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RESEARCH REPORT

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The Geochronological and Geoarchaeological Context of the Clovis-Age La Prele Mammoth Site (48CO1401), Converse County, Wyoming

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ABSTRACT
The La Prele Mammoth site (48CO1401), located in Converse County, Wyoming, contains a Clovis-age occupation associated with the remains of a subadult mammoth (*Mammuthus columbi*). In this paper, we present the geochronological and geoarchaeological context of the site. The La Prele Mammoth site is buried in an alluvial terrace of La Prele Creek, a tributary of the North Platte River, which acts as an important migration corridor through the Rocky Mountains. Archaeological remains, buried by a series of flood deposits, occur within or below a well-developed buried A horizon, referred to as the Mammoth Soil. Bioturbation of the site has resulted in vertical artifact movement, though peaks in artifact density are evident in vertical artifact distributions and likely represent the occupation surface. Radiocarbon dating of this occupation, including several new dates, suggests an age of 12,941 ± 56 calendar years ago (cal yr BP).

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KEYWORDS
Clovis; geochronology; radiocarbon; Wyoming; northwest Plains USA

1. Introduction

The La Prele Mammoth site (48CO1401), located near Douglas, Wyoming, was initially investigated in 1987 by Dr. George Frison. These investigations revealed the partial remains of a subadult Columbian mammoth (*Mammuthus columbi*) as well as a chipped stone flake tool and two flakes in situ, and seven additional flakes recovered in the laboratory from sediments within plaster casts of mammoth ribs (Byers 2002; Mackie et al. 2020b; Surovell et al. 2021; Walker et al. 1988). The missing skeletal elements likely eroded away by La Prele Creek before its discovery. Subsequent investigations confirmed the cultural association of the La Prele mammoth (Mackie et al. 2020b). The Clovis-age occupation is buried in alluvial deposits on the left bank of La Prele Creek in Converse County, Wyoming, approximately 1.6 km from its confluence with the North Platte River.

The site likely represents a mammoth kill and subsequent aggregation of multiple groups of people in a camp adjacent to or possibly ringing the mammoth. Hearth-centered activity areas, preserved to the west and south of the mammoth, exhibit relatively high densities of chipped stone artifacts (up to hundreds to thousands of pieces per m^2)[1] separated by areas of low density. Also recovered from artifact clusters in the camp area were hematite transported from the Hartville Uplift, bone needles, butchered remains of non-proboscidean large mammals, evidence for hearth features, and burned bone (Mackie et al. 2020a, 2020b; Surovell et al. 2021; Zarzycka et al. 2019).

The site sits in a well-known topographic gap between the Southern and Middle Rocky Mountains that is occupied by the North Platte River Valley. Because it allows for relatively easy passage across the spine of the Rockies, this valley served as an important passageway followed by a number of historic emigrant trails, including the Oregon, Mormon, and California trails. This route is also one of the least-cost pathways of North American colonization proposed by Anderson and Gillam (2000). The historic importance of the North Platte River valley likely mirrors its prehistoric importance as a migration corridor. It is likely no coincidence that a major railway passed within 50 m of the site and that Fort Fetterman, constructed to protect migrants on the Bozeman Trail, is located within 1 km of the site. This area has always been one of importance to migrating people on a continental scale from the earliest inhabitants to the present day. The reason for the site occurring in its exact location within this

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migration corridor likely has more to do with the death of the mammoth, which might have been encountered at the site or somewhere nearby.

The depositional context of archaeological sites provides insight into age, site formation, and paleoenvironmental setting. In that vein, this paper follows the examples set by numerous geoarchaeological studies of Clovis archaeological sites and components (Albanese 1986; Albritton 1966; Antevs 1959; Bryan and Ray 1940; Driese et al. 2013; Ferring 1995; Gilmer 2013; Graham et al. 1981; Haury 1953; Haury, Sayles, and Wasley 1959; Haynes 1995; Haynes 2007; Haynes 2018; Haynes et al. 1998; Haynes and Agogino 1966; Holliday 1997; Holliday et al. 1994; Holliday and Allen 1987; Mandel, Holen, and Hofman 2005; Sanchez et al. 2014; Waters, Pevny, and Carlson 2011). Here we report the stratigraphic and geochronologic context of the site occupation and consider natural processes of site formation and the geologic context of the cultural materials. Understanding the effects of the site formation processes on this archaeological assemblage is a critical first step given the geologic filter through which the archaeological record must be interpreted. On small scales, geoarchaeological analyses can be informative about site integrity and the interpretation of spatial patterning. On large scales, they speak to settlement patterns, site distributions, and human-environmental interaction.

Mackie et al. (2020b) confirmed the association between cultural materials and the mammoth remains, and generated an estimated age of the site of 12,846 ± 29 calendar years ago (cal yr BP) using the IntCal13 calibration curve (Reimer et al. 2013). Herein, we test the hypothesis that there is only one occupation level represented at the La Prele site and estimate a new age of the site, using the IntCal20 Northern Hemisphere calibration curve (Reimer et al. 2020) and additional dated samples.

1.1. Background and site setting

The occupation at the site is buried in alluvial sediments of a terrace of La Prele Creek, a tributary of the North Platte River. La Prele Creek heads in the Laramie Range, flowing northeasterly for approximately 45 km where it joins the North Platte River upstream of Douglas, Wyoming (Figure 1). The site is located less than 2 km from the current confluence of the North Platte River and La Prele Creek, a third-order stream with a catchment area of 457 km^2. The North Platte is one of two major branches of the Platte River and heads in northern Colorado, flowing northward into central

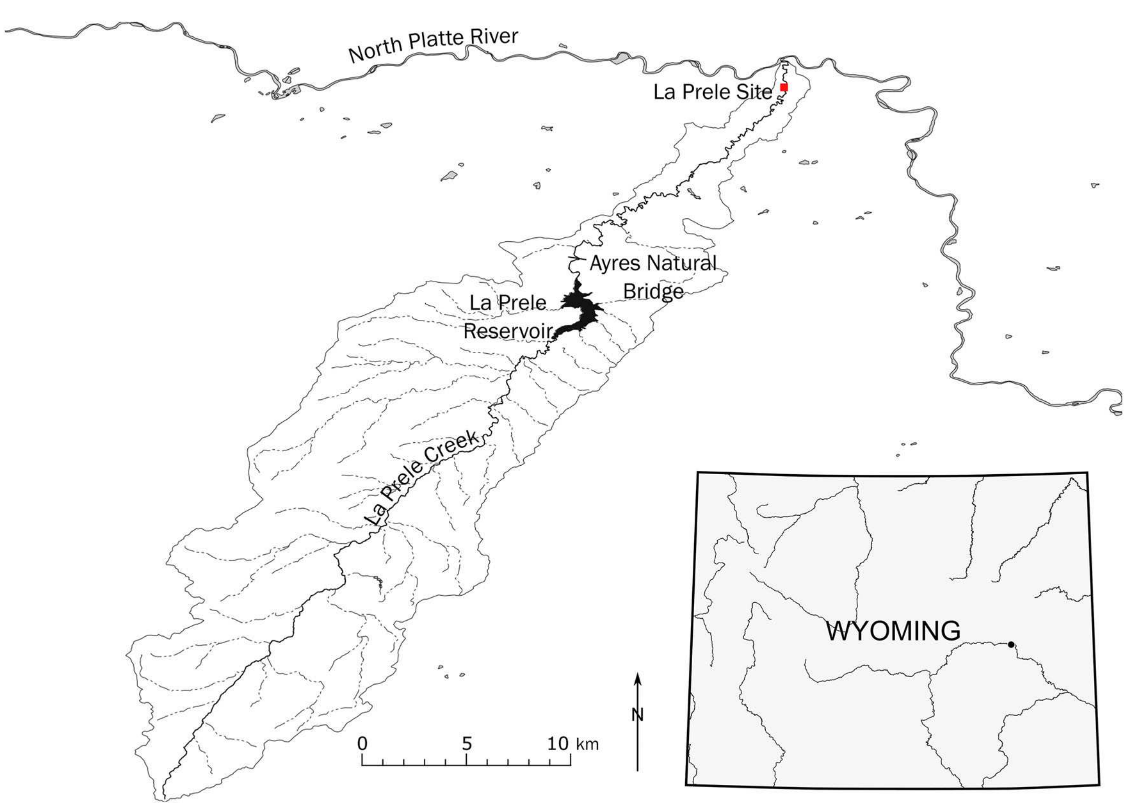

Figure 1 La Prele Creek drainage basin showing the location of the La Prele Mammoth site with respect to the confluence of the creek with the North Platte River. Inset map of the state of Wyoming showing major rivers and the location of the site.

Wyoming before turning southeastward flowing into Nebraska. The North Platte River basin covers approximately 80,470 km^2, about one quarter of the surface area of the state of Wyoming. Meanders of the North Platte have likely been as close as 600–700 m from the site in the past.[2] La Prele Creek serves as the water source for the La Prele Reservoir, built in 1909 just upstream from Ayres Natural Bridge, a large limestone arch under which flows the creek.

In the site area, the creek is incised into Paleocene Fort Union Formation bedrock consisting of yellowish-gray sandstone and siltstone with coal beds and carbonaceous shales (McLaughlin and Ver Ploeg 2008). To the west of the site, slopes rise to hilltops more than 50 m above the valley floor representing strath terraces of the North Platte River (Figures 2 and 3a). These Platte gravels are actively being quarried. Capping these gravels in places is a loess of uncertain age, though possibly Peoria. Isolated pockets of loess are preserved on the valley slopes as well. Two strath terraces occur on the east side of the valley. Fort Fetterman sits on the lower of these, close to the mouth of La Prele Creek. In the valley proper, three Late Quaternary alluvial terraces are present. In the site area, the valley is crosscut obliquely from southeast to northwest by the abandoned grade of the Chicago and North Western Railroad, which rises 10 m above the valley floor (Figures 2 and 3). Sediments from the site may have been quarried in the construction of the grade, but it appears that most of the construction materials were taken out of a cut into the Fort Union Formation bedrock to the southeast.

