting blinds, several other stone structures are recorded on this site. One, located at the north end of the cairn line where bison would have first entered the drive line, is in an area of multiple rock outcrops and exposed regolith bedrock and may be a shaman structure. Shaman structures are places where the shaman would orchestrate and direct both the people and the hunt and lure the bison in by supernatural means (Brink 2008). It was created by lifting stones out of a hole and piling them around its perimeter, creating a structure that is roughly 5 m x 5 m in outside diameter and about a meter deep in the central pit. The area in which this structure is constructed is surrounded by several natural depressions, but they appear to have been created by natural processes where fine sediments were washed away by hydraulic action causing the regolith in these locations to slump into a hole, rather than from the removal of stones to create a perimeter around the resulting depression. The shaman structure is located just above a spring and pond, which may or may not have been a factor in determining the location of this structure. The feature is too far from the pond to have been used as a blind to kill animals coming to drink. Another shaman structure is located adjacent to the jump off (Figure 13). This is a common arrangement at jump and trap sites. This feature is created by stacking stones around a crack in the bedrock and designing sighting cairns that focus on important parts of the drive system.

Figure 13.Interior view of the stacked stone shaman structure near the jump off. The left tube points northwest across the north end of Burro Flats to a spot on the mountainside at far right of this image and which might have been used as a command point for the whole bison driving and jumping endeavor. The right-hand tube points north to the spot on the horizon at the right side of this image where the bison would first come into view for those working at the jump site. Photo credit: Todd Guenther

Dating

Several samples from the remnant logs and tree stumps of a ghost forest found below the jump and a bison horn sheath found behind one of the blinds in the upper driveline were collected for radiocarbon dating (Table 1). The dates on the tree stumps range between 1220 ± 30 BP to 2780 ± 30 BP. The bison horn sheath dated to 140 ± 30 BP. These dates do not necessarily provide an accurate age for site use because the dates from the tree samples tell us when the trees died, and the horn sheath could have come from a lone animal rather than one that was being driven.

Several tree slab samples, most likely Engelmann Spruce or Subalpine Fir or White Bark Pine (Morgan et al. 2014), were collected for radiocarbon dating (Figure 13). The results from these samples show that the trees located around the Dinwoody site are between 1220 ± 30, 1390

± 30 and 2090 ± 30 years BP. These dates from the C14 samples are from various stumps across the hillside and point to a higher tree line between 2700 to 120 BP in this area. However, these dates do not provide an accurate age for the Dinwoody site.

Table 1. Radiocarbon dates from Beta Analytic from the bison horn sheath found in the drivelines and from wood samples collected from the ghost forest, and flagpole remnant found between cairns in the upper driveline.

Sample Data	Conventional Radiocarbon Age	^{13}C	Conventional Radiocarbon Age
Beta-442677 (Horn Sheath)	70 ± 30 BP	-20.5 (^{15}N= +5.4)	140 ± 30BP
Beta- 442678 (Wood 1#)	1170 ± 30 BP	^{13}C = -22.2	1220 ± 30 BP
Beta- 442679 (Wood 2#)	2030 ± 30 BP	-21.4	2090 ± 30 BP
Beta-442680 (Wood 3#)	1350 ± 30 BP	-22.6	1390 ± 30 BP
Beta- 473066 ("Flagpole" Remnant; see discussion below)	2960 ± 60 BP	-22.5	2910 ± 30 BP

In 2018, we collected samples of soil beneath several cairns and blinds for Optically Stimulated Luminescence (OSL) dates. Optically Stimulated Luminescence dates the silicate mineralogical content of soil (Athanassas et al. 2015), estimating the number of years that have passed since the sample was last exposed to sunlight. With that in mind, we collected samples from all three drivelines, focusing on those with the most potential to produce siliceous material for a sample. The choices were limited as most of the cairns in the system were stacked on bedrock. Samples from five cairns were collected, two from blinds 1 and 4 located in the high driveline, one from the Arrow Pass blind, two from cairn 22, located in the middle driveline, and cairn 8, located in the lower line. Samples were collected with the assistance of Carlie Ideker a lab manager at the Utah State University Luminescence lab. The samples were collected in a zero light environment and placed within zero light containers, wrapped in duct tape, to ensure no light would reset the samples (Figure 14). Secondary samples of both the soil and rock near the cairn were taken for lab calculations. The samples were transferred down to the luminesces lab where I spent a week at the Utah State University OSL lab under the guidance of Carlie Ideker processing the samples for dating.

Figure 14. Collecting an OSL samples from under one of the blind structures from the upper driveline complex with the help of Carlie Ideker. Photo Credit: Todd Guenther

The lab determined the dates from these samples using single-grain and small-aliquot methods (these methods of measurements were chosen based on the size of the sample after pretreatment). The dates on the samples (Table 2) suggest that the Dinwoody Jump was used between about 800 to 200 years before present and may have been remodeled several times.

Table 2. Results of the five OSL samples from the Dinwoody complex features. Analysis was conducted at Utah State University Luminescence lab.

Preliminary Table:

07-12-2019

Sample #	USU #	depth (m)	# analyses in age calc (total run)	dose rate (Gy/ka)	PRELIMINARY equivalent dose, Gy (2SE)	PRELIMINARY OSL age, ka (2SE)	Method
High Driveline Blind 1	USU-2908	0.38	53 (500)	4.41 ± 0.22	1.50 ± 0.48	0.3 ± 0.1	Single-grain
High Driveline Blind 4	USU-2909	0.09	42 (1400)	2.54 ± 0.13	0.34 ± 0.14	0.1 ± 0.1	Single-grain
Arrow Pass Blind	USU-2910	0.13	30 (1800)	2.79 ± 0.12	1.46 ± 0.68	0.5 ± 0.3	Single-grain
Middle Driveline Cairn 22	USU-2911	0.62	11 (17)	3.00 ± 0.14	0.61 ± 0.34	0.2 ± 0.1	Small-aliquot
Lower Driveline Cairn 8	USU-2912	0.12	4 (17)	2.57 ± 0.12	1.47 ± 0.47	0.6 ± 0.2	Small-aliquot

Early Soil Chemistry and eDNA

To find a trace of organic evidence of bison, soil samples were collected from four locations in the suspected processing area directly below the jump, and control samples were collected above and to both sides of the butchering area (Guenther 2016). These samples were tested for elevated levels of sporormiella at University of Utah Red Lab in the Geography Department. Sporormiella is a fungus found in the guts of large herbivores such as bison and if elevated levels were detected in the soil samples, then it could indicate past butchering and the decomposition of stomach contents from the remains of a gut analysis (Petersen 2017). The analysis provided a negative result. In 2019, we collected another set of soil samples to look for evidence of ancient DNA in the soil of the processing/butchering area. Samples were collected in a transect line that spanned the suspected butchering area (Figure 15). The soil samples were collected into cloth sediment bags and sent to Zymo Research Corporation for analysis. As of this time no results have been returned because of the COVID-19 pandemic (Figure 16).


Figure 15. Collecting soil samples for eDNA analysis. Photo credit: Todd Guenther.

