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RESEARCH

Estimating the Size and Density of the La Prele Site: Implications for Early Paleoindian Group Size

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Abstract

The La Prele site (ca. 12,940 cal BP) is a deeply buried, single-component mammoth kill and campsite in Wyoming (USA). The site was discovered eroding from a creek bank 3 m deep within a 7-m tall terrace scarp, and prior investigations have primarily focused on excavations accessible from the creek bank, using heavy machinery to remove sterile overburden to access the deeply buried deposits. This approach has allowed excavations to occur safely outside of deep pits, but it has limited our ability to assess the total size and density of the site. To determine total site extent, we conducted systematic bucket auger testing of the La Prele site terrace, attempting 189 augers between 1.6 m and 6.2 m deep across the landform. We use a simulation and other mathematical procedures to infer artifact density from auger artifact counts and interpolate artifact densities across the site using GIS. We determine that La Prele is around 4500 m^2 in area and likely contains a buried bison bonebed and two additional artifact concentrations comparable to or exceeding the size and density of previously excavated areas. We use these insights to infer Early Paleoindian group size, concluding that around 30 people occupied La Prele.

Keywords Paleoindian · Geoarchaeology · Simulation · Geospatial · Group size

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Introduction

Hunter-gatherer group size is a simple measure with complex implications for explaining culture. Group size influences the frequency and distance of movements (Grove, 2009), the likelihood of corporate ownership and food storage (Freeman & Anderies, 2015), degree of socioeconomic complexity (Keeley, 1988), and perhaps even the evolution of the hominid neocortex (Dunbar, 1992), among a range of other factors (Kelly, 2013). Thus, one can infer a great deal about the lifeways of hunter-gatherers by knowing group size.

The ethnographic record has produced baseline estimates for hunter-gatherer group size (Binford, 2001; Hamilton et al., 2018; Kelly, 2013), but extrapolating those estimates into the past is more difficult. This is especially true of novel situations for which the ethnographic record can produce limited insights, such as for the first people in the Americas. For the past, archaeologists must rely upon proxy measures for population size, such as floor area (Ortman & Coffey, 2017; Ortman et al., 2015), number of campsite features (Hamilton et al., 2018), or settlement size (Lobo et al., 2022; Whitelaw, 1991). While these methods can be fraught with uncertainty, they can at least serve as an approximation for group size for the distant past.

Employing these methods, archaeologists have estimated settlement group sizes for hunter-gatherer (Ortman et al., 2022), middle range (Ortman & Coffey, 2017), and complex (Ortman et al., 2015) societies of the recent past. However, these methods grow more difficult for the distant past, when sites are exposed on the surface and mixed with artifacts from later time periods, partially destroyed, and/or deeply buried. Roughly speaking, the older a site is, the more likely it is to suffer from one or more of these issues, each of which can confound attempts to estimate group size. Moreover, ancient campsites are invariably associated with foragers for whom site reoccupation during successive years may increase the archaeological signature of campsite size and lead to group size overestimation. Thus, ancient sites require a specific combination of ideal circumstances to provide even roughly accurate estimates for group size. We argue that the La Prele site (La Prele) is that sort of site.

La Prele is an Early Paleoindian mammoth kill and campsite buried within a terrace along La Prele Creek, a tributary of the North Platte River in eastern Wyoming (Mackie et al., 2020, 2022; Surovell et al., 2021). La Prele is buried between 3 and 5 m deep in the third alluvial terrace (herein referred to as the La Prele terrace) of La Prele Creek, a sequence that spans approximately 20,000 to 8000 cal BP (Allaun et al., 2023). We have discovered evidence for archaeological remains neither above nor below the Early Paleoindian occupation. Close to 10 years of excavations have revealed three hearth-centered activity areas argued to have been houses, each of which contains a mix of flaking debris, faunal remains, stone tools, red ocher nodules, and rare artifacts like bone needles and beads. The house artifact clusters are each located approximately 15 m apart and are dispersed to the west and south of the La Prele mammoth remains.

In some ways, La Prele is an ideal site to study Early Paleoindian group size because we argue that it has a single component and appears largely intact away from its eastern margin (Allaun et al., 2023). However, La Prele is also deeply buried, which makes determining total site size difficult using conventional archaeological testing methods. Like most sites created by foragers, it is also not amenable to study using traditional remote sensing methods like ground penetrating radar or magnetometry. To address these difficulties, we use a systematic survey by bucket auger to determine total site size and estimate artifact density. We begin by describing the history of our understanding of the La Prele site extent. We then describe our field methods, simulation and statistical procedures, and geospatial protocols. We present our results and discuss their implications inferring Early Paleoindian group size, comparing La Prele to several other Rocky Mountain sites of comparable age and to the ethnographic record.

History of the La Prele Site Extent

Avocational collectors from Douglas, Wyoming found La Prele in 1986 while walking the banks of La Prele Creek when they discovered mammoth bones eroding from exposed terrace sediments. George Frison excavated the mammoth in 1987 in a 3 m × 4 m block (Fig. 1a), discovering several chipped stone artifacts that led him to interpret the site as a mammoth kill, an interpretation later questioned before the site was reinvestigated in the 2010s (Byers, 2002). Returning to the site in 2014, we did not know if the mammoth at La Prele was associated with stone tools, much less how extensive the site might be. Excavations surrounding Frison's 1987 excavation (Block A) yielded few artifacts. However, the first hints of a larger site emerged toward the end of the 2014 season when a crew member accidentally discovered a chopping tool buried in the cultural level 15 m southeast of Block A while expanding a trail across the face of the terrace to facilitate carrying buckets for water screening.

This inadvertent discovery led to the first year of excavations at Block B in 2015, which uncovered a red ocher stain (Zarzycka et al., 2019) associated with an assemblage of chipped stone and faunal artifacts, a discovery that confirmed the cultural association at the site (Mackie et al., 2020), increased its estimated size to at least 80 m^2, and eventually led to the realization that site contained domestic areas with likely residential features (Mackie et al., 2022). Since recognizing that La Prele was more extensive than its mammoth bonebed, our investigations have primarily been guided by a pro-active search for the site extent. This has made the known extent progressively larger alongside continuing investigations (Fig. 1b).

We conducted initial bucket auger attempts to track the extent and slope of paleosol S-1 west of the mammoth in 2014. Paleosol S-1 is the lowest buried A horizon across much of the site, and the Early Paleoindian occupation occurs 20 to 40 cm beneath its upper contact (Allaun et al., 2023). Most augers we attempted struck rocks prior to reaching the cultural level. The few augers that reached the cultural level did not produce obvious evidence for the archaeological site such as large chunks of bone or stained sediment, but these augers were not screened because we were primarily interested in stratigraphy at this time. Thus,

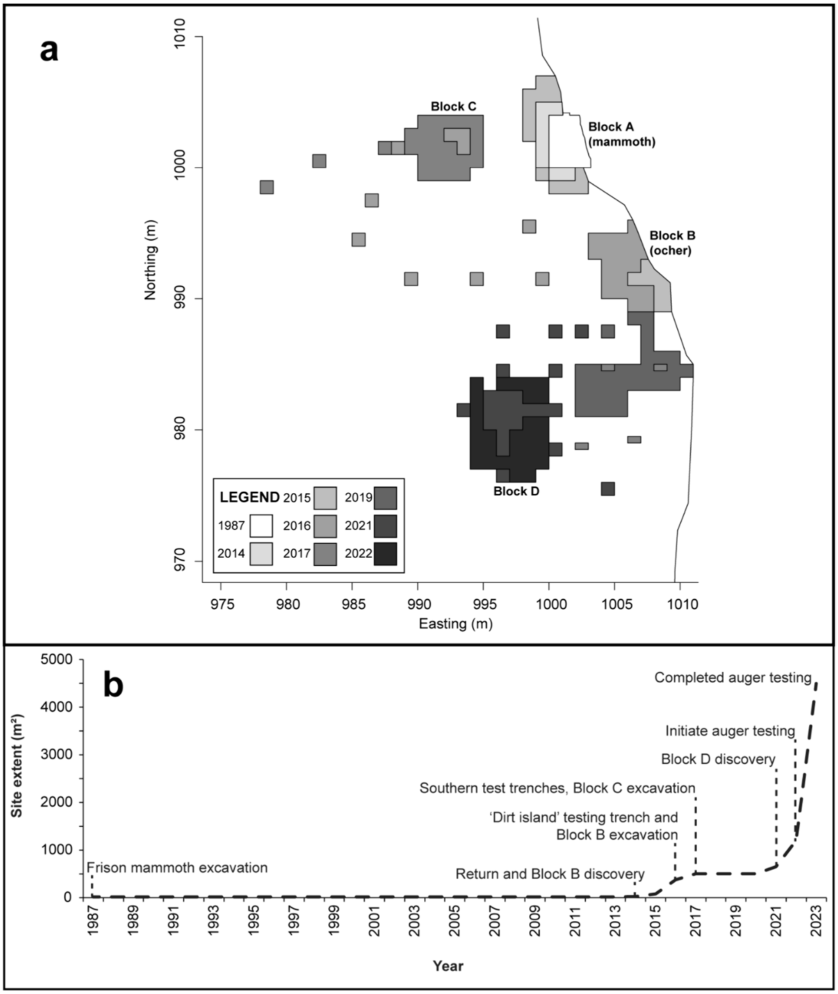


Fig. 1 La Prele site investigations by year. **a** Map of primary excavation years by year of excavation. **b** Change in site area through time noting major investigation milestones

we decided early in the project that determining the site extent with bucket augers would likely not be feasible and turned to other methods for several years.