The only known cultural materials associated with the site are buried approximately 3 m below the modern surface in the third terrace (T3) of La Prele Creek. Remnants of T3 are preserved on the opposite side of the valley, although they are difficult to investigate as state highway WY-93 was built on their surface (Figure 3b). The eastern edge of the site is truncated by stream erosion that likely removed the missing skeletal elements of the mammoth and part of the site (Figure 4). Two younger terraces are present in the site area. T2 is most widespread, and T1 occurs locally along the modern stream course.

2. Methods

2.1. Geoarchaeology

Stratigraphy at the La Prele Mammoth site has been observed in a number of geologic trenches, excavation units, and auger holes (Figure 4). Augering was performed in 2014 to assess the degree to which a buried soil, found to be associated with the mammoth remains in the 1987 excavation, formed a continuous surface. Six geologic trenches excavated by backhoe and three hand-excavated trenches were placed in T3 and T2 to investigate the geology of the terraces (see supplement online material for in-depth discussion of trenching). Stratigraphic sections were described in the field. Allostratigraphic units[3] were labeled alphabetically, with A representing the lower-most stratum. Soils were given alphanumeric designations (e.g., S-1), with S-1 representing the lower-most identified buried soil.

The soil-sedimentary sequence at the site was further investigated in a sediment column (LP-C1) collected to determine the impact of pedogenesis, sedimentation, and erosion on site formation. LP-C1 was taken along a cleaned profile of T3 from the surface to a depth of 5 m below surface between Block A and Trench 1 (Figure 4). Due to the depth of the column, samples were collected in arbitrary 10-cm intervals. Samples collected for laboratory analysis underwent a number of analyses including: manual sieving for gravel content (Wentworth 1922); particle size analysis by Pario digital hydrometer for per cent sand, silt, and clay content (Durner, Iden, and von Unold 2017); Chittick apparatus for percent carbonate

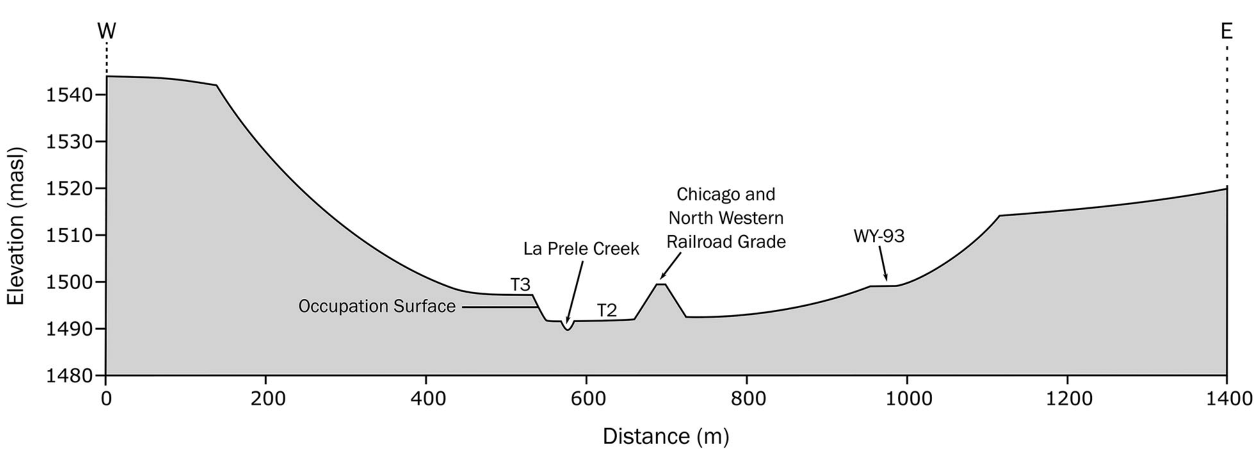

Figure 2 Generalized cross section of the valley of La Prele Creek showing remnant terraces of the North Platte River and the La Prele terrace sequence. T1 is not shown. It is less than one meter in height and where it occurs, it is inset against T2.

(a)

(b)

Figure 3 Aerial photographs from the 2021 field season. The excavation is marked by an arrow in both images. (a) Looking west showing the strath terrace of the North Platte River and gravel quarry west of the site and the abandoned railroad grade crossing La Prele Creek. (b) Looking southeast showing the terraces to the east of the site.

content (Machette 1983); and Loss on Ignition for per cent organic carbon content (Ball 1964).

2.2. Occupation history

Because artifacts span 60 cm of depth, we used three approaches to examine vertical artifact dispersal and occupation history: correlations of artifact counts between excavation levels, refitting, and a statistical measure of stratigraphic integrity. These analyses allow us to test the hypothesis that all artifacts are derived from the same archaeological component. Falsifying that hypothesis would suggest the presence of multiple occupations at the site.

First, we examined correlations between artifact counts from different levels for excavation units (n = 66) with at least 20 pieces of chipped stone.[4] If artifacts in upper and lower levels are derived from a single occupation surface, we expect a positive correlation between the number of artifacts on the occupation surface and levels above and below it. If there are multiple occupations, there should be no correlation between artifact counts in levels above and below the occupation surface.

Artifact refits provide the most direct evidence of vertical artifact dispersal. We have completed systematic refitting for parts of Blocks B and D, resulting in a total of 107 known refitting (subsequent removals) and conjoining (broken pieces) artifacts. We examine

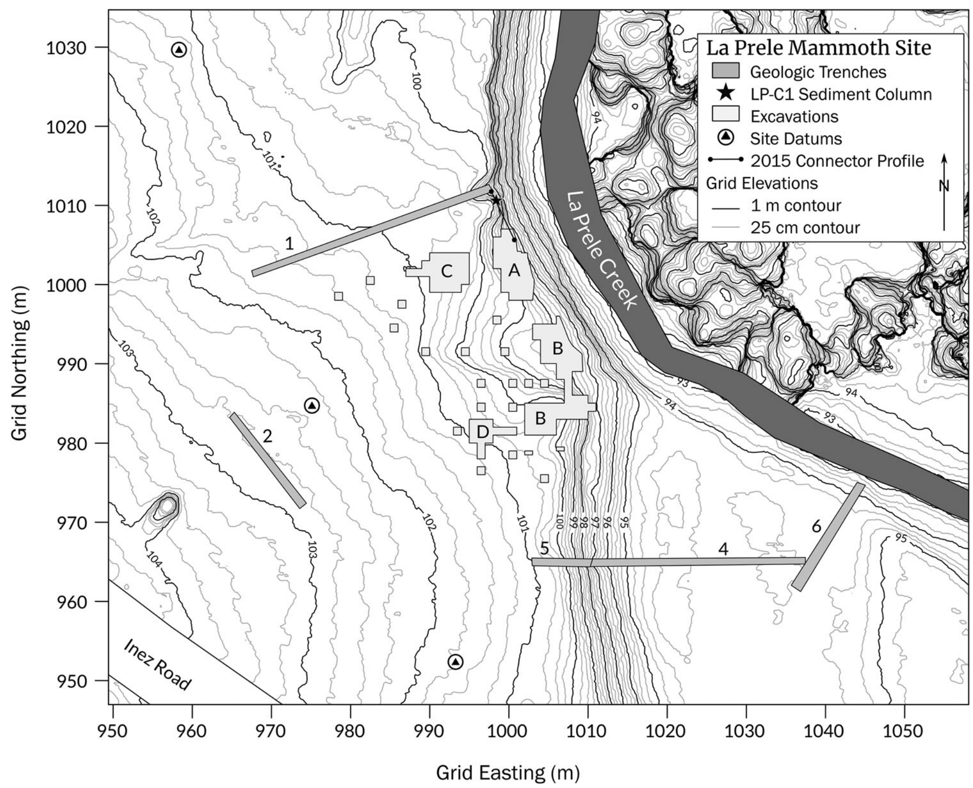

Figure 4 Map of La Prele Mammoth site showing excavation areas through 2021, geologic trenching, and the location of the sediment column (LP-C1). Archaeological excavation blocks are designated as Blocks A, B, C, and D.

the scale and distribution of refitted artifacts to test the same hypothesis.

Finally, we applied Surovell et al.'s (2022) Apparent Stratigraphic Integrity (ASI) Index for assessing the stratigraphic integrity of the cultural occupation of the site. That index is based on changes in artifact counts between adjacent 5-cm levels in excavated sites. Simulated cases of vertical mixing in multicomponent sites were used to validate the method, and then the method was applied to a series of Paleoindian and purported pre-Clovis sites in North America. It was shown that sites with an ASI Index of < 0.3 show low stratigraphic integrity and significant vertical mixing, while those with ASI Index of 0.4 or greater show high levels of integrity. We calculated ASI indexes for three excavation blocks (Blocks B, C, and D)[5] and compared them to published values from other Paleoindian sites. To calculate ASI Indexes for each block, we used only artifacts mapped in situ and binned artifact counts into even 5-cm levels.

3. Results

3.1. Allostratigraphy and pedostratigraphy of the La Prele Mammoth site

The hand-dug portions of Trench 1 (Table S1, Figure S1) reveal the bottom four stratigraphic units (A, B, C, and D), all of which are coarse-grained alluvium. Stratum A, the lowermost unit, consists of mixed gravels and sands disconformably overlying the Fort Union Formation bedrock. Stratum B consists of poorly sorted sands and gravels. Strata A and B have only been observed in Trench 1. Stratum C, bedload alluvium, was exposed in Trench 1 as well as in all hand-excavated trenches and consists of poorly sorted sands and gravels. North of the site, Stratum C is capped by a well-developed A horizon. This soil is not evident in Trench 1 but was observed in two hand-excavated trenches to the north of the site, HT19-001 and HT19-002 (Figures S5c and S5b). A charcoal lens associated with this soil was observed in HT19-002. Gravels within these exposures of the unit display carbonate accumulation on the undersides of larger clasts (> 64 mm). Stratum D consists of poorly sorted, bedded sands and gravels and was observed in Trench 1 and HT19-003 (Figure S5a). Larger clasts within Stratum D in HT19-003 exhibited some degree of oxidation. Stratum D appears to represent sandy alluvial channel fill cut into Stratum C (Figure S6). Above Stratum D, Stratum E consists of sediment with sand content varying from 40 to 59 per cent (Table 1). Evident in LP-C1 is an increase in inorganic carbon content associated with the shift from sand to silt loam within this stratum at a grid elevation of 96.083 m (Figure 5). At the base of LP-C1, Stratum E

Table 1 Sediment column laboratory data.

