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Article

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We use three proxy methods to test whether climate change associated with the Younger Dryas (YD) from ca. 12,900 to 11,600 cal BP affected human populations in North America: (1) frequency analyses of Paleoindian projectile points from across the continent, (2) assemblage data from 11 Paleoindian quarry sites in the southeastern United States, and (3) summed probability analyses (SPA) of radiocarbon dates from across North America and a number of regions in the northern hemisphere of the Old World. The results of each analysis suggest that a significant decline or reorganization of human population occurred during the initial centuries of the Younger Dryas, albeit playing out somewhat differently in different regions. Settings formerly heavily utilized, such as stone quarries in the southeast, were apparently no longer heavily utilized, while over large areas a substantial decline in the numbers of diagnostic projectile points and radiocarbon estimations occurs. In the latter half of the YD a rebound in population or settlement is indicated by the projectile point and SPA datasets in a number of areas.

Introduction

How abrupt, large-magnitude climate changes affect different species, including our own, is a subject of considerable research interest at present, given the rapid climate change our planet appears to be undergoing. The most extreme cooling event since the last Glacial Maximum is the Younger Dryas (YD), which began about 12,900 BP (all dates are in calendar or calibrated years before present or BP, unless otherwise noted) and persisted for approximately 1300 years (Alley 2000). Whether a significant decline or reorganization in human population occurred at the start of the Younger Dryas cold period ca. 12,900 BP has been the subject of appreciable recent debate (cf., Firestone, et al. 2007, Anderson et al. 2008a, b, 2009a; Buchanan et al. 2008; Collard et al 2008; Meltzer 2009). While the reason for the onset of YD is subject to ongoing debate, that changes in climate and biota occurred in many areas is widely accepted, although how this played out in different regions, and among human populations, is not well understood. In this paper, we explore what happened to human populations in North America during the Younger Dryas using three somewhat interrelated lines of evidence: (1) Paleoindian projectile point frequency data; 2) usage patterns at 13,000-year-old lithic quarries, and 3) summed probabilities analyses of radiocarbon dates.

Climate and Culture Change: Basic Assumptions

An extensive literature documents how changes in climate affect biotic communities and human societies. Climate parameters such as the type, rate, and magnitude of change shape whether cultural change was major or minor and whether population bottlenecks or extinctions occurred. Of particular importance to human societies were how food supplies were affected, and whether there were changes in the incidence and intensity of epidemics, civil unrest, or warfare (e.g., Anderson et al. 2007; Fagan 2000, 2004; Rosen 2007; Zhang et al. 2007). A recent episode of global cooling of shorter duration than the YD was the Little Ice Age (LIA), which occurred from the 1300s to the 1800s AD. The LIA had a significant effect on human populations worldwide, with substantial population decline in some areas brought about by crop failure, civil unrest, warfare, and epidemic disease, (e.g., Fagan 2000; Kremer 1993; Zhang et al. 2007). The YD occurred when most human populations had not yet made the transition to agricultural food production, or developed organizationally large and complex societies, which were presumably more vulnerable to, but also better able to buffer, the effects of climate change. Abrupt swings in climate have occurred many times since our species emerged ca. 150-300 kyr BP (Labeyrie et al. 2003; National Research Council 2002). As such, resolving how the YD affected hunting-gathering societies is also important for understanding earlier periods of prehistory.

Analysis Results (1): Clovis and Post-Clovis Projectile Point Frequencies in North America

Paleoindian projectile points across North America occur within a number of geographically widespread, presumably contemporaneous stylistic horizons (Figure 1). The 'Clovis horizon' is dated to ca. 13,050 to 12,900 BP, just prior to the YD, and is characterized by classic Clovis points which typically have flat to weakly indented bases and fluting only part way up the blade (Waters and Stafford 2007). These were replaced during the early part of the Younger Dryas by a 'Full-Fluted horizon' characterized by points with deeply indented bases and lengthy flutes of the Folsom, Gainey, Barnes, Cumberland, and Redstone types, displaying what Goodyear (2006) has called 'instrument assisted' fluting either by indirect percussion or pressure. These points were in turn replaced by a wide range of unfluted forms later in the Younger Dryas. While the post-Clovis stratigraphic placement and absolute dating of the Folsom type is well established, the temporal range of some of the other full-fluted and some of the unfluted forms is less well documented in some regions, and is made on stylistic and technological grounds.

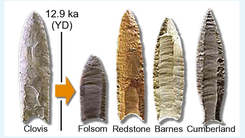

Figure 1. Clovis (weakly fluted) and Immediate Post-Clovis (fully fluted) projectile point forms in North America.

Figure 2. PIDBA Main Page at http://pidba.utk.edu

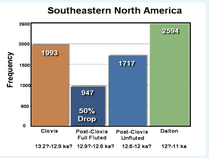

Figure 3. Graph showing number of points of each major stylistic horizon from Clovis to Dalton found in the Southeastern U.S.

