Bison jumps (Bison sp.) jumps are landscape-embedded locations where hunter-gatherers stampeded ungulate herds over cliffs or ridges, resulting in mass kills. Great Plains foragers often employed this type of communal hunting strategy throughout prehistory (Brink 2008; Byerly et al. 2005:596; Polk 1979), perhaps as early as the Paleoindian period (Dibble 1970; Dibble and Lorrain 1968). At the Wold Bison Jump (48JO966; hereafter referred to as WBJ) in north-central Wyoming (Figures 1a, 2), a gathering basin of prime ungulate grazing habitat abuts a 40–50-m-tall plateau to the south. V-shaped cairn alignments extend southward across the top of the plateau, where this landscape feature then drops off into a steep cliff. Previous geospatial studies of bison jumps (or possible jumps) focus on inductive analysis of surrounding landscapes using the jump as a known, unvarying focal point of analysis (e.g., Byerly et al. 2005:599–605; Carlson 2011; Guenther 2014). While this approach is inductive, at WBJ we attempt to obtain a more general understanding of how bison jumps operate. Why are the jump and drive lines situated at this topographical position rather than elsewhere on the surrounding landscape? In other words, is bison jump location primarily predicted by minimizing visibility at the Wold site, Johnson County, Wyoming?

Brigid S. Grund, Spencer R. Pelton, Todd A. Surovell, Neffra A. Matthews, and Tommy A. Noble

The Wold Bison Jump (48JO966) is a communal bison (Bison bison) hunting site in Johnson County, Wyoming. It likely represents a single kill event precipitated by Great Plains foragers between A.D. 1433 and 1643. Operating the jump required that prehistoric hunters drive stampeding bison up a steep slope in order to position them within a V-shaped drive line configured to funnel them toward a cliff. Using iterative models of least cost paths, topographic cross-sections, and visibility analysis, we test which landscape-embedded variables are optimized at the jump site as compared to other potential localities across the study area. We find that this site's placement is primarily explained by minimizing the distance at which the cliff face is visible and secondarily by minimizing the cost of slope and curvature routes ascending into the drive lines. Our procedure could hypothetically be used to predict optimal jump locations on similar landscapes.
this particular location optimal in terms of topography and visibility as compared to other potential drive lines and jumps across the study area?

Frison (1973:7) once suggested that bison jump placement is connected with “[m]any intangibles. . . . Certain geomorphological features appear upon observation to have been ideal but were never used. In the final analysis, the success or failure of any given jump or trap was determined by actual experiment.” While we acknowledge that bison jump locations may appear to be influenced by “intangibles” to an on-the-ground observer, our analysis suggests that several quantifiable variables (primarily visibility) explain the location of WBJ. The methods proposed here are not specific to this site and could potentially be employed to explain or predict bison jump locations on other landscapes. Our results further indicate that variables such as slope, which appear optimized to an observer tangibly standing within the drive lines at WBJ, do not necessarily concord with quantitative analysis as expected. This finding potentially explains the disparity between actual and perceived “ideal” jump locations observed by Frison (1973) decades ago.

**Background**

WBJ is located 23 km west/southwest of Kaycee, Wyoming, in the foothills of the southern Bighorn Mountains at an elevation of 1,600 m asl. It is less than 400 m north of the Middle Fork of the Powder River. From the site, the river flows out of the Bighorn Mountains to the west and into the Powder River Basin to the east (Figure 1a). The site is situated within a large valley between the Bighorn Mountains and the Powder River Basin that is known as “Hole in the Wall Country.”

Archaeologists documented WBJ beginning in 1985. Three archaeological investigations in 1985 (Albanese et al. 1985), 2013, and 2014 (Pelton 2015) resulted in a total of four test pits in the site’s bonebed, 10 m² of test excavations in and around the bonebed, and approximately 640 acres

---

**Figure 1. Location of Wold Bison Jump and five iterations of least cost path models leading from the foraging basin to the back side of the bluff:** (a) location map; (b) cost = slope¹, 1/244 least cost paths intersect drive lines; (c) cost = slope², 0/244 least cost paths intersect drive lines; (d) cost = abs(curvature)¹, 115/244 least cost paths intersect drive lines; (e) cost = abs(curvature)², 143/244 least cost paths intersect drive lines and 147/244 are within 40 m; (f) cost = abs(curvature)³, 156/244 least cost paths intersect drive lines and 213/244 are within 40 m.