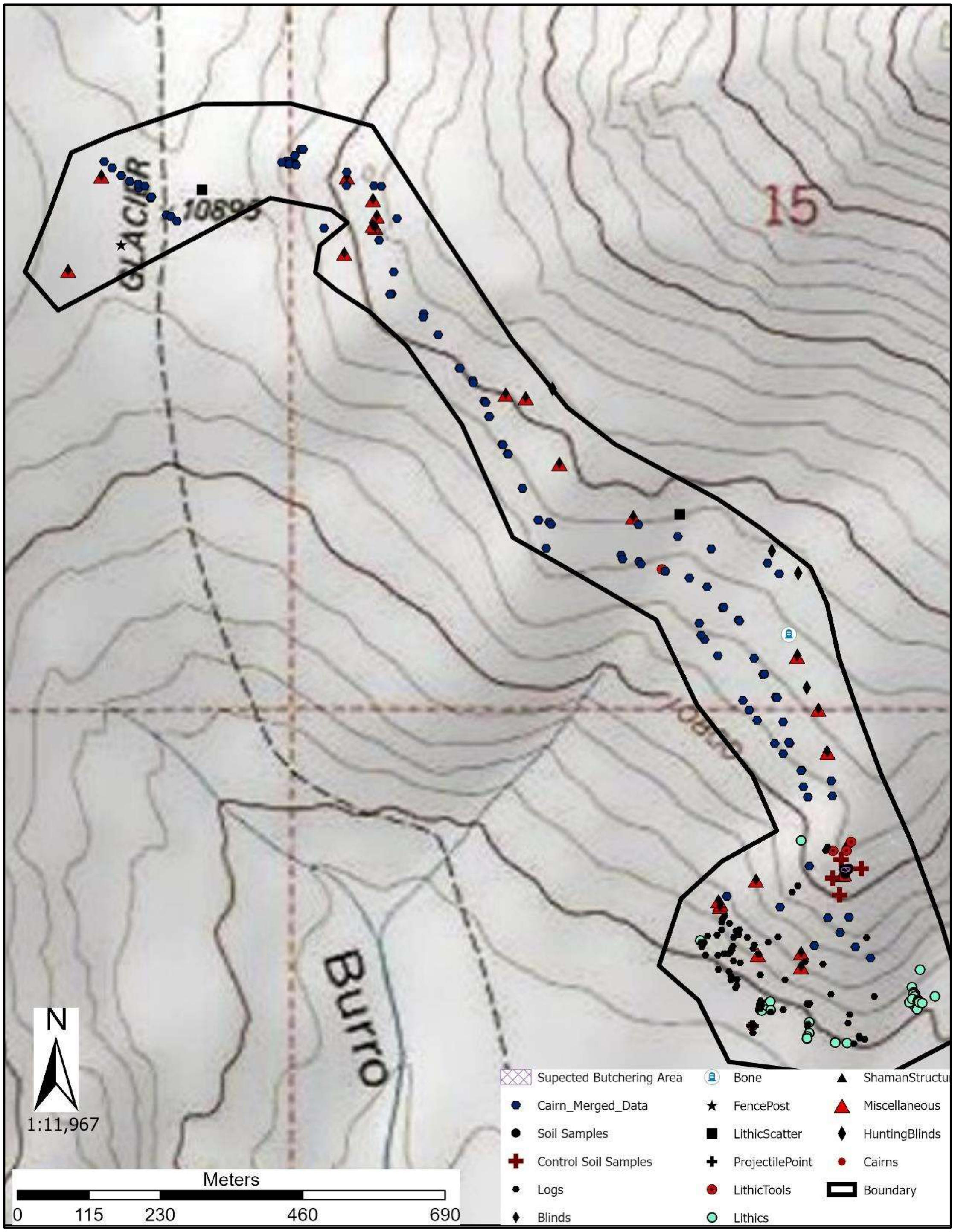

Figure 16**.** Map of the entire site 48FR7982- Dinwoody Bison Jump complex. Displaying culmination of work done on this site from 2016 through 2019. Map created by Morgan Robins

The Problem: is the Dinwoody a Jump Site?

To summarize, the Dinwoody Bison Jump is some 730 m/2,400 ft higher than the next highest jump in Wyoming. This unusual fact has caused some to question whether it is a bison jump. Some doubt that bison climbed so high into the mountains, and suggest that if this is a kill site, it may have been used for communal hunting of other big game species. Did prehistoric bison climb high into the mountains? Del Nelson of the US Forest Service provided the CWC team with skeletal bison remains that he collected between 2,550 m/8,300 ft and 3,380 m/11,100 ft in the Wind River, Gros Ventre, and Absaroka Mountains since the 1960s. These samples were radiocarbon dated between 100-400 years before present. Isotopic analyses of these remains are ongoing. Cannon and others have further documented bison at elevation in other parts of the GYE. Cannon (2007) shows that in the early 19th to 20th century 'High-altitude' bison specimens were sighted in alpine regions of Colorado, Wyoming and Montana. More recently, in 1974, a biologist reported on bison remains "...above timberline in the Big Horn Mountains of northern, Wyoming (Wilson 1974; Cannon 2007). Cannon's article also mentioned that with "...climate-driven ice/snowfield melting in high-altitude and high-latitude regions, a new source of bison remains has been uncovered" (Cannon 2007: pp. 44; see also Lee et al. 2006).

Due to looting, no diagnostic artifacts have been recovered from the Dinwoody site. The two projectile points collected nearest to the site are both from the Paleoindian Period. One is a Folsom base collected near the entrance to the driveline (Adams et. al. 2014), the other is a Plains parallel-oblique lanceolate point collected below the butchering area. Both points predate the drivelines and jump complex. The dates from the OSL results show that the built stone features indicate that the system of three converging drivelines was probably built, redesigned, and reused between about 800 and 150 years ago. This was roughly from the end of the Medieval Climate Maximum through the Little Ice Age, during what Frison called the "Classic" Late Prehistoric bison jumping era (Frison 1978: 229).

The Dinwoody site consists of all the components of a bison jump as outlined by Frison (Frison 1978: 229-231) and Kornfeld et.al. (2010) by having high bluffs that could cripple or kill when the animals were stampeded, a long line of cairns to serve as reference points to guide the hunters and an area with several square kilometers for grazing and gathering the bison to run through the system (Kornfeld et al. 2010). To paraphrase Frison, a bison driveline complex is composed of two parts: a grazing area that attracts bison in sufficient numbers in a location from which the bison can be moved to a second feature that is situated so bison can be driven over it and crippled or killed. To herd or move the bison toward the jump, drivelines are built consisting of long lines of cairns. These cairns were usually not large: some contained only four or five boulders, others could contain 20 or more. The driveline cairns provide an important function in handling bison. The cairns were usually placed and built in such a manner as to impart information to the drivers that would aid them in moving the bison herd. This involved more than merely running along behind the buffalo. The herd had to be prevented from stampeding prematurely. It had to be carefully manipulated to keep it on the predetermined path. Failure to do so resulted in loss of the herd.

Occasionally hunting blinds were placed in the cairn lines where additional people were needed to strengthen weak points in the drivelines. Blinds were commonly placed where the drivelines crossed over finger ridges at Dinwoody. At some sites, vertical brush, sticks, or poles were placed in or between the cairns to increase their visibility. The drivelines could be straight, or curve around geographic features or obstacles between the gathering area and the jump. The drive lines served as reference points to help the hunters coordinate their movements with those of the buffalo, all of which needed to be perfectly timed to the split second: responses to movements of the animals meant the difference between success and failure.

Figure 17. Many of the Dinwoody driveline cairns consist of rocks stacked on boulders orbedrock outcrops. Some resemble human torsos and heads. Other Dinwoody driveline cairns consist of long rocks propped upright.Photo credit: Todd Guenther.

Figure 18. Another example of how many of the Dinwoody driveline cairns consist of rocks stacked on boulders or bedrock outcrops. Some resemble human torsos and heads. Other Dinwoody driveline cairns consist of long rocks propped upright. Photo credit: Todd Guenther.

Figure 19. Another example of how many of the Dinwoody driveline cairns consist of rocks stacked on boulders or bedrock outcrops. Some resemble human torsos and heads. Other Dinwoody driveline cairns consist of long rocks propped upright. Photo credit: Todd Guenther.

Through our research, evidence indicates that branches and poles were placed vertically in some Dinwoody driveline cairns, much as they were at the Head-Smashed-In site in Alberta, Canada (Brink 2008, p. 97-101; Figure 20-21). The remnant of one such Dinwoody 'flagpole' or 'deadman' was discovered between blinds in the upper driveline (Figure 22). The >10cm diameter base of a pole was recorded standing in the center of a carefully arranged stacked stone feature. Fragmentary remnants of the pole extending nearly two meters from the *in situ* base were found where they had blown over and fallen between talus rocks. This wood was probably long-dead when it was incorporated into the driveline. The sample radiocarbon dated at 2910 +/- 30 BP, IRMS δ13C: -22.5 o/oo, (3158 - 2960 cal BP) (95.4%) 1209 - 1011 cal BC. This is likely an example of "the old wood problem." Other tree trunk and stump remnants exposed on the surface adjacent to the drivelines have been dated between about 1,000 and 2,000 years before present. The OSL dates in the Late Prehistoric between about 800-150 years ago for the built stone features do not support the radiocarbon ages for the drivelines

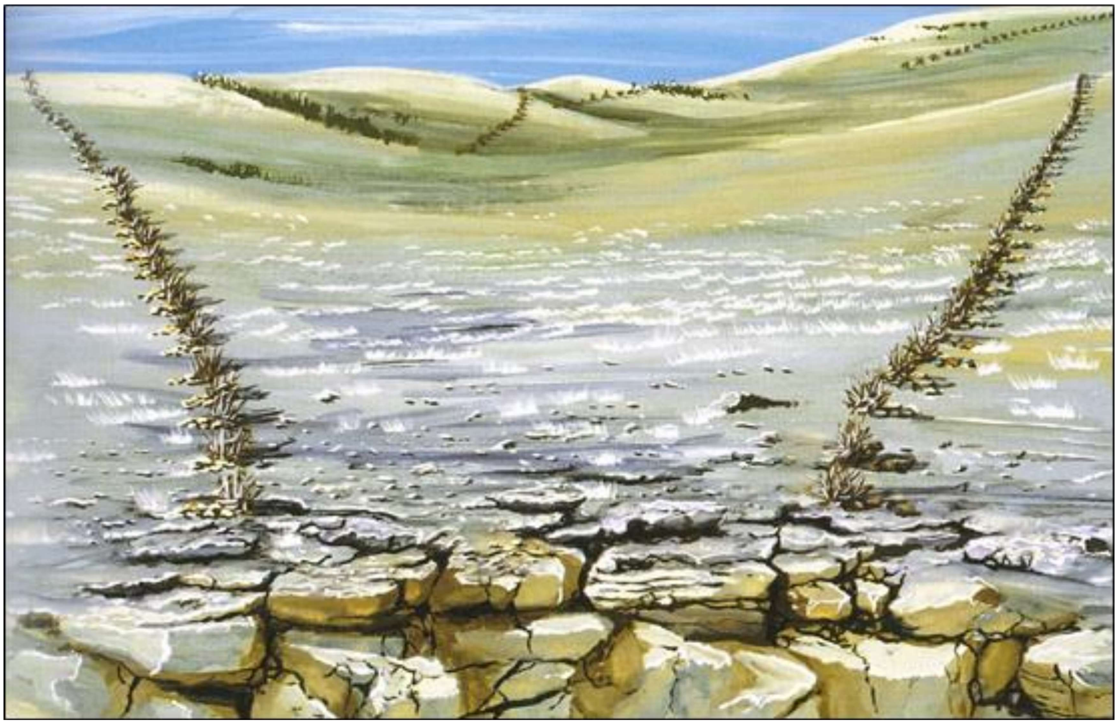

Figure 20. Driveline funnel converging at clifftop scarp or jump off. Flagpoles, or "deadmen," inserted in cairns create a visual guide to help control and direct bison herd movements. From Brink, Imagining Head-Smashed-In, p. 101.

