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Spatiotemporal dynamics of the Clovis–Folsom transition

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ABSTRACT

Despite the importance of the Clovis–Folsom transition for understanding the history of western North America, its spatiotemporal dynamics remains unclear. Here we report a three-part study in which we investigated the transition using radiocarbon dates from Clovis and Folsom sites. In the first part of the study, we used dates from Folsom site-phases to determine when and where Folsom originated. In the second part of the study, we employed Clovis and Folsom dates in analyses designed to determine whether Folsom spread via demic diffusion or cultural diffusion. In the third part of the study we investigated the velocity of the Clovis–Folsom transition. The analyses suggest that Folsom first appeared around 12,800 calBP in the northern High Plains and spread north and south from there. They also suggest that the spread of Folsom was, at least in part, the result of population expansion. In addition, the analyses indicate that the spread of Folsom was relatively fast for a prehistoric diffusion but well below the maximum velocity that has been estimated for such events. These findings, in turn, have implications for the hypotheses that have been put forward to explain the Clovis–Folsom transition. They refute the idea that the Clovis–Folsom transition resulted from an extraterrestrial impact over northern North America at 12,900 ± 100 calBP but are consistent with the alternative proposal that the transition was a response to climate-driven environmental change.

1. Introduction

The transition from Clovis to Folsom is an important event in the prehistory of western North America. The transition began shortly after 13,000 calendar years before present (calBP) and involved a number of alterations in behavior. Perhaps the most conspicuous of these was a change in projectile points: Folsom points are different in shape, tend to be smaller, and have more invasive channel flakes compared with Clovis points. Other important technological changes concern production techniques and toolkit structure. Clovis tools were produced using both biface and blade reduction, whereas Folsom tools were manufactured using only biface reduction (Bradley, 1993). Folsom toolkits were more diverse than their Clovis counterparts, commonly including large numbers of formal end scrapers (Collins, 1999) and occasionally ultrathin bifaces and radial-break tools (Frison and Bradley, 1980; Root et al., 1999). In addition to these technological changes, the transition involved shifts in hunting practices and land use. Available evidence suggests that Clovis hunters exploited a wide range of game, including mammoth, mastodon, bison, and caribou (Grayson and Meltzer, 2002; Waguespack and Surovell, 2003; Cannon and Meltzer, 2004; Surovell and Waguespack, 2009). In contrast, Folsom hunters appear to have specialized in the hunting of bison (Amick, 1994; MacDonald, 1998). This difference may be due to the extinction of the majority of North American megafaunal species at the end of the Pleistocene. However, bison were not the only large game available to Folsom Paleoindians, so it is unlikely that the extinction of the megafauna fully explains the shift in hunting practices between Clovis and Folsom. With regard to land use, caches of lithic materials are well known from the Clovis period but have not been recorded for the succeeding Folsom period (Collins, 1999). In addition, where Clovis and Folsom co-occur in space, Folsom points have been recovered in much greater numbers than Clovis points (Collard et al., 2008). Both lines of evidence suggest that Clovis and Folsom Paleoindians used the landscape differently.

Whereas the behavioral changes involved in the Clovis–Folsom transition are relatively well understood, its spatiotemporal

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dynamics remain unclear. Here we report a study in which we investigated this issue using radiocarbon dates from Clovis and Folsom sites. In the first part of the study, we used dates from Folsom site-phases to determine when and where Folsom originated. We then employed Clovis and Folsom dates in analyses designed to determine whether Folsom spread via demic diffusion or cultural diffusion. In the third part of the study, we used the Folsom dates to investigate the velocity of the transition.

2. When and where did Folsom originate?

To understand the Clovis–Folsom transition it is necessary to know when and where Folsom first appeared. Surprisingly, however, neither Folsom's first appearance nor its center of origin has been formally investigated. Researchers have speculated about both (Boldurian and Cotter, 1999; Wormington, 1957), but so far no attempt has been made to establish them analytically. To rectify this situation, we collated the available radiocarbon dates from Folsom sites, calibrated them, and then carried out two analyses.

