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Bayesian Revision of the Folsom Age Range Using IntCal20

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ABSTRACT
Folsom is an early Paleoindian archaeological tradition found in the North American West. Here we report new AMS radiocarbon dates for the Barger Gulch and Lindenmeier sites in Colorado along with unsuccessful dating attempts for Blackwater Draw, the Mitchell Locality, Shifting Sands, and Lipscomb on the Southern Plains. We applied Bayesian modeling using IntCal20 to our updated set of Folsom dates and estimate that the Folsom tradition lasted for a period spanning between 355–510 years at the 68 per cent credible interval or 325–650 years at the 95 per cent credible interval, starting sometime between 12,845–12,770 calendar years ago (cal yr BP) and ending sometime between 12,400–12,255 cal yr BP. Additionally, we model the spans of the start and end boundaries and find that both the adoption and abandonment of Folsom technology occurred over relatively short periods, less than 100 years and likely less than 50 years.

KEYWORDS
Folsom; radiocarbon dating; Bayesian; Barger Gulch; Lindenmeier

1. Introduction

Folsom sites are found throughout the Great Plains and parts of the adjacent Rocky Mountains and Southwest regions of North America. The Folsom archaeological complex or tradition is well-known because it played a central role in resolving the debate concerning the antiquity of people in the Americas through the documented association of Folsom artifacts with extinct bison (Meltzer 2006, 2015; Wormington 1957). Researchers have inferred from Folsom stone-tool assemblages that Folsom hunter-gatherers were highly mobile and specialized in hunting ancient bison, though there was likely some geographic variability in these adaptive strategies (Amick 1994, 1996; Andrews, LaBelle, and Seebach 2008; Buchanan et al. 2018, 2019; Carlson et al. 2016; Hofman 1992, 2002; Jennings 2012, 2016; Jennings, Pevny, and Dickens 2010; Kelly and Todd 1988). Although the Folsom tradition is well-known, the age range is still uncertain due to small sample sizes and the vagaries of dating (Haynes 1964, 1969, 1984, 1993; Haynes et al. 1992; Hofman 1995; Holliday 2000; Holliday and Johnson 1986; Surovell et al. 2016; Taylor, Haynes, and Stuiver 1996). The most recent analysis by Surovell et al. (2016) reassessed the age range of Folsom using stringent acceptance criteria for radiocarbon samples. Their results indicated Folsom lasted about 440 years from 12,610–12,170 calendar years before present (cal yr BP), a period that begins after the extinction of the megafauna and the start of the Younger Dryas Chronozone. Importantly, Surovell et al. (2016) cautioned that because their results were based on a small sample of dates the Folsom age range is likely to expand on both the younger and older ends of the reported range with additional sampling.

The motivation for the present study is two-fold. First, Surovell et al. (2016) called to increase the sample of high-quality radiocarbon ages for Folsom by acquiring new samples with good cultural association from known Folsom occupations. Surovell et al.'s (2016) study shows that advances in the pretreatment and subsequent minimization of contamination in bone samples opens up the possibility of providing new dates from the abundant bone recovered from known Folsom bison kill and butchering locales. With this in mind our project secured bone samples from Folsom

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sites in the Rocky Mountains and Great Plains regions for dating. We report our dating attempts here. Second, the availability of the new IntCal20 calibration curve that uses improved methods and extends tree ring calibration to 13,910 cal yr BP impacts the calibration of Folsom-aged dates (Reimer et al. 2020; Reinig et al. 2020). Using this new calibration curve we analyzed the set of reliable ages for the Folsom period, including our newly obtained dates, using Bayesian modeling to estimate the age range of the Folsom period. Bayesian modeling explicitly considers the error involved in dating, not only in each dated sample, but also the error involved in estimating the starting and ending dates of the Folsom age range given the sample size. This is a particularly important source of statistical error in studies such as these where the sample size of high-quality radiocarbon dates that meet Surovell et al.'s (2016) criteria is small. As such, the best estimates for the start and end of the Folsom period are not simply the oldest and youngest dated samples but are the entire distributions of error around these events. We report our new Folsom dates and the Bayesian modeling of the Folsom age range below.

2. Materials and methods

2.1. Samples

Over the last 70 years archaeologists generated dozens of radiocarbon dates attributed to the Folsom tradition. Unfortunately, the majority of these dates are now considered imprecise or erroneous as they have been subject to significant or unknown contamination, are not clearly associated with past human activity, or were mistakenly affiliated with human activity that did not occur during the Folsom period (e.g., Holliday and Johnson 1986). Following 'chronological hygiene' procedures established by several researchers (in particular, see Pettitt et al. 2003) and now applied routinely in different spatiotemporal settings (e.g., Fitzpatrick 2006; Nolan 2012; Taché and Hart 2013), Surovell and colleagues honed the Folsom radiocarbon record in 2016. Specifically, Surovell et al. (2016; also see Carlson et al. 2016) argued that bone is now the preferred material to sample for dating Folsom sites because it can be attributed, usually directly (i.e., bones within kill or butchering features, bones with cutmarks or intentionally burned), to past human activities and is spared from the old-wood problem. They argued that although using bone samples for dating was once considered detrimental due to the inability to remove contamination, newly improved XAD resin chromatographic and ultrafiltration methods (Brown et al. 1988; Stafford et al. 1988, 1991) perform significantly better in removing potential contaminants. Surovell et al. (2016) also considered charcoal, seeds, or other organic samples recovered from within well-defined hearth features as potentially reliable samples to date. They cautioned that these samples must be identified to species to limit the old-wood problem and treated to reduce potential contamination.

Applying these chronological-hygiene criteria to the Folsom radiocarbon record, Surovell et al. (2016, Table 1) identified 37 reliable dates from 12 components at 10 sites. Most of the reliable dates were measured on bone collagen, three were on highly-burned or calcined bone, and five were on charcoal from well-defined and documented hearth features. This set of reliable Folsom dates included three new dates from Hanson and one new date from Hell Gap, two sites located in Wyoming.

Table 1 New successful and unsuccessful radiocarbon assays for Folsom samples.

Site	State	Sample	Material	^{14}C yr BP
Lindenmeier**	CO	Aeon-2559	Bison scapula	10,335 ± 35*
Shifting Sands	TX	AA-111651	Bone	610 ± 22
Shifting Sands	TX	AA-111652	Bone	No collagen
Shifting Sands	TX	AA-113161	Bison petrosal bone	359 ± 28
Shifting Sands	TX	AA-113162	Bison petrosal bone	111 ± 24
Shifting Sands	TX	AA-113163	Bison petrosal bone	No collagen
Blackwater Draw	NM	AA-111653	Bone	No collagen
Blackwater Draw	NM	AA-111654	Bone	No collagen
Blackwater Draw	NM	AA-111655	Bone	No collagen
Mitchell Locality	NM	AA-113160	Bison petrosal bone	861 ± 55
Barger Gulch Loc. B1≠	CO	AA-109925	Calcined bone	10,874 ± 61*
Barger Gulch Loc. B1†	CO	AA-109926	Calcined bone	10,922 ± 61*
Barger Gulch Loc. B2‡	CO	AA-112887	Calcined bone	10,718 ± 41*
Lipscomb	TX	AA-111495	Bone	No collagen

*Dates are considered high-quality and reliable.
**δ^{13}C value = −14.22
≠East Block hearth at Barger Gulch Locality B. δ^{13}C value = −22.2.
†Main Block hearth at Barger Gulch Locality B. δ^{13}C value = −21.6.
‡South Block hearth at Barger Gulch Locality B. δ^{13}C value = −23.3.