---
of systematic surface survey in the site’s drive lines and gathering basin. In the following, we summarize the results of these investigations.

Comparable to other bison jumps (e.g., Frison 1970, 1971; Nieves-Zedeño et al. 2014:34; Reeves 1978; Witkind 1971), WBJ consists of several natural and cultural features, including a gathering basin, drive lines, and a bonebed. Unlike some other jumps, archaeologists have not yet discovered an associated campsite, which may have been buried in the floodplain of the Middle Fork of the Powder River, or possibly destroyed by stream erosion. At WBJ, the gathering basin is located in a valley north of the bison jump, which is dissected by several ephemeral drainages and one perennial waterway called Sheep Creek. There are steep erosional features throughout the gathering basin, but it is relatively unbroken terrain compared to the surrounding area.

Drive lines are typically alignments of low rock mounds sometimes augmented by wooden poles and flagging (Brink 2008). They were used to coerce or constrain bison as they moved from the gathering basin to the jump edge. WBJ’s drive lines and jump are positioned on a narrow, NE-SW trending plateau south of its gathering basin and 40–50 m above the surrounding valley floor. The plateau is capped by several meters of bedload alluvium in a cemented conglomerate containing large cobbles and boulders, which hunters used to construct drive line cairns. Hunters had to drive bison up a hill, which we refer to as “ascension hill,” on the north side of the plateau and off of a cliff on the south to operate WBJ.

We documented 67 cairns that comprise three alignments in the WBJ drive line. Most cairns are in two alignments positioned in a V-shape that converges at the jump’s cliff edge, and a few are positioned in a diffuse alignment between these. Typically, cairns possess between one and five stones (for an image of a typical cairn, see Pelton 2015:Figure 6) and are placed between 10 and 15 m apart. As the cairn lines approach the cliff’s edge, they become more closely spaced and more massively constructed, with several cairns in this area possessing over 30 stones. Decreasing cairn spacing in proximity to the jump point likely helped to constrain the bison herd as they neared the cliff edge.

The WBJ bonebed is located on a colluvially active slope at the bottom of a 5–15-m-tall cliff, in an area of roughly 30 × 30 m. Bison bones, lithic artifacts, charcoal, and fire altered rock are buried around 30 cm deep in fine-grained sediment interspersed with cobbles and cliff spalls. Several bison limb bones recovered from excavation possess impact fractures and green bone breaks suggestive of intensive processing. We recovered six quartzite and 17 Goose Egg Formation chert flakes (Burk and Thomas 1956) from excavations in the bonebed, as well as a complete quartzite biface. The majority of flakes (15), including all quartzite flakes and the biface, are from a single 1 × 1-m unit located between several large boulders at the northeastern margin of the bonebed deposit. Potentially, this area served as a sheltered work area at the time of the site’s use. Because we presently possess a small sample of the bonebed (8 m² of an estimated 900 m² deposit), we do not provide an estimate of the minimum number of individual bison in the bonebed, nor an estimate of seasonality.

We submitted six radiocarbon samples from WBJ. Four of these are bison bone from the bonebed and two are from buried sediments surrounding the bonebed. The 2σ calibrated age ranges of the oldest and youngest age estimates from the four bonebed samples largely overlap. Therefore, we have little reason at the moment to suspect the bonebed represents more than one jump event, but it is possible that additional events could be identified in deeper excavations. All four radiocarbon age estimates fall on a reversal of the Intcal13 calibration curve (Reimer et al. 2013), which extends their potential calibrated age range to a 210-year span between A.D. 1433 and 1643 (Pelton 2015:10).