In 2016, we excavated a C-shaped trench connecting Blocks A and B extending 25 m into the La Prele terrace to a depth just above that of the cultural level, between 3 and 4 m below ground surface. This trench began being called the "dirt island" trench due to the rectangular and isolated portion of unexcavated sediment in its center (Mackie et al., 2020: Fig. 1). We placed 1 m × 1 m test units in the trench floor to prospect for additional artifact concentrations, a method we came to use for the next several years. Most of those units yielded cultural materials, and this effort extended the site 18 m west for a total extent of around 375 m^2. The 2016 testing led to the discovery of Block C.

In 2017, concurrent with Block C excavations, we excavated two backhoe trenches south of Block B extending around 10 m west from the La Prele Creek cutbank into the La Prele terrace. We placed four 1 m × 50 cm test units in their floors. These tests produced few artifacts, but they yielded the first diagnostic spear point from the site, the distal portion of a Clovis projectile point (Surovell et al., 2021: Fig. 11.8c). These tests extended the site 11 m further south and led to a total estimated site size of around 500 m^2.

After a hiatus in 2018, we excavated a test unit and a series of hand trenches into the La Prele Creek cutbank in 2019 north of Block A along with a block excavation of an area around the location of the Clovis point find in 2017 (Allaun et al., 2023). In 2019, we did not know if Pleistocene sediments remained intact north of Block A or if they had been eroded by incision of La Prele Creek during the Holocene. We were able to trace the S-1 paleosol at least 60 m north of Block A, but we found no artifacts associated with these sediments. Block excavation around the Clovis point discovery yielded a low-density scatter of artifacts and bone and did not increase the site's extent.

After another hiatus in 2020 due to the COVID-19 pandemic, we resumed excavations in 2021 west of the 2017 Clovis point discovery and 2019 block. Rather than placing a block blindly, we opened an extensive (~ 15 m × 20 m) area using a large backhoe and excavated a series of 1 m × 1 m test units systematically spaced every 3 m in an effort to discover additional artifact clusters. Here, we discovered Area D, the densest area of La Prele discovered thus far, likely representing an extensively occupied house floor and adjacent yard area. The Block D excavation in 2021 and 2022 extended the La Prele site boundary another 10 m west for an estimated site area of 650 m^2.

Motivated by results from Block D, we resumed an attempt at finding the site extent through systematic auger testing in 2022. Upon finding buried artifacts through some initial auger testing in 2022, we placed a deeply excavated pit with a 2.5 m × 1 m test unit in its base near two artifact-yielding auger tests to confirm results. This unit confirmed that intact buried deposits related to the La Prele occupation exist 40 m northwest of Block C, expanding the site extent to at least 1200 m^2. Proof of concept in hand, we expanded our auger testing in 2023 to subsume a large unexplored region of the La Prele terrace in all directions from the known site extent, which we describe herein.

Methods

Identification of the La Prele site extent is complicated by several sources of uncertainty attending subsurface sampling (Banning, 2023; Kintigh, 1988; Krakker et al., 1983; Stone, 1981). The likelihood of discovering buried archaeological sites with subsurface sampling is a function of three primary probabilities summarized by Kintigh (1988). First, a test must be placed within a site boundary, which is a function of the site's size and the testing layout. Second, a test within a site must intersect an artifact, which is a function of artifact density and test size. Lastly, archaeologists must be able to detect recovered artifacts, which is a function of how sediments are processed for artifact identification (*i.e.*, screened or trowel sorted). One should develop subsurface testing methods that maximize the probability of discovery while working within budget and time constraints.

For this project, we are not finding a *new* site but interested in finding artifacts within a *known* site to estimate its density and extent. Based on previous investigations, we know that La Prele poses several challenges to this goal. First, at a site level, artifacts are highly clustered in 6 m to 7 m-wide concentrations with areas of 10 m to 15 m between them largely devoid of artifacts rather than a continuous scatter of artifacts (Surovell et al., 2021). Thus, we estimate that only around 20% of the site's area contains artifacts at all. This sort of highly clustered artifact distribution is difficult to detect using subsurface testing methods (Kintigh, 1988: Fig. 7).

Artifact distributions within each cluster do not make things any easier. The three artifact clusters previously investigated are hearth-centered activity areas, likely all within houses (Mackie et al., 2022). Each cluster contains a relatively dense accumulation of artifacts near its center that rapidly dissipates toward its edges. This type of "sinusoidal" artifact distribution effectively reduces the readily detectable site (or cluster) extent from its total width to the width of its densest portion (Kintigh, 1988: Fig. 7). Finally, previous investigations have demonstrated that La Prele artifact densities are generally sparse, deeply buried greater than 3 m, and dominated by very small flakes (Mackie et al., 2020), all factors that make finding artifacts difficult through subsurface testing.

Given these constraints, we settled on the following testing strategies. First, the site's depth fundamentally constrains the types of testing methods at our disposal. We could either (a) remove 3 m to 5 m of site overburden over a large area to expose the cultural level, (b) place long, 3 m to 5 m deep trenches at intervals across the inferred extent of the site and test in their floors, or (c) use bucket augers to systematically sample the deposit. The use of shovel probes or square meter test units is not an option at La Prele. Given the cost, safety, and enormous environmental impact of stripping overburden from the site or excavating deep trenches, we decided that systematic auger probe testing was the only viable option.

Following this, using small diameter auger probes of 3.25″ or 4″ severely constrains the quantity of sampled site deposits, thus creating a low probability of recovering artifacts even if an activity area is intersected by the testing grid. This factor is exacerbated by a highly clustered, sparse artifact distribution. To partially mitigate these constraints, we water-screened all sampled sediments through 1/16″ mesh to maximize the likelihood of identifying recovered artifacts.

Finally, the clustered, sinusoidally distributed artifacts from La Prele are difficult to detect with subsurface methods without adequate sample grid spacing and proper configuration. Krakker and colleagues (1983) call to attention that optimal grid spacing can be determined as a function of the radius of the targeted site (or artifact cluster) size with the formula $r\sqrt{2}$, where $r=$ site radius. For instance, if one is interested in detecting sites or artifact clusters 7 m in diameter, then grid spacing should be no more than 5 m. Otherwise, artifact clusters may be missed if their centers lie near the midpoint between four sample locations. Krakker and colleagues (1983) further suggest that hexagonal grid configurations are superior to square grids at detecting sites based on geometric characteristics, but Kintigh (1988) suggests negligible differences based on Monte Carlo simulations of various site sizes and configurations. Balancing these realities with practical field constraints, we decided to use a square grid spaced at 5-m intervals for our auger testing grid with the recognition that some small and/or sparse artifact clusters may have been missed if sampled at their margins.

We established our grid on even meter site coordinates, mapping locations with a total station. We used soil bucket augers with the capability to extend at least 6 m to excavate each auger test (Fig. 2), though not all tests extended that deeply. If we hit a rock that obstructed progress, we moved the auger test to one side no more than

Fig. 2 2023 auger testing at La Prele showing length of auger as it nears the deeply buried cultural level

10 cm and attempted again. We abandoned a given auger test after encountering rocks three times, noting it as inconclusive and documenting the depth at which we encountered obstructions.

We discarded all sediment above the depth at which we began collecting it for screening. We determined collection depth primarily in relation to the S-1 and S-2 paleosols, two easily discernible, deeply buried A horizons in the La Prele terrace sediments that overlie the occupation level (Allaun et al., 2023). Soil S-2 is overthickened, rich in organic matter and secondary carbonates, and typically exists around 1 m above the cultural level. Upon reaching soil S-2, we discarded an additional two or three buckets and then began collecting auger sediments around 50 cm above the soil S-1 A horizon. Upon reaching soil S-1, identifiable by its notably dark hue, we recorded its depth below ground surface. We continued to auger at least 1 m below S-1, collecting all sediment until we were certain that collected sediment incorporated the cultural level. We water-screened all collected sediment through 1/16th-inch mesh (~ 1.6 mm) and searched the matrix for artifacts in the field, discarding all non-cultural matrix.