Surovell and colleagues (2016) were able to obtain calcined bone and collagen from Hanson and Hell Gap, respectively, from extant bone collections associated with these sites.

Our intent in this study is to follow the protocols established by Surovell et al. (2016) and sample known Folsom kill and butchering locales for bone to date. We obtained bone samples from six Folsom sites, including Lindenmeier (Wilmsen and Roberts 1978), Barger Gulch (Surovell and Waguespack 2007; Surovell et al. 2005), Blackwater Draw Locality No. 1 (i.e., the Clovis site) (Boldurian 1991; Hester 1972), the Mitchell Locality adjacent to Blackwater Draw (Boldurian 1990), Shifting Sands (Hofman, Amick, and Rose 1990), and Lipscomb (Hofman 1995) (Figure 1). At Barger Gulch there is a possibility that separate hearths at the site represent multiple occupations or components (separate Folsom occupations at the same site). Previous excavations at all six sites recovered evidence of Folsom points in association with bison bone. Prior attempts to radiocarbon date material were made at all these sites except Shifting Sands (Surovell et al. 2016; Taylor, Haynes, and Stuiver 1996). The Lindenmeier (Colorado) and Barger Gulch (Colorado) sites are located on the Central Plains and Rocky Mountains, and Shifting Sands (Texas), Lipscomb (Texas), Blackwater Draw Locality No. 1 (New Mexico), and Mitchell Locality (New Mexico) are located on the Southern Plains.

2.2. Sample processing

Most of the samples (13 of 14) for radiocarbon age estimation were processed and analyzed at the University of Arizona's Accelerator Mass Spectrometry Lab. The exception was one sample from Lindenmeier that was processed by Aeon Laboratory in Tucson, Arizona (the procedures for the Aeon lab sample processing and analysis are provided in the Supplemental Materials). At the Accelerator Mass Spectrometry Lab, calcined bone samples were prepared following previously established protocols (Lanting, Aerts-Bijma, and van der Plicht 2001; Olsen et al. 2008). Briefly, approximately 500 mg of bone was soaked in 2% sodium hypochlorite solution for 48 h at room temperature to remove organic material. The sample was then rinsed three times with deionized water and then placed in 1M acetic acid for 24 h at room temperature. It was rinsed extensively with deionized water and dried in a vacuum oven at 60°C. After converting the sample to powder, it was then hydrolyzed in 85% phosphoric acid in an evacuated tube, at 50°C for 18 h. The liberated CO_2 was cryogenically purified from the other hydrolysis products, and then converted to graphite. An aliquot of CO_2 was used to determine the carbon $\delta^{13}C$ ratio using an off-line IRMS. These values were used for isotope fractionation correction. Radiocarbon measurements were carried out on a National Electrostatics Corporation 3.0 MeV AMS instrument using the methods described in Jull, Burr, and Hodgins (2013).

For unburned bone samples, bones were drilled to extract collagen. First, the bone surface was milled away, and the bone crushed and sieved to 0.5–1.0 mm particle size. The resulting material was then washed by ultrasonication for 1 h in deionized water at room temperature. The collagen extraction treatment was an acid/base/acid extraction using a custom continuous flow system. Collagen ghosts were gelatinized at 65°C for 24 h, and then filtered through a 0.45 micron filter. This material was freeze dried and yield calculated. It was re-suspended in water and then this solution was passed through pre-washed 30,000 molecular weight cut-off ultrafiltration membrane. Lastly, the retained fraction was washed in water and freeze dried.

2.3. Bayesian modeling

Complexities in the calibration curve are especially pronounced for the late Pleistocene in general, and the Younger Dryas chronozone in particular (Taylor et al. 1996a, 1996b; Surovell et al. 2016). Use of the Bayesian method (Bronk Ramsey 2009) can help compensate for the increase in uncertainty of calibrated radiocarbon dates due to erratic departures (wiggles) in the calibration curve (Kutschera et al. 2007) and to guard against overestimations of calibrated ranges and estimated boundaries.

All dates in our sample were calibrated and modeled using the IntCal20 calibration curve (Reimer et al. 2020) and OxCal v. 4.4 (Bronk Ramsey 2009). Dates were first organized into individual phases that correspond with individual sites. Each of these individual phases was assigned start and end boundaries. Each of these individual site-phases was then incorporated into a larger, single phase representative of the Folsom tradition as an event with a start and an end. Trapezium boundaries were used to model the start and end boundaries of the overall Folsom Tradition phase to account for the temporal nature of cultural transitions (Lee and Bronk Ramsey 2012). In contrast to the use of simple boundaries, which forces all dates to be distributed in an even block over the span of the phase, trapezium boundaries recognize that the earliest and latest dates for a phase are likely to be less abundant as they come into existence and then fade away. This does not impose a temporality onto the phase (e.g., rapid or gradual); trapezium boundaries merely define the shape of the