Grid elevation (m)	Stratum	Classification	Per cent clay†	Per cent silt†	Per cent sand†	Per cent gravel‡	Per cent $CaCO_3$‡	Per cent LOI‡
100.13 – 100.23	G	Gravelly sandy loam	6.38	23.28	70.35	23.23	0.93	1.65
100.03 – 100.13	G	Very gravelly sandy loam	9.78	26.38	63.84	38.76	2.78	1.49
99.93 – 100.03	G	Very gravelly sandy loam	15.44	14.18	70.39	42.65	0.00	1.74
99.83 – 99.93	G	Gravelly sandy loam	13.59	25.12	61.29	17.03	0.37	2.33
99.73 – 99.83	G	Gravelly sandy loam	4.93	29.19	65.88	20.54	0.56	2.20
99.63 – 99.73	G	Gravelly sandy loam	14.68	19.36	65.96	18.03	0.19	1.74
99.53 – 99.63	G	Very gravelly sandy loam	9.90	17.06	73.04	46.47	0.56	1.78
99.43 – 99.53	G	Gravelly sandy loam	13.72	16.55	69.73	27.48	0.56	1.67
99.33 – 99.43	G	Gravelly sandy loam	13.86	16.86	69.28	32.56	1.30	1.72
99.23 – 99.33	G	Sandy loam	13.69	12.11	74.20	14.52	1.67	1.56
99.13 – 99.23	G	Gravelly sandy loam	14.80	17.58	67.62	15.25	1.66	1.51
99.03 – 99.13	G	Sandy loam	12.79	12.27	74.94	6.82	1.47	1.35
98.93 – 99.03	G	Sandy loam	11.88	17.41	70.71	7.84	1.12	1.57
98.83 – 98.93	G	Sandy loam	10.68	21.89	67.43	4.12	3.13	2.01
98.73 – 98.83	G	Very gravelly sandy loam	8.72	15.74	75.54	40.64	2.61	0.64
98.63 – 98.73	G	Very gravelly sand	5.37	3.80	90.83	52.29	0.18	0.56
98.53 – 98.63	G	Very gravelly sandy clay loam	22.29	7.27	70.43	51.80	0.74	0.83
98.43 – 98.53	F4	Loam	18.49	38.62	42.89	5.13	1.87	2.37
98.33 – 98.43	F3	Loam	19.67	41.98	38.35	0.42	1.31	2.58
98.23 – 98.33	F3	Loam	15.69	43.36	40.95	0.27	1.29	2.55
98.13 – 98.23	F3	Loam	17.85	40.14	42.01	0.08	2.24	2.49
98.03 – 98.13	F3	Loam	24.92	45.90	29.18	0.03	1.84	2.37
97.93 – 98.03	F2b	Silt loam	25.36	50.80	23.84	0.08	1.31	3.51
97.83 – 97.93	F2b	Silt loam	26.25	53.24	20.52	0.28	1.65	1.57
97.73 – 97.83	F2b	Silt loam	22.11	51.53	26.37	0.03	2.03	2.50
97.63 – 97.73	F2b	Silt loam	25.09	57.68	17.23	0.01	2.22	2.55
97.53 – 97.63	F2a	Silt loam	24.07	60.65	15.28	0.05	4.93	4.15
97.43 – 97.53	F2a	Silty clay loam	32.61	50.32	17.08	0.04	4.42	3.30
97.33 – 97.43	F2a	Loam	17.41	48.97	33.63	0.06	4.47	3.13
97.23 – 97.33	F2a	Loam	16.43	47.89	35.68	0.00	5.86	2.29
97.13 – 97.23	F2a	Silt loam	19.53	56.03	24.45	0.01	7.76	3.61
97.03 – 97.13	F1b	Silt loam	25.58	62.50	11.92	0.04	3.69	4.06
96.93 – 97.03	F1b	Silt loam	18.97	62.76	18.27	0.04	8.46	3.06
96.83 – 96.93	F1a2	Silt loam	22.84	63.78	13.37	0.18	9.71	4.85
96.73 – 96.83	F1a2	Silt loam	17.80	57.29	24.91	0.27	8.23	3.92
96.63 – 96.73	F1a2	Loam	24.87	49.39	25.74	0.38	20.33	2.36
96.53 – 96.63	F1a1	Loam	19.95	46.94	33.12	0.09	16.23	3.19
96.43 – 96.53	F1a1	Loam	16.49	46.42	37.09	0.15	15.30	1.96
96.33 – 96.43	E	Loam	8.39	44.71	46.89	0.03	14.55	1.48
96.23 – 96.33	E	Loam	15.17	35.17	49.66	0.24	11.95	1.90
96.13 – 96.23	E	Loam	17.91	41.95	40.14	0.10	17.17	2.39
96.03 – 96.13	E	Silt loam	3.05	57.24	39.71	0.03	21.23	2.42
95.93 – 96.03	E	Silt loam	16.68	59.41	23.91	0.18	19.75	2.36
95.83 – 95.93	E	Silt loam	15.66	67.70	16.64	0.02	14.18	2.54
95.73 – 95.83	E	Silt loam	9.03	57.41	33.57	0.06	7.46	2.12
95.63 – 95.73	E	Silt loam	0.00	50.85	49.15	0.02	4.48	1.96
95.53 – 95.63	E	Sandy loam	6.68	43.35	49.97	0.13	3.50	1.78
95.43 – 95.53	E	Silt loam	2.05	57.39	40.56	1.02	1.65	2.13
95.33 – 95.43	E	Loam	9.18	40.48	50.34	0.13	0.91	1.15
95.23 – 95.33	E	Sandy loam	13.30	27.40	59.30	0.39	0.55	1.45

†Per cent of fine fraction.
‡Per cent of total sample.

is represented by fine sands. Generally, Stratum E has very few gravels. However, within the hand trenches and Trench 1, distinct lenses of coarse sands and gravels were observed (Figure S5c). At least one burn level is present in Stratum E, observed in HT19-002, HT19-001, and the northernmost test unit north of the site at an elevation of between 96.05 and 96.20 m, and directly underlying the cultural occupation in excavation Block B (Figure S6).

All archaeological remains at the La Prele Mammoth site are contained within Stratum F, which lies indistinctly above Stratum E. The lower portion of Stratum F (F-1) consists of overbank alluvial deposits from multiple floods of the La Prele Creek. These events are separated by several periods of stability, marked by periods of pedogenesis. F-1a1 includes the Paleoindian occupation and consists of loam and has some pedogenic modification apparent in the increase in organic matter content associated with S-1a. F-1a2 contains the buried soil S-1b and consists of silty loam and considerable pedogenic carbonates. Secondary gypsum occurs as well, including crystalline coatings on the surfaces of some bones. F-1b contains the buried soil S-1c (Table 1). Laboratory data display a slight increase in

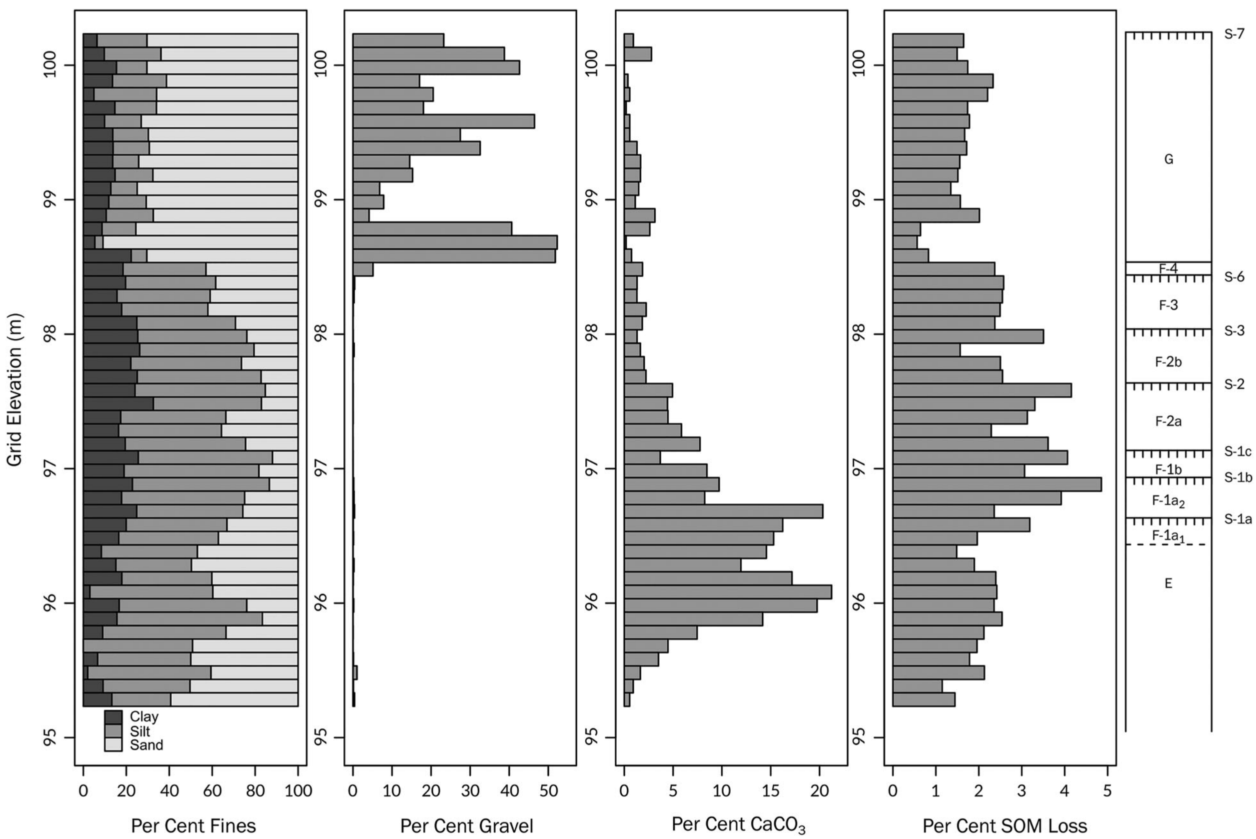

Figure 5 Sedimentary analysis of sediment column LP-C1 showing percent clay, silt, and sand composition of the fine (< 2 mm) sedimentary fraction, and per cent gravel, per cent calcium carbonate, and per cent soil organic matter loss of the total sample. The far right column displays the corresponding allostratigraphic units.