The relationship between artifact density and auger bucket artifact frequency can be estimated based on basic proportional relationships (herein the *Poisson mean*) between auger bucket size and densities per m^2 using the equation $d = n/s$, where d = artifact density per m^2, n = frequency of sample artifacts, and s = area of sample unit in m^2 (*i.e.*, bucket auger area). However, archaeological spatial distributions are not perfectly uniform, so sampled artifact frequency should exhibit a range of possible values given a single artifact density. This range of variation can be understood using the Poisson probability distribution or simulated. Here, we present a simulation and corresponding graphical outputs to present the relationship between an observed artifact density and the likely recovery of artifacts (Online Resource 1).

First, the simulation establishes artifacts/m^2 for N artifacts in a random uniform distribution for a 1 m × 1 m square. Next, a circular "auger bucket" of a specified diameter (3.25, 4, or 5 inches or 8.3, 10.2, or 12.7 cm) is placed in the center of the square. Artifacts within the auger bucket area are identified using the distance formula, where those artifacts whose distance from the center of the unit is less than or equal to the auger bucket radius are tabulated as present within the auger bucket. The simulation assumes that all artifacts are small enough to be collected by a bucket auger, and in this case, where most artifacts are small flakes, it is a reasonable assumption. This process is repeated 100 times to develop summary statistics for expected auger bucket artifact frequency for a given artifact density. Once a given density iterates 100 times, density increases and that process is repeated at a higher level in the nested *for* loop hierarchy (Fig. 3).

We supplement these quantitative measures of artifact density with a probability statistic derived from the Poisson distribution. Determining the probability of finding at least one artifact can be calculated precisely using the formula $p = 1 - e^{(-d \times a)}$ where e = the natural log constant, d = the density of artifacts per m^2, and a = the area of the sample unit in m^2 (*i.e.*, bucket auger area) (Stone, 1981).

We use the *Poisson mean* to estimate artifact densities across the site using interpolation procedures executed in QGIS V. 3.12.1. To fill in areas of the auger grid already subsumed by excavations, we assigned 11 auger tests to areas within

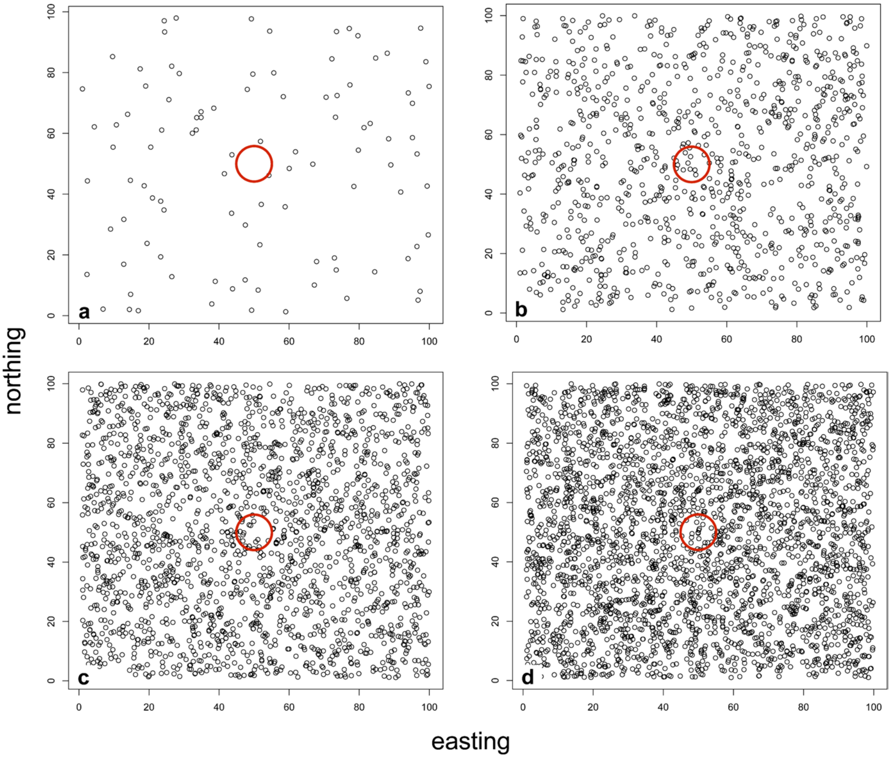


Fig. 3 Visual examples of auger test simulation developed for this study depicting a 4-inch wide auger and artifacts densities of 100 (**a**), 1000 (**b**), 2000 (**c**), and 3000 (**d**) artifacts/m.^{2}

or adjacent to completed excavations that would have intersected our auger grid had we extended it into the excavation block and determined flake density for each auger based on counts from the surrounding 50 cm × 50 cm quadrants. If an auger was surrounded by four quadrants, then we determined density based on total count. If an auger was surrounded by one to three quadrants, then we used the counts present and extrapolated to 1 m^2 to determine flake density (*e.g.*, five flakes from one quadrant would equal 20 flakes/m^2).

We used the heatmap (kernel density estimation) and inverse distance weighting (IDW) tools in the QGIS V. 3.12.1 processing toolbox to interpolate flake densities and the soil S-1 surface across the site, respectively. For the heatmap tool, we set the radius parameter to 6 m based on previous excavation results that revealed artifact clusters of around this size. Thus, it would likely be inappropriate to extrapolate the influence of any given data point past around 6 m at La Prele. We set the output raster cell size to 10 cm square. In the tool's advanced parameters, we set weight from field to the predicted flake density for each auger. We set kernel shape to triweight, a function that heavily weights the sample point and decays steeply to the radius extent, a distributional pattern similar to that observed for the sinusoidal artifact distributions documented at La Prele.

For the IDW tool, we set the output raster size to 5 m to mimic auger spacing and minimize the "bullseye" effect wherein individual data points exert undue influence on interpolated results. IDW tool results vary considerably depending on the distance coefficient value p specified by the user. The p coefficient determines the rate at which weighting decays with distance from a given data point. Lower values (*e.g.*, 1) decay slowly with distance, resulting in a more "averaged" interpolated surface. Higher values (*e.g.*, 3) decay quickly with distance, resulting in individual data points having more influence on the interpolated surface. Deciding the value of p depends on which aspects of the interpolated surface in which one is interested. Here, we vary p between 1 and 2 for interpolating the soil S-1 surface.

Results

Fieldwork

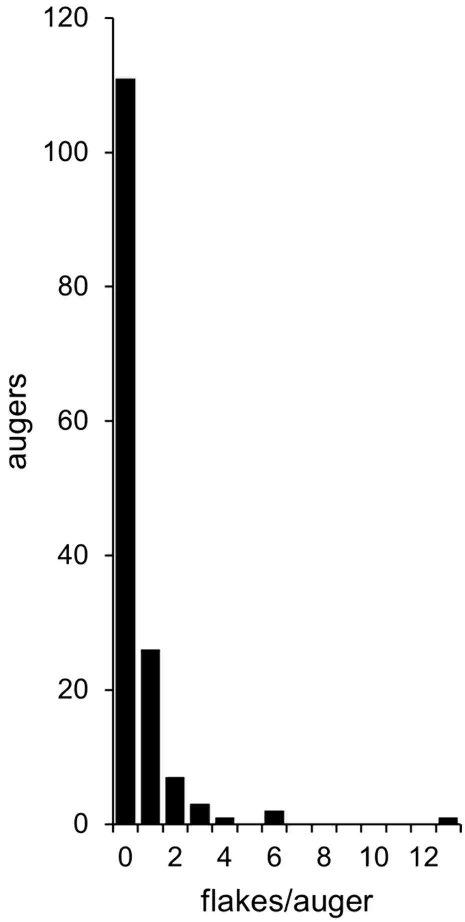
We attempted 189 augers, completing 151 of them through the cultural level without hitting obstructions. We visually identified S-1 in 133 of completed augers (88%), confirming that the La Prele site sediments are intact over a large area of the La Prele terrace. Augers in which we did not identify S-1 were due to the soil being weakly expressed, confused with other soils in localized areas, or field error. S-1 ranges in depth below ground surface from 90 cm in a gully near the northernmost auger tests to 5.4 m in the westernmost augers, where the modern ground surface slopes upward toward the west. In terms of site grid elevation, we detected S-1 spanning 2.12 m of relief, from a low elevation of 96.32 m to a high of 98.44 m. We note that the single lowest elevation of 96.32 m is an outlier relative to other augers by around 30 cm, with most of the lowest elevation values around 96.60 m.