By the time foragers used WBJ, bison jumping had been occurring on the Great Plains of North America for at least several thousand years (Brink 2008; Reeves 1978). The practice began on the Northwest Plains between five and six thousand years ago in a core area centered on the U.S. state of Montana and the Canadian province of Alberta. Late in prehistory, beginning around A.D. 1200, bison jumping shifted southward into Wyoming and as far south as northern Colorado (Cooper 2008:259–262; Witkind 1971). WBJ seems to be part of this regional expansion of bison jumping southward from its core area in the Northwest Plains, along with other sites such as the Glenrock Bison Jump (Frison 1970) and the Vore Site...
(Reher and Frison 1980). Given its age and location, WBJ was potentially used by the ancestral Crow, but there are not yet material remains, such as pottery, to establish its cultural affiliation (Frison 1976, 1980).

**Methods**

Factors thought to influence bison jump position within a given landscape are summarized elsewhere (Byerly et al. 2005:599; Carlson 2011:38) but include proximity to water and tracts of grass, the presence of long and flat potential drive lines, visible obscurity of cliffs, and steepness of cliff faces. At WBJ, the scale of our study area (approximately 6.5 km² including and surrounding the jump location), the relative homogeneity of the cliff face, and the jump’s known propinquity to high-quality foraging areas predisposed us to focus our quantitative analyses on three spatial investigations meant to elucidate how the WBJ operated. These include (1) least cost paths from the gathering basin and up the ascension hill to the top of the plateau (Figures 1b-f, 2), (2) a morphological characterization of the ascension hill itself (Figure 3b–d), and (3) the visibility of potential jump locations to a 1.5-m-tall observer, the approximate height of an adult bison (Halloran 1960:216–217) (Figures 4–6). All of our analyses were carried out in ArcGIS 10.2.2.

**Least Cost Paths as Potential Drive Lines**

We photogrammetrically produced a 1-m resolution Digital Surface Model (DSM) of the study area. It was essential to obtain a DSM with a fine enough resolution to adequately depict the terrain features in question. As a DSM with a greater frequency than 10-m post-point spacing was not readily available, it was necessary to create one.

Photogrammetry, which utilizes a series of overlapping photographs to derive three-dimensional surface data, was employed in this venture (Matthews et al. 2016). We used imagery from the United States Department of Agriculture, Farm Service Agency, National Agriculture Imagery Program (NAIP). Eight overlapping NAIP images (with a ground resolution of .93421 m/pixel), taken in 2009, were processed in Agisoft PhotoScan Pro Version 1.1.6. A method of bad point
removal and optimization was employed to reduce error during the image alignment phase. An internal accuracy (or geometric precision) was reported at .15 pixels root mean squared error. Finally, a 1-m digital orthoimage and DSM were produced for use in these analyses.

From the DSM, we calculated surface slope and curvature. Curvature represents the slope of

| Table 1. Topographical Summary Statistics for All Transects Displayed in Figure 3. |
|------------------------------------------|-----------------|-----|-----|------------------------|------------------------|
| Within Drive Entrance (X1) | Outside Drive Entrance (X2) | n1  | n2  | Test Statistic (U) | p-value |
| Curvature Range (°) | 98.541 | 101.349 | 194 | 764 | 70756 | < .001 a |
| μ (°) | .070 | .113 | 194 | 764 | 71665 | .330 |
| Slope Maximum (°) | 37.940 | 40.549 | 194 | 764 | 45779 | .193 |
| μ (°) | 14.681 | 14.603 | 194 | 764 | 66736 | <.001 b |
| σ (°) | 8.972 | 9.617 | 194 | 764 | 41297 | <.001 a |
| Sum (°) | 2348.184 | 2335.706 | 194 | 764 | 66784 | .033 b |
| Sum of Slope / Elevation Gain (°/m) | 68.719 | 71.892 | 194 | 764 | 46363 | <.001 a |

Note: Values were aggregated twice; first by transect and second by type of transect (within or outside drive entrance). Only data aggregated by type of transect are reported in this table. Since these variables are all non-normally distributed based on a Kolmogorov-Smirnov Test, values were tested for statistically significant difference in medians using Mann-Whitney U Tests.