pedogenic inorganic carbon associated with S-1c. Together, these three buried soils form the Mammoth Soil. The northeastern portion of the site seems to be the only location where all three A horizons are evident due to the presence of lower-most S-1a, suggesting a localized zone of pedogenesis closely associated with the mammoth remains (Figure S6). Elsewhere at the site, the Mammoth Soil is identifiable by the welding together of these three soils (see Mackie et al. 2020b, figure 3). Augering revealed a continuous buried Pleistocene surface represented by the Mammoth Soil across T3, except where augers were unable to penetrate gravels in gully fills. This soil correlates in time with well-known Younger Dryas black mats from western North America (Haynes 2008). Its paleoclimatic significance in relation to other black mats is not clear. Stratum F also contained a number of other buried soils, not associated with archaeological remains. F-2a contains S-2, a discontinuous soil that does appear to be present in the sediment column as an increase in organic matter. However, lab analyses show an increase in pedogenic clays associated with this buried A horizon. F-2b, which consists of silt loam, contains another buried soil, S-3. The upper portion of Stratum F is marked by several discontinuous buried soils, none of which were apparent in the sediment column collected adjacent to Trench 1, but all of which appear in Trench 1. In parts of the site, Stratum F reaches to the modern surface. However, in Trench 1 and in the sediment column, the stratum is truncated by the downcutting of La Prele Creek in the Early to Middle Holocene. This is represented by channel gravelly to very gravelly sand and sandy loam in Stratum G, which lays disconformably above Stratum F and forms a very clear contact at an elevation of 98.483 m.

Preserved in Trench 2 are Holocene gully fill deposits derived from the slopes to the west of the site (Figure S2). The western slope of the valley is an area of active rill formation. Approximately 1.2 m of coarse sands and gravels (Strata H and I) filled an abandoned channel. When active, this gully cut into the F Strata in the site and joined La Prele creek in the vicinity of Block B. It did not cut deep enough to affect the occupation, at least in the preserved areas of the site.

Exposures of T2 alluvium were profiled in Trenches 4 and 6 (Figures S3 and S4). T2 is inset against the basal gravels (Stratum D) of T3. Coarse bedload sands and gravels (Stratum J) are overlain by horizontally-bedded fine-grained clayey sands (Strata K and L) with fine oxidation mottling occurring locally. A very thin (2 cm) burn layer with fine charcoal and ash was present in upper Stratum L and extended over 2 m in length. On its western side, T2 is draped by sloughed sediments from T3. A modern soil caps the terrace tread.

3.2. Stratigraphic position of the occupation

Cultural materials occur in F1, about 3 m below the modern surface. While artifacts display vertical dispersion up to 60 cm, most material occurs within 15–20 cm of depth between elevations of 97.3–97.5 m (Figure 6). In all excavated areas, a distinct peak in artifact density can be identified, which likely represents the occupation surface. The occupation surface gradually dips to the north, mirroring the likely grade of La Prele Creek. From Block D, in the south, to Block C, in the north, the occupation surface drops 10 cm in elevation over 26 m of distance, or 0.38 cm per m. The depth of the occupation surface relative to the A horizon of the Mammoth Soil varies across the site. Farther north, in Blocks B and C, the highest densities of artifacts occur within or just below the A horizon (Figure 6a and b). In those areas where artifacts occur within the soil, peak densities are typically towards the lower depths of the A horizon. Farther south, in Block D, the highest artifact density occurs below the A horizon (Figure 6c). This is indicative of varying deposition by flooding across the site, with more deposition occurring in the southern part of the site and less in the north. In the south, the Mammoth Soil appears as two buried A horizons. In Blocks B and C, the soil is a welded thick A horizon. Farther north, in Trench 1, the Mammoth Soil is identifiable as three thin A horizons (S1a, S1b, and S1c). In excavation, no buried A horizons have been found below the archaeological remains indicating that cultural materials predate the formation of S1 and were subsequently buried by a series of floods. Previous analysis of weathering, specifically of weathering profile height of the mammoth remains, further suggests that the remains were buried by episodic flooding followed by periods of stability (Byers 2002). This fits with the long-noted pattern of landscape stability following Early Paleoindian occupations associated with Younger Dryas black mats and wet meadow soils (Haynes 2008).

3.3. Occupation history and vertical artifact dispersal

To test whether artifacts above and below the occupation surface are derived from that surface, we completed correlation analysis for counts of artifacts between the occupation surface in Block D and levels above and below it. We treat the 5 cm level from 97.50 to 97.45 m as likely encompassing the occupation surface as it exhibits the highest artifact densities for the block as a whole. Correlations between artifact counts for that level and for a level 10 cm below and 25 cm above it are highly significant ($p < 0.001$), whether using a parametric correlation on logged artifact counts, or nonparametric (Spearman's rho or Kendall's tau) correlation. This provides strong evidence that all artifacts are derived from a single occupation surface. It also shows that it is possible to predict approximately how many artifacts will be encountered on the occupation surface well before (at least 25 cm above) it has been reached in excavation, a finding that comports well with our experience excavating the site.

This finding is mirrored by refit distributions. Vertical distances separating refitting artifact pairs provide clear evidence for post-depositional movement of artifacts up and down from the occupation surface while also confirming the typical scale of movement. Artifacts from the occupation surface have been found refitting to pieces above and below it. To date, we have identified a sum of 109 refitting or conjoining artifacts, the great majority of which are conjoins. Vertical distances separating refit pairs range from 0 to 17.7 cm. As is typical for refit distance distributions, they are highly right-skewed with small distances being most common. The mean vertical distance separating refitting artifacts for the site is 2.4 cm, and 90 per cent of artifacts are separated by less than 5 cm in the vertical dimension.

These results are mirrored by ASI Index values for three excavation blocks. For Blocks B and C, ASI Indexes are very similar at 0.411 and 0.402, respectively[6]. These values are typical for stratified Late Pleistocene and Early Holocene sites in Wyoming (Figure 7). Block D, exhibiting significantly higher artifact densities, has an ASI Index of 0.533, a value similar to well-preserved sites in the Tanana River basin of Alaska (Surovell et al. 2022). Despite showing clear geomorphic indicators of bioturbation and unambiguous evidence of vertical artifact dispersal, all areas of La Prele show significantly higher stratigraphic integrity than the pre-Clovis sites of Cooper's Ferry, Gault, and Debra L. Friedkin (Surovell et al. 2022).

3.4. Bioturbation

Intensive bioturbation is evident in excavations throughout the site where krotovinas are apparent in a range of sizes resulting from large rodents to small insects. Two patterns of bioturbation have been detected