The dates were obtained from a number of different sources (Table 1). We included only dates with secure associations between dated organic material and diagnostic Folsom projectile points. Following Pinhasi et al. (2005), we excluded uncalibrated dates with standard errors in excess of 200 years. We used pooled mean dates for site-phases with multiple radiocarbon assays. We did this to prevent site-phases with multiple dates from biasing the results. Where a pooled mean date was not available from the literature, we calculated one using Calib 5.1 (Stuiver and Reimer, 1993). In total, our Folsom dataset included 13 pooled mean dates. Three of the sites in our sample have multiple Folsom site-phases (Cooper, Lubbock Lake, and MacHaffie). In these cases we employed only the oldest Folsom site-phase in our analyses. The approximate locations of the sites are shown in Fig. 1.

We calibrated the single and pooled mean dates with the downloadable version of CalPal using the CalPal-2007$_{\text{Hulu}}$ calibration curve (Weninger and Jöris, 2008; Weninger et al., 2007).

In the first analysis, we employed Pinhasi et al.'s (2005) method for identifying a center of origin from radiocarbon dates. In this method, a site is designated as the origin and its distance from each of the other sites computed. Thereafter, the correlation between the distances and the ages of the other sites is measured. This procedure is repeated until all the sites have served as the origin. The final step of the method involves comparing the correlation coefficients. The site that yields the highest negative correlation coefficient when it is designated the origin is deemed to be the most likely center of origin (Hamilton and Buchanan, 2007). Distances among sites were measured as great-circle arcs. The latter were obtained from the latitude and longitude coordinates associated with each site. Minitab 15 was used to carry out the analysis.

In the second analysis, we measured the correlation between the sites' latitudes and the correlation coefficients obtained in the previous analysis. The goal of this analysis was to determine the direction and slope of the spatial gradient emanating from the origin. Again, the analysis was carried out with Minitab 15.

The results of the first analysis indicate that Hell Gap, Wyoming, is the most likely of the sites in the sample to be the center of origin for Folsom. When Hell Gap was designated as the origin, the correlation coefficient was -0.77. The other correlation coefficients ranged from -0.76 to 0.40. Hell Gap dates to 12,800 ± 150 calBP. Thus, this analysis suggests that Folsom originated around 12,800 calBP in the northern High Plains.

When we measured the correlation between the sites' latitudes and the correlation coefficients, we obtained a correlation coefficient of -0.75 and a p-value of <0.001 (Fig. 2). This strong, negative relationship indicates that the northern Folsom sites are generally older than the southern Folsom sites. Like the results of the

Table 1
Clovis and Folsom radiocarbon dates and calibrated ages used in the analyses. Uncalibrated dates marked with an asterisk are pooled mean dates that were calculated specifically for this study. Where necessary, uncalibrated dates were rounded up before calibration.