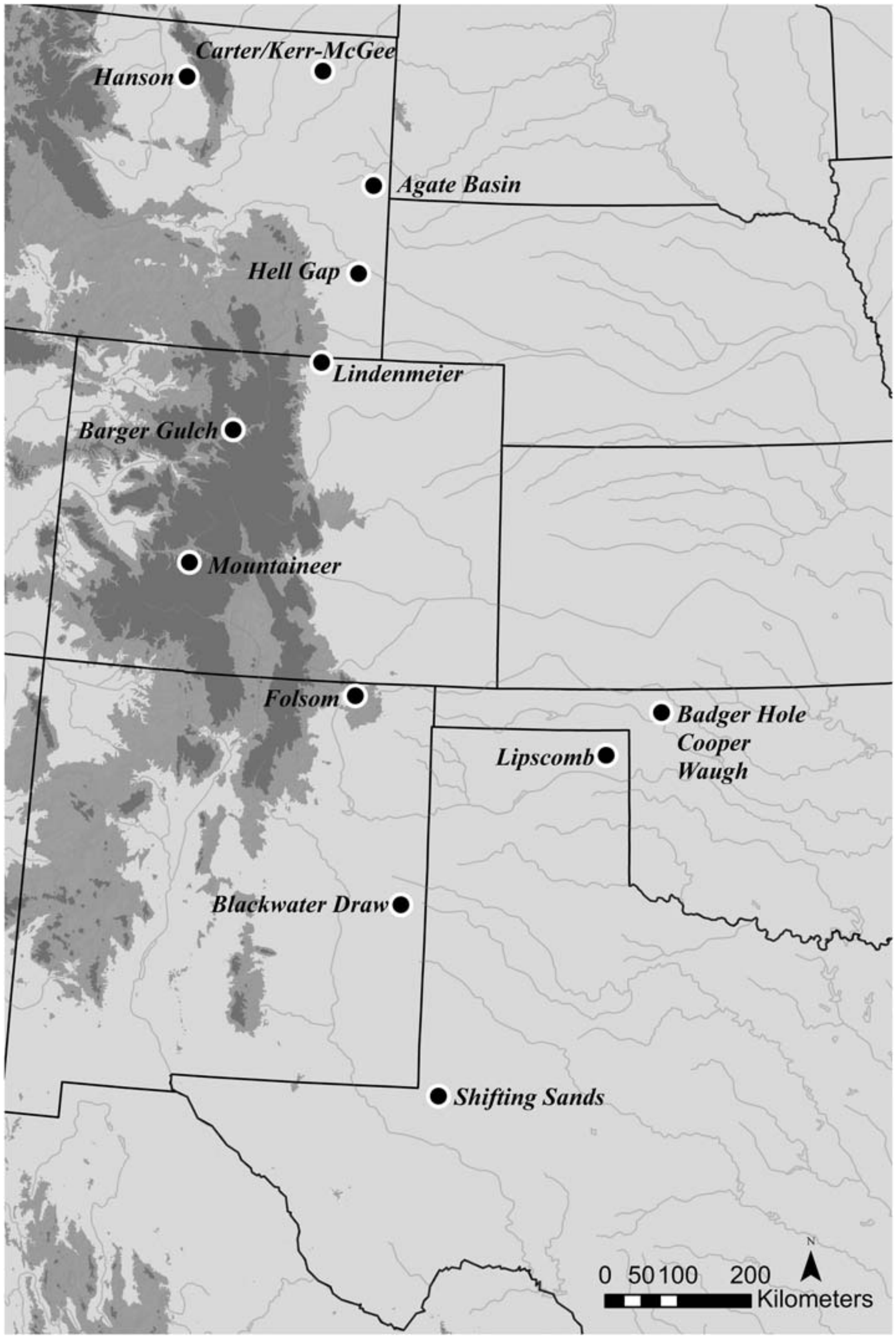

Figure 1 Location of Folsom sites discussed in text. The Blackwater Draw location encompasses the Mitchell Locality.

distribution of likelihoods (dates) within a phase. The trapezium boundary command also returns a span for each boundary that provides an estimate for these temporalities (e.g., how rapid or how gradual). A span command was included in the overall model to produce an estimate of the span for the Folsom tradition while an order command was included to estimate the order that each individual site was first occupied. The output from the order command provides a probability for each set of pairwise dates and boundaries. Using this command, we can provide an overall estimated order in which each site was first occupied and investigate any geographic trends in our radiocarbon data. All modeled dates and ranges are presented in italics and rounded to the nearest five years. Ranges are presented at both the 68% and 95% credible ranges (more precisely these are 68.3% and 95.4%). The actual ages for individual dates or boundaries have an equal chance of falling anywhere within these estimated ranges. All model code is included in the Supplemental Materials.

3. Results

Our efforts to date bone from extant Folsom collections were partially successful. We were able to obtain reliable radiocarbon ages from two of the six Folsom sites we attempted to date (Table 1). We obtained four new reliable ages, three from calcined bone fragments from three different hearths at Barger Gulch Locality B and one from a bone sample from Lindenmeier. Detailed descriptions of the context of the successfully dated samples from Barger Gulch and Lindenmeier are presented in the Supplementary Materials. Insufficient collagen extraction hampered our ability to reliably date samples from the Blackwater Draw, Mitchell Locality, Shifting Sands, and Lipscomb sites. Together with the 33 reliable radiocarbon ages identified by Surovell et al. (2016)[1], there are currently 37 reliable radiocarbon ages associated with Folsom in the western United States.

3.1. Bayesian estimation of the Folsom calibrated age range

The new high-quality radiocarbon dates presented here add a site and component to the previous set of reliably dated sites and components reported by Surovell et al. (2016), bringing the total to 11 sites and 14 components. Modeled age ranges for the 37 Folsom samples are presented in Table 2. The resulting model has an A_{model} value of 116.4 and an A_{overall} value of 115.6, well above the accepted threshold of 60, indicating good agreement among model parameters and available radiocarbon dates.

The start of the Folsom tradition is estimated to have occurred sometime in the range of 12,845–12,770 cal yr BP (68% credible interval) (or 12,910–12,750 cal yr BP at the 95% credible interval), while the end of the Folsom tradition is estimated within the range of 12,400–12,255 cal yr BP (68% credible interval) (or 12,430–12,125 cal yr BP at the 95% credible interval) (Figure 2). The modeled span for the start boundary is 0–25 years (68%) or 0–85 years (95%). The modeled span for the Folsom tradition end boundary is 0–30 years (68%) or 0–100 years (95%). The modeled overall span for the Folsom tradition is estimated to have lasted between 355–510 years at the 68% credible interval or 325–650 years at the 95% credible interval (Figure 3). We used the order command in OxCal to return probabilities for each of the modeled start boundaries for each individual site (Figure 2; Table S2).

4. Discussion

Folsom is a well-known Paleoindian archaeological tradition that ranged across most of the Great Plains, and parts of the Southwest and Rocky Mountains regions of western North America during the late Pleistocene. Over the past 70 years great efforts have been expended in trying to obtain absolute age estimates for Folsom occupations (Haynes 1964, 1969, 1984, 1993; Haynes et al. 1992; Hofman 1995; Holliday 2000; Holliday and Johnson 1986; Surovell et al. 2016; Taylor, Haynes, and Stuiver 1996). Here, we have added to the small set of reliable dates for the Folsom tradition by obtaining four new radiocarbon ages for two Folsom sites. Notably, our new dates include the oldest potential calibrated age determination for a Folsom site, 13,055–12,740 cal yr BP (95% credible interval) (AA-109926), obtained on calcined bone from a feature at the Barger Gulch site in Colorado, and the youngest calibrated age estimate, 12,465–11,945 cal yr BP (Aeon-2559), from the well-known Lindenmeier site in Colorado. Thus, as predicted by Surovell and colleagues (2016; also see Prasciunas and Surovell 2015), increasing the sample of dates for Folsom, even by four dates in this case, has expanded the known age range for Folsom. This also reaffirms that our sample of dates for this period remains small and new dates will continue to be informative.

Given that the new dates from Barger Gulch are among the oldest produced for the Folsom tradition and because the new dates on calcined bone are older than previous dates from the site obtained on charcoal, we discuss the site and dates in more detail. Barger Gulch is shallowly buried, and excavations spanning 10 years produced only Folsom diagnostic material (Mayer et al. 2005; Surovell and Waguespack 2007; Surovell et al. 2001, 2005; Waguespack and Surovell 2014). Stratigraphic and archaeological evidence from the site has indicated that only Folsom archaeology is present at the site and the three excavated blocks represent single occupations (see site description in the Supplementary Materials; Surovell 2009; Surovell et al. 2005; Waguespack and Surovell 2014). Initial efforts to date the site by Surovell and colleagues (Surovell et al. 2003, 2005) used dispersed flecks of charcoal, but those were complicated by the presence of abundant charcoal produced by natural fires post-dating the Folsom occupation. Two charcoal samples (10,770 ± 70 ^{14}C yr BP, Beta-173385 and 10,470 ± 40 ^{14}C yr BP, Beta-173381) recovered from the vicinity of a hearth feature in the Main Block were argued to best date the Folsom occupation (Surovell and Waguespack 2007). However, in the absence of clear anthropogenic concentrations of charcoal, it was not clear if those samples were truly derived from human action or natural fire. For this reason, we selected samples of calcined bone for dating reported in this study.