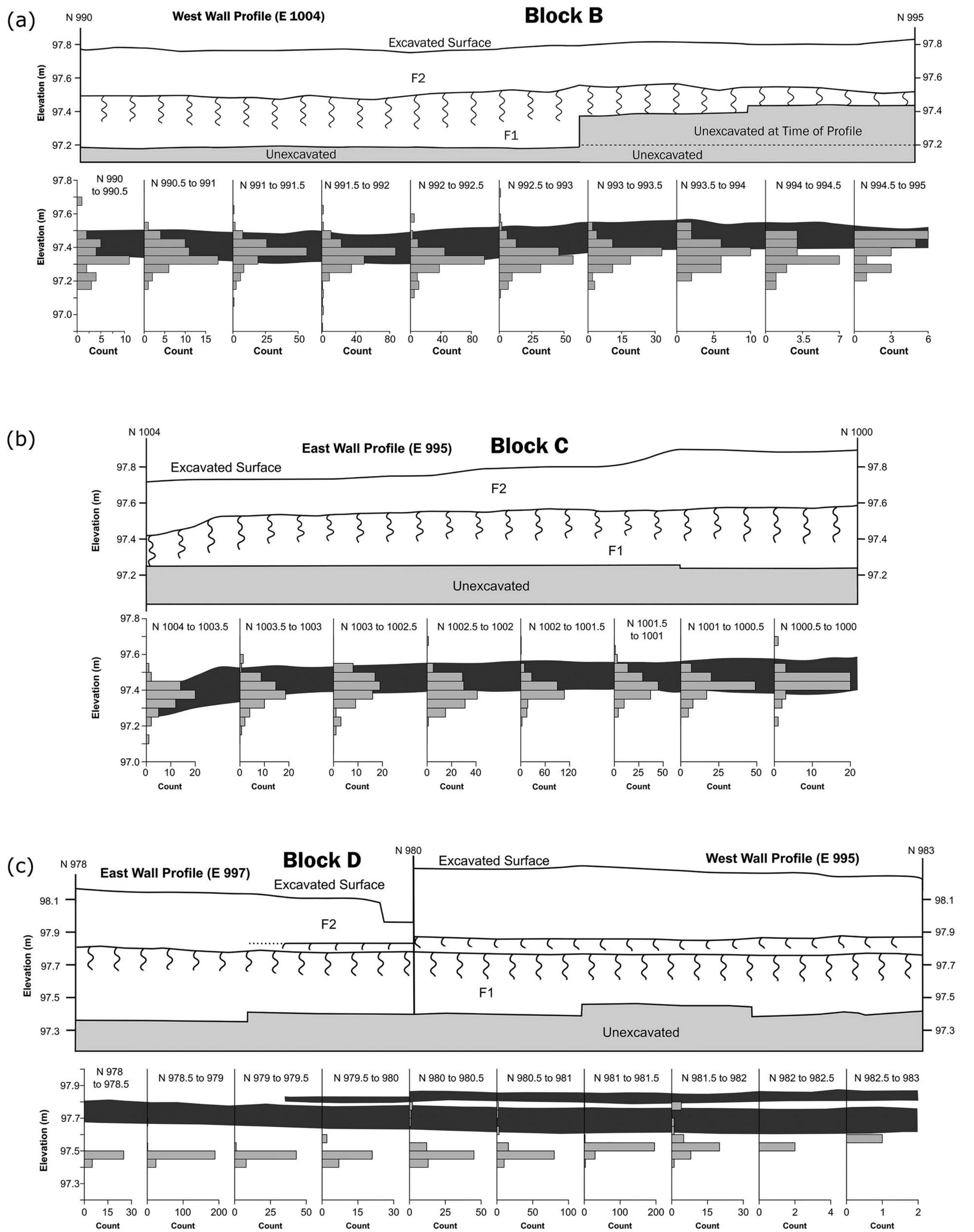

Figure 6 Excavation profiles and vertical artifact densities in (a) Block B, (b) Block C, and (c) Block D. In the upper of the figure pairs, the Mammoth Soil is represented by vertical squiggly lines. In the lower of the figure pairs, the dark gray bands represent the visible buried A horizon of the Mammoth Soil. In some places this soil is welded, as in Blocks B and C. In other places, this soil is represented by two separate buried A-horizons, as in Block D. Artifact densities for Blocks B and C include piece-plotted and screen artifacts from the blocks in their entirety for the Northings shown. Artifact densities for Block D only show piece-plotted artifacts west of E998 for all Northings shown.

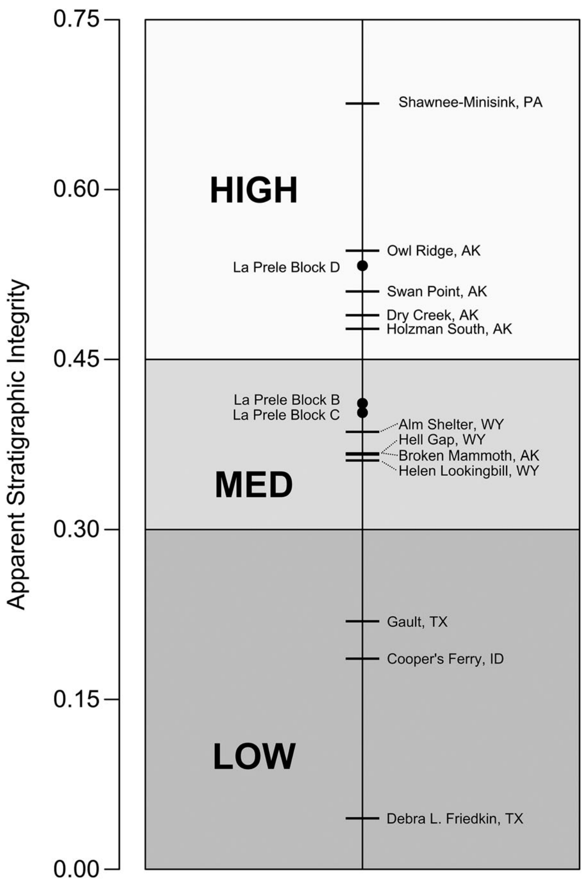

Figure 7 Apparent Stratigraphic Integrity Index values for three excavation blocks at the La Prele Mammoth site (black circles) in comparison to a sample of previously published stratified Paleoindian sites (horizontal lines) (from Surovell et al. 2022).

at the site (Figure 8). The first is a classic example of bioturbation, apparent in lighter stratigraphic zones as intrusive dark-colored sediment resulting from pervasive burrowing, and in the darker, organic-rich A horizons as lighter sediment marking apparent krotovinas (Figure 8a). Fossorial mammals and insects are the likely culprits of this mixing. Micromammal remains and gastropods are common in parts of the site. This pattern of intensive bioturbation appears to indicate that the site was buried in a rich and ecologically active riparian zone along the floodplain of La Prele Creek. A unique pattern of bioturbation was discovered at the site in July 2017. At the end of the field season, Block C was left uncovered overnight. When investigators returned to the site in the morning, a raindrop-like pattern of bioturbation was apparent on the surface of the block (Figure 8b). However, these dispersed, small (< 1 cm in diameter) krotovinas were not the result of rain drops, but possibly by some sort of ground-nesting insect, such as alkali bees (Cane 2003). Bioturbation at the site has resulted in the vertical dispersion of artifacts, with some cultural materials moving to significant depths. However, a peak in artifact density is detectable in excavated areas within a 15–20 cm range of depths (Figure 6). Size sorting is also evident, with smaller artifacts moving greater distances as a result of this vertical dispersion.

3.5. Geochronology

Sediments, soils, and the Clovis occupation have been dated using radiocarbon and OSL methods. We divide dates into geologic and archaeological samples. Geologic samples for dating were taken from trenches and exposures on the face of T3 (Tables 2 and 3). Archaeological dates were produced from samples collected during excavations and from mammoth bone collected by the discoverers of the site (Table 4). We begin by discussing the age of sediments and soils in T3 and then turn to the age of the Clovis occupation. We end with a brief discussion of the age of T2 alluvial deposits.

3.5.1. T3 geologic dates

A total of 38 radiocarbon and eight OSL ages provide age control for the formation of T3. Samples were taken from Trenches 1 and 5 and from cleaned exposures on the face of the terrace. Geologic radiocarbon ages include dates from soil organic matter and charcoal samples. All radiocarbon dates were calibrated using the IntCal20 Northern Hemisphere calibration curve (Reimer et al. 2020). Both radiocarbon and luminescence methods produced some anomalous dates. At least three OSL dates (USGS 2014, USGS 2016, and USGS 2017) are significantly older than would be expected by their stratigraphic position. The most likely explanation for OSL dating errors is partial bleaching. Some radiocarbon samples are anomalously old as well. Four samples on humins from bulk sediment from Trench 5 (AA-112531, AA-112532, AA-112534, and AA-112535) are older than expected with apparent dating errors of up to 5000 years. These samples had very low organic content and have likely been affected by particulate coal in the fine sedimentary fraction derived from the coal-bearing Fort Union Formation (Brown 1958; McLaughlin and Ver Ploeg 2008). Other samples with higher organic matter content in the same trench produced dates in the expected age range as confirmed by the dates in Trench 1. The presence of significant amounts of pedogenic organic carbon appears to swamp the effects of ancient carbon contamination, but with only small inputs of pedogenic carbon, coal contamination from the surrounding bedrock can have a serious effect on radiocarbon ages on soil organic matter from the site.

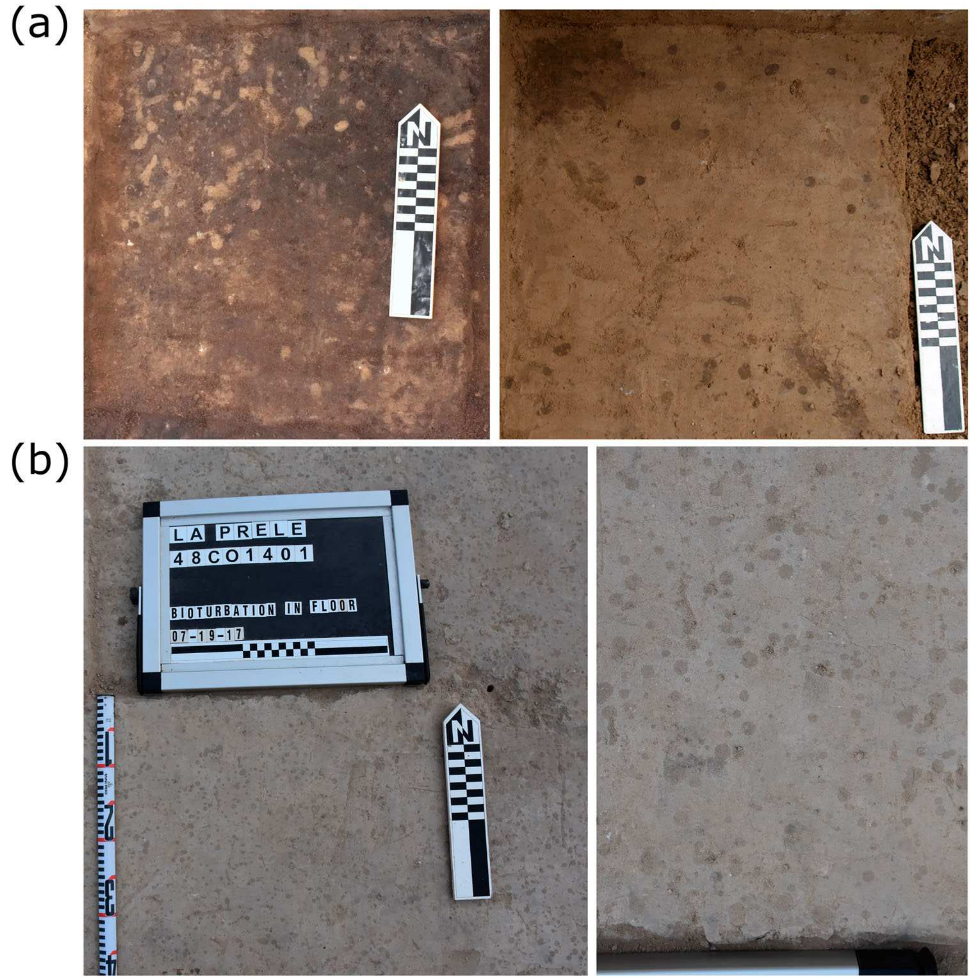

Figure 8 Bioturbation patterns including (a) classic pattern and (b) raindrop pattern.