*aIndicates a statistically significant difference in the hypothesized direction.

*bIndicates a statistically significant difference opposite what was expected.
the slope; values that deviate significantly from zero indicate a highly undulating landscape, whereas values close to zero indicate flat surfaces.

Next, we evenly distributed a grid of start points for least cost paths throughout the portion of the gathering basin directly adjacent to the jump location (Figures 1b–f, 2). We placed start points on the corners of a 100 × 100-m grid extending across approximately 245 ha of the foraging basin, resulting in the creation of 245 least cost path origins. This was accomplished by creating a fishnet of polygons across the entire study area, then using the Feature to Point tool to convert the fishnet to points. The gathering basin was digitized, and then the point layer was clipped to the boundary of the gathering basin area.

We represented the least cost path destination by a polyline digitized as closely as possible to the crest of the ascension hill using curvature as a background raster. We calculated least cost paths from each start point to the top of the ridge crest using various weights of slope, curvature, and combinations of slope and curvature. We used ArcGIS ModelBuilder to automate this iterative process. Essentially, the model calculates cost distance and backlink rasters for the given model run’s slope/curvature cost from the ridge crest. Then, it iterates through start points and, for each start point, calculates the least cost path between it and the ridge crest polyline. Each single least cost path raster is then converted to a polyline, which is in turn appended to a shapefile that will eventually contain all least cost paths for the given cost surface. The least cost paths generated by five of these models are shown in Figure 1b–f.

We evaluated each model by calculating the number of paths (out of 245) intersecting the entrance to the drive lines. In essence, these paths represent routes of least resistance while traveling from various points in the gathering basin to the top of the plateau. We designed these models to test the hypothesis that foragers placed the V-shaped drive line cairns atop the plateau in a location optimal for capturing bison traversing the “easiest” route up the ascension hill from the gathering basin, in terms of lowest cumulative slope and/or curvature cost. Since Wold was a successful kill site, bison were obviously driven up the back side of the plateau somehow. If the drive line cairns align with paths of least resistance through the gathering basin and up the ascension hill, this would indicate that prehistoric hunters relied heavily on natural topography to funnel bison into the trap, thus minimizing the amount of effort required to control the herd before reaching the constructed features.

**Morphology of Ascension Hill**

We quantified the ascension hill’s topography across nearly 1 km of cross-sectional transects extending up the north side of the plateau (Figure 3). The purpose of this analysis was to compare the portion of the ascension hill leading to the entrance of the drive lines to portions that do not. For this analysis, we constructed parallel cost paths generated at a larger (zoomed in) scale than in the first portion of the study. We reasoned that paths generated at the scale of the entire gathering basin (as we examined in part one) might swamp the potentially high costs incurred at the ascension hill (the steepest portion of the bison drive). In this case, 958 parallel transects of 158 m in length were placed at 1 m intervals across the ascension hill, each following one possible route from the bottom to the top of the plateau.

To construct the transects, we digitized a line parallel to the hillslope and extending its entire length. Using the editor tools, we constructed a parallel line on top of the hill slope perpendicular to the direction of the not-yet-constructed, cross-sectional transects. Then, we constructed points every 1 m for each line, retaining object ID values. The point to polyline tool was used to connect point x from one line to point x on the other line. This produced a polyline shapefile of transects covering the entire back of the ascension hill. To extract topographical characteristics from underlying rasters, we first converted transects into a 1 × 1-m raster assigning each line’s object ID to represent a new cell value in the new raster. We used the Zonal Statistics as Table tool to extract summary statistics from underlying topography rasters, using object ID as the zone field. Finally, we joined transect polylines to the summary statistics table, using object ID to link them.