Site	State	Culture	# dates	uncalBP	±1σ	calBP	±1σ	Source(s) of uncal date
Agate Basin	WY	Folsom	3	10,690	70	12,690	50	Frison and Stanford (1982), Holliday (2000)
Barger Gulch B	CO	Folsom	2	10,540	35	12,600	50	Surovell (2003)
Black Mountain	CO	Folsom	1	10,631	84	12,630	80	Jodry et al. (1996)
Blackwater Draw	NM	Folsom	5	10,290	90	12,130	230	Taylor et al. (1996)
Bobtail Wolf	ND	Folsom	4	10,608*	110	12,530	160	Root et al. (1996)
Bonfire Shelter	TX	Folsom	4	10,090	100	11,680	230	Cooper and Byerly (2005), Holliday (2000)
Cooper	OK	Folsom	1	10,600	40	12,650	40	Johnson and Bement (2009)
Folsom	NM	Folsom	6	10,490	20	12,510	90	Meltzer (2006)
Hanson	WY	Folsom	4	10,260	90	12,060	230	Holliday (2000)
Hell Gap	WY	Folsom	2	10,820	170	12,800	150	Haynes et al. (1992), Haynes (2009)
Indian Creek	MT	Folsom	2	10,420*	59	12,360	160	Davis and Baumler (2000)
Lindenmeier	CO	Folsom	3	10,660	60	12,680	50	Holliday (2000)
Lubbock Lake (Area 6)	TX	Folsom	2	10,329*	72	12,230	180	Holliday (2000)
MacHaffie	MT	Folsom	1	10,390	40	12,330	150	Davis et al. (2002)
Mountaineer	CO	Folsom	4	10,407*	17	12,360	140	Stiger (2006)
Waugh	OK	Folsom	2	10,390	60	12,330	170	Hofman (1995)
Anzick	MT	Clovis	2	11,040	35	12,950	70	Waters and Stafford (2007)
Blackwater Draw	NM	Clovis	1	10,914	72	12,850	70	Haynes (2008)
Casper	WY	Clovis	1	11,190	50	13,120	70	Frison (2000)
Colby	WY	Clovis	2	10,870	20	12,800	40	Waters and Stafford (2007)
Dent	CO	Clovis	3	10,990	25	12,880	60	Waters and Stafford (2007)
Domebo	OK	Clovis	1	10,960	30	12,860	60	Waters and Stafford (2007)
Indian Creek	MT	Clovis	1	10,980	110	12,910	110	Waters and Stafford (2007)
Jake Bluff	OK	Clovis	3	10,765	25	12,730	20	Waters and Stafford (2007)
Kanorado	KS	Clovis	2	10,980	40	12,880	70	Waters and Stafford (2007)
Lange-Ferguson	SD	Clovis	3	11,080	40	12,980	60	Waters and Stafford (2007)
Lehner	AZ	Clovis	12	10,950	40	12,850	70	Waters and Stafford (2007)
Lubbock Lake	TX	Clovis	2	11,100	60	12,990	70	Waters and Stafford (2007)
Murray Springs	AZ	Clovis	8	10,885	50	12,820	60	Waters and Stafford (2007)
Sheaman	WY	Clovis	3	11,224	50	13,150	60	Haynes (2008)