Figure 21. Constructing a flagpole, or "deadman," in a driveline cairn. From Brink, *Imagining Head-Smashed-In*, p. 99.

Figure 22.The remnant of a flagpole, or deadman, between two blinds in the Upper Driveline that was documented by CWC Field school. Photo credit: Todd Guenther

Frison goes on to say that drive lines may have had supernatural significance, and that the whole communal kill operation was carried out in a context of shamanistic controls. Although the drive lines reflect a thorough understanding of bison behavior, the shaman undoubtedly provided an added measure of security for a successful operation. Many communal hunting sites include features interpreted as shaman pits or structures where prayers, ceremonies, and offerings could be made. There is evidence for this at both ends of the Dinwoody drive system, with a Shaman structure adjacent to the Dinwoody Jump and one located on Arrow Pass at the beginning of the driveline system (Figure 23). A person seated in the pit could look through two "sighting tubes" that were built into this structure. One points westward at a hilltop lookout across the valley, the other guides the viewer's eye toward the point in the driveline funnel where bison first appear on the horizon on route to the jump off point (Figure 24).

Figure 23. Shaman structure adjacent to the Dinwoody Jump. A person seated in the pit could look through two "sighting tubes" that were built into this structure. One points westward at a hilltop lookout across the valley, the other guides the viewer's eye toward the point in the driveline funnel where bison first appear on the horizon enroute to the jump off point. Photo credit: Todd Guenther

Figure 24.View through "sighting tube" showing where on the horizon bison leave Williamson Corrals Meadow and first come into view from the jump off area. Photo credit: Todd Guenther.

The final part of the drive line is where the 'funnels' created by the cairn lines converge as they approach the actual jump. Here the bison herd was carefully maneuvered to a predetermined position behind the jump off, then forced through a sharp turn, after which an effort was made to suddenly stampede the herd into a tightly packed formation over a small ridge which obscured the jump off scarp. This important strategy kept the bison from seeing the jump off until the very last minute when the hunters' changed tactics. No longer carefully and deliberately manipulating the animals, they did everything they could to make them panic. However, even the stampede had to be controlled. The animals had to be forced together in tight formation, pushed at top speed and headed in exactly the right direction so that the followers would force the leaders over the scarp. Even a slight deviation in the approach would have sent the herd down a steep slope instead of over the scarp, thus wasting the entire effort. To make sure there was no deviation, hunters hid behind brush piles, hides, in blinds, or other artificial means of concealment so they could appear at the stone piles at the proper moment to urge the stampeding animals over the precipice. Split second timing was critical.

A problem with the Dinwoody drivelines is that the cairns near the terminal end are spaced farther apart than is common in most bison drive systems. It is likely that these gaps were bolstered with logs and tree branches, as is common in nearby drive systems for bighorn sheep and other bison drives including 48NA13, the Split Rock Bison Jump (Bromley 2006; Figure 25). The practice of utilizing logs in drivelines would have been familiar to Dinwoody hunters who would have seen, if not built or used the numerous bighorn sheep traps in the Upper Wind River area. Wood was readily available at the Dinwoody site: a prehistoric ghost forest of white bark pine (Morgan et al. 2014) stumps and logs adjacent to the driveline and jump likely provided raw materials. This forest radiocarbon dates between 1,000 and 2,000 years before present and is located just below / downslope along the last quarter mile / 0.4 km of the driveline. In addition to providing logs to bolster the drivelines, the edge of the forest itself would have created a visual barrier to help direct bison (unlike elk, bison do not enter thick timber to escape predators) being moved along the side of Arrow Mountain. In other words, it appears likely that the driveline was constructed along tree line, using deadfall logs, across the side of Arrow Mountain to the jump site. All these components are continued evidence that this site is indeed a bison jump.

Figure 25. Remnant of log wall component of bison driveline and pound at 48NA13 in the Sweetwater Rocks (Bies 1984; Bromley 2006). It is likely that similar structures were constructed between stone cairns to bolster the drivelines at the Dinwoody Bison Jump. Photo credit Todd Guenther.

However, although the Dinwoody site components look like a bison jump, some may question whether this complex was used to hunt bison, or other animals, or if it was even a kill site at all? Communal drive systems for other animals incorporated many of the same components including gathering areas, converging drivelines with doglegs near the end, obscuring ridges, and shaman structures. The primary, and crucial difference between the different drive systems was at the terminus. Bighorn sheep, elk, and pronghorn antelope all behave very differently and thus require varying communal hunting strategies. Because of the Dinwoody Jump's high elevation, it has been repeatedly suggested that the site may have been used for bighorn sheep hunting. This ignores the facts that (1) bighorns flee to rocky areas like the Dinwoody jump off scarp to escape predators. Sheep would not perish or be crippled in those boulders. For that reason, (2) bighorn sheep drive systems invariably end at carefully constructed log traps, not rocky scarps. The scarp at the terminus of the three converging Dinwoody drivelines make the site completely unsuitable for communal hunting of bighorn sheep (Figure 26).

It has also been suggested that the Dinwoody Jump was used for elk which inhabit the Dinwoody in larger numbers than bighorn sheep. But this driveline system, and especially the terminus, are significantly different in size, design, and use of terrain than other elk drive systems documented by the CWC Field Schools in the Dinwoody and those in Colorado as recorded by Benedict (1975), Brunswig (2015), LaBelle (2005, 2013), Pelton (2013), and others. Research on other high alpine drives in Colorado shows that although bison are known from such alpine settings, these high-altitude game drives likely relate to culling other large game such as elk and bighorn sheep (LaBelle and Pelton 2013). Evidence for this comes from faunal remains discovered at these sites. In addition, several high-alpine drivelines documented in the Colorado Front range contain a constructed rock wall funnel positioned on the landscape so as to drive game uphill, a design element likely included to take advantage of the behavioral tendencies of bighorn sheep (LaBelle and Pelton 2013). A review of the literature reveals as well that elk drive systems do not terminate at scarps. Elk do not drive like bison; in other words, their herd behavior cannot be manipulated in the same way, thus the structural differences in elk drive systems as described by us and other researchers. In general, archaeologists have observed that elk in this area herd differently from bison. The elk that have been noted in this area tend to scatter in various directions when encountering humans or other natural pressures whereas bison herd toward a singular point or area rather than scattering. Overall, it seems that rather than focus on a singular food source to hunt, hunter-gatherers instead changed their food procurement strategies depending upon where they were on the landscape at the given moment and possibly where they planned to move next (LaBelle 2005).

Figure 26. CWC field school students mapping the Dinwoody jump off / scarp. The deep cracks between the boulders and bedrock would have crippled or killed many bison, but not bighorn sheep. It is possible, perhaps probable, that logs were arranged below the jump off to create a pound that would have prevented injured bison from escaping. Photo credit: Todd Guenther

Using soil phosphorus analysis at the Dinwoody Bison Jump (48FR7682)

While we are confident the Dinwoody site is a bison jump, this interpretation is admittedly hampered by the lack of a bonebed. I decided to try using geochemical soil analysis examining phosphorus levels in soils from the butchering area below the scarp and control samples collected above, below, and to the sides of the butchering area. Although only 5-15cm of soil exists above bedrock in the butchering area on this site, the presence of elevated phosphorus levels could indicate the decomposition of significant quantities of bone following a kill and butchering episode. While this would not prove the bone was from bison, we believe that this site could only have been used for bison procurement, and that elevated phosphorus levels would support that interpretation. This type of geochemical method has not been previously tested at high elevation hunting sites. For that reason, it was decided to use the same method at a nearby site with substantial, stratified bison bone deposits of likely similar age.