We collected artifacts associated with the cultural occupation from 57 augers (38% of completed augers), including flakes, red ocher nodules, and faunal remains (Online Resources 2). In total, our auger tests expanded the known site extent to a minimum of 80 m north to south by 75 m east to west. These dimensions translate to a minimum estimated area of 3500 m^2 (conforming closely to the extent of positive augers and excavations) to a maximum of 5500 m^2 (generalizing between positive auger tests to fill voids in the site extent margins). We consider 4500 m^2 to be a decent middle ground estimate for La Prele's current known extent.

Forty augers yielded flakes, 7 yielded ocher, and 30 yielded pieces of bone. Auger flake frequency ranges from 1 to 13 and is heavily right-skewed, with most augers producing zero or one flake and only seven (4.6%) producing more than two (Fig. 4). This pattern is consistent with the previously excavated portion of the site in which areas with high artifact densities are rare and areas containing sparse or non-existent artifact densities are common.

We recovered a total of 78 flakes from which we have conservatively identified five raw material types. Flake raw material frequencies include 21 Hartville Formation (or similar Pennsylvanian-aged) chert, 18 White River Group chert, 5 pink

Fig. 4 Histogram of auger tests by flake count. Mean flakes per auger is 0.52



quartzite, 4 brown quartzite, and 27 white quartzite with black inclusions. The Hartville Formation and White River Group cherts from augers are consistent with raw materials previously excavated from La Prele (*e.g.*, Mackie et al., 2020: Fig. 9) that outcrop south and east of the site. The provenance of the three quartzite varieties recovered from augers is not known, but quartzite with these color variations exists in the Pennsylvanian-aged Casper Formation, which outcrops on both sides of the Laramie Range no less than 30 km south of the site (Eckles & Guinard, 2015). The abundance of white quartzite flakes with black inclusions, which comprise over a third of the recovered auger flakes, is especially surprising given its rarity in the excavated assemblage. Most of these flakes were from augers in the western and northern portions of the auger grid, but we also recovered three flakes of this material from an auger (#23–58) 4 m west of Block D.

We recovered 11 pieces of red ocher from seven augers, ranging from one to four pieces in each. Red ocher was typically present as nodules smaller than 5 mm and discerned from locally present background hematite by their ability to streak red.

Red ocher from augers is visually comparable to nodules of Powars II hematite previously recovered from Block B (Zarzycka et al., 2019), but we have not attempted geochemical sourcing of auger ocher.

Faunal remains were typically small slivers of cortical bone. However, three auger tests contained large fragments of bone that appear to have been freshly broken from large bones as the auger passed through them and one auger (#23–85) contained a possible small piece of mammoth ivory. The three augers with large chunks of bone contain > 85% of the bone recovered from augers by mass and are contiguous with each other near the west end of the auger grid (Fig. 5). Given their anomalous character and their direct association with flakes, we suspect that these augers represent another bonebed at La Prele. We conducted zooarchaeology by mass spectrometry (ZooMS) analysis on bone fragments from these augers and concluded that the bone is *Bison sp.* (Buckley et al., 2009).

Density Estimation

We used two different auger bucket widths (3.25 and 4 inches) during our auger test survey but did not document which tests were excavated with which auger buckets. Roughly, we completed around half of all auger tests with each. Thus, we used a faux width of 3.625″ to average the two auger bucket widths and the *Poisson mean* to assign artifact density estimates for each auger test. Using this method, we estimate our augers detected artifact densities of 150 artifacts/m^2 for one auger flake to 1953 artifacts/m^2 for 13 auger flakes.

Simulation results provide a range of variation for the relationship between auger artifact counts and actual artifact density given a random uniform artifact distribution (Fig. 6). In general, artifact density and count are more closely related at low densities, which maintain tightly constrained ranges, than high densities, which exhibit a looser relationship between artifact density and count. For example, at densities of 200 artifacts and below, the range of possible artifacts spans only 0 to 5 total artifacts whereas a density of 1500 exhibits a range of 3 to 20 and a density of 3000 exhibits a range of 13 to 39. This variation may also be expressed probabilistically by calculating the standard deviation of the Poisson mean ($\sqrt{\lambda}$), or 1.6 ± 1.3, 12.2 ± 3.5, and 24.3 ± 4.9 artifacts for densities of 200, 1500, and 3000 artifacts/m^2, respectively.

As discussed, the most common auger flake count is zero, accounting for 111 out of 151 completed augers (74%), and this result is worth further discussion. Zero flake augers represent a combination of samples derived beyond the site's extent and samples placed within sparse areas of the site where we did not intersect artifacts. Poisson probability estimates that we had a 95% probability of recovering at least one artifact from deposits containing between 370 (4″ bucket) and 560 (3.25″ bucket) artifacts/m^2, and 450 artifacts/m^2 for our faux auger bucket width of 3.625″ (Fig. 7). Thus, augers that contain zero flakes are almost certainly derived from deposits containing fewer than 560 artifacts/m^2, and likely far fewer. As expected, simulation results are consistent with Poisson probability estimates (Figs. 5 and 6). It is nearly impossible for areas of the site containing more than around 500

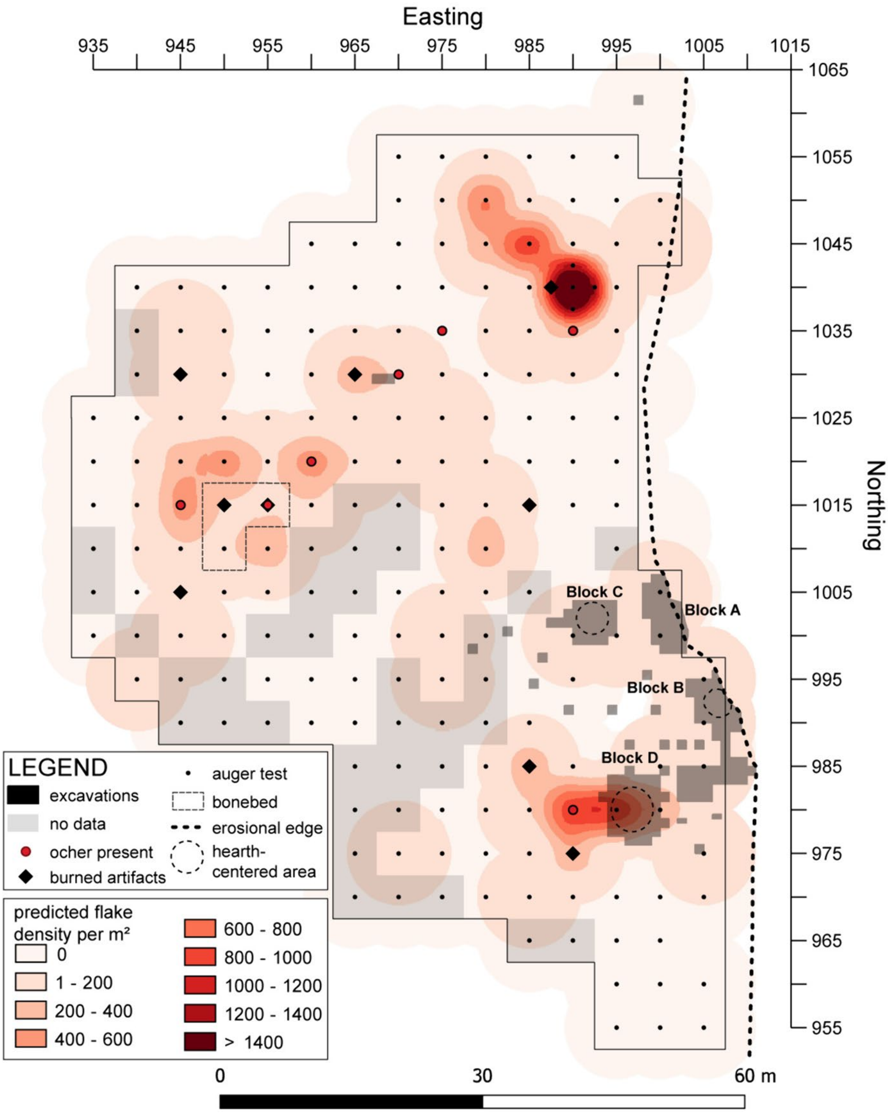


Fig. 5 Summary of auger test investigations at La Prele. Estimated flake densities are derived using the Poisson mean. Auger locations plotted on prior excavations are projected for use in this study and not actually completed

artifacts/m^2 to produce zero flakes. To contextualize this result, flakes in previously excavated Block B reach a maximum density of around 300 flakes/m^2 and those in Block C reach 440 flakes/m^2, both in 1- to 2-m-wide areas at their centers. Thus, auger sampling of areas within La Prele of comparable density to Blocks B and C could have easily produced zero flakes, especially if the auger did not sample the area from near its center.