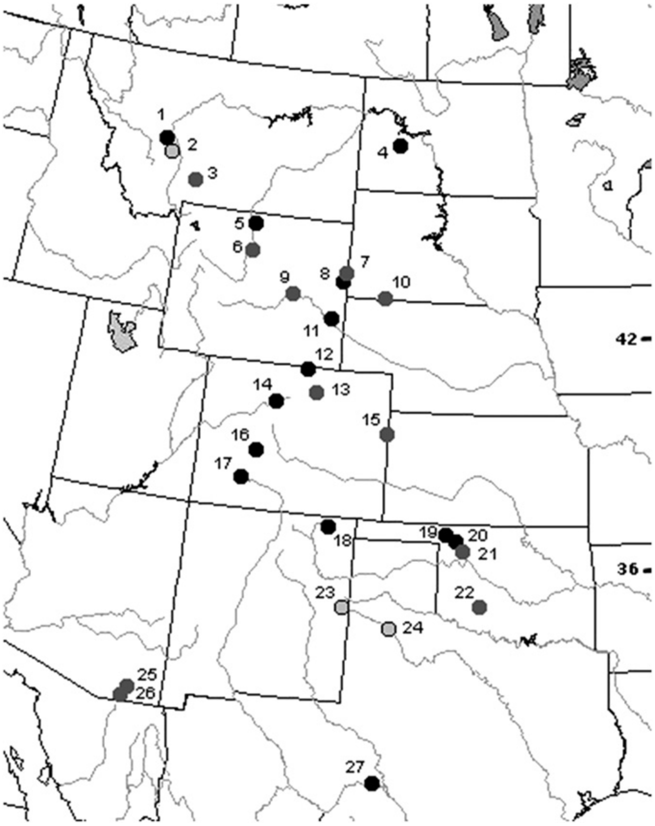

Fig. 1. Approximate locations of Clovis and Folsom sites used in the analyses. Map created with MapPad 2.0 (NOAA, 1999). Black dots indicate Folsom sites, gray dots indicate Clovis sites, and light gray dots with black outer rings indicate sites where both Clovis and Folsom have been radiocarbon dated. Key to sites: 1, MacHaffie; 2, Indian Creek; 3, Anzick; 4, Bobtail Wolf; 5, Hanson; 6, Colby; 7, Sheaman; 8, Agate Basin; 9, Casper; 10, Lange-Ferguson; 11, Hell Gap; 12, Lindenmeier; 13, Dent; 14, Barger Gulch B; 15, Kanorado; 16, Mountaineer; 17, Black Mountain; 18, Folsom; 19, Waugh; 20, Cooper; 21, Jake Bluff; 22, Domebo; 23, Blackwater Draw; 24, Lubbock Lake; 25, Murray Springs; 26, Lehner; 27, Bonfire Shelter.

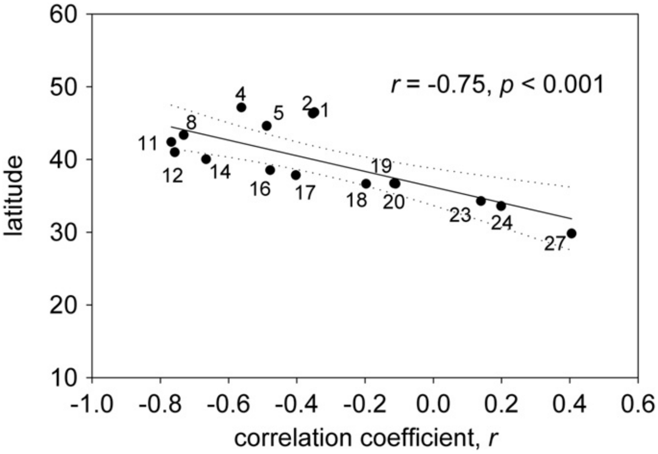

Fig. 2. Plot of latitude by correlation coefficient associated with the regression of calibrated age and distance from origin using each Folsom site as a potential origin in order to identify a center of origin for Folsom. See Fig. 1 caption for key to sites.

preceding analysis, this supports the idea that Folsom originated in the northern High Plains and spread north and south from there.

3. Was Folsom's spread the result of demic diffusion or cultural diffusion?

Archaeologists have identified two processes that have the potential to explain large-scale transitions in prehistory: demic diffusion (movement of people) and cultural diffusion (movement of ideas). However, determining which of these processes is responsible for a given transition can be problematic. Cultural diffusion is often assumed to be faster than demic diffusion because social learning can occur both within and across generations, whereas population growth can occur only across generations. But recent work has shown that demic diffusion can be rapid if colonizing populations have niche preferences that limit dispersal through ecological corridors such as river valleys (Campos et al., 2006; Hamilton and Buchanan, 2007; Rodriguez-Iturbe et al., 2009). Despite these problems, it is possible to generate some expectations that can be used to differentiate the two processes archaeologically. Distinguishing between demic diffusion and cultural diffusion in the archaeological record is problematic only where there is evidence of a diffusive spread of a novel trait into a region that has evidence of a population already in place. In cases where there is no evidence of a pre-existing population, the diffusive process must have been demic, as only an immigrant population could have introduced the trait into the region. Currently, it is unclear whether or not Clovis and Folsom overlap (Haynes, 1984; Taylor et al., 1996). With this in mind, we compared the distributions of the available radiocarbon dates for Clovis and Folsom to identify periods of overlap and possible hiatuses.

The Clovis dates we used come from site-phases that contain diagnostic Clovis artifacts and are located within the geographic range of Folsom (Table 1, Fig. 1). Most of these dates were obtained from Hamilton and Buchanan (2007). We supplemented the dates from the latter source with two recently published Clovis dates, one from the Blackwater Draw site, New Mexico, and the other from the Sheaman site, Wyoming (Haynes, 2008). The Folsom dates were the same as those used in the previous two analyses. All the dates were calibrated with the downloadable version of CalPal using the CalPal-2007$_{\text{Hulu}}$ calibration curve (Weninger and Jöris, 2008; Weninger et al., 2007).