Wiggins Fork (48FR7470)

The Wiggins Fork Bison Jump (48FR7470) is located about 32 km/20 mi north of the Dinwoody site (about a two-day hike for prehistoric hunter gatherers) just outside Dubois, Wyoming on the south bank of the Wiggins Fork River at an elevation of 6,880 feet. The Wiggins Fork complex consists of a massive drive line network that spans approximately 41 km^2/16 mi^2 and consists of twelve interlocking/overlapping 'funnels' leading to five probable separate jump/kill sites along the riverbank (Grindle et. al, 2021). The CWC Field Schools have been working to document this complex since 2013. The Wiggins Fork kill site sits on a light-grey volcanic conglomerate and white tuff, containing clasts of igneous rocks (Love and Christenson 1985). The sediments on this site consist of Absher-Popshia-Sinkson complex (http://websoilsurvey.nrcs.usda.gov). Exposure of the site by the Wiggins Fork and excavations in 2020 by the CWC field school shows at least two buried kill events (Figure 27; Grindle et. al, 2021). A total of three salvage blocks were conducted during the 2020 field season exposed bone that was eroding out of the riverbank.

Figure 27.Wiggins Fork bone bed stratification and soil strata from salvage excavations in 2020. Photo Credit: Todd Guenther

Soil Analysis Phosphorus

Phosphorus is the second most abundant element in a body. After death, phosphorus tends to bind with other elements found in soil. When elements such as phosphorus (P) are introduced to the soil through decomposition there is a change in the configuration of chemical compounds (Linderholm 2007), with phosphorus bonding to other elemental ions such as Calcium (Ca) or Iron (Fe). Phosphorus can be deposited through human waste, ash from hearths, burials, and, importantly for our purposes, organic discard piles. Archaeologists have used elevated levels of phosphorus to detect evidence of human activity at other archaeology sites around the world (Holliday and Gardner 2007). The use of phosphorus for reconstructing activity areas in archaeological sites is perhaps the first widespread use of the chemical record in archaeology (Herron 2001). The method basically identifies locations where large amounts of organic matter were once concentrated and, in this way, reflects certain activity areas within the site (Weiner 2010: 223).

Methods

Wiggins Fork Field Methods

Eleven samples were collected from the Wiggins Fork jump. Seven of the samples were collected from four distinct strata that were exposed by the excavation units and mapped by geoarchaeologist William Eckerle. Stratum I is a dark brown non-bedded, muddy cobbly gravel that comes from a toe slope depositional environment (Eckerle 2020), in matrix-supported gravel suspected to be from colluvium/debris flow (slurry mixture movement). Stratum I is overlain by Stratum II and the over bank deposits are approximately 110 cm thick. Stratum III is a dark-reddish brown, non-bedded, mud that derives from alluvial overbank sediment. The lower bonebed lies in the lower part of stratum III; the second bonebed lies at the contact of stratums III and IV (Eckerle 2020). Stratum IV is a very dark grayish brown, non-bedded silt with a single mud bed inter-layer and has been identified by Eckerle as overbank deposits. Stratum V is a black non-bedded, silt to sandy silt overbank alluvium containing the upper bone bed and highly decomposed organic matter. Stratum VI overlies stratum V and consists of a dark grayish brown, non-bedded very fine sand alluvial point bar that possesses a C2 horizon (Eckerle 2020; Figure 28).

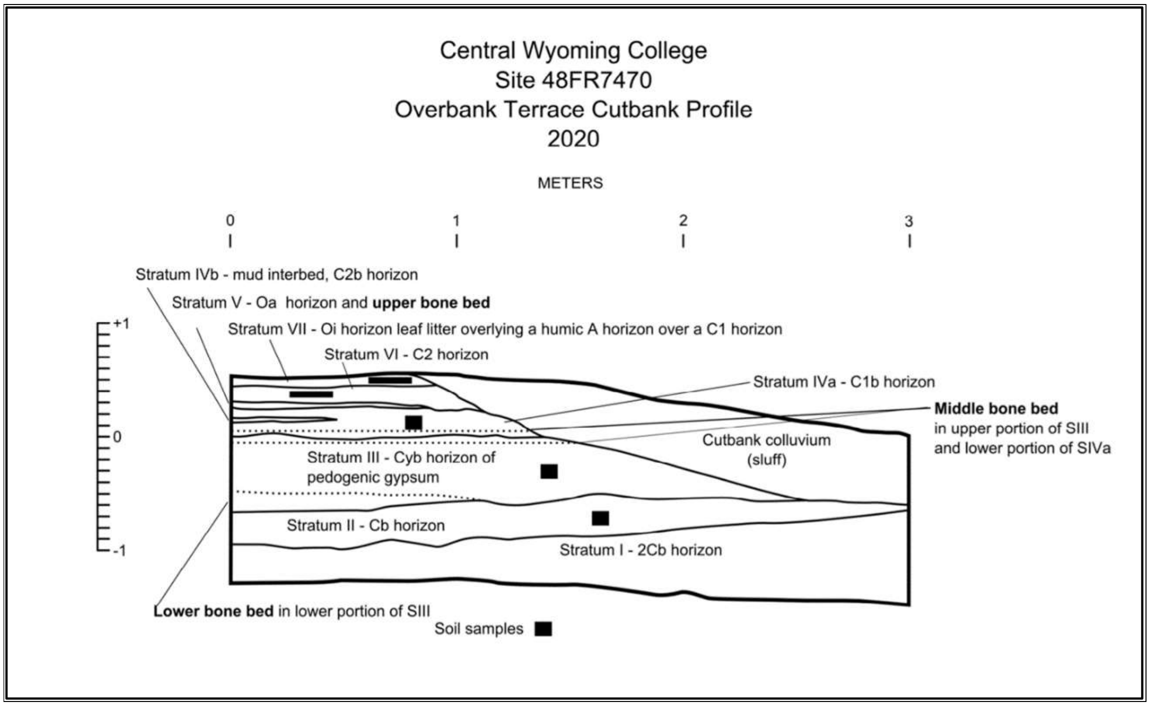

Figure 28. The soil profile from Wiggins Fork where soil samples from the bonebed area were collected. Drawn by William Eckerle 2020 Geoarchaeology Report.

There is very little modern soil formation, but within the modern soil formations are weak traces of soil gypsum and a thin organic deposit on the surface (not very decomposed) containing mica grains in them. Soil samples for this site were taken from strata I through VI. Another three samples were collected as controls from 25 and 50 m outside the known butchering area ~55 cmbs (centimeters below surface) and two meters from the riverbank/terrace edge. Two samples were collected upstream from the site, and one from 25 m downstream, just before the steep, rocky colluvial slope that forms the valley wall and that prevented a second sample further downstream. The profile that provided the downstream sample contained a dark soil band at 45 cmbs that might be anthropogenic and related to the jump, although there were no bones present in the sample collection holes (Figure 29). The samples were placed into cloth artifact bags and transferred to the University of Wyoming.

Figure 29. The soil profile from Wiggins Fork where soil samples from the bonebed area were collected. Photo Credit Morgan Robins

Dinwoody Field Methodology

The Dinwoody samples come from soil samples collected in 2016 for sporormiella. In total nine samples were collected, five inside the suspected butchering area, and four from different locations outside the butchering area (Figure 30). The soil at Dinwoody extends 10-20 cmbs, over aridic bedrock. The shallow soil did not offer many places for samples to be taken and combined with time constraints, limited the number of possible samples. Samples were collected in medium size plastic artifact bags, which were left open after collection to allow soil moisture to escape. The sample bags were labeled with location data, date of collection and a brief description as to the depth and location of where the sample was taken (Figure 31). After collection, some sediment bags were transported to the University of Utah Geography Department RED Lab and the remainder were retained at Central Wyoming College until the summer of 2020 when they were transferred to the University of Wyoming for analysis.