We classified transects as intersecting or not intersecting the entrance to the drive line funnel (Figure 3a). For each transect, we extracted slope, curvature, and elevation values in 1 m intervals from underlying rasters. We calculated summary...
statistics, including maximum, mean, sum, and range, for each variable across each transect. These statistics were further aggregated into two groups depending on whether transects intersect the drive line entrance. We tested groups for significant differences using Mann-Whitney U tests (Table 1). Bison generally avoid traversing steep slopes and prefer “gentle gradients in elevation” (Bruggeman et al. 2008:640; see also Bruggeman et al. 2007). Therefore, we predicted that within the drive lines, maximum slope values would be relatively low, mean slope values would be minimized compared to the amount of elevation gain, and curvature values would be close to zero.

Visibility of Cliff
Successful bison jumps are often obscured until bison herds are in close proximity to them. This prevents the herd from altering its trajectory away from the cliff face, thereby avoiding the jump and escaping unharmed. To understand the location of the WBJ in terms of visibility, we asked three interdependent questions:

1. From any given location on the top of the plateau, what percentage of the cliff face is visible to a 1.5-m-tall bison (Figure 4)?
2. From any given location on the top of the plateau, what percentage of the actual jump is visible to a 1.5-m-tall bison (Figure 5)?
3. From where can a 1.5-m-tall bison see the cliff directly in front of it while perpendicularly traveling toward it across the top of the plateau (Figure 6)?

We designed our visibility analyses to test the hypothesis that foragers placed the WBJ drive lines adjacent to the least visible location across the entire southeastern cliff face.

To answer the first two questions, we digitized the edge of the cliff using the underlying curvature raster as a guide. At 1 m intervals along the cliff face, we calculated areas across the landscape...
where each point is and is not visible. Finally, for every 1 m\(^2\) across the landscape, we calculated the percentage of points along the cliff (Figure 4) or actual jump (Figure 5) that are visible from that location.

To do this, we constructed line-of-sight transects every 1 m, as in the previous section, but oriented them perpendicularly toward the cliff face. Then we intersected transects with the digitized cliff face to yield a point layer; these points comprise the “observers” in ArcGIS’s Visibility tool. In ModelBuilder, we iterated through each point, calculating visibility at each point for the entire study area. We used a surface offset of 1.5 m (contemporary female Bison bison are 1.4 m and bulls are 1.6 m tall, on average, at the shoulder; Halloran 1960:216–217), a ground surface height of 0 m, and opted to include curvature of the earth corrections. The output visibility rasters are Boolean; a value of zero characterizes cells where the point on the cliff is not visible, and a value of 1 characterizes cells where the point on the cliff is visible. After visibility rasters were created for each point along the cliff face, we used the Weighted Sum tool to add the values of all the visibility rasters together. Dividing the raster cell values by the number of points along the cliff face then gives the percentage of the cliff visible from each given location. The percent visibility of the actual jump line can be calculated in the same way by summing only the visibility rasters associated with the points contained within the drive line cairns. We expected that the cliff edge inside the drive line cairns would be characterized by relatively low visibility compared to other locations.

The spatial analysis required to answer question three was more complex than the others; for a layout of the ModelBuilder process, see Figure 7. Essentially, we calculated the maximum distance at which each point on the cliff is visible to a 1.5-m-tall observer standing on a transect extending from the cliff point to the northwest side of the

![Figure 5. Visibility analysis indicating the percentage of the jump visible to a 1.5-m-tall observer standing at any given location atop the plateau.](image-url)
plateau (Figure 6). More specifically, we calculated visibility rasters for each point along the cliff face, as described above. Then we converted the Boolean visibility rasters to polygons using the Raster to Polygon tool. We clipped the visibility polygons to the extent of the plateau, using the edge of the cliff face as one of the polygon borders. We selected the visible polygon (Boolean value = 1), and used the intersect tool to determine where transects perpendicular to the cliff face intersect the visibility polygon. We appended the newly created visibility transects to a polyline shapefile that, after all the model iterations, eventually contained visibility transects across the entire length of the cliff face. This ModelBuilder workflow is visually explained in Figure 7. We expected that lines of sight within the drive line cairns would be significantly shorter than lines of sight elsewhere.