We began by plotting the two sets of calibrated dates against latitude. We employed the 95% standard errors for the dates to be conservative with respect to the likelihood of supporting the demic diffusion hypothesis. Subsequently, we employed an approach that has been used recently to address questions regarding prehistoric demography—summed probability distribution analysis (Buchanan et al., 2008; Collard et al., 2008, 2010; Erlandson et al., 2001; Gamble et al., 2004, 2005; Gkiasta et al., 2003; Shennan and Edinborough, 2007). The rationale for this approach is that, because the number of site-phases in a given time period can be expected to relate monotonically to population size, changes in summed probability distributions of calibrated ^{14}C dates derived from different site-phases serve as a proxy for changes in population size. Based on the dates-by-latitude plot, we generated two summed probability distributions, one for Clovis and Folsom dates from sites between 48°N and 36°N latitude and one for Clovis and Folsom dates from sites below 36°N.

The dates-by-latitude plot indicates that Clovis and Folsom overlapped in time between 48°N and 36°N latitude (Fig. 3). In this region there are eight Folsom site-phases that overlap with Clovis: Agate Basin, Barger Gulch B, Bobtail Wolf, Black Mountain, Cooper, Folsom, Hell Gap, and Lindenmeier. Below 36°N, Clovis and Folsom sites do not overlap temporally. Thus, the dates-by-latitude analysis suggests that between 48°N and 36°N latitude Folsom could have spread via demic diffusion or cultural diffusion, but below 36°N it must have spread via demic diffusion.

The 48–36°N summed probability distribution shows continuous occupation of this region, whereas the <36°N summed probability distribution shows a hiatus in occupation of at least a century beginning around 12,700 calBP (Fig. 4). As such, this analysis is consistent with the previous one. It also suggests that between 48°N

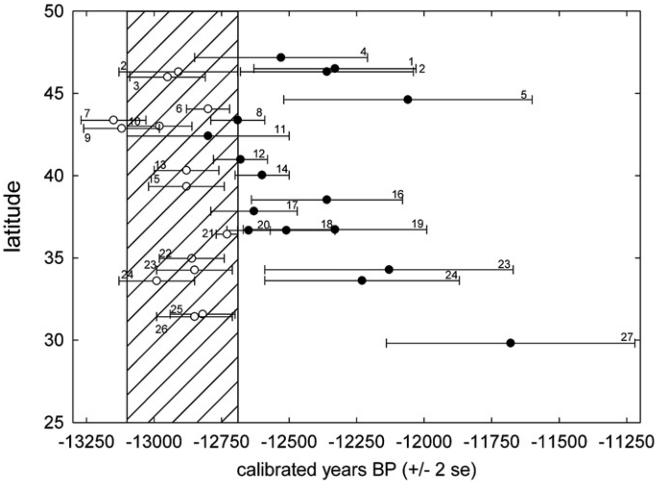

Fig. 3. Plot of Clovis (open circles) and Folsom (filled circles) calibrated radiocarbon ages with two standard errors (whiskers) by latitude and calibrated years before present. The diagonally hatched box indicates Clovis and Folsom temporal overlap. See Fig. 1 caption for key to sites.

and 36°N Folsom could have spread via demic diffusion or cultural diffusion, but below 36°N it must have spread via demic diffusion.

A possible problem with the dates-by-latitude and summed probability distribution analyses is the existence of a “cliff” in the calibration curve between 12,900 and 12,700 calBP (Hajdas et al., 2006; Muscheler et al., 2008). Caused by rapid increases in atmospheric δ^{14}C, such calibration curve anomalies are problematic because they have the potential to artificially reduce dates’ error ranges. This is significant in relation to the dates-by-latitude and summed probability distribution analyses because it increases the likelihood of finding a hiatus between Clovis and Folsom. To evaluate this possibility, we used a randomization-based version of the Mann-Whitney U test to assess whether the pre-calibration error ranges of the dates that fall in the 12,900–12,700 calBP period are significantly larger than the dates’ post-calibration error ranges. The two sets of error ranges were not statistically different (5000 iterations, $U = 1.7801$, $p = 0.2020$). This indicates that the cliff in the calibration curve between 12,900 and 12,700 calBP did not artificially reduce the dates’ error ranges, and therefore did not bias the results of the dates-by-latitude and summed probability distribution analyses.