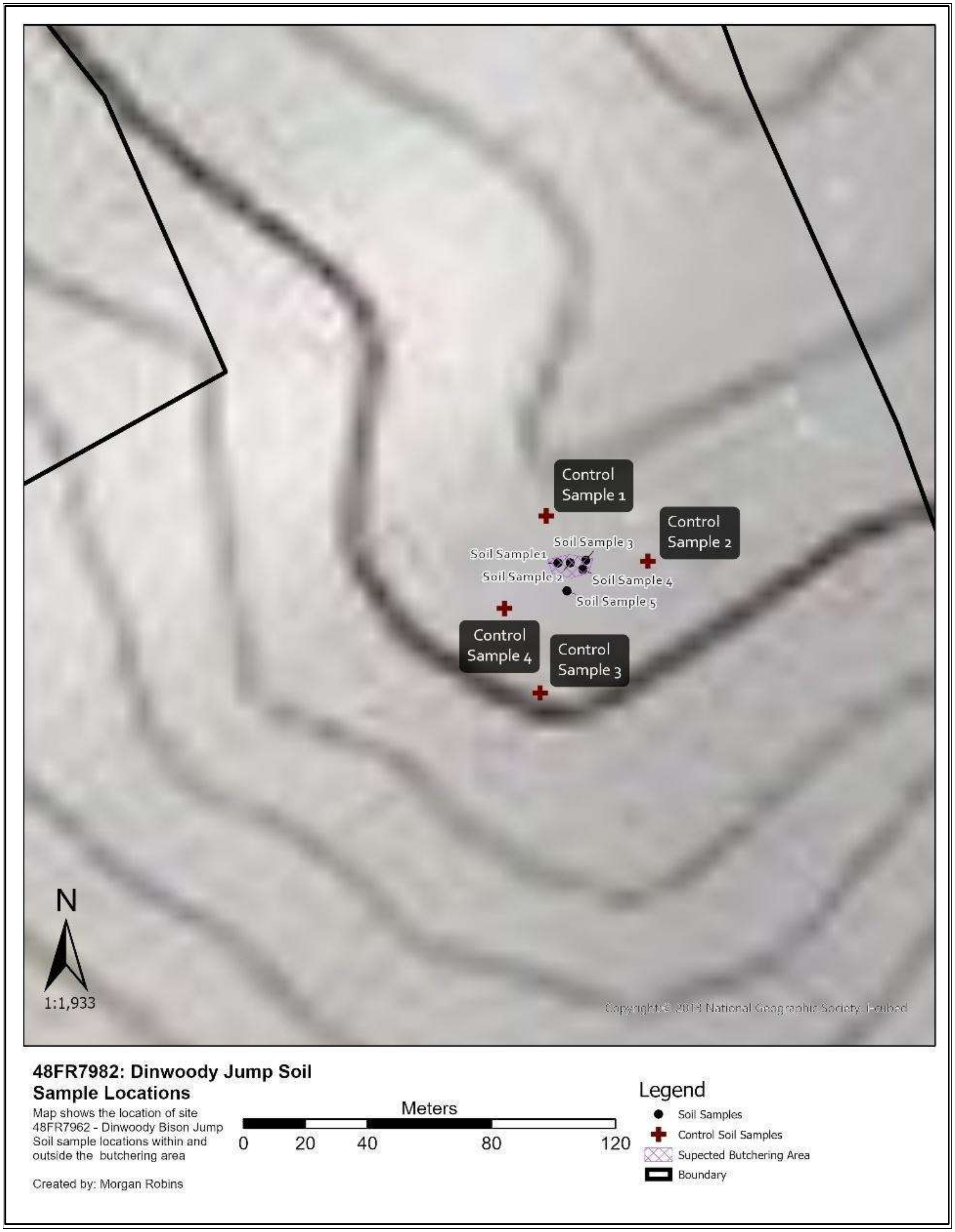

Figure 30. Map showing the location of the soil samples collected from the Dinwoody Jump. Map created by Morgan Robins.

Figure 31. Collecting soil samples from the Dinwoody Bison jump butchering area in 2016. Photo Credit: Todd Guenther

Lab Methods

Once at the University of Wyoming, samples from both the Dinwoody and the Wiggins Fork were sieved through a 2mm screen to remove larger materials and separate the soil/sediment into finer material to be dried. In between the sieving of the soil samples the screen was cleaned. Once screened, the samples were then placed into an QL Model 10 lab oven that was set to 40ºC and left to dry for twenty-four hours; drying the samples at a temperature below 50ºC would not burn off any phosphorus. Once dried the samples were collected into glass vials and labeled with the site and stratum/soil sample number.

Both sets of samples were then ground using a ball mill grinder with a stainless-steel receptacle and balls. The samples were ground for two minutes and then placed into new glass vials using a weighting paper funnel and again labeled with the site name and the soil sample/stratum number and a lower case ‘g’ to indicate that the samples had been ground. After each sample had been ground, the steel capsule was cleaned, using fine grain sea sand that was placed into the capsule and then ground for a minute to clean the capsule of left-over soil residue from the processed sample. Once cleaned, the capsule and the grinding balls were washed with methanol and allowed to dry. All instruments and tools used in grinding the soil samples were also cleaned in methanol after each sample was processed.

Total P and Ca Bound P

Lithium Metaborate ($LiBO_2$) Bead Making Total P

Dr. Zhujon Zhang provided the method used for bead making and included adjustments made for Wyoming's calcareous soils, based on the method of Roberts et al. (1999). The lithium metaborate ($LiBO_2$) that was used to create the beads for this analysis were made of trace metal grade. Once the beads were created, they were then dissolved in a 10% V/V trace metal grade nitric acid solution in 250 mL clear Nalgene bottles. Once the beads dissolved, 4mL of dissolved bead solution was pipetted into 15 mL test tubes that were labeled with the soil sample location and number.

The sample quantities for this analysis were 0.25 g of soil sample and 0.75 g of $LiBO_2$. The soil sample was sandwiched between layers of ½ the total $LiBO_2$ used in this analysis: 0.75 g x .5 = 0.375 g (0.375 g of $LiBO_2$ + 0.25 g of Sample + 0.375 g of $LiBO_2$). Samples were weighed in graphite crucibles on a balance. Once the samples were weighed, they were placed into a muffle furnace for 30 minutes at 1000^{o} C (before being placed into the furnace a tray sample map was recorded to indicate sample location and ID so that samples could be identified after removal from the furnace). After 30 minutes, the samples were removed and left to cool in their graphite crucibles for 5-10 minutes. To serve as a control, two blank beads ($LiBO_2$ alone) were made to provide standards for the analysis.

Once cooled, the beads were removed from their crucibles and placed into 250 mL clear Nalgene bottles labeled with the site ID and the soil/stratum location. Beads were dissolved into a 10% V/VACS grade nitric acid solution, and then placed in a shaker overnight to agitate the mixture to help dissolve the beads. A blank sample was also created to be included in the analysis. In total, five standards were created for instrument calibration purpose (Table 3). The samples were analyzed on a Perkin Elmer Optima 8300 Inductively coupled plasma optical emission spectrometer (ICP-OES) at the University of Wyoming Geology and Geophysics aqueous geochemical lab.

Table 3. LiBO2 Standards concentration. *Dilution WF SS 5; Total: 5.329g + Sample: 0.539g =9.89g.

LiBO2 Standards made from 10% HNO3 LiBO2

Standard #	***P in ppm***
1	0.886
2	1.711
3	3.222
4	6.382
5	12.795

Sequential Extraction Ca Bound-P (HCL)

Reference for this analysis comes from Tiessen and Moir (2008) and was provided by Dr. Zhang and Janet Dewey's own Procedure for Sequential Extraction of Uranium for uranium-vanadate mineral bearing rocks (2017). Both analyses were modified for these specific soil sample tests. For the sequential extraction analysis, 1 g samples were weighed into 50 mL round polypropylene bottom centrifuge tubes with screw lids. Sample vials were labeled with site ID and soil/stratum location. This two-step extraction took two days to complete. For Step 1, 20 mL of 0.5 M concentration of ammonium acetate was added to1.0 g of sample. The samples were then placed on the shaker for 30 minutes (with the caps Parafilmed to prevent leaks). The ammonium acetate step is to remove absorbed P. After 30 minutes, the samples were centrifuged for 10 mins at a speed of 3000 rpm. The solution was decanted into a 50 mL vial that was labeled ‘step 1’. At the end of day one, to keep the samples from cementing to the bottom of the test tubes, 4 mL of deionized water was added to the 50 mL round polypropylene bottom centrifuge tubes and left to sit overnight. At the start of day two, an additional 20 mL of deionized water was added to the 50 mL round polypropylene bottom centrifuge tubes. The tubes were then placed back on the shaker for five minutes and then transferred back to the centrifuge and spun again for 10 minutes at 3000 rpm. After that, the solution was added to 50 mL vials labeled ‘Step 1’ and brought to a total of 50 mL in volume with deionized water. These vials are archived for later use.

During Step 2 of the analysis, the samples underwent the second extraction process with HCL (Hydrochloric Acid). The purpose of this step is to extract Ca-bound P from the samples and determine if there is any material that would indicate bone in the samples. To begin this process 25 mL of 1.0 M HCL was added to the 50 mL round polypropylene bottom centrifuge tubes containing samples that had been processed with Step 1. The samples were capped and placed back on the shaker for 30 minutes. After 30 minutes the samples were centrifuged for 10 mins at a speed of 3000 rpm. The solution was decanted into a 50 mL vial that was labeled ‘Step 2’. Then, 10 mL of deionized water was added to the 50 mL round polypropylene bottom centrifuge tubes that contained the sample. The samples were placed back on the shaker for 5 minutes and then centrifuged for 10 minutes at 3000 rpm. After that, the solution was added to 50 mL vials labeled ‘Step 2’ and brought to a total of 50 mL in volume with deionized water.

The next step was to take the ‘Step 2’ 50 mL vials and pipet 4 mL of the solution into 15 mL test tubes that are labeled with the site ID and soil/stratum location for the analysis by ICP-OES. Five standards were prepared in a 0.5 M hydrochloric acid (ACS Grade) (Table 4). Once created, all samples were placed on special trays and ready for the ICP-OES. While the machine was being prepped and calibrated for this analysis, a file on the lab computer was created to store the data that would come from the analysis on the soil samples from both sites and be used as a back-up or help conduct re-runs of samples in the future.