Age-depth models were created for Trenches 1 and 5 (Figure 9) using the Bchron package (v. 4.7.6; Haslett and Parnell 2008) for R (R Core Team 2021). These models are oversimplified because they assume continuous sedimentation and do not take into account erosional intervals. We therefore consider them to provide general approximations of the ages of deposits. The Trench 1 model is based on OSL and radiocarbon dates, and the model spans most of the stratigraphic sequence, except for the uppermost stratum (F4). We also excluded dates from the G strata as they are cut into the F strata. Based on two OSL ages, the basal coarse-grained alluvium of T3 (Stratum A) began accumulating just after the Last Glacial Maximum, ca. 20,000 cal yr BP, and continued until ca. 16,400 cal yr BP (Stratum D) (Figure 9a). The upper contact of the overlying and much finer Stratum E dates to around 13,400 cal yr BP. Periodic overbank deposition represented by strata F1 through F3 in Trench 1 date from about 13,400 to 9400 cal yr BP. We have no dates on F4 from Trench 1, but there are such dates from Trench 5 (Figure 9b), and it suggests that overbank deposition on T3 ceased around 7500–7000 cal yr BP. When the age-depth models for both terraces are overlain, they show strong agreement (Figure 9c). Age-depth models from both trenches allow independent estimates for the age of the F1 stratum that buried the Clovis occupation. From Trench 1, F1 accumulated between ca. 13,400 and 12,000 cal yr BP, and from Trench 5 between ca. 13,400 and 11,700 cal yr BP. For the dated portions of T3, the average rate of deposition for strata A through F4 was around 0.45 mm per year over 11,800 years in the Late Pleistocene and Early Holocene.

One OSL and five radiocarbon dates provide age control for strata G1 through G4 in Trench 1. The humin and humate fraction of one radiocarbon sample (AA-104815 and AA-104842, respectively) originally thought to be charcoal is anomalously old with both fractions dating to greater than 25,000 ^{14}C yr BP. We suspect we dated a small fragment of coal redeposited in Holocene alluvium. The singular OSL age (USGS 2018) from the G strata suggests that the sands and gravels of

Table 2 Geologic radiocarbon dates.

Sample no.	Location	Stratum	Material	Fraction	$\delta^{13}C$	^{14}C age ± σ (BP)
Beta-579894[b]	T3 Cutbank	E	Soil organic matter	Humins	−23.5	14,490 ± 40
AA104814[b]	Trench 1	E	Charcoal	Humins	−25.9	10,963 ± 50
AA104892[b]	Trench 1	E	Charcoal	Humins	−25.3	10,650 ± 100
AA104893[b]	Trench 1	E	Charcoal	Humates	−25.3	9,600 ± 160
AA105841[b]	Trench 1	E	Charcoal	Humates	−25	30,110 ± 340
AA112526[b]	Trench 5	F1	Bulk sediment	Humins	−24.2	10,443 ± 29
AA112537[b]	Trench 5	F1	Bulk sediment	Humins	−23.6	11,559 ± 46
AA110386[b]	Trench 5	F1 (S1)	Soil organic matter	Humins	−23.7	9940 ± 34
AA110388[b]	Trench 5	F1 (S1)	Soil organic matter	Humates	−23.5	9835 ± 34
AA105496[a]	T3 Cutbank	F1 (S-1a)	Soil organic matter	Humins	−25.4	10,382 ± 40
AA105497[a]	T3 Cutbank	F1 (S-1a)	Soil organic matter	Humates	−24.5	9871 ± 48
D-AMS 004329[a]	T3 Cutbank	F1 (S-1b)	Soil organic matter	Humates	−11.6	10,154 ± 47
D-AMS 004329[a]	T3 Cutbank	F1 (S-1b)	Soil organic matter	Humins	−25.5	10,323 ± 39
AA105646[a]	T3 Cutbank	F1 (S-1c)	Soil organic matter	Humins	−25	9924 ± 75
AA105803[a]	T3 Cutbank	F1 (S-1c)	Soil organic matter	Humates	−25.13	9631 ± 52
AA112531[b]	Trench 5	F2	Bulk sediment	Humins	−24.6	13,680 ± 120
AA112530[b]	Trench 5	F2	Bulk sediment	Humins	−25.4	9918 ± 29
AA110384[b]	Trench 5	F2	Charcoal	Humins	−26.3	9320 ± 61
AA112529[b]	Trench 5	F2	Bulk sediment	Humin	−24.6	10,881 ± 33
AA112528[b]	Trench 5	F2	Bulk sediment	Humins	−24.9	9935 ± 28
AA112527[b]	Trench 5	F2	Bulk sediment	Total organic matter	−23.5	9746 ± 29
AA110385[b]	Trench 5	F2 (S2)	Soil organic matter	Humins	−23.2	8676 ± 32
AA110387[b]	Trench 5	F2 (S2)	Soil organic matter	Humates	−24.1	9662 ± 57
AA104818[a]	Trench 1	F3	Charcoal	Humins	−10.6	8619 ± 64
AA104816[a]	Trench 1	F3	Charcoal	Humates	−11.4	8592 ± 44
AA112533[b]	Trench 5	F3	Bulk sediment	Humins	−24.3	9392 ± 36
AA112532[b]	Trench 5	F3	Bulk sediment	Humins	−25	12,986 ± 56
AA110383[b]	Trench 5	F3	Charcoal	Humins	−24.3	9855 ± 37
AA109424[a]	Trench 1	F-3b	Charcoal	Humates	−24.7	8844 ± 28
AA112536[b]	Trench 5	F4	Bulk sediment	Humins	−22.6	6557 ± 59
AA112535[b]	Trench 5	F4	Bulk sediment	Humins	−22.9	8790 ± 120
AA111131[b]	Trench 5	F4	Charcoal	Humins	−12	8,344 ± 46
AA112534[b]	Trench 5	F4	Bulk sediment	Humins	−21.4	10,074 ± 29
AA104815[a]	Trench 1	G1	Charcoal	Humins	−28.9	34,260 ± 970
AA105842[a]	Trench 1	G1	Charcoal	Humates	−27.6	25,700 ± 350
AA105802[a]	Trench 1	G3	Charcoal	Humins	−24.9	4820 ± 37
AA106010[a]	Trench 1	Upper G3	Bulk sediment	Humins	−23.5	4789 ± 59
AA106011[a]	Trench 1	Upper G3	Bulk sediment	Humates	−21.1	4645 ± 33
AA108810[b]	Trench 4	L	Charcoal	Humins	−23.1	2989 ± 26
AA108787[b]	Trench 4	L	Charcoal	Humins	−23.6	233 ± 28

[a]Dates from Mackie et al. (2020b).
[b]Dates from this paper.

G1 were deposited around 7000 cal yr BP, while radiocarbon ages from G3 date to around 5400 cal yr BP, providing an age estimate for the abandonment of the T3 surface (Table 2).

3.5.2. The age of the Clovis occupation

To date, a total of 18 radiocarbon dates have been produced on samples recovered from excavations or on mammoth bone collected by the site's discoverers (Table 4; Figure 10). These dates include bone collagen, calcined bone, and charcoal samples. We consider only the bone dates to directly date the Clovis occupation because it is difficult to distinguish between charcoal of natural and cultural origins. The charcoal samples include the humin (AA-105498) and humate (AA-105499) fractions from a charcoal sample collected in association with mammoth bone in Block A and a humin fraction (AA-107604) from a sample in association with a hearth feature in Block B. All three samples produced fairly consistent ages ranging from 12,800 ± 61 cal yr BP (AA-105499, 10,844 ± 73 ^{14}C yr BP) to 12,873 ± 58 cal yr BP (AA-105498, 10,969 ± 52 ^{14}C yr BP). These dates are one to two centuries younger than our age estimate for the Clovis occupation, so we suspect they were deposited in overbank events that buried the site. They are also consistent with age estimates for stratum F1 from the age-depth profiles generated from dates in Trenches 1 and 5.

Bone dates from the site are extremely variable with ages ranging from ca. 10,000 (CAMS-74661) to 17,000 cal yr BP (AA-109297) (Figure 10). On the old end of that range is a date on five combined fragments of what we believed were calcined bone. The resulting date (13,997 ± 90 ^{14}C yr BP, AA109297) is clearly anomalous and well outside of the known Clovis age range (Figure 10). The carbonate fraction of calcined bone is derived from a combination of carbon endogenous to the bone and gasses in the combustion environment (Chatters et al. 2017; Hüls et al. 2010; Lanting, Aerts-Bijma, and van der Plicht 2001; Olsen et al. 2013; Surovell et al. 2016; Zazzo et al. 2012;

Table 3 Geologic optically stimulated luminescence dates.