Table 2 New and extant Folsom dates used in this study. Calibrated and modeled contiguous ranges are presented at the 68% and 95% credible intervals (calibrated and modeled ranges can be reproduced using the OxCal code provided in Supplemental Materials).

Site	Lab number	Material	Age (^{14}C yr BP)	Error	Calibrated (68%)	Calibrated (95%)	Modeled (68%)	Modeled (95%)	Reference
Badger Hole	UCIAMS-98369	Bone collagen	10,300	25	12,420–11,940	12,445–11,885	12,445–12,395	12,465–12,305	Bement et al. 2012
Badger Hole	PSU-5144/UCIAMS-111184	Bone collagen	10,395	35	12,475–12,100	12,485–12,045	12,460–12,380	12,485–12,290	Carlson 2015
Badger Hole	PSU-5457/UCIAMS-122579	Bone collagen	10,370	25	12,460–12,100	12,470–12,005	12,455–12,380	12,475–12,295	Carlson 2015
Carter/Kerr-McGee	UCIAMS-122572	Bone collagen	10,600	25	12,685–12,620	12,700–12,500	12,670–12,505	12,690–12,495	Carlson 2015
Carter/Kerr-McGee	UCIAMS-122573	Bone collagen	10,520	25	12,620–12,485	12,625–12,475	12,625–12,490	12,665–12,480	Carlson 2015
Cooper Lower	CAMS-94850	Bone collagen	10,600	40	12,695–12,510	12,720–12,490	12,675–12,620	12,700–12,505	Johnson and Bement 2009
Cooper Lower	PSU-6077/UCIAMS-140849	Bone collagen	10,560	30	12,670–12,495	12,685–12,485	12,675–12,615	12,690–12,500	Carlson 2015
Cooper Lower	PSU-6078/UCIAMS-140520	Bone collagen	10,570	30	12,675–12,500	12,690–12,485	12,675–12,620	12,690–12,500	Carlson 2015
Cooper Lower	PSU-6079/UCIAMS-140581	Bone collagen	10,630	30	12,710–12,620	12,725–12,510	12,675–12,620	12,710–12,510	Carlson 2015
Cooper Middle	CAMS-82407	Bone collagen	10,530	45	12,660–12,480	12,690–12,330	12,665–12,490	12,680–12,480	Johnson and Bement 2009
Cooper Middle	PSU-6075/UCIAMS-140847	Bone collagen	10,565	30	12,670–12,495	12,685–12,485	12,665–12,495	12,680–12,485	Carlson 2015
Cooper Middle	PSU-6076/UCIAMS-140848	Bone collagen	10,575	30	12,675–12,500	12,690–12,485	12,665–12,500	12,685–12,490	Carlson 2015
Cooper Upper	CAMS-94849	Bone collagen	10,505	45	12,620–12,475	12,680–12,195	12,625–12,485	12,670–12,475	Johnson and Bement 2009
Cooper Upper	PSU-6073/UCIAMS-140845	Bone collagen	10,550	30	12,670–12,495	12,685–12,485	12,660–12,495	12,680–12,485	Carlson 2015
Cooper Upper	PSU-6074/UCIAMS-140846	Bone collagen	10,525	30	12,675–12,500	12,690–12,485	12,660–12,495	12,680–12,490	Carlson 2015
Folsom	CAMS-74656	Bone collagen	10,450	50	12,610–12,190	12,620–12,095	12,595–12,540	12,615–12,465	Meltzer 2006
Folsom	CAMS-74658	Bone collagen	10,450	50	12,610–12,190	12,620–12,095	12,595–12,540	12,615–12,465	Meltzer 2006
Folsom	CAMS-96034	Bone collagen	10,475	30	12,610–12,470	12,620–12,195	12,595–12,540	12,610–12,470	Meltzer 2006
Folsom	CAMS-74657	Bone collagen	10,500	40	12,615–12,475	12,675–12,195	12,600–12,540	12,615–12,475	Meltzer 2006
Folsom	CAMS-74659	Bone collagen	10,510	50	12,620–12,480	12,690–12,195	12,605–12,535	12,615–12,475	Meltzer 2006
Folsom	CAMS-74655	Bone collagen	10,520	50	12,620–12,480	12,690–12,195	12,605–12,535	12,615–12,475	Meltzer 2006
Hanson	AA-106384	Calcined bone	10,626	77	12,725–12,505	12,745–12,480	12,710–12,625	12,735–12,495	Surovell et al. 2016
Hanson	AA-106385	Calcined bone	10,600	77	12,710–12,495	12,745–12,280	12,710–12,625	12,735–12,495	Surovell et al. 2016
Hanson	AA-106386	Calcined bone	10,688	77	12,745–12,620	12,765–12,490	12,720–12,625	12,745–12,500	Surovell et al. 2016
Mountaineer	CAMS-105764	Bone collagen	10,440	50	12,600–12,105	12,615–12,055	12,490–12,325	12,580–12,255	Stiger 2006
Mountaineer	CAMS-105765	Bone collagen	10,295	50	12,435–11,885	12,460–11,830	12,470–12,355	12,480–12,260	Stiger 2006
Mountaineer	UCIAMS-11240	Bone collagen	10,380	30	12,465–12,100	12,475–12,045	12,475–12,345	12,480–12,265	Stiger 2006
Mountaineer	UCIAMS-11241	Bone collagen	10,445	25	12,590–12,200	12,610–12,105	12,490–12,330	12,585–12,265	Stiger 2006
Mountaineer	AA-98753	Bone collagen	10,328	100	12,460–11,940	12,605–11,760	12,480–12,350	12,500–12,245	Morgan 2015
Waugh	NZA–3602	Charcoal	10,379	85	12,470–12,055	12,615–11,885	12,585–12,370	12,615–12,280	Hofman 1995
Waugh	NZA-3603	Charcoal	10,404	87	12,485–12,055	12,620–11,940	12,590–12,365	12,620–12,275	Hofman 1995
Barger Gulch B1	AA-109925	Calcined bone	10,874	61	12,835–12,745	12,920–12,725	12,785–12,745	12,825–12,730	This study
Barger Gulch B1	AA-109926	Calcined bone	10,922	61	12,890–12,755	13,055–12,740	12,790–12,745	12,830–12,735	This study
Agate Basin	UCIAMS-122570	Bone collagen	10,430	25	12,580–12,190	12,595–12,100	12,590–12,325	12,600–12,200	Carlson 2015
Hell Gap	AA-77592UF	Bone collagen	10,490	62	12,625–12,200	12,685–12,100	12,620–12,465	12,685–12,270	Surovell et al. 2016
Lindenmeier	Aeon-2559	Bison scapula	10,335	35	12,440–11,995	12,465–11,945	12,455–12,360	12,475–12,230	This study
Barger Gulch B2	AA-112887	Calcined bone	10,718	41	12,740–12,700	12,755–12,670	12,740–12,700	12,755–12,670	This study