Table 4. Sequential Extraction Standard concentrations. *Another standard was created based on early results so a new Dilution of WF SS 5 HCL; Total: 4.659 g + Sample: 1.085 g = 4.294 g

Sequential Extraction Standards made from 0.5M HCL

Standard #	***P in ppm***
1	8.963
2	15.736
3	32. 910
4	66.223
5	129.805

Results

The ICP-OES data are from samples that were diluted. To calculate the base dilution factor for this solution the volume of the diluted samples, which in this case was 50 mL per method requirements, was divided by a sample weight. The base dilution factor was then multiplied by the P pm results collected from the ICP-OES to arrive at corrected values for both the total-P and Ca-bound P results.

Two statistical analyses were run in R studio to test for significant differences between the butchering areas and non-butchering areas at each site: Welch's T-test and a Mann-Whitney U-test (Wilcox test). The Welch's T-test is suited for instances where the sample sizes are unequal. The Mann-Whitney U-test determines whether the distribution of the dependent variable is the same for the two independent groups in each dataset. The confidence interval for both tests is 0.05.

Wiggins Fork Total P

With an obvious bonebed, Wiggins Fork acts as a control on the use of total-P and Ca-bound P to measure the prior presence of a no-longer-present bonebed at Dinwoody (Figure 32). The difference between the bonebed and control samples at Wiggins Fork is not significant when using the Welch two-sample test ($t = -2.1975$, $df = 6.7596$, $p = 0.06532$). However, the Mann-Whitney U-test did produce a significant difference ($W = 1$, $p = 0.03333$).

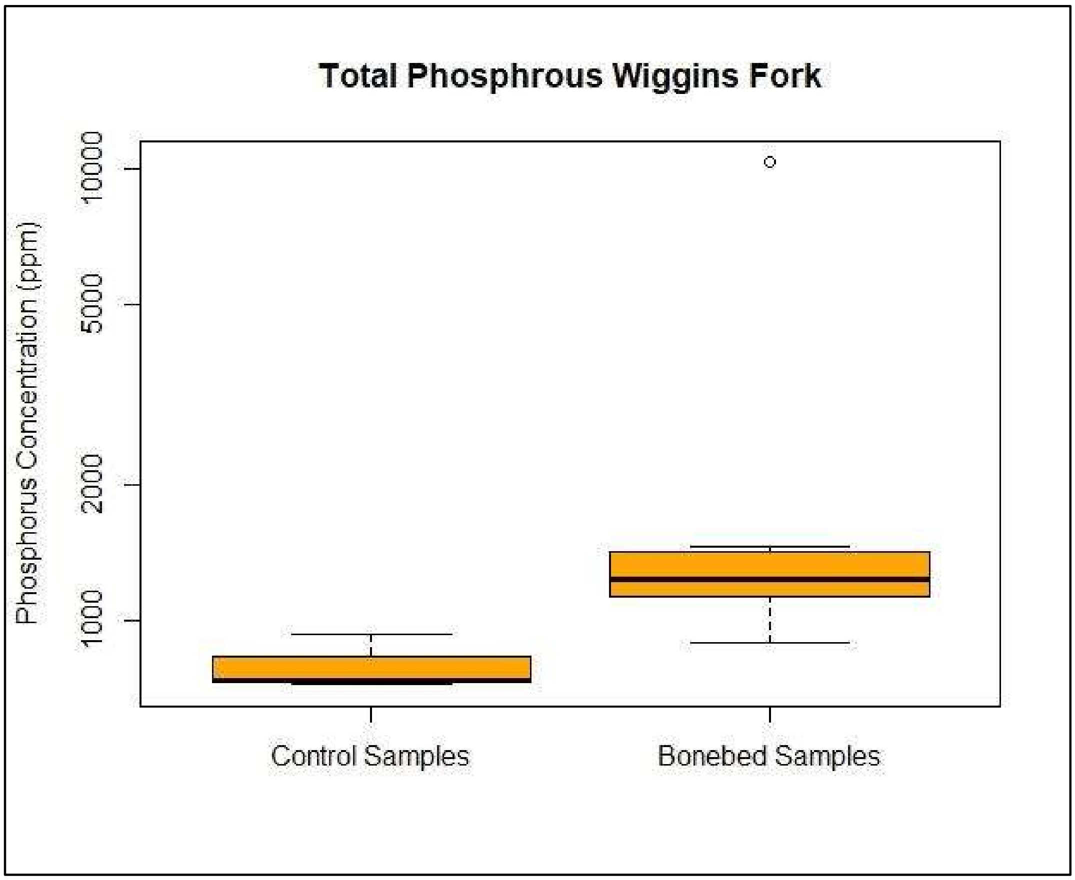

Figure 32. Box and Whisker plot shown the total phosphorus concentration results from the Wiggins Fork control and soil samples.

Wiggins Fork Ca-bound P

As with the Total-P result, a Welch Two-Sample t-test found no significant difference between the bonebed and control samples for Ca-bound P ($t = -2.1855$, $df = 6.8918$, $p = 0.06571$) (Figure 33). The Mann-Whitney U-test, as before, did produce a significant result for Ca-bound P ($W = 1$, $p = 0.03333$). Given that both Mann-Whitney U-tests found a significant and that the

Welch Two-Sample t-test produced p values only slightly above the confidence of 0.05, we have some confidence that total P and Ca-bound P can track the former presence of a bonebed at Dinwoody.

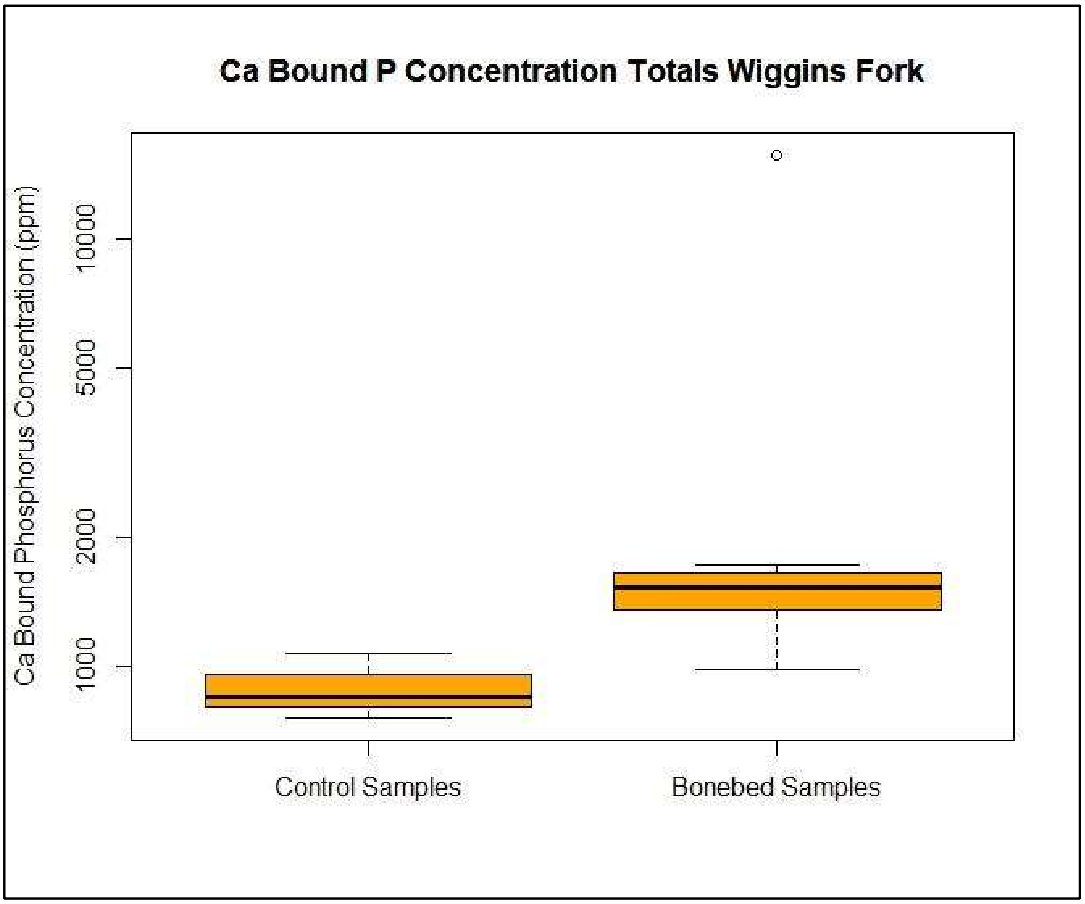

Figure 33. Box and Whisker plot shown the total phosphorus concentration results from the Wiggins Fork control and soil samples.

Dinwoody Total P

The Welch Two-Sample t-test produced a significant different between the hypothesized butchering and non-butchering areas ($t = -3.0592$, $df = 6.8061$, $p = 0.01899$) (Figure 34); oddly the Mann-Whitney U-test did not ($W = 2$, $p = 0.0639$), although as with the Dinwoody two-sample test, the p-value for the Mann-Whitney test is only slightly above the determined alpha of 0.05.