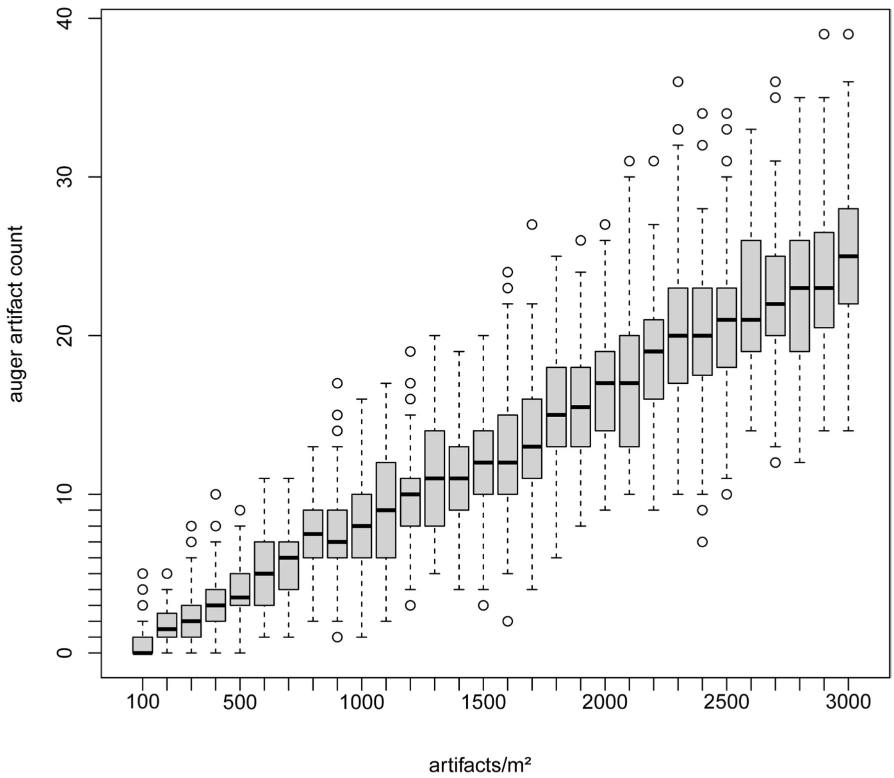


Fig. 6 Simulation results for a 4-inch bucket auger showing the range and distribution of expected artifacts from buried archaeological deposits with artifact densities between 100 and 3000 m^2. Black lines represent medians, gray boxes are interquartile ranges, and dashed lines are 95% confidence intervals

Geospatial Analysis

The two versions of IDW interpolation used to model the soil S-1 surface each provide their respective interpretive benefits (Fig. 8). A distance coefficient value of $p=1$ results in an overall "smoother" topographic depiction (Fig. 8a). On the other hand, it obscures potentially meaningful topographic variation and results in a less precise estimate of local elevation. For instance, in Block D, where S-1 elevation is well known to be positioned at around 97.85, interpolation using a distance coefficient of $p=1$ estimates elevations between 97.50 and 97.60. A distance coefficient of $p=2$ results in an overall "messier" topographic depiction, but highlights several features obscured by a value of $p=1$ and is more accurate (Fig. 8b). For instance, S-1 elevations for Block D are more accurately estimated between 97.75 and 97.85.

In general, the soil S-1 surface dips toward the northeast at a range of slopes between 0.2 and 3.9°. Most slopes range between 0.2 and 1.5° with an average of around 1.0°. The steepest slopes detected in the site are near its western edge, and the surface is essentially flat in its northernmost portions, where it contains

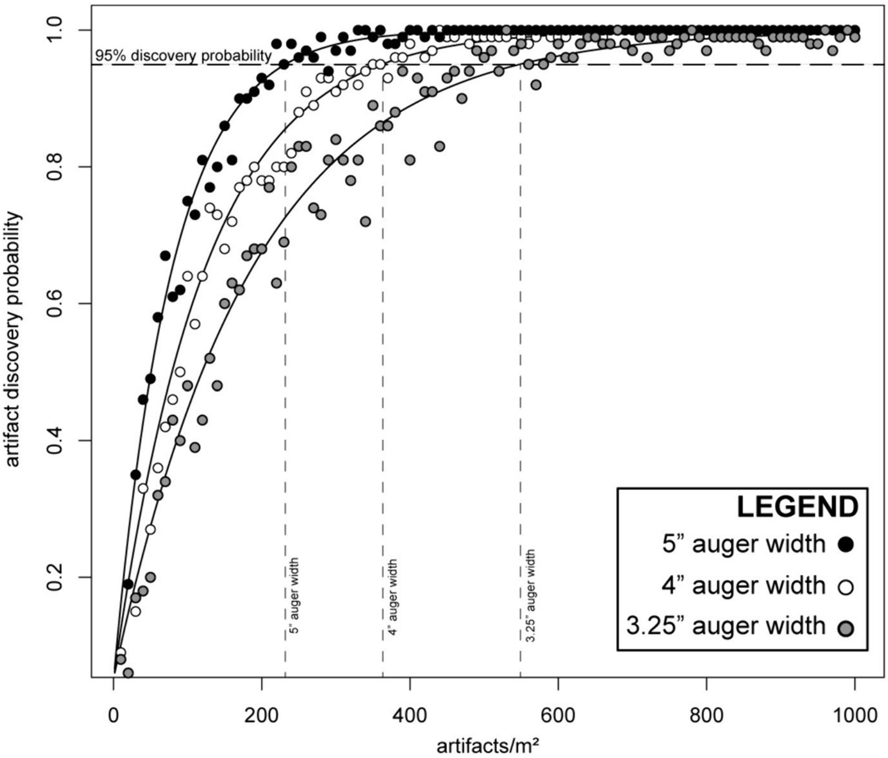


Fig. 7 The probability of finding any artifact from an auger bucket for artifact densities between 10 and 1000/m^2 and three different auger bucket sizes. Points represent simulated data, and lines represent the Poisson probabilities for each auger bucket size

a shallow (20–30 cm) depression (Fig. 8). A slope estimate of 0.28° presented by Allaun et al. (2023) between Blocks D and C is within the low end of slope estimates for the site, a result of having been estimated in a relatively flat area. The interpolated surface in the northern end of the site appears to depict a shallow basin, perhaps a floodplain feature of La Prele Creek, but we remain cautious in that interpretation until further investigation.

A shallow swale or drainage bisects the S-1 surface west of our previous excavation blocks from south to north. In the more localized version of the IDW interpolation (Fig. 8b), this swale contains a relatively deep depression in the vicinity of N995/E975 where an auger detected S-1 at a site elevation of 96.77, or around 80 cm lower than the auger 5 m to its north. Soil S-1 was not detected in other surrounding augers, either because they hit obstructions or because S-1 was not visible, so it is unknown how extensive this anomalously low S-1 is.

S-1 was weakly expressed in the westernmost auger tests at elevations over around 98.0 m, likely because the S-1 surface rises out of riparian environments and into the surrounding uplands. S-1 is divided into two soils, previously identified as soils S-1b and S-1c, in much of the northern portion of the site roughly

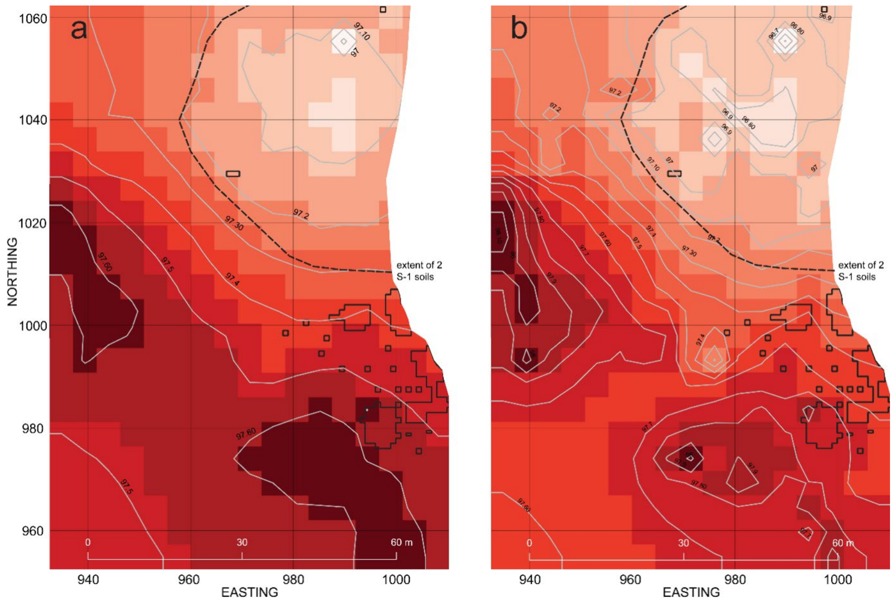


Fig. 8 Two versions of inverse distance weighted interpolation of soil S-1 for La Prele using distance coefficient values $p = 1$ (**a**) and 2 (**b**). Excavation noted as solid lines and extent of two S-1 soils noted as dashed line. Contour lines denote site grid elevation in 10-cm intervals. Raster surface denotes elevation values. The La Prele site occupation surface roughly conforms to this overlying soil

conforming to elevations below 97.20 (Fig. 8). This lowest portion of the site apparently received overbank alluvial deposition derived from La Prele Creek flood events that the higher elevations did not. These soils are spaced around 25 cm apart where visible in test units and stratigraphic profiles, suggesting multiple depositional events separate them.