4. How fast was the Folsom diffusion compared to other diffusions in prehistory?

Lastly, we investigated the transition’s velocity as represented by the average rate at which Folsom occupations appeared throughout their range. To estimate the average rate of Folsom’s diffusion, we employed Fort’s inverse regression technique (Fort, 2003; Fort and Mendez, 2002; Fort et al., 2004a,b; Hamilton and Buchanan, 2007; Pinhasi et al., 2005). In this technique, velocity is the inverse slope of the OLS linear regression of age by distance. The Folsom dates were the same as those used in the previous analyses. As before, we calibrated the dates with the downloadable version of CalPal using the CalPal-2007$_{\text{Hulu}}$ calibration curve (Weninger and Jöris, 2008; Weninger et al., 2007). Having obtained an estimate of the velocity of Folsom’s diffusion, we compared it to rates for a number of other prehistoric cultural diffusions that have been estimated with radiocarbon dates.

We found the velocity of Folsom’s northward diffusion from Hell Gap to be 1.9 km per year (95% CIs: 1.2–2.6 km per year) and the velocity of its southward diffusion from Hell Gap to be 1.4 km per year (95% CIs: 1.2–1.7 km per year). The overall velocity of the Folsom diffusion was 1.6 km per year (95% CIs: 1.4–1.9 km per year). Using a resampling procedure to counter the effects of the relatively small size of the sample of dates increased the latter rate slightly to 1.7 km per year (95% CI: 1.4–2.0 km per year).

All the diffusion velocities we obtained for Folsom are considerably slower than the velocity that has been estimated for the expansion of Clovis across North America a few centuries earlier. According to Hamilton and Buchanan (2007), the rate of Clovis’ spread was 5.1–7.6 km per year (95% CIs: 1.9–14.1 km per year). So, even in the region in which Folsom may have spread by cultural diffusion, its spread was significantly slower than the spread of Clovis. In contrast, the spread of Folsom was considerably faster than both the initial colonization of Europe by anatomically modern humans and the post-Late Glacial Maximum recolonization of northern Europe. The former is estimated to have occurred at about 0.4 km per year (Mellars, 2006), the latter at around 0.8 km per year (Fort et al., 2004b). The diffusion of Folsom was also faster than the spread of the Neolithic across Europe. The rate at which the latter occurred has been estimated to be 0.6–1.3 km per year (Fort et al., 2004a; Pinhasi et al., 2005). Thus, the velocity of the spread of Folsom was relatively fast but nowhere close to the maximum that has been estimated for prehistoric diffusion events using radiocarbon dates.

5. Discussion

The analyses reported here suggest that the Clovis–Folsom transition began around 12,800 calBP on the northern High Plains and spread north and south from there. They also suggest that the transition was mediated, at least in part, by demic diffusion. It is unclear whether in the northern Plains (between 48°N and 36°N latitude) the replacement of Clovis by Folsom involved demic diffusion, cultural diffusion, or a combination of the two, but current