Sample name	Location	Stratum	H_2O content[†]	K (per cent)[‡]	U (ppm)[‡]	Th (ppm)[‡]	Cosmic dose (Gy/ka)[§]	Total Dose Rate (Gy/ka)	Equivalent Dose (Gy)	n	Scatter[?]	Age (BP)
USGS 2016	Trench 1	F2	1 (55)	1.00 ± 0.06	2.41 ± 0.32	4.69 ± 0.57	0.19 ± 0.01	1.82 ± 0.13	47.6 ± 2.16	6 (10)	0.12	26,150 ± 2210
USGS 2012	Trench 1	A	2 (14)	2.70 ± 0.07	5.01 ± 0.28	19.1 ± 0.67	0.14 ± 0.01	5.31 ± 0.13	98.9 ± 3.64	17 (20)	0.14	18,630 ± 830
USGS 2013	Trench 1	D	0 (27)	3.27 ± 0.05	2.92 ± 0.28	21.5 ± 0.45	0.15 ± 0.01	5.31 ± 0.09	91.3 ± 2.08	19 (20)	0	17,190 ± 520
USGS 2014	Trench 1	E	11 (39)	1.38 ± 0.04	3.02 ± 0.25	11.0 ± 0.44	0.18 ± 0.01	2.79 ± 0.08	49.3 ± 4.01	6 (20)	0.14	17,670 ± 1530
USGS 2015	Trench 1	E	8 (54)	1.26 ± 0.04	2.34 ± 0.18	9.8 ± 0.37	0.18 ± 0.01	2.35 ± 0.07	32.5 ± 1.37	11 (20)	0.35	13,830 ± 710
USGS 2017	Trench 1	F3	1 (52)	0.59 ± 0.05	1.23 ± 0.18	3.08 ± 0.49	0.22 ± 0.02	1.17 ± 0.11	14.2 ± 0.41	8 (20)	0.49	12,140 ± 1210
USGS 2018	Trench 1	G1	0 (23)	3.36 ± 0.05	1.98 ± 0.22	16.1 ± 0.51	0.24 ± 0.02	4.96 ± 0.14	36.2 ± 2.38	19 (20)	0.25	7300 ± 520

All dates from Mackie et al. (2020b).

[†]Field moisture, with figures in parentheses indicating the complete sample saturation. Ages calculated using approx. 30 of the saturated moisture.

[‡]Analyses obtained using high-resolution gamma spectrometry (Ge detector).

[§]Cosmic doses and attenuation with depth were calculated using the methods of Prescott and Hutton (1994).

[¶]Number of replicated equivalent dose (De) estimates used to calculate the final overall equivalent dose. Figures in parentheses indicate the total number of measurements included in calculating the represented equivalent dose and age using the minimum age model (MAM) except for USGS-2012, USGS-2013, and USGS-2018, which used the central age model (CAM).

[?]Dose rate and age for fine-grained 250–90 micron sized quartz. Exponential + linear fit used on equivalent doses, errors to one sigma, ages and errors rounded.

Table 4 Radiocarbon dates from excavations.

Sample No.	Location	Stratum	Material	Fraction	$\delta^{13}C$	^{14}C age ± σ (BP)
CAMS-74661[a]	Block A	F1	Bone collagen	XAD amino acids		8890 ± 40[†]
CAMS-72350[a]	Block A	F1	Bone collagen	Gelatin		9060 ± 50[†]
OxA-36958[c]	Block A	F1	Bone collagen	Ultrafiltered collagen	−19.5	9320 ± 45[†]
PSUAMS-7962[d]	Block C	F1	Bone collagen	XAD amino acids	−18.1	10,165 ± 50[†]
UGAAMS-55663[d]	Block D	F1	Calcined bone	Apatite carbonate	−26	10510 ± 30[†]
PSUAMS-7961[d]	Block B	F1	Bone collagen	XAD amino acids	−16.5	10,550 ± 50[†]
AA108894[b]	Block B	F1	Bone collagen	Ultrafiltered collagen	−17.9	10,654 ± 58[†]
UCIAMS-40174[c]	Block A	F1	Bone collagen	Gelatin		10,760 ± 30[†]
AA108895[b]	Block B	F1	Bone collagen	Ultrafiltered collagen	−16.4	10,776 ± 59[†]
AA105499[b]	Block A	F1	Charcoal	Humates	−25.1	10,844 ± 73
AA107604[b]	Block B	F1	Charcoal	Humins	−26	10,873 ± 35
UCIAMS-206764[c]	Block A	F1	Bone collagen	XAD amino acids		10,965 ± 30[†]
AA105498[b]	Block A	F1	Charcoal	Humins	−25.1	10,969 ± 52
OxA-X-2736-14[c]	Block A	F1	Bone collagen	Hydroxyproline	−22.7	11,035 ± 50[†]
PSUAMS-7965[d]	Block A	F1	Bone collagen	Ultrafiltered collagen	−20.2	11,050 ± 60[†]
AA108893[b]	Block A	F1	Bone collagen	Ultrafiltered collagen	−20.3	11,066 ± 61[†]
AA107104[b]	Block B	F1	Calcined bone	Apatite carbonate	−23	11,190 ± 130[†]
AA109297[b]	Block B	F1	Calcined bone	Apatite carbonate	−19.7	13,997 ± 90[†]

[†]Direct date on Clovis occupation.
[a]Dates from Byers (2002).
[b]Dates from Mackie et al. (2020b).
[c]Dates from Devièse et al. (2018).
[d]Dates from this paper.

Zazzo et al. 2013). Although a slight old wood effect is possible when dating calcined bone if old wood was used in the hearth feature (Olsen et al. 2013; Snoeck, Brock, and Schulting 2014) that burned the bone samples, an error of this magnitude (ca. 4000 years) is extremely unlikely. Not only would such an error require the burning wood to have been at least 4000 years old at the time, but samples seriously affected by combustion gasses should have a $\delta^{13}C$ value similar to wood (∼−25‰) (Snoeck, Brock, and Schulting 2014). The $\delta^{13}C$ of this sample, as measured by the accelerator (−19.7‰) suggests an alternative cause. Our working hypothesis is that one fragment was misidentified as calcined bone when instead it was a redeposited fragment of carbonate mineral, possibly limestone. Another calcined bone date (UGAMS-55663) is younger than expected at 10,510 ± 90 ^{14}C yr BP, and was likely contaminated by secondary carbonates.

Variation in bone collagen dates from the site suggests that collagen has been affected by varying amounts of young contamination. Supporting this hypothesis, dates from a single mammoth span more than 2800 calendar years (Table 4). Multiple pretreatment methods have been used to isolate collagen from samples including dating of gelatin, XAD purification, ultrafiltration, and isolation of hydroxyproline, and our results suggest that no one pretreatment method is preferred, with the possible exception of isolation of hydroxyproline. Only one date has been produced using this method so far, but it is among the oldest dates from the site. Because it is unlikely that an organic contaminant older than the bone itself has affected collagen samples, we believe the oldest dates on collagen provide the most accurate date of the Clovis occupation.

Four dates, including the hydroxyproline date (OxA-X-2736-14), two dates on ultrafiltered collagen (AA-108893 and PSUAMS-7965), and one date on XAD-purified collagen (UCIAMS-206764) cluster around 11,000 ^{14}C yr BP. These four dates in addition to one calcined bone date (AA-109297) form a statistically homogeneous subset using the Long and Rippeteau (1974) method for testing for contemporaneity of radiocarbon dates. When combined using the OxCal method (Ramsey 2009) after calibration, they suggest an age of 12,941 ± 56 cal yr BP for the occupation of the site.

The combined chronostratigraphic analyses of the La Prele Mammoth site suggest the existence of a well-preserved occupation consisting of the synchronous deposition of a mammoth and three associated activity areas deposited approximately 12,941 ± 56 cal yr BP. This age fits well within the highly constrained Clovis period as defined by Waters, Thomas, and Carlson (2020). It also falls within the age estimates for stratum F1 derived from the age-depth models for T3. This date is approximately 100 years older than our previous age estimate for the site (Surovell et al. 2021). This difference can be accounted for by the use of the IntCal20 (Reimer et al. 2020) instead of the IntCal13 (Reimer et al. 2013) calibration curve and one new date (PSUAMS-7965) that has been added to this average since the previous age estimate was produced.

3.5.3. T2 geologic dates

Charcoal was not common and no buried soils were evident from our exposures of T2 alluvium in Trench 4. Two radiocarbon dates on charcoal provide control