Kernel density estimation (KDE) of auger flake counts reveals three dense artifact concentrations at La Prele (Fig. 5). The first area, located in the southeast portion of the site, is associated with the Block D house floor and an area to its west. KDE predicts an area of around 5 m north to south extending 7 m west of Block D in which flake densities exceed 500/m^2. We suspect that this concentration might represent an additional residential structure west of the one observed in Block D.

The second area is located near the west side of our auger grid on the northeast-facing slope of one of the steeper portions of the S-1 surface. As previously mentioned, its most distinguishing feature is a possible bison bonebed near its center as indicated by three contiguous augers that produced large chunks of bone. Of these, the auger test in the northwest of the L-shaped concentration (N1015/E950) produced the most bone, so we suspect this auger is nearest the center of the bone deposit. Given a total area of around 75 m^2, the bone concentration must represent more than one animal, since the bones from a single bison would occupy far less space. A bone deposit of this extent is more comparable in size to the kill area at, for instance, Stewart's Cattle Guard, where close to 50 bison were killed (Jodry, 1999). The nature and size of this deposit awaits confirmation via testing. The possible bonebed feature is associated with three 6-m to 9-m-wide flake clusters reaching estimated densities of around 470 flakes per m^2.

The third area is located at the far northern portion of the auger grid near the center of the S-1 surface depression. One auger test in this area (#23–109, N1040/E990) yielded 13 flakes, a data point that anchors an exceptionally dense concentration of flakes, bone, and possible ivory for which KD estimates reach just over 2200 flakes/m^2. This area contains a ~ 6 m diameter central portion with flake densities exceeding 1000/m^2 associated with burned artifacts. This central portion extends into a larger NW–SE-trending concentration containing between 400 and 1000 flakes/m^2 in a ~ 20 m × 5 m area. We placed radial auger tests at 2.5-m intervals in each of the four cardinal directions from auger #23–109 to help guide placement of an excavation block in this area, a form of adaptive sampling (Banning, 2023). It is important to note that flake KDE's may be inflated due to the more tightly space auger tests. However, its size and density are comparable to that of Block D, suggesting a similar type of area, perhaps containing multiple residential structures.

Finally, we recovered burned artifacts from nine augers, including five with burned or calcined bone and four with burned flakes. These burned artifacts are distributed throughout the site, both in the high-density concentrations discussed and in areas with seemingly sparse evidence for occupation. Burned artifacts at La Prele have thus far been almost solely associated with the centers of hearth-centered activity areas, most of which likely lie within houses (Mackie et al., 2022). Thus, the mere presence of burned artifacts is a good indication of a nearby hearth and perhaps interior house space (Surovell, 2022). Given this, it appears as though La Prele contains at least nine additional hearth-centered activity areas, including at least five within dense artifact accumulations like Block D and four within more ephemeral accumulations like Blocks B and C.

Challenges

Auger test results have contextualized our excavations in several important ways. First, it is apparent that La Prele Blocks A, B, and C, which collectively contain a mammoth kill and two hearth-centered activity areas that we spent four field seasons excavating, would likely *not* have been discovered through auger testing. Of 11 augers that would have intersected our excavations, we estimate that only two of them would have recovered flakes using the *Poisson mean*, both from the dense artifact concentration in Block D. One of those augers would have most likely produced 11 flakes and the other would have produced 2. In other words, an excavation area that has produced a lithic assemblage of more than 46,000 artifacts would be represented by only about 13 flakes in our systematic auger grid.

Given the generally low flake densities over much of our excavations in Blocks A, B, and C, we estimate that the rest of augers would have produced between 0 and 0.1 artifacts, effectively making these areas of the site invisible to auger testing. Few quadrants within the excavated blocks contain high enough artifact densities to detect with augers. Moreover, those few places with high artifact densities are localized within one or two 50 cm × 50 cm quadrants near the centers of each artifact cluster, thus minimizing their chance of discovery. This reality certainly draws attention to the limitations of systematic auger testing, but it also suggests that artifact concentrations of similar size and density may be present throughout areas of the site that presently appear vacant.

Second, we failed to identify in augers two phenomena documented during prior excavations that seem notable. We did not encounter another red ocher stain during auger testing similar to the one documented in Block B (Mackie et al., 2022; Zarzycka et al., 2019), either because it is small enough to evade detection between auger tests or because it is unique within the site. The stained pink sediment would have certainly been visible in bucket augers had we encountered it. Had our auger grid been extended over Block B, it would have likely failed to pick up the Block B ocher stain because it is situated squarely between two auger tests. Further, we did not identify any brown, translucent chert of the Green River Formation akin the type found in Block C, whose artifacts are produced exclusively from this material (Mahan, 2020). Thus, Block C remains unique in its use of southwest Wyoming chipped stone raw material at the site.

Discussion

Is La Prele a Single Occupation?

We have established the presence of a large campsite containing multiple concentrations of artifacts likely representing several residential features and a bison bonebed through auger testing at La Prele. As indicated by a 2022 test excavation previously discussed, auger artifacts are located within the same stratigraphic level as the excavated site, so they are roughly the same age. However, there remains the possibility that they were deposited during multiple site occupations that occurred within a relatively short time period. Three lines of evidence lead us to suspect that all artifacts thus far recovered from La Prele derive from the same occupational event.

First, we have now recovered mammoth ivory from four separate artifact concentrations at La Prele, from excavated Blocks A, B, and D and from auger test #23–85 within the northern artifact concentration (Herron, 2022). Given rapid degradation of ivory left exposed on the surface in temperate climates, we assume that these ivory artifacts were dispersed across La Prele artifact concentrations at the same time shortly after the mammoth was killed. Ivory links much of the site from its southern to northern extent.

Second, much of the site shares the same few raw materials, including both chipped stone types and red ocher. La Prele is not associated with locally available chert or quartzite sources, so all stone tool material was carried into the site from at least several tens of kilometers away. Much of the chipped stone raw material from the site is from the Hartville Formation, at least 50 km distant, and the White River Group, which outcrops within 20 km but within which chert is heterogeneously distributed. These raw material sources are found throughout the site's known extent from both excavations and auger tests. A distinctive white quartzite with black inclusions of unknown provenance is also found in auger tests and excavations throughout the site. Additionally, red ocher that is a macroscopic match to the Powars II source (Pelton et al., 2022) has been recovered from all areas of the site, including excavated Blocks B and D and seven auger tests.

Lastly, we have for several years recovered bison bone from excavations at La Prele (Surovell et al., 2021), but we were unaware of its source. With the discovery of a possible bison bonebed deposit from augers near the western edge of the site, we now have a plausible source for those bison remains. Bison remains link all areas thus far investigated at La Prele.

Although we have not yet linked multiple areas of La Prele through stone tool refits, shared materials between all site areas strongly suggest a single occupation during which a mammoth and some unknown number of bison were hunted and after which people established a campsite during one occupational event. Given this scenario, we argue that La Prele is a good candidate for estimating site size and occupancy.

Early Paleoindian Campsite Comparisons

Early Paleoindian campsites (*i.e.*, pre-12,000 cal BP) are among the rarest North American archaeological sites that exist. Those that reflect a close approximation of their original extent and configuration are rarer still. When buried, such campsites are often truncated by erosion (Frison, 1984; Frison & Stanford, 1982; Haury et al., 1959; Kornfeld & Larson, 2009) or incompletely documented due to the constraints of determining the extents of deeply buried sites (Gingerich, 2011; Waters et al., 2011; Wilmsen & Robert Jr, 1978). When exposed on the surface, Early Paleoindian campsites have a high likelihood of being mixed with artifacts of later time periods (Allaun, 2019; Dawson & Judge, 1969; Sánchez-Morales, 2018), which can create inaccurate size estimates. Beyond these constraints, campsites often contain evidence for reoccupation, which can alter the sizes of single occupations considerably (Andrews et al., 2008). Thus, Early Paleoindian campsites with the right combination of preservation, documentation, and occupational characteristics from which archaeologists can derive size estimates are uncommon.