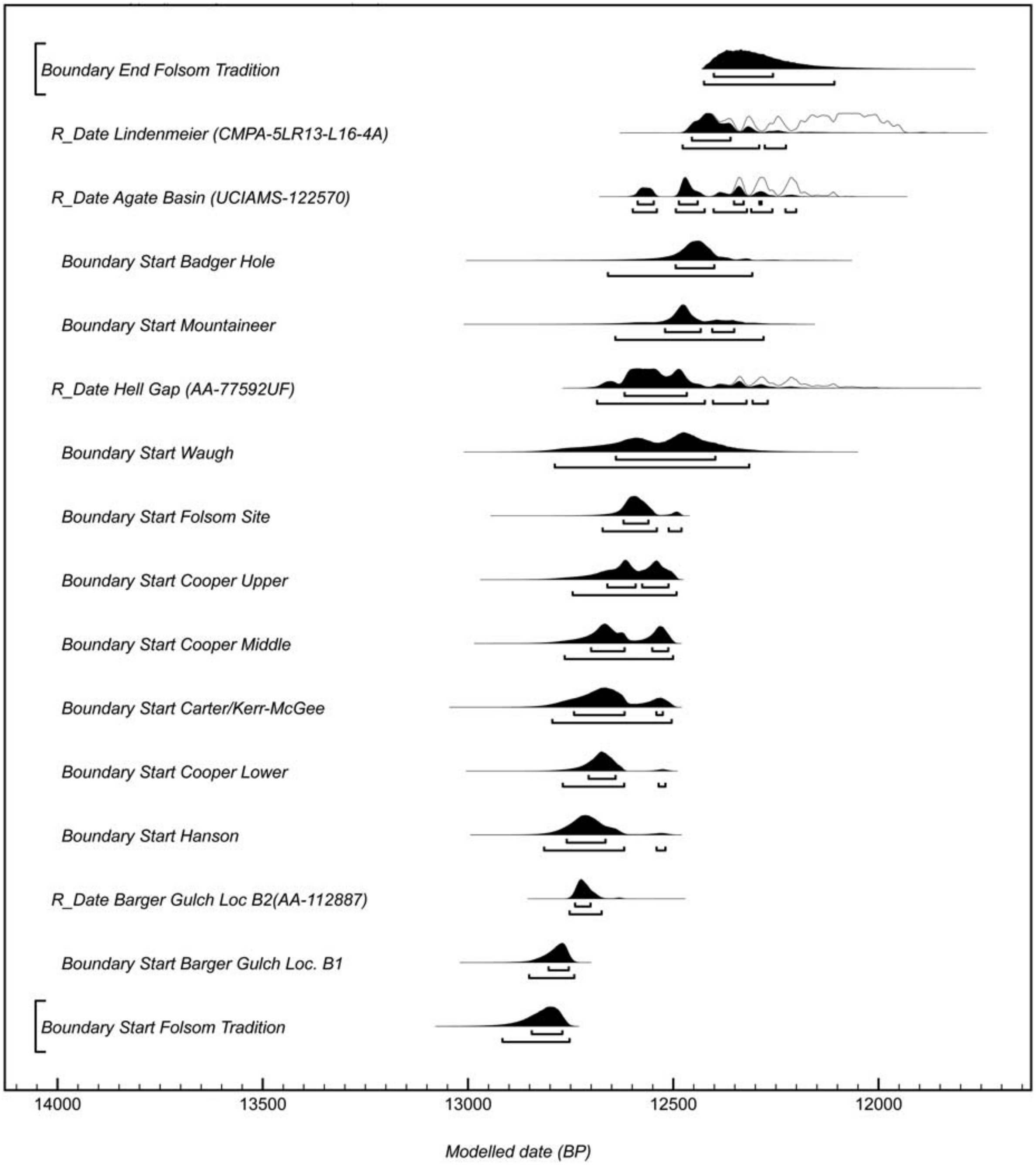

Figure 2 Modeled start and end boundaries for the Folsom tradition (top and bottom posterior probability estimates) and modeled start boundaries for each of the individual sites included in this study. Site are ordered from earliest to latest (from bottom to top) using the order command in OxCal. Order probabilities are presented in Table 2. Some sites only had a single available date (labels beginning with R_Date). Bars underneath posterior probability estimates represent 68% and 95% credible intervals.

Several studies indicate that the carbonate fraction of calcined bone is a fairly reliable material for radiocarbon dating (Chatters et al. 2017; Lanting et al. 2001; Snoeck, Brock, and Schulting 2014; Zazzo and Saliège 2011; Zazzo et al. 2012, 2013), but it can almost always be assumed to have been produced by human action when present in archaeological sites because it is rarely a result of natural fires (Buenger 2003; Traylor et al. 1990). This is in part because bones buried only a few centimeters beneath the ground surface cannot reach sufficient temperatures to calcine when exposed to surface fires (Bennett 1999; Buenger 2003; Lentz, Gaunt, and Willmer 1996; Stiner et al. 1995; Traylor et al. 1990). Therefore, unlike charcoal where there is no good way to separate cultural from natural specimens, in the case of calcined bone recovered from hearth features, there is no doubt that it was produced by human agency and that it should generally yield accurate ages. There are reasons, however, why

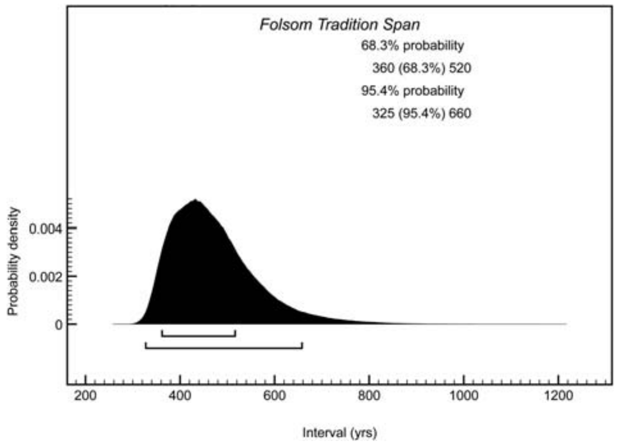

Figure 3 Modeled span (in years) for the Folsom tradition based on all available dates and model parameters. Bars underneath the posterior probability estimate represent 68% and 95% credible intervals.

radiocarbon dates on calcined bones might be too old or too young. The carbon remaining in apatite after recrystallization during the calcination process is largely derived from the bone itself and from the combustion fuel. If the fuel is significantly older than the bone, a mild old-wood effect can result (Annaert et al. 2020; Olsen et al. 2013; Zazzo et al. 2012). We discount this possibility based on the evidence that the two dates from the Main and East Blocks are statistically contemporaneous ($t = 0.3$, df = 1, $P = 0.584$), making it implausible that contamination affected them identically. A more parsimonious explanation is that they are accurately dating the same occupation. In addition, based on experimental burning of bone, Snoeck, Brock, and Schulting (2014, 600) found that samples with lower (more negative) $\delta^{13}C$ values are those most likely to have more carbon derived from combustion sources than from the bone itself. The oldest calcined bone dates from Barger Gulch have the highest $\delta^{13}C$ values, and therefore old wood is not likely to be a problem (see Table 1). Finally, if natural fires post-dating the occupation had affected these dates, the error would be in the opposite direction (i.e., they would be too young). We suggest that this evidence resolves any outstanding issue with the dating of the Barger Gulch site and it currently stands as the oldest dated Folsom site.