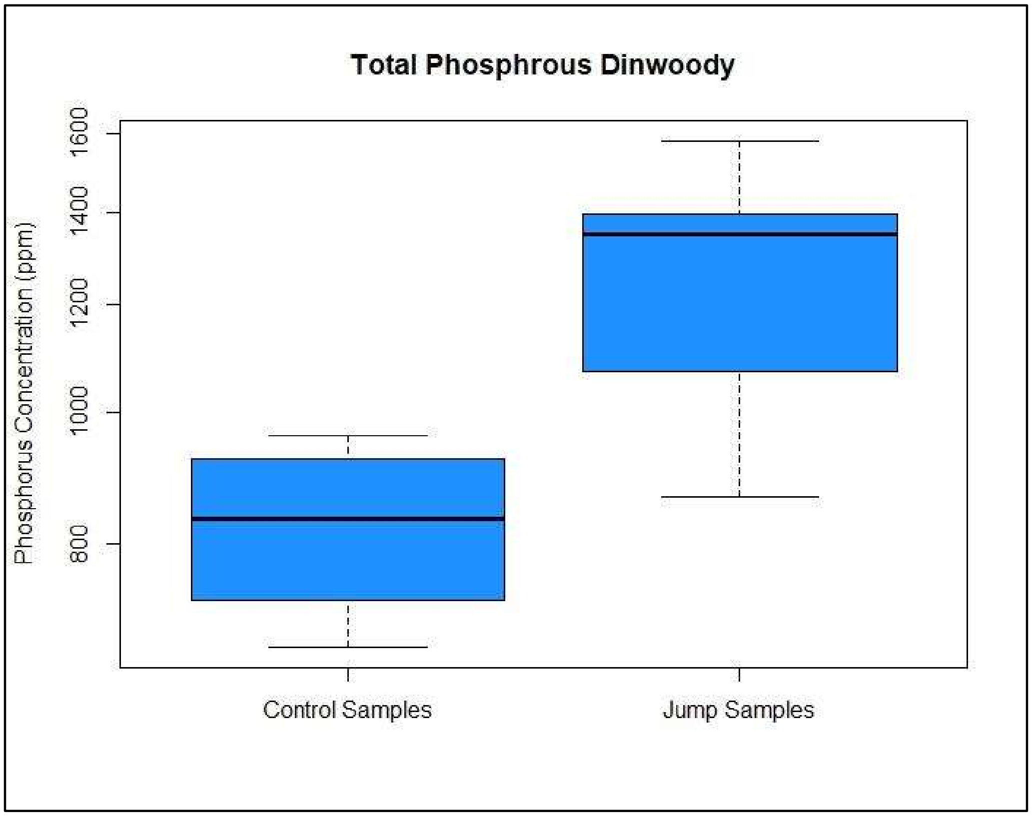

Figure 34. Box and Whisker plot shown the total phosphorus concentration results from the Dinwoody Jump control and soil samples.

Dinwoody Ca-Bound P

The Welch Two-Sample t-test found no significant difference between the Ca-bound P of the hypothesized butchering and non-butchering areas ($t = -1.2911$, $df = 5.1786$, $p = 0.2513$) (Figure 35). Likewise, the Mann-Whitney U-test for the Ca-Bound P also showed no significant difference between the Ca-bound P of the hypothesized butchering and non-butchering areas ($W = 6$, $p = 0.4127$). With both tests producing results clearly above the predetermined alpha of 0.05, the null hypothesis of no difference cannot be rejected.

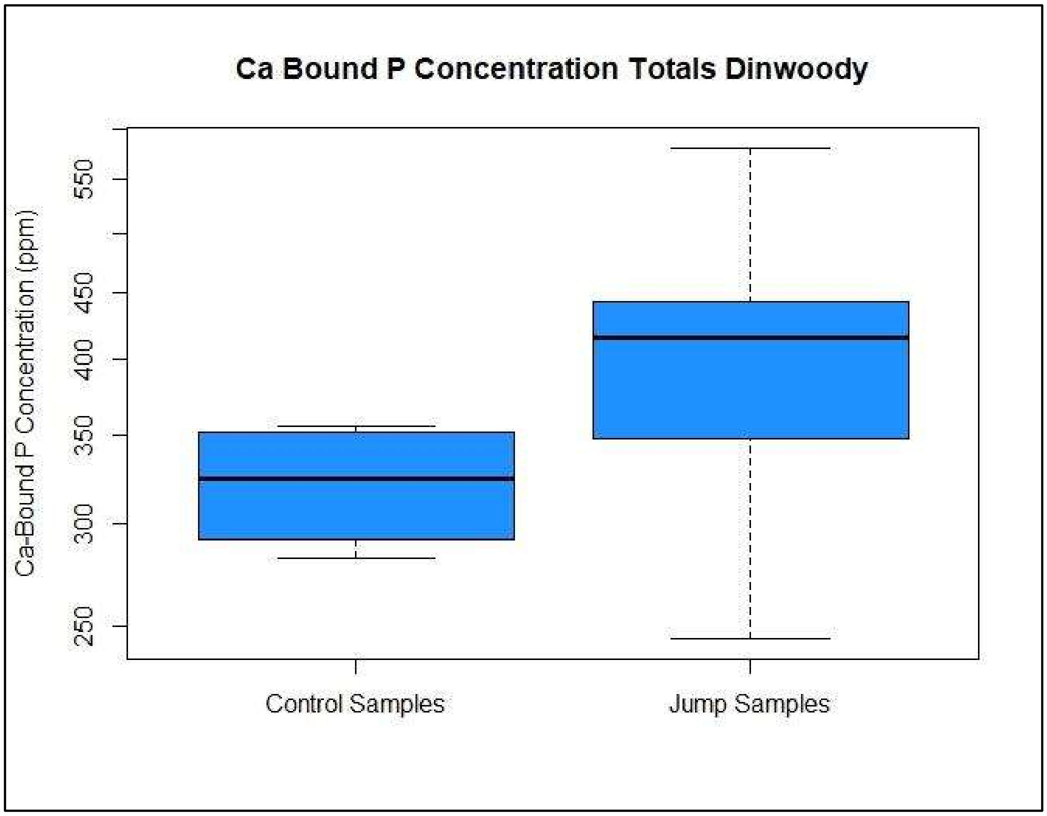

Figure 35. Box and Whisker plot shown the Calcium Bound Phosphorus concentration results from the Dinwoody Jump control and soil samples

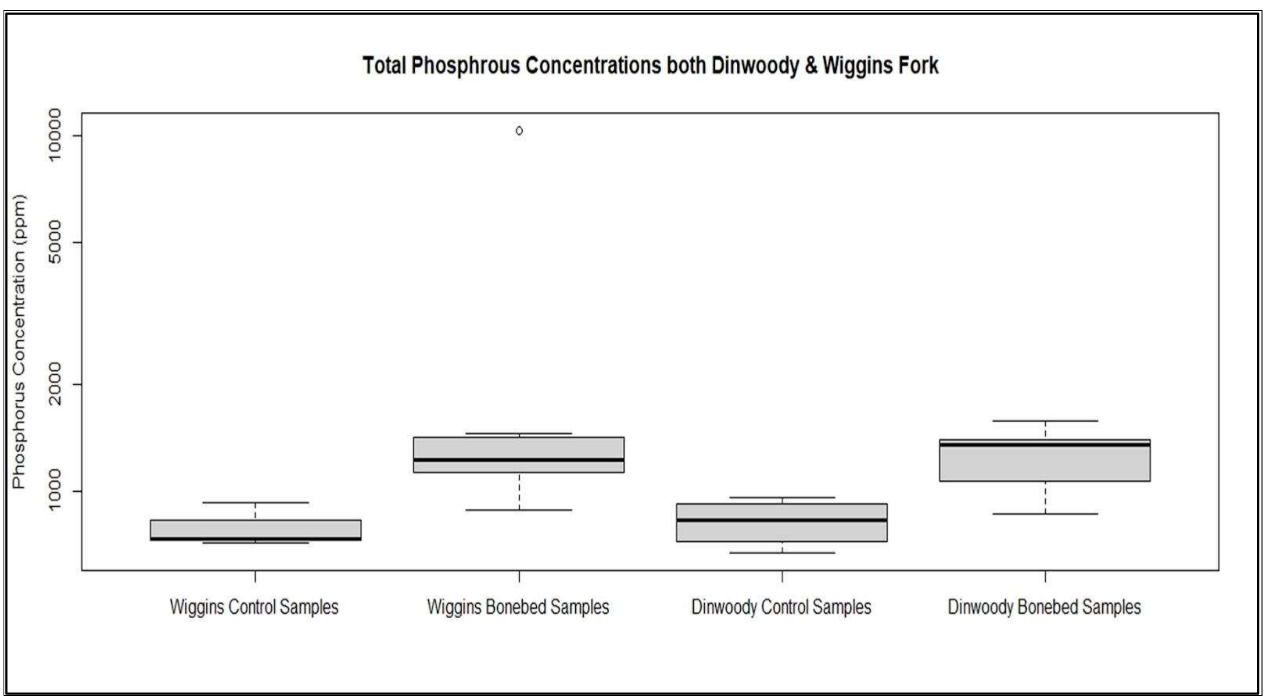

Figure 36. Box and Whisker plot showing the Total Phosphorus concentration results from the Wiggins Fork and Dinwoody samples.