Results

Least Cost Paths as Potential Drive Lines

Least cost paths setting cost equal to slope, slope\(^2\), curvature, curvature\(^2\), and curvature\(^3\) are shown in Figure 1b–f, respectively. Despite numerous model iterations varying the weight of slope and curvature costs, and contrary to expectations, least cost paths generally fail to predict the entrance to the drive lines. Our initial goal was to vary model cost weights over numerous iterations in order to determine the weight(s) that best predict the drive line entrance. However, the poor predictive value of least cost paths at this scale precluded us from evaluating these variations for model effectiveness. See the next section for an explanation.

Morphology of Ascension Hill

Topographical characterizations of ascension hill cross-sections indicate that possible ascension
paths leading into the drive entrance tend to have relatively low maximum slope values (Figure 3b). They are also characterized by relatively low slope standard deviations and a small range of curvature values (indicating that there is little variation in slope, so transects are flat and constant, rather than undulating; Figure 3c). Despite having low and constant slope values, transects leading into the drive entrance are not unique in these characteristics. Notably, the hillside just southwest of the drive entrance is less costly in terms of slope and flatter than the hill leading directly into the drive lines. In fact, the summed slope cost of transects outside the drive line entrance is significantly lower than within it (Table 1). This finding explains why least cost paths fail to predict the entrance to the drive lines at large and small scales; although the hillside leading up to the drive entrance produces low cost paths, there are low(er) cost paths elsewhere.

Other topographical indices are also informative in explaining the location of the drive entrance. For example, low overall slope cost per elevation gain (sum of slope:total rise) characterizes the drive entrance relatively well (Figure 3d, Table 1). This index is significantly lower within the drive lines than outside them (2-tailed Mann-Whitney U: \( \bar{x}_1 = 68.7 \, ^\circ/m, n_1 = 194; \bar{x}_2 = 71.9 \, ^\circ/m, n_2 = 764; U = 46363; p < .001 \)). The slope:rise index demonstrates that the drive line entrance was placed in a location that minimizes overall slope cost while maximizing elevation gain over the shortest possible distance. However, there is much overlap between values within and outside the drive lines, indicating that the slope:rise index alone would not function as a reliable predictor of drive entrance location.

**Visibility of Cliff**

Figure 4 shows the percentage of the cliff visible to a 1.5-m-tall bison standing at any location on top of the plateau. Interestingly, a large proportion of the cliff is visible from within the drive lines. However, Figure 5 reveals that, while portions of the cliff are visible from within the drive, the jump itself tends to be obscured.

While the above visibility figures are instructive, the data presented in Figure 6 form the crux of our analysis. Figure 6 shows where the cliff edge is visible to a 1.5-m-tall bison traveling perpendicularly toward it on a transect across the plateau. Though the figure includes disconnected

---

**Figure 7. ModelBuilder workflow (within ArcGIS) used to conduct the visibility transect analysis shown in Figure 6.**
lines of sight for illustrative purposes, statistics were calculated using the maximum distance at which the cliff is visible for each transect. Lines of sight within the drive lines are significantly shorter than those outside them (2-tailed Mann-Whitney U: $\bar{x}_1 = 5.9$ m, $n_1 = 28; \bar{x}_2 = 14.0$ m, $n_2 = 709; U = 4553; p < .001$). Additionally, the shortest 1.2 percent of sight lines all lie within the drive line cairns. This finding indicates that visibility transects across the landform at WBJ not only explain the location of the actual jump, but could potentially be used to predict optimal jump locations on similar landscapes. Once optimal jump location is established using this method, the drive line entrance could potentially be predicted by identifying the nearest low-cost path up the backslope using secondary explanatory variables (e.g., sum of slope/elevation gain). The significant correlation between low cost paths up the ascension hill and the location of the drive entrance established in part two of our analysis indicates that, although backslope topography influences drive line placement, it is trumped by the need to maximize obscurity of the cliff. The actual predictive value of this method remains to be tested, since we currently do not have access to any 1 m DSMs from other bison jumps.