With the new set of radiocarbon dates from 14 components, our analyses indicated that the Folsom tradition lasted for a period of ca. 355–510 years, starting sometime between 12,845 and 12,770 cal yr BP and ending sometime between 12,400 and 12,255 cal yr BP. The variance in the estimate of the age range of the Folsom tradition is a combination of the error associated with individual dates, and the small sample size, both of which are modeled explicitly in the Bayesian framework. This age range appears to be coincident with the onset of the Younger Dryas Chronozone at 12,850 cal yr BP (Steffensen et al. 2008). Our estimate for the initial appearance of Folsom also overlaps with conventional estimates of the end of the Clovis period (Waters, Stafford, and Carlson 2020). We expect some temporal overlap if the transition from Clovis to Folsom was a cultural evolutionary process, that is a diffusion process of cultural traits that are innovated and subsequently spread through a population. This expectation contrasts with the replacement hypothesis that posits Clovis populations were replaced by Folsom (perhaps through some catastrophic event). Our findings indicate the former is more likely.

Given the small sample of reliable Folsom dates, understanding whether the Folsom culture spread by cultural or demographic diffusion (cf. Collard et al. 2010) is difficult to discern at this time. The resolution and representativeness of the models presented here undoubtedly will increase or be altered as new radiocarbon determinations are acquired and added to the model framework. Future work should leverage a robust program of simulations to determine from where and how many new dates should be acquired and how these new dates might affect modeled outputs and estimations. Such simulations, structured using the model framework presented here, could be used as support for future funding and analyses aimed at increasing the resolution and representativeness of the current model. In this regard, expanding efforts may require resolving the relationship of Midland to Folsom, which some researchers suggest are the same tradition (Amick 1995; Jennings 2012, 2016). Reliably dating Midland sites, such as the recent dating of a Midland site in Texas (Winkler-1) to 12,106–11,310 cal yr BP (Blaine, Skinner, and Hall 2017), might prove useful for modeling diffusion. With advances in methods to isolate uncontaminated bone collagen for dating, further dating efforts should concentrate on obtaining bone samples from well-documented Folsom contexts.

Note

1. We report 33 reliable Folsom dates from the Surovell et al. (2016) study. This number excludes two dates (UCIAMS-122571 and SI-3733) reported from the Agate Basin site that Surovell et al. (2016) suggest may have been contaminated and the two charcoal dates (Beta-173385 and Beta-173381) from Barger Gulch that have been replaced by the calcined dates reported in this study.

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References

Amick, D. S. 1994. "Folsom Diet Breadth and Land Use in the American Southwest." PhD diss., Department of Anthropology, University of New Mexico, Albuquerque.

Amick, D. S. 1995. "Patterns of Technological Variation among Folsom and Midland Projectile Points in the American Southwest." *Plains Anthropologist* 40 (151): 23–38.

Amick, D. S. 1996. "Regional Patterns of Folsom Mobility and Land Use in the American Southwest." *World Archaeology* 27 (3): 411–426.

Andrews, B. N., J. M. LaBelle, and J. D. Seebach. 2008. "Spatial Variability in the Folsom Archaeological Record: A Multi-Scalar Approach." *American Antiquity* 73 (3): 464–490.

Annaert, R., M. Boudin, K. Deforce, A. Ervynck, K. Haneca, A. Lentacker, and C. Snoeck. 2020. "Anomalous Radiocarbon Dates from the Early Medieval Cremation Graves from Broechem (Flanders, Belgium): Reservoir or Old Wood Effects?" *Radiocarbon* 62 (2): 269–288.

Bement, L. C., B. J. Carter, P. Jelley, K. Carlson, and S. Fine. 2012. "Badger Hole: Towards Defining a Folsom Bison Hunting Complex Along the Beaver River, Oklahoma." *Plains Anthropologist* 57 (221): 53–62.

Bennett, J. L. 1999. "Thermal Alteration of Buried Bone." *Journal of Archaeological Science* 26 (1): 1–8.

Blaine, J. C., S. A. Skinner, and M. A. Hall. 2017. "The Saga of Winkler-1: A Midland Site in Southeast New Mexico." *PaleoAmerica* 3 (1): 48–73.

Boldurian, A. T. 1990. "Lithic Technology at the Mitchell Locality of Blackwater Draw: A Stratified Folsom Site in Eastern New Mexico." *Plains Anthropologist* 35 (130): 1–115.

Boldurian, A. T. 1991. "Folsom Mobility and Organization of Lithic Technology: A View from Blackwater Draw, New Mexico." *Plains Anthropologist* 36 (137): 281–296.

Bronk Ramsey, C. 2009. "Bayesian Analysis of Radiocarbon Dates." *Radiocarbon* 51 (1): 337–360.

Brown, T. A., D. E. Nelson, J. S. Vogel, and J. R. Southon. 1988. "Improved Collagen Extraction by Modified Longin Method." *Radiocarbon* 30: 171–177.

Buchanan, B., B. Andrews, J. D. Kilby, and M. I. Eren. 2019. "Settling into the Country: Comparison of Clovis and Folsom Lithic Networks in Western North America Shows Increasing Redundancy of Toolstone Use." *Journal of Anthropological Archaeology* 53: 32–42.

Buchanan, B., B. Andrews, M. J. O'Brien, and M. I. Eren. 2018. "An Assessment of Stone Weapon Tip Standardization during the Clovis-Folsom Transition in the Western United States." *American Antiquity* 83 (4): 721–734.

Buenger, B. A. 2003. "The Impact of Wildland and Prescribed Fire on Archaeological Resources." PhD diss., Department of Anthropology, University of Kansas, Lawrence, Kansas.

Carlson, K. 2015. "The Development of Paleoindian Communal Bison Kills: A Comparison of Northern to Southern Plains Arroyo Traps." PhD diss., Department of Anthropology, University of Oklahoma, Norman.

Carlson, K. A., B. J. Culleton, D. J. Kennett, and L. C. Bement. 2016. "Tightening Chronology of Paleoindian Bison Kill Sites on the Northern and Southern Plains." *PaleoAmerica* 2 (2): 90–98.