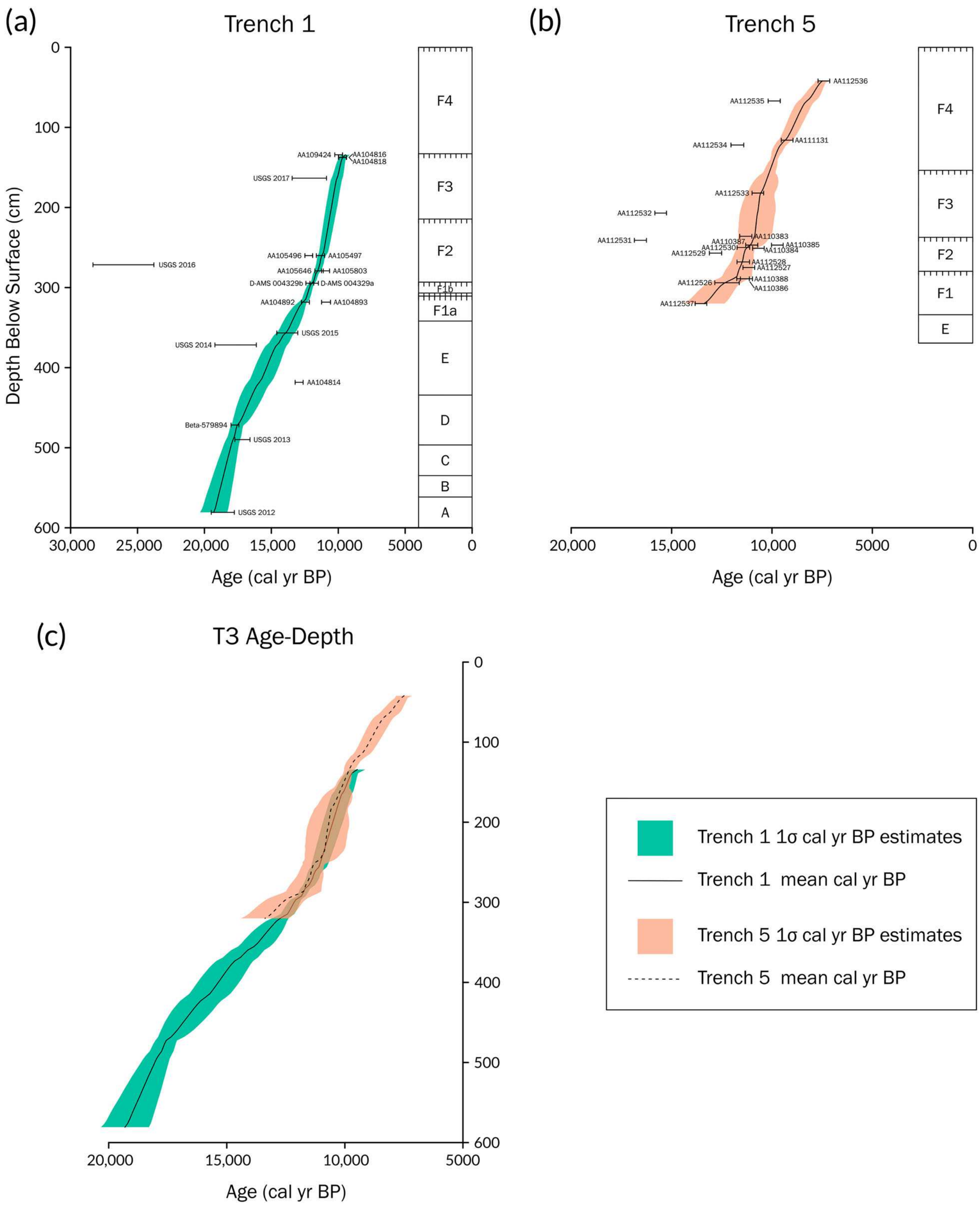

Figure 9 Age-depth models for (a) Trench 1, (b) Trench 5, and (c) overlain age-depth models for Trenches 1 and 5. Polygons show one-sigma calibrated age estimates by depth. Allostratigraphic correlations shown to the right of (a) and (b). Radiocarbon dates are shown as one sigma continuous calibrated age ranges.

for the age of T2, both from stratum L. The oldest date (AA-108810) indicates resumption of deposition along La Prele Creek in the Late Holocene by ca. 3200 cal yr BP. The younger date (AA-108787) of 233 ± 28 cal yr BP suggests abandonment of the T2 surface within the last 300 years.

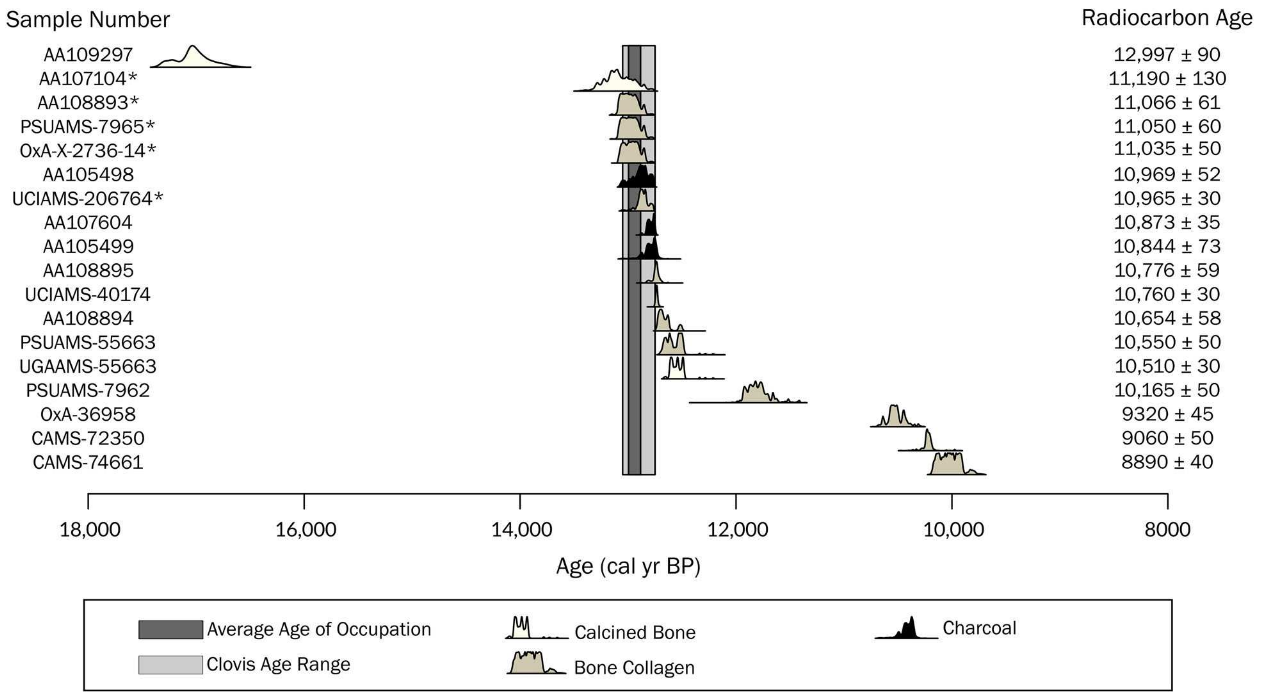

Figure 10 Radiocarbon ages of charcoal, bone collagen, and calcined bone. The light gray band represents the Clovis age range of 13,050–12,750 cal yr BP, as defined by Waters, Thomas, and Carlson (2020). The dark gray band represents the average age of the Clovis occupation at 12,941 ± 56 cal yr BP. The starred sample numbers (e.g., AA107104*) indicate the five samples combined to calculate the average age of the occupation.

4. Discussion and conclusions

Identifying sites occupied by the first peoples in North America is notoriously difficult. To do so requires the perfect combination of conditions. Clovis-age sites are rare and no doubt reflect low population densities at the time. When populations are relatively low, the archaeological record is expected to be sparse. For Clovis sites to be discoverable further requires that the sediments in which they are buried survive some 13,000 years of geologic process. Despite these limiting conditions, the La Prele Mammoth site arguably represents the earliest excavated archaeological site in Wyoming to date (cf. Frison 1982; Haynes, Surovell, and Hodgins 2013), at an estimated age of 12,941 ± 56 cal yr BP.

Since we began work at the La Prele Mammoth site, we have learned of other mammoths discovered nearby. We know of the exact location of discovery of one of these mammoths and know the general find locations of two others, all of which were found in tributaries of the North Platte River. The Bishop Mammoth, named after L. C. Bishop, the individual who found the proboscidean remains in the 1930s, is located about 16 km south southeast of the La Prele Mammoth. Radiocarbon dates on the Bishop Mammoth also place it firmly within the Clovis period as defined by Waters, Thomas, and Carlson (2020). This mammoth is located in a tributary of Bedtick Creek, and like the La Prele Mammoth site, is less than 2 km from the confluence of the creek with the North Platte River. Additional, but as of yet uninvestigated, mammoth remains occur in Alkali Gulch, the next major tributary of the North Platte to the west of La Prele Creek, and an unnamed draw about 22 km south of Douglas known locally as Red Gulch. These four buried mammoth finds occur within a 35 km reach of the North Platte suggesting that Late Pleistocene sedimentary contexts are commonly preserved in streams of this area. Though it would require additional study to know for certain, it is possible that this area preserves high densities of Late Pleistocene mammoths, much like the upper San Pedro Valley of southeastern Arizona (Ballenger 2010; Ballenger and Mabry 2011).

This pattern of preservation continues through the larger region, especially downstream where multiple localities in or near the Hartville Uplift are known to preserve Late Pleistocene aged mammoths, and/or archaeology in alluvial contexts. Those include the Hell Gap site (Irwin-Williams et al. 1973; Larson, Kornfeld, and Frison 2009; Pelton et al. 2017), the Box Elder Springs site (Wiewel 2008), the Jewett Mammoth (Frison 2004, 48–49), Patten Creek (unpublished data), and the Fort Laramie Folsom site (Beaubien 1951). Similar deposits are not uncommon in the South Platte

River Basin east of the Colorado Front Range at sites such as Lindenmeier (Haynes 2003; Wilmsen and Roberts 1984), Dent and other sites associated with the Kersey Terrace (Brunswig 2007; Haynes et al. 1998; Meyer 2020; Wheat 1979). Basins associated with the northernmost ranges of the Southern Rocky Mountains appear to preserve abundant alluvial deposits of Late Pleistocene age that commonly contain archaeological components. The La Prele Mammoth site is one example of a much larger phenomenon in the region.

At the La Prele Mammoth site, sediments of T3 began accumulating ca. 20,000 cal yr BP, ultimately burying the mammoth and a single occupation level represented by the Clovis-age archaeology, and continued until the cessation of overbank deposits ca. 7000 cal yr BP. Though bioturbation has resulted in the vertical displacement of artifacts, peaks in artifact density are readily identifiable in vertical artifact distributions. These peaks are predictable and replicated throughout all excavation areas within about a 15–20 cm range of elevations. Despite the impact of bioturbation at the site, the Clovis-age occupation, buried by a series of floods of La Prele Creek, is stratigraphically discrete with no mixing from overlying or underlying cultural levels and dates to approximately 12,941 ± 56 cal yr BP. The La Prele Mammoth site contributes to a small but ever-growing dataset on the distribution, formation, and preservation of Clovis period archaeological sites.

Notes

1. All sediments were water screened through 1/16” mesh.
2. The presence of particulate coal throughout T3 alluvium suggests La Prele Creek, which cuts through Fort Union Formation locally, is the source of all sediment, and not the North Platte River.
3. Allostratigraphic units differ from lithostratigraphic units in that the timing of the accumulation of the unit is considered, and are not solely defined on the basis of lithology.
4. We add one to artifact counts because these values exhibit a log-normal distribution, and adding allows for the inclusion of levels with zero artifacts in them in parametric correlation.
5. We exclude Block A because artifact counts are too low to use this method.
6. ASI Indexes for each block are calculated using the following artifact counts for 5 cm levels: Block B, 0, 3, 8, 18, 23, 6, 3; Block C, 0, 7, 24, 24, 9, 3; Block D, 0, 7, 105, 189, 753, 424, 19, 15, 13, 9, 12, 1.

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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