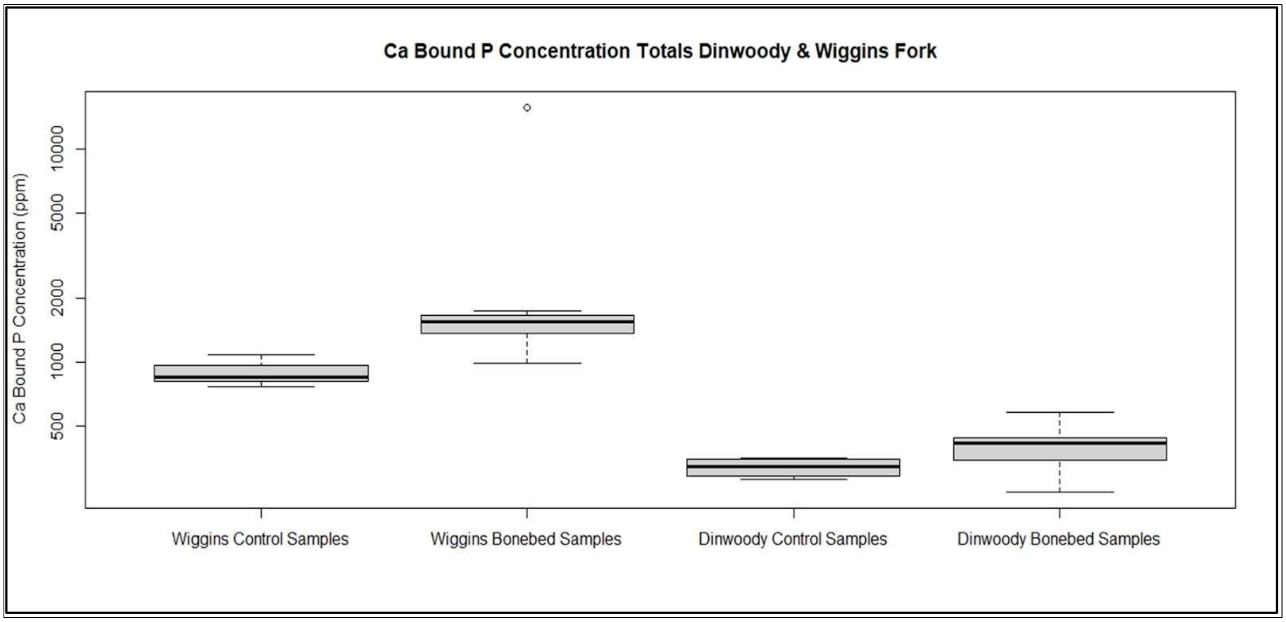

Figure 37. Box and Whisker plot shows the Calcium Bound Phosphorus concentration results from the Wiggins Fork and Dinwoody samples.

Discussion

The results from both the Total-P and Ca-bound P conducted on the Wiggins Fork samples suggest that phosphorus analyses to locate a kill/butchery area show promise. At this site the statistical tests for both Total P and Ca-bound P found a statistically or nearly statistically significant difference between sediment samples taken within and outside the known butchering area. At Dinwoody, Total P showed a significant or nearly significant difference between the hypothesized butchering and non-butchering areas, whereas Ca-bound P did not. However, the difference between the Ca-bound P is trending in the hypothesized direction: higher in the known or hypothesized butchering areas (Figures 36 and 37). This, in fact, is true for Total-P and Ca-bound P at both sites.

At the Wiggins Fork site, the kill/butchering area is known since it is marked by well-preserved bison bone. The non-butchering area is much easier to determine. At Dinwoody, we could only postulate where the butchering and non-butchering areas are located based on the heavy lithic debitage concentration below the jump off. Perhaps our results reflect uncertainty on the location of the areas.

Figure 38 shows the samples that were collected, their sample numbers, and their concentrations of Ca-bound P reflected in circle size. This map suggests that the control samples, the areas outside the postulated kill/butchering area, have similar Ca-bound concentrations. Samples within the hypothesized kill/butchering area have the expected elevated levels of Ca-Bound P, except SS 3 which is similar to the control samples. Perhaps SS 3 is just beyond the edge of the kill/butchering area or located in an area where no animal happened to fall and should have been counted as a control sample.

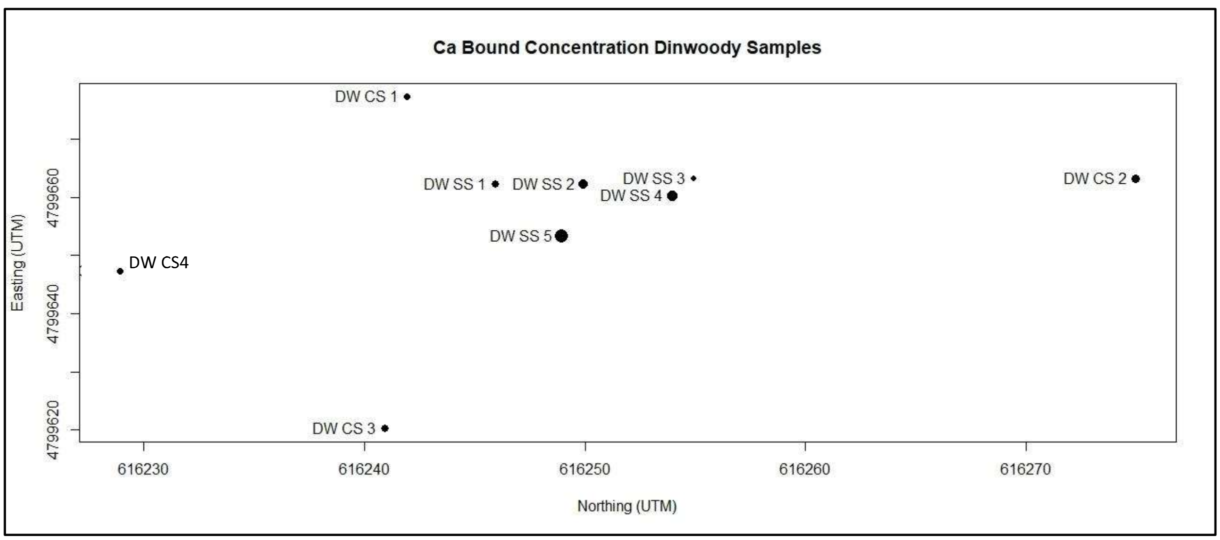

Figure 38. Plot map displaying sample locations across the Dinwoody site and the Calcium Bound Phosphorus concentration measurement from the ICP-OES.

A small sample size is a potential issue as a single mislocated sample could alter the statistical results. A total of 18 samples were tested, nine from Dinwoody and nine from Wiggins Fork. Small sample size might account for the lack of clear statistical significance in the Welch's test at Wiggins Fork and a larger sample size might confirm that these differences are significant.

Conclusion

The results from Wiggins Fork suggest that Total-P and Ca-bound-P may be useful to track former bonebeds where there may be no visible bone. At Dinwoody, Total-P provided support for the hypothesis that the site is a kill site, while Ca-bound P did not. Although there are issues with sample size, the results lend credence to the interpretation of the Dinwoody site as a kill site. These results are preliminary and further testing is needed to show that soil phosphorus analysis can be used successfully in archaeological contexts to confirm kill/butchery areas. To do so, the Wiggins Fork analysis needs to be replicated on other known kill/butchery sites. At Dinwoody, more soil samples per area are needed to determine if the Ca-bound results are a mis-approximation of the kill/butchery area and alleviate any effects of small sample size.

The use of soil chemical analysis to analyze phosphorus concentrations in archaeological sites has not, until now, been used in a high elevation context. As others have found, however, soil/sediment chemistry makes a strong contribution to understanding use of space in an archaeological site (Middleton 2004). The fact that the results reported here are promising, suggests another way that phosphorus analysis can be used to reconstruct prehistoric behaviors where the most obvious evidence of that behavior, in this case, large animal bones, may not have been preserved. The goal of this project was to use sediment phosphorus analysis to test whether game was processed at the postulated butchering area at the Dinwoody site and, in so doing, to provide support for interpretation of the site as a communal drive site. The results show a difference between soil samples taken from areas in the suspected butchering area and outside the area both at the Wiggins Fork control site and the test site, Dinwoody. These results lend support to the interpretation of the site as a kill site, perhaps a bison jump. If correct, then the Dinwoody site is evidence of high elevation, large game communal hunting in the Wind River Mountains.

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