Chatters, J. C., J. W. Brown, S. Hackenberger, P. McCutcheon, and J. Adler. 2017. "Calcined Bone as a Reliable Medium for Radiocarbon Dating: A Test Using Paired North American Samples." *American Antiquity* 82 (3): 593–608.

Collard, M., B. Buchanan, M. J. Hamilton, and M. J. O'Brien. 2010. "Spatiotemporal Dynamics of the Clovis–Folsom Transition." *Journal of Archaeological Science* 37 (10): 2513–2519.

Fitzpatrick, S. M. 2006. "A Critical Approach to 14 C Dating in the Caribbean: Using Chronometric Hygiene to Evaluate Chronological Control and Prehistoric Settlement." *Latin American Antiquity* 17: 389–418.

Haynes Jr, C. V. 1964. "Fluted Projectile Points: Their Age and Dispersion." *Science* 145 (3639): 1408–1413.

Haynes Jr, C. V. 1969. "The Earliest Americans." *Science* 166 (3906): 709–715.

Haynes Jr, C. V. 1984. "Stratigraphy and Late Pleistocene Extinction in the United States." In *Quaternary Extinctions: A Prehistoric Revolution*, edited by P. S. Martin and R. G. Klein, 345–353. Tucson: University of Arizona Press.

Haynes, C. V. 1993. "Clovis-Folsom Geochronology and Climatic Change." In *From Kostenki to Clovis*, edited by O. Soffer and N. D. Praslov, 219–236. Boston: Springer.

Haynes Jr, C. V., R. P. Beukens, A. J. T. Jull, and O. K. Davis. 1992. "New Radiocarbon Dates for Some Old Folsom Sites: Accelerator Technology." In *Ice Age Hunters of the Rockies*, edited by D. J. Stanford and J. S. Day, 83–100. Niwot: University Press Colorado.

Hester, J. J. 1972. *Blackwater Locality No. 1: A Stratified Early Man Site in Eastern New Mexico*. Taos, New Mexico: Fort Burgwin Research Center.

Hofman, J. L. 1992. "Recognition and Interpretation of Folsom Technological Variability on the Southern Plains." In *Ice Age Hunters of the Rockies*, edited by D. J. Stanford and J. S. Day, 193–224. Niwot: University Press Colorado.

Hofman, J. L. 1995. "Dating Folsom Occupations on the Southern Plains: The Lipscomb and Waugh Sites." *Journal of Field Archaeology* 22: 421–437.

Hofman, J. L. 2002. "High Points in Folsom Archaeology." In *Folsom Technology and Lifeways*, edited by J. E. Clark and M. B. Collins, 399–412. Special Publication No. 4. Tulsa, Oklahoma: Lithic Technology, Department of Anthropology, University of Tulsa.

Hofman, J. L., D. S. Amick, and R. O. Rose. 1990. "Shifting Sands: A Folsom-Midland Assemblage from a Campsite in Western Texas." *Plains Anthropologist* 35 (129): 221–253.

Holliday, V. T. 2000. "The Evolution of Paleoindian Geochronology and Typology on the Great Plains." *Geoarchaeology* 15 (3): 227–290.

Holliday, V. T., and E. Johnson. 1986. "Re-evaluation of the First Radiocarbon Age for the Folsom Culture." *American Antiquity* 51 (2): 332–338.

Jennings, T. A. 2012. "Clovis, Folsom, and Midland Components at the Debra L. Friedkin Site, Texas: Context, Chronology, and Assemblages." *Journal of Archaeological Science* 39 (10): 3239–3247.

Jennings, T. A. 2016. "The Impact of Stone Supply Stress on the Innovation of a Cultural Variant: The Relationship of Folsom and Midland." *PaleoAmerica* 2 (2): 116–123.

Jennings, T. A., C. D. Pevny, and W. A. Dickens. 2010. "A Biface and Blade Core Efficiency Experiment: Implications for Early Paleoindian Technological Organization." *Journal of Archaeological Science* 37 (9): 2155–2164.

Johnson, E., and L. C. Bement. 2009. "Bison Butchery at Cooper, a Folsom Site on the Southern Plains." *Journal of Archaeological Science* 36 (7): 1430–1446.

Jull, A. J. T., G. S. Burr, and G. W. L. Hodgins. 2013. "Radiocarbon Dating, Reservoir Effects, and Calibration." *Quaternary International* 299: 64–71.

Kelly, R. L., and L. C. Todd. 1988. "Coming into the Country: Early Paleoindian Hunting and Mobility." *American Antiquity* 53 (2): 231–244.

Kutschera, W., P. Steier, F. Weninger, and W. M. Wild. 2007. "The Principle of the Bayesian Method." *International Journal for Egyptian Archeology and Related Disciplines* 16: 317–324.

Lanting, J. N., A. T. Aerts-Bijma, and J. van der Plicht. 2001. "Dating of Cremated Bones." *Radiocarbon* 43 (2A): 249–254.

Lee, S., and C. Bronk Ramsey. 2012. "Development and Application of the Trapezoidal Model for Archaeological Chronologies." *Radiocarbon* 54 (1): 107–122.

Lentz, S. C., J. K. Gaunt, and A. J. Willmer. 1996. *Fire Effects on Archaeological Resources, Phase I: The Henry Fire, Holiday Mesa, Jemez Mountains, New Mexico*. Fort Collins, CO: Rocky Mountain Forest and Range Experiment Station, U.S. Forest Service.

Mayer, J. H., T. A. Surovell, N. M. Waguespack, M. Kornfeld, R. G. Reider, and G. C. Frison. 2005. “Paleoindian Environmental Change and Landscape Response in Barger Gulch, Middle Park, Colorado.” *Geoarchaeology* 20 (6): 599–625.

Meltzer, D. J. 2006. *Folsom: New Archaeological Investigations of a Classic Paleoindian Bison Kill*. Berkeley: University of California Press.

Meltzer, D. J. 2015. *The Great Paleolithic War: How Science Forged an Understanding of America’s Ice Age Past*. Chicago: University of Chicago Press.

Morgan, B. M. 2015. “Folsom Settlement Organization in the Southern Rocky Mountains: An Analysis of Dwelling Space at the Mountaineer Site.” PhD diss., Department of Anthropology, Southern Methodist University, Dallas.

Nolan, K. C. 2012. “Temporal Hygiene: Problems in Cultural Chronology of the Late Prehistoric Period of the Middle Ohio River Valley.” *Southeastern Archaeology* 31 (2): 185–206.

Olsen, J., J. Heinemeier, P. Bennike, C. Krause, K. M. Hornstrup, and H. Thrane. 2008. “Characterisation and Blind Testing of the Method for Radiocarbon Dating of Cremated Bone.” *Journal Archaeological Science* 35 (3): 791–800.

Olsen, J., J. Heinemeier, K. M. Hornstrup, P. Bennike, and H. Thrane. 2013. “‘Old Wood’ Effect in Radiocarbon Dating of Prehistoric Cremated Bones?” *Journal of Archaeological Science* 40 (1): 30–34.