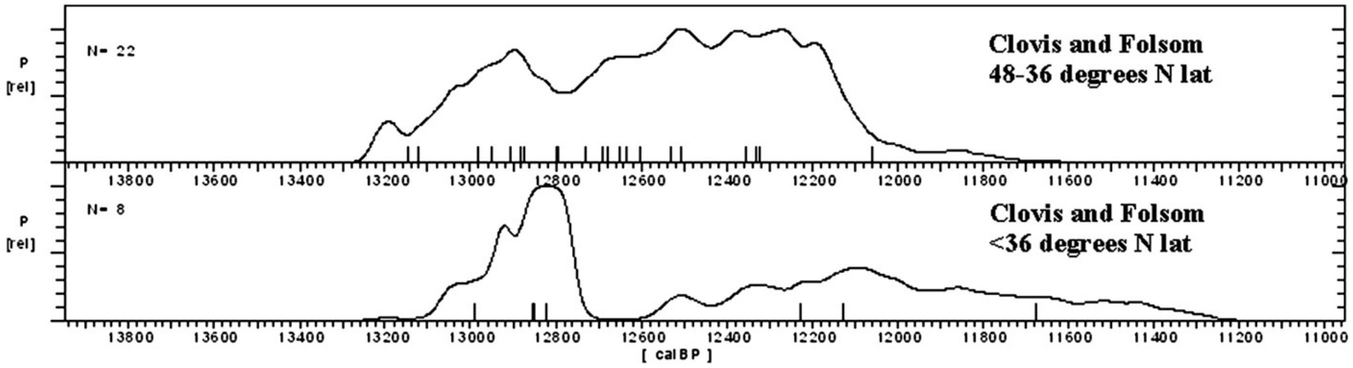

Fig. 4. Summed probability distribution plots of Clovis and Folsom calibrated ages by latitudinal band.

data suggest that the spread of Folsom south of 36°N was likely the result of demic diffusion. Lastly, the analyses suggest that the Clovis–Folsom transition occurred at a rate of around 1.7 km per year.

The main potential shortcoming of the analyses reported here is the size of the samples of Clovis and Folsom dates we used. Both samples are considerably smaller than we would like. However, our samples are of a similar size to the samples of radiocarbon dates used in a number of comparable Paleoindian studies published in the last few years (e.g. Hamilton and Buchanan, 2007; Waters and Stafford, 2007). Moreover, recently some researchers have made strong claims about the Clovis–Folsom transition in high-profile journals without analyzing the available radiocarbon data (or any other archaeological evidence for that matter) (e.g. Firestone et al., 2007; Kennett et al., 2009). So, the results of our analyses are no less robust than the results of several recent Paleoindian studies and considerably more robust than those of several others.

Our analyses not only provide a model of the Clovis–Folsom transition that makes clear, quantitative predications about the archaeological record that can be tested with additional research, they also have implications for the debate about the causes of the Clovis–Folsom transition. The conventional explanation for the transition focuses on environmental change (Haynes, 1964; Irwin-Williams and Haynes, 1970). According to this hypothesis, Clovis was modified in response to climate-driven environmental changes, and the result of the modifications was the culture we refer to as Folsom. Recently, Firestone et al. (2007) have outlined a competing explanation for the Clovis–Folsom transition. They contend that one or more large low-density extraterrestrial objects impacted or exploded over northern North America 12,900 ± 100 calBP with massive effects. This impact, they suggest, was accompanied by a high-temperature shock wave, changes in pressure that would have resulted in hurricane-force winds, and extensive groundcover burning from the impact and superheated ejecta. Together, these caused a continent-wide environmental collapse, which in turn resulted in the extinction of the North American megafauna, and population decline and major cultural changes among the Paleoindians. The Clovis–Folsom transition is one of the cultural changes that Firestone et al. (2007) claim resulted from the environmental collapse caused by the impact event.

The environmental change hypothesis and the extraterrestrial impact hypothesis make different predictions about Folsom's center of origin and the co-occurrence of Clovis and Folsom. Evidence pertaining to environmental change in the Folsom region immediately before and during the Clovis–Folsom transition is limited at the moment. However, a recent analysis of pollen from localities in North Dakota, South Dakota, and Texas suggests that between 13,400 and 11,300 calBP the Great Plains, which comprise the bulk of the Folsom region, generally became more open (Meltzer and Holliday, 2010). This analysis also suggests that the change to a more open landscape began several hundred years earlier in the Northern Plains than it did in the Southern Plains (Meltzer and Holliday, 2010). As such, the environmental change hypothesis predicts that Folsom would have developed in the north and spread southwards. In addition, because it contends that Folsom developed from Clovis, the environmental change hypothesis also predicts that Clovis and Folsom would have overlapped in time in the north but not necessarily in the south. The extraterrestrial impact hypothesis' predictions regarding Folsom's center of origin and the co-occurrence of Clovis and Folsom are the opposite of the predictions of the environmental change hypothesis. Given that the effects of the impact event would have been more pronounced in the northern part of the continent than in the south, the extraterrestrial impact hypothesis predicts that Folsom would have developed in the south and spread northward, and that if Clovis and Folsom overlapped in time anywhere they would have done so in the south and not the north.