The most well-known and remarkable of such sites is Massachusetts' Bull Brook, which contains 36 activity loci arranged in a circular configuration measuring 170 m × 135 m (Robinson et al., 2009), or a total of around 17,000 m^2 (Fig. 9). Investigators have argued since Bull Brook's earliest reporting that it represents the single occupation campsite of a large group aggregation event (Jordan, 1960), a gathering made possible through organized communal caribou hunts (Robinson et al., 2009). Several northeastern Early Paleoindian sites are known for their large size (Dincauze, 1996), but Bull Brook is the largest and remains the archetype for Early Paleoindian group aggregation sites.

The Early Paleoindian record of the Great Plains and Rocky Mountains does not contain a site of comparable size or fidelity as Bull Brook. No region does. However, the region contains several Early Paleoindian campsites whose extents are preserved and relatively well defined through extensive archaeological research, including Rio Rancho (Dawson & Judge, 1969; Huckell & Kilby, 2001; Judge, 1970; Ruth,

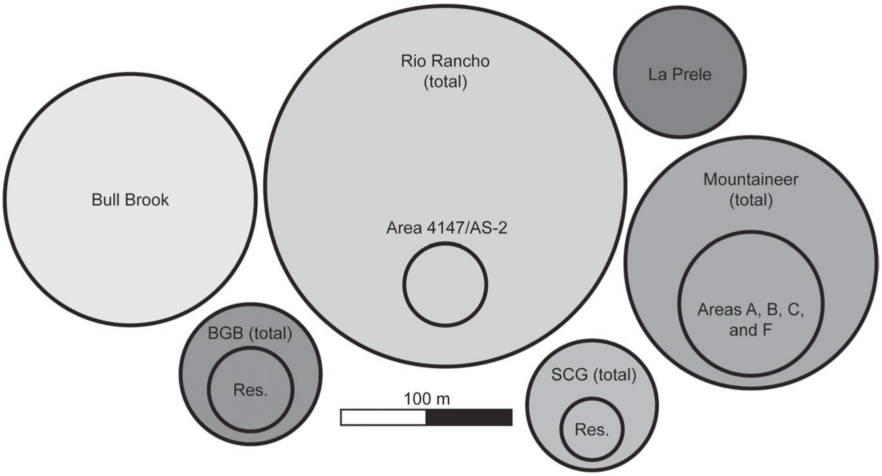


Fig. 9 Schematic size estimates for major single occupation Early Paleoindian campsites. BGB, Barger Gulch Locality B; SCG, Stewart's Cattle Guard; Res., residential area

2013), Stewart's Cattle Guard (Jodry, 1999), Mountaineer (Andrews et al., 2021), and Barger Gulch Locality B (Surovell, 2022).

The Rio Rancho Folsom campsite is in the Rio Grande Valley north of Albuquerque, NM. The entire site subsumes an area of at least 35,000 m^2 of exposed surface artifacts, but it consists of three primary areas in which most artifacts were found with large areas between them devoid of artifacts: areas 4146, 4147/AS-2, and 4148. Areas 4147/AS-2 and 4148 both contain two artifact concentrations around which Dawson and Judge (1969) based their excavations, while area 4146 contains only one. Site investigators have argued that the expansive site was formed by multiple occupations of small bands rather than a single group aggregation event.

Of the three Rio Rancho site areas, area 4147/AS-2 is the best candidate for a fully delineated, single occupation site for several reasons. First, the western two areas (4147/AS-2 and 4148) contain solely Folsom artifacts, while the eastern (4146) contains a mix of Folsom and later time periods (Dawson & Judge, 1969). Of the two single-component areas, Huckell and Kilby (2001) and later Ruth (2013) report that the extent of area 4148 is likely incomplete, but the extent of area 4147/AS-2 seems accurate at around 1800 m^2. Lastly, Dawson and Judge (1969) argue that the artifacts from the two concentrations at area 4147/AS-2 are distinct from the other areas at Rio Rancho, perhaps representing "different bands" occupying two residential households located around 20 m apart (Ruth, 2013). Taken together, area 4147/AS-2 at Rio Rancho appears to represent a single occupation that contains two artifact concentrations within an area of around 1800 m^2.

Moving further north, the Stewart's Cattle Guard Folsom bison kill and campsite is located on the eastern edge of the San Luis Valley near Great Sand Dunes National Park in Colorado (Jodry, 1999). Stewart's Cattle Guard is buried up to a meter deep in dune sand and minimally mixed with artifacts of later eras. The site is extensively excavated and certainly represents a single occupational event during which Folsom foragers killed and processed close to 50 bison and then camped in a residential area of the site. Within an estimated total area of 4500 m^2, Jodry (1999) identified at least five hearth-centered activity areas she argues represent the footprints of houses. The residential area of the site is around 1000 m^2.

The Mountaineer Folsom site is located on top of a prominent mesa (Tenderfoot Mountain) in the Gunnison Valley of Colorado (Andrews, 2010; Andrews et al., 2021). The site is exposed at the surface and shallowly buried in loess collected within bedrock fissures. The top of Tenderfoot Mountain contains many concentrations of chipped stone artifacts, but its western edge contains around 10 clusters of Folsom artifacts unmixed with artifacts of later time periods. Within the extent of Folsom artifacts at Mountaineer, there are five excavated areas: A, B, C, D, and F. Areas A, B, C, and F are located along the western margin of Tenderfoot Mountain associated with five surface artifact clusters, and Area D is located on a low rise 100 m northeast of those areas associated with another five clusters. The Area D block excavation subsumes two artifact clusters, and four other clusters are associated with each of Areas A, B, C, and F.

Excavations in Areas A, B, C, and F have revealed the presence of four house foundations situated between 30 and 50 m apart created by overturning bedrock, inside of which exist dense accumulations of artifacts (Morgan, 2015; Morgan & Andrews, 2016, 2022). Site investigators have not argued for a contemporaneous occupation between all areas and have specifically argued that Area D appears to represent a separate occupation than other site areas (Andrews, 2010). However, we think that their consistent characteristics and linear arrangement along the edge of Tenderfoot Mountain seem like compelling evidence for the contemporaneity of Areas A, B, C, and F. This portion of the site subsumes an area of 130 m × 60 m, totaling around 4500 m^2. Including Area D, the Mountaineer site has a total area of around 13,000 m^2.

The Barger Gulch Locality B (BGB) Folsom campsite is in Middle Park, CO, near the Colorado River southeast of the town of Kremmling (Surovell, 2022). BGB is partially buried below a shallow Early to Middle Holocene soil and partially exposed due to erosion (Surovell et al., 2005). All excavated portions of the site contain only Folsom diagnostic artifacts, and the site appears to represent a single occupational event. Three block excavations (Main, East, and South) each revealed the footprint of a residential structure (Surovell & Waguespack, 2007), and Surovell (2022) estimates another seven based on clusters of surface artifacts for a total of 10 residential structures at BGB. Surovell (2022) estimates a primary residential area extent of 1800 to 1900 m^2. Including a surface scatter of Folsom artifacts at the west end of the site that may or may not be related to the residential occupation, the site extent totals around 5300 m^2. Finally, using several methods for estimating site occupancy, Surovell (2022) estimates between 10 and 200 people occupied the site, but most likely between 40 and 50.

Estimating La Prele Site Occupancy

Our estimated site extent for La Prele is remarkably comparable to that of other Early Paleoindian sites in the Rocky Mountains, specifically the total extents of BGB, Stewarts Cattle Guard, and Mountaineer Areas A, B, C, and F (Fig. 9). We have argued that La Prele contains evidence for at least three residential dwellings and a mammoth kill in the approximately 650 m^2 area we have investigated through excavation and testing so far, but we cannot yet determine how many residential dwellings might remain unexcavated at the site. A crude extrapolation to the estimated total site size might suggest a six- to sevenfold increase in residential dwellings, or between 18 and 21. However, occupancy estimates based on house floor area (Ortman & Coffey, 2017) or number of site features (Hamilton et al., 2018) inferred from our small sample of the site would be entirely conjectural until more of the site is excavated. Moreover, ethnographic studies of camp size have demonstrated that camp occupancy is not a linear function of camp size, but is sublinear (Hamilton et al., 2018; Lobo et al., 2022; Whitelaw, 1991). As camp occupancy increases, the size of that camp increases faster, so extrapolation of houses per investigated area in one portion of the site to its entire extent is likely not an accurate reflection of site occupancy.