Pettitt, P. B., W. Davies, C. S. Gamble, and M. B. Richards. 2003. “Palaeolithic Radiocarbon Chronology: Quantifying Our Confidence beyond Two Half-lives.” *Journal of Archaeological Science* 30: 1685–1693.

Prasciunas, M. M., and T. A. Surovell. 2015. “Reevaluating the Duration of Clovis: The Problem of Non-representative Radiocarbon.” In *Clovis: On the Edge of a New Understanding*, edited by A. M. Smallwood and T. A. Jennings, 21–35. College Station: Texas A&M University Press.

Reimer, P. J., W. E. Austin, E. Bard, A. Bayliss, P. G. Blackwell, C. B. Ramsey, M. Butzin, et al. 2020. “The IntCal20 Northern Hemisphere Radiocarbon Age Calibration Curve (0–55 cal kBP).” *Radiocarbon* 62 (4): 725–757.

Reinig, F., A. Sookdeo, J. Esper, M. Friedrich, G. Guidobaldi, G. Helle, B. Kromer, et al. 2020. “Illuminating IntCal during the Younger Dryas.” *Radiocarbon* 62 (4): 883–889.

Snoeck, C., F. Brock, and R. J. Schulting. 2014. “Carbon Exchanges between Bone Apatite and Fuels during Cremation: Impact on Radiocarbon Dates.” *Radiocarbon* 56 (2): 591–602.

Stafford Jr, T. W., K. Brendel, and R. C. Duhamel. 1988. “Radiocarbon, 13C and 15N analysis of fossil bone: Removal of humates with XAD-2 resin.” *Geochimica et Cosmochimica Acta* 52: 2257–2267.

Stafford, Jr, T. W. P. E. Hare, L. Currie, A. J. T. Jull, and D. J. Donahue. 1991. “Accelerator Radiocarbon Dating at the Molecular Level.” *Journal of Archaeological Science* 18: 35–72.

Steffensen, J. R. P., K. K. Andersen, M. Bigler, H. B. Clausen, D. Dahl-Jensen, H. Fischer, K. Goto-Azuma, et al. 2008. “High-resolution Greenland Ice Core Data Show Abrupt Climate Change Happens in Few Years.” *Science* 321 (5889): 680–684.

Stiger, M. 2006. “A Folsom Structure in the Colorado Mountains.” *American Antiquity* 71 (2): 321–351.

Stiner, M. C., S. L. Kuhn, S. Weiner, and O. Bar-Yosef. 1995. “Differential Burning, Recrystallization, and Fragmentation of Archaeological Bone.” *Journal of Archaeological Science* 22 (2): 223–237.

Surovell, T. A. 2009. *Toward a Behavioral Ecology of Lithic Technology: Cases from Paleoindian Archaeology*. Tucson: University of Arizona Press.

Surovell, T. A., J. R. Boyd, C. V. Haynes, Jr, and G. W. Hodgins. 2016. “On the Dating of the Folsom Complex and Its Correlation with the Younger Dryas, the End of Clovis, and Megafaunal Extinction.” *PaleoAmerica* 2 (2): 81–89.

Surovell, T. A., and N. M. Waguespack. 2007. “Folsom Hearth-centered Use of Space at Barger Gulch, Locality B.” In *Frontiers in Colorado Paleoindian Archaeology: From the Dent Site to the Rocky Mountains*, edited by R. S. Brunswig and B. Pitblado, 219–259. Boulder: University of Colorado Press.

Surovell, T. A., N. M. Waguespack, M. Kornfeld, and G. C. Frison. 2001. “Barger Gulch Locality B: A Folsom Site in Middle Park, Colorado.” *Current Research in the Pleistocene* 18: 58–60.

Surovell, T. A., N. M. Waguespack, M. Kornfeld, and G. C. Frison. 2003. *The First Five Field Seasons at Barger Gulch, Locality B, Middle Park, Colorado*. Laramie: Technical Report No. 26, George C. Frison Institute of Archaeology and Anthropology, University of Wyoming.

Surovell, T. A., N. M. Waguespack, J. H. Mayer, M. Kornfeld, and G. C. Frison. 2005. “Shallow Site Archaeology: Artifact Dispersal, Stratigraphy, and Radiocarbon Dating at the Barger Gulch Locality B Folsom Site, Middle Park, Colorado.” *Geoarchaeology* 20 (6): 627–649.

Taché, K., and J. P. Hart. 2013. “Chronometric Hygiene of Radiocarbon Databases for Early Durable Cooking Vessel Technologies in Northeastern North America.” *American Antiquity* 78 (2): 359–372.

Taylor, R. E., C. V. Haynes, Jr, and M. Stuiver. 1996. “Clovis and Folsom Age Estimates: Stratigraphic Context and Radiocarbon Calibration.” *Antiquity* 70: 515–525.

Taylor, R. E., C. V. Haynes, Jr, and M. Stuiver. 1996a. “Clovis and Folsom Age Estimates: Stratigraphic Context and Radiocarbon Calibration.” *Antiquity* 70: 515–525.

Taylor, R. E., C. V. Haynes, Jr, and M. Stuiver. 1996b. Development and Extension of the Calibration of the Radiocarbon Time Scale: Archaeological Applications. *Quaternary Science Reviews* 15: 655-668.

Traylor, D., L. Hubbell, N. Wood, and B. Fiedler. 1990. *The 1977 La Mesa Fire Study: An Investigation of Fire and Fire Suppression Impact on Cultural Resources in Bandelier National Monument*. Santa Fe: Southwest Cultural Resources Center, Professional. Papers Number 28.

Waguespack, N. M., and T. A. Surovell. 2014. “A Simple Method for Identifying Households Using Lithic Assemblages: A Case Study from a Folsom Campsite in Middle Park, Colorado.” In *Lithics in the West*, edited by D. H. MacDonald, P. L. Yu, and W. Andrefsky, 35–49. Missoula: University of Montana Press.

Waters, M. R., T. W. Stafford, and D. L. Carlson. 2020. “The Age of Clovis—13,050 to 12,750 cal yr BP.” *Science Advances* 6: eaaz0455.

Wilmsen, E. N., and F. H. Roberts, Jr. 1978. *Lindenmeier, 1934-1974: Concluding Report on Investigations*. Washington DC: Smithsonian Contributions to Anthropology.

Wormington, H. M. 1957. *Ancient Man in North America*. Denver: Denver Museum of Natural History.

Zazzo, A., M. Lebon, L. Chiotti, C. Comby, E. Delqué-Količ, R. Nespoulet, and I. Reiche. 2013. "Can We Use Calcined Bones for Radiocarbon Dating the Paleolithic?" *Radiocarbon* 55 (3): 1409–1421.

Zazzo, A., and J.-F. Saliège. 2011. "Radiocarbon Dating of Biological Apatites: A Review." *Palaeogeography, Palaeoclimatology, Palaeoecology* 310 (1–2): 52–61.

Zazzo, A., J.-F. Saliège, M. Lebon, S. Lepetz, and C. Moreau. 2012. "Radiocarbon Dating of Calcined Bones: Insights from Combustion Experiments under Natural Conditions." *Radiocarbon* 54 (3–4): 855–866.