The results of our study clearly falsify the predictions of the extraterrestrial impact hypothesis. Both the finding that the northern Folsom sites are earlier than the southern Folsom sites, and the finding that there is a hiatus between Clovis and Folsom in the south of the latter's range as well as spatial and temporal overlap of Clovis and Folsom in the north run counter to the predictions of the extraterrestrial impact hypothesis. In contrast, these findings are consistent with the predictions of the environmental change hypothesis. Thus, our study not only clarifies the spatiotemporal dynamics of the Clovis–Folsom transition but also sheds light on the transition's likely causes.

With regard to further research, a couple of tasks suggest themselves. One is to date more Folsom sites. Although, as we pointed out earlier, our samples of radiocarbon dates are in line with those used in previous studies, there is clearly a pressing need for radiocarbon dates from more Folsom sites. Currently, securely dated Folsom sites occur only in the Great Plains and Rocky Mountains. However, there are Folsom sites in several other regions that are, as yet, undated (Amick, 1994; Holliday et al., 2006; Judge, 1973). As far as assessing the validity of the findings of the study reported here are concerned, the Folsom sites of the Rio Grande Valley would be a particularly good focus of a dating project. Given their southerly location, they have the potential to provide a strong test of our findings regarding not only the origin and direction of spread of Folsom but also the velocity of the Clovis–Folsom transition.

The other obvious task is to determine why the Folsom diffusion was slower than the Clovis one. Perhaps the most obvious hypothesis is that Clovis populations spread through a landscape previously unoccupied by humans, whereas the Folsom spread occurred in the context of competing Clovis populations. However, while competition with Clovis populations may account for the relatively slow speed of the Folsom diffusion above 36°N latitude, it cannot explain the relatively slow speed of the diffusion below 36°N latitude, given that our analyses show that below 36°N latitude Clovis disappeared 200–300 years before Folsom appeared. Another possibility is that Folsom's rate of spread is linked to the spatiotemporal dynamics of the aforementioned episode of environmental change. If Folsom is an adaptation to the opening of the landscape between 13,400 and 11,300 calBP, then its rate of spread might be expected to have been governed by the speed at which that opening occurred. This hypothesis makes the testable prediction that Folsom should appear shortly after open habitat communities become established in different parts of western North America.

6. Conclusions

The radiocarbon date-based analyses reported here shed new light on the spatiotemporal dynamics of the Clovis–Folsom transition. First, they suggest that Folsom appeared around 12,800 calBP on the northeast Plains and spread north, south, and west from there. Second, they suggest that the spread of Folsom was, at least in part, the result of population expansion. The replacement of Clovis by Folsom in the northern Plains could have involved demic diffusion, cultural diffusion, or some combination of the two. But the existence of a hiatus between Clovis and Folsom south of 36°N indicates that the spread of Folsom into that region must have been a consequence of population expansion. Third, the analyses suggest that the Clovis–Folsom transition occurred at a rate of about 1.7 km per year, which is relatively fast for a prehistoric diffusion but still well below the maximum velocity that has been estimated for such events. These findings, in turn, have implications for the hypotheses that have been put forward to explain the Clovis–Folsom transition. They refute the idea that the Clovis–Folsom transition resulted from an extraterrestrial impact over northern North America at 12,900 ± 100 calBP (Firestone et al., 2007), but are consistent with the alternative hypothesis, which contends that the transition was the result of Clovis Paleoindians adjusting their behavior to deal with climate-driven environmental changes (Haynes, 1964; Irwin-Williams and Haynes, 1970). Needless to say, these conclusions are only as reliable as the currently available data, and should be re-assessed as new data become available.

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