Given this, total site extent is likely our best means of estimating site occupancy at La Prele. Using 188 ethnographic cases compiled by Hamilton et al., (2018: Supplemental Table 1) in which camp size and occupancy are known, we conducted linear regression analysis on the natural logged values for camp size and site occupancy values (Fig. 10; Table 1). Using the regression mean for all ethnographic cases and site size estimates of 3500, 4500, and 5500 m^2, we estimate La Prele site occupancy between 30 and 33 people. Using only ethnographic cases from arid regions where occupations are not constrained by dense vegetation (sub-Saharan Africa and Australia), we estimate site occupancy between 29 and 33 people. The one standard deviation error for both samples spans a wide range between 10 and 100 people. Given ethnographic analogy, our best estimate for La Prele occupancy is around 30 people.

Conclusions

We expanded the known La Prele site extent sevenfold with the use of systematic bucket auger testing to around 4500 m^2, and we learned several lessons in the process. First, the bigger the auger, the better it is at finding buried sites. We used the tools available to us for this project, which included auger buckets of both

Table 1 La Prele site occupancy estimates based on total campsite size and regression equations produced using linear models from data presented by Hamilton et al. (2018). We calculated one standard deviation errors around individual values

La Prele site extent estimate (m^2)	Occupancy estimates All ethnographic camps *(ln(occupancy) = 0.1851(ln(camp size)) + 1.8938*	 Arid camps *(ln(occupancy) = 0.2609(ln(camp size) + 1.2411)*
3500	30 (10 to 92)	29 (10 to 85)
4500	32 (10 to 96)	31 (11 to 91)
5500	33 (11 to 100)	33 (11 to 96)

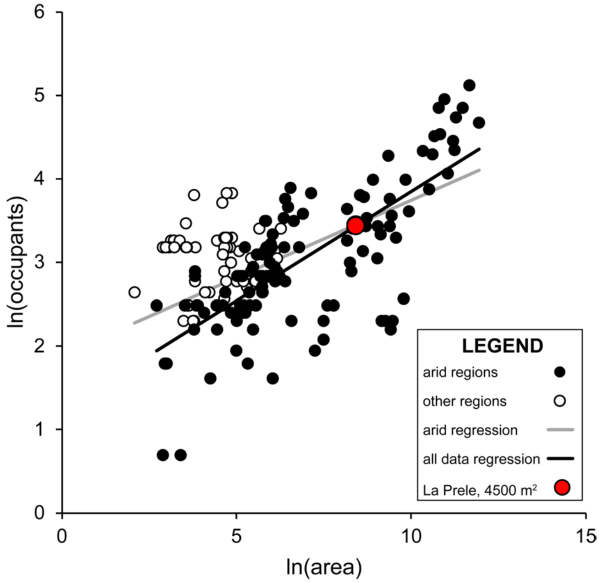


Fig. 10 Ethnographically documented ($N=188$) campsite size and occupancy scaled to natural log on both axes (Hamilton et al., 2018)

3.25 and 4 inches in diameter. In retrospect, standardizing auger bucket size to the largest diameter available makes the analysis of field results more straightforward and maximizes one's chances of recovering buried artifacts. If available, 5-inch bucket augers are ideal, but they are also more difficult to operate in rocky strata where they have a greater potential to intersect a large cobble that obstructs progress.

Second, we highly recommend the use of 1/16th-inch water screening for artifact recovery to maximize the likelihood of detecting buried artifacts. Most of the flakes we recovered from augers would have been missed using 1/8th-inch wire mesh and dry screening. We recognize that water screening is not always available on site during testing projects, but the benefit is great enough to justify bucketing sediment and water screening off-site if necessary.

Lastly, given the highly clustered, sinusoidally distributed artifacts found in activity areas of 6 m to 7 m wide at La Prele, a square grid spaced at 5-m intervals was necessary to detect site features. In retrospect, an even smaller grid spacing would have been more appropriate given known site characteristics in which artifact densities great enough to confidently detect with auger probes exist within 1-m to 2-m-wide clusters near the centers of activity areas. For this project, in which artifacts were buried 3 m to 5 m deep, conducting an auger probe grid spaced at 1-m to 2-m intervals (over 500 total auger probes) was simply not feasible given time and budget constraints, but we recognize the value.

Simulation and *Poisson mean* estimation suggest that finding even one artifact in a bucket auger equates to a relatively dense archaeological deposit of 150 artifacts/m^2. Using the *Poisson mean* combined with KDE, we estimate that some unexcavated portions of La Prele might contain densities exceeding 2200 artifacts per m^2. Density estimation also suggests that we probably failed to identify in our auger survey many activity areas at La Prele of comparable densities to previously excavated Blocks B and C. Obviously, there is much more to be found at La Prele.

The combined evidence suggests that La Prele contains several additional hearth-centered activity areas, many of which likely represent houses, and at least two completely unexplored site areas to the west and north of comparable size to that of the area we have spent the last 10 years excavating. One of these areas, on the west side of the site, possibly contains a bison bonebed that may be the source of bison bone previously recovered from the site. The other area seems to contain a dense accumulation of chipped stone comparable to that identified through excavations in Block D.

We know that a portion of La Prele has eroded down La Prele Creek but are unsure how much. Both the mammoth of Block A and the ocher stain of Block C were obviously truncated by erosion at the time of excavation. The two S-1 paleosols documented during this project in the northeast portion of the site suggest that La Prele Creek was near enough to the site at the time of its formation to contribute overbank flood sediments to its burial, so the Creek may have bounded the site on its east side near its modern alignment. We are also unsure if we have detected the true edges of the site to the south and north. In the south, an alluvial fan derived from an older Pleistocene terrace scarp west of the site has contributed large cobbles to sediments overlying the La Prele occupation level, making auger probe sampling ineffective in this portion of the site. To the northwest, we are simply not confident that we have reached the site's edge because the site is bounded by only a single row of negative auger probes along most of its northern margin due to time constraints.

These caveats aside, we note that La Prele's estimated size is comparable to several extensively investigated, single occupation Early Paleoindian campsites in the Rocky Mountains, which are consistently between 4000 and 5000 m^2. Sites of this size housed an estimated 30 people given expectations from the ethnographic record. This number is worth contextualizing in these concluding remarks (Binford, 2001; Hamilton et al., 2007). Hunter-gatherer social networks are organized into roughly six hierarchical orders from individuals to entire ethnic populations, a global pattern collectively described by Horton laws (Hamilton et al., 2007). A population of 30 people falls in between ethnographic averages for dispersed extended family groups (Horton order 3) and aggregated groups (Horton order 4). Dispersed extended family groups exist "during the most dispersed phases of the mobility cycle" and typically consist of 15 to 17 people comprising several nuclear families. At an estimated 30 people, La Prele would fall on the high end of ethnographically documented dispersed extended family groups. Aggregated groups exist "during the most aggregated phases of the mobility cycle" and typically consist of 50 to 58 people comprising several extended family groups that meet perhaps once a year during annual aggregation events (Hamilton et al., 2007:2196). La Prele would fall within the low end of variation in these types of groups.

We remain agnostic regarding the type of group that occupied La Prele but offer a couple relevant observations. In support of a relatively large extended family group, La Prele contains remarkably consistent chipped stone raw material across the site, suggesting that most people on site traveled to it together from the southeast. On the other hand, chipped stone materials from Block C and some from Block A suggest ties to southwest Wyoming, implying that a small subset of the campsite arrived from a different direction. This might suggest that La Prele represents a relatively small aggregated group comprised primarily of an extended family but containing some members from further away. Future excavations intended to verify the findings of auger testing will hopefully inform what type of Early Paleoindian group created La Prele.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10816-024-09662-9.

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Author Contribution Spencer R. Pelton, Todd A. Surovell, Madeline Mackie, Robert Kelly, and Matthew J. O'Brien contributed to the study conception and design. Spencer R. Pelton, Paul H. Sanders, and Todd A. Surovell processed field data and collected artifact information. Spencer R. Pelton programmed the auger simulation, conducted other mathematical calculations, and conducted all geospatial analysis. Todd A. Surovell provided assistance with mathematical calculations and helped draft Fig. 1. Sarah A. Allaun and McKenna Lytinski conducted zooarchaeology by mass spectrometry analysis on artifacts presented in this study. Spencer R. Pelton wrote the first draft of the manuscript and drafted all figures, and all authors commented on or made substantive changes to previous versions of the manuscript. All authors read and approved the final manuscript.

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Data Availability All primary data is included as Supplementary Information.

Declarations

Competing Interests One author (Surovell) is serving as an editorial board member of *The Journal of Archaeological Method and Theory* at the time of submission. He has recused himself from the editorial process.

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