Conclusion

At Wold Bison Jump, we find that visual obscurity of the jump cliff primarily explains the site’s placement on the landscape. Other variables, including slope and curvature of potential paths leading to the drive lines, do not independently explain the location of the drive entrance or jump point. However, a two-step predictive modeling approach that first determines optimal jump location based on visibility and then locates the nearest low-cost paths leading up the ascension hill could potentially be used to identify bison jump locations on other, similar landscapes (assuming they also contain high-quality bison grazing habitat and a gathering basin) or to assess the viability of jump locations in doubt (e.g., Bonfire Shelter; see Byerly et al. [2007]).

While predictive modeling is an indispensable technique for identifying archaeological sites, more salient to archaeological interpretation is the insight into communal hunting and site placement that our analysis provides. As a relatively late example of a mass bison kill, WBJ represents the culmination of thousands of years of Great Plains buffalo hunting. Though we initially expected prehistoric hunters to rely heavily on natural topography to direct bison through the gathering basin and up the ascension hill to the top of the plateau, this is not the case at WBJ. Of all the topographic variables measured here, only cliff obscurity is optimized at this position on the landscape. If WBJ was placed primarily to minimize visibility, this implies that foragers positioned drive lines and cairns to discourage bison from following natural paths of least resistance as they were driven across the landscape. In this paper, we present a spatial analysis procedure that could potentially be used to compare WBJ to other jumps of various ages in order to understand the progression from early to late bison driving strategies. We expect that these sites exhibit diachronic change in how natural features are employed, as foraging cultures expanded their knowledge of bison behavior and either by intentional trial-and-error or a serendipitous drift toward optimality, learned how to most effectively map anthropogenic modifications onto existing topography.

Acknowledgments. We are indebted to the Wold Foundation for providing funding to support excavation and dating of the WBJ. Funding for the GIS analysis was provided by the Rocky Mountain Urban and Regional Information Systems Association scholarship, and funding to present it at the 2016 SAA Conference was provided by a Phi Kappa Phi Love of Learning Award and the University of Wyoming Anthropology Department, presented to Grund. The Wyoming State Historic Preservation Office provided a paid internship for Pelton to prepare a National Register of Historic Places nomination form for this site, supervised by John Laughlin and Judy Wolf. This paper was significantly improved with comments from two anonymous reviewers, David Byerly, and several discussions with Robert L. Kelly, though any faults are of course our own. We would also like to thank Robert L. Kelly, Danny Walker, Madeleine Mackie, and the students for their roles in the 2013/2014 field school excavations at Wold. Pablo Gerónimo Messineo kindly translated our abstract into Spanish. Last but not least, we extend our deep gratitude to the Wold landowners. Without their cooperation and support, this research would not have been possible.

Data Availability Statement. The 1-m resolution digital surface model on which these analyses are based was created photogrammetrically by Matthews and Noble and is stored, care of Neffra Matthews, at the BLM National Operations Center in Denver, Colorado.
References Cited

Albanese, John, Allen Darlington, William Eckerle, and Julie Francis

Brink, Jack

Bruggeman, Jason E., Robert A. Garrott, P. J. White, Fred G. R. Watson, and Rick W. Wallen


Burk, C. A., and Horace D. Thomas

Byerly, Ryan M., Judith R. Cooper, David J. Meltzer, Matthew E. Hill, and Jason M. LaBelle


Carlson, Kristen

Cooper, Judith Rose

Dibble, David S.

Dibble, David S., and Dessamah E. Lorrain
1968 Bonfire Shelter: A Stratified Bison Kill Site, Val Verde County, Texas. Miscellaneous Papers No. 1, Texas Memorial Museum Publications, University of Texas, Austin.

Frison, George C.


Guenthner, Marissa Anne

Halloran, Arthur F.

Matthews, Neffra A., Tommy A. Noble, and Brent H. Breithaupt

Nieves-Zedeño, Maria, Jesse A. M. Ballenger, and John R. Murray

Pelton, Spencer R.

Polk, Michael R.

Reeves, Brian O. K.

Reher, Charles A., and George C. Frison


Witkind, Max

Submitted February 24, 2016; Revised May 11, 2016; Accepted May 12, 2016.