The Paleoindian Database of the Americas, or PIDBA, is available on-line (Figure 2), and integrates database and GIS technology to make locational data on nearly 30,000 projectile points, attribute data on over 15,000 artifacts, and image data on nearly 10,000 Paleoindian era points from across North America. These data indicate a substantial drop in the numbers of artifacts and presumably people in many parts of North America during the early centuries of the Younger Dryas. In the Southeastern U.S., this decline is particularly dramatic, on the order of 50% (Figure 3). The pattern of post-Clovis decline in eastern North America appears much the same in the central part of the continent in an area defined by twenty-one states and provinces in the Great Basin, Rocky Mountains, and Great Plains. A decline of ca. 37% occurs between Clovis and presumably related fluted forms (n=4020) and subsequent Folsom and presumably related Midland and Sedgwick types (n=2527) (Figures 4, 5). Pertinent questions in such analyses, of course, include whether changes in numbers of points represent: 1) changes in numbers of people or settlement patterns; 2) a reorganization of technology; 3) biases in the collection of points; 4) errors in point identification or dating; 5) changes in the duration of point usage, both for an individual tool and for the point style; and 6) the effect of geological factors that may affect artifact deposition and preservation. In spite of these concerns, using numbers of sites, artifacts, or radiocarbon dates as a proxy measure of human population is widely used in archaeology (e.g., Miller et al. 2004; Rick 1987; Thomas 2008:440-442).

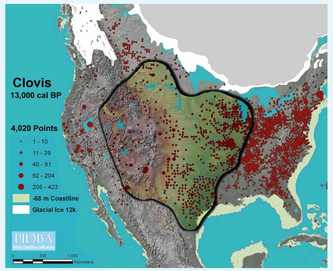

Figure 4. Clovis and presumably related fluted point distributions in the central United States (excluding Folsom). Note the visually greater abundance of these points than Folsom points, shown in Figure 5, in the same area.

Figure 5. Folsom and related point distributions in the central United States. A clear reduction in numbers is evident compared to Clovis incidence in the same area (Figure 4).

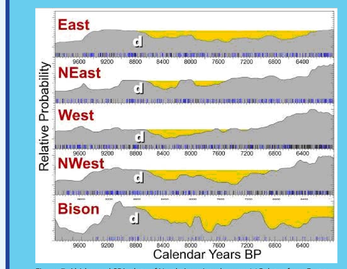

Figure 7. Altithermal SPA plots of North American human 14C dates from East to the Northwest, along with a plot of continental bison dates. All of the declines begin around 8,800 BP, as marked at "d." The short vertical lines along the bottom of each plot represent individual 14C median dates. Calendar years are on the x-axis and the y-axis displays curve amplitudes using a relative scale that applies only to each plot and cannot be used to compare demographic levels between regions.(Data from CARD 2005)

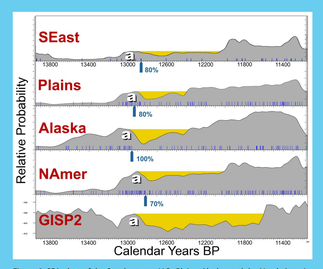

Figure 8. SPA plots of the Southeastern U.S., Plains, Alaska, and the North American continent, with the GISP2 temperature proxy profile for comparative purposes. The occurrence of 14C peaks-and-troughs at the YD onset at "a" matches the one in the GISP2 temperature proxy profile. The apparent declines in the number of 14C dates for 200 years before and after the YD onset are marked by the arrows and range from 70% to 100% (with an uncertainty of about 20%). (Data from Anderson et al. 2004, Buchanan et al. 2008; CARD 2005).

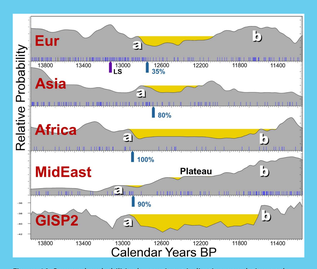

Figure 10. Summed probabilities by continent indicating population peaks-and-troughs at "a" near the YD onset and extending to the start of the Holocene at 'b', with the GISP2 temperature proxy profile for comparative purposes. The arrows mark the beginning of 200 years intervals during which date densities drop by 35% to 100% compared to the previous 200 years. (References for radiocarbon dates employed in Table 2).

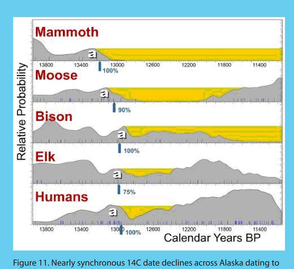

Figure 11. Nearly synchronous 14C date declines across Alaska dating to the YD onset. All species apparently suffered from 75% to 100% declines during the 200 years following each arrow. (Data from Guthrie 2006 and the CARD database).

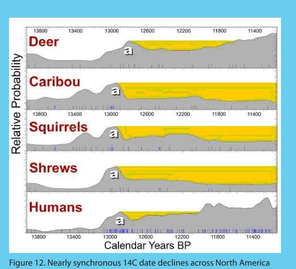

Figure 12. Nearly synchronous 14C date declines across North America at the start of the YD at "a". Data are from the CARD database for deer (including antelope), caribou, squirrels, shrews, and humans.

Analysis Results (2): Southeastern Quarry Assemblages

Examination of archaeological assemblages from 11 major stone quarry sites used extensively during the Clovis era (and for most for much of prehistory thereafter as well) in the southeastern United States indicates immediate post-Clovis, 'Full-Fluted horizon' use of many of these quarries was minimal (Figure 6, Table 1). A major decline in population or reorganization in technology and settlement away from such locations appears to have occurred. Of 11 sites examined, only one (Carson-Conn-Short) and possibly two others (Boyd-Ledford, Sinclair) show much evidence for immediate post-Clovis utilization by makers of Redstone and Cumberland points. Seven other sites have either no evidence of immediate post-Clovis usage (Wells Creek, Adams, Roeder, Ezell, Big Pine Tree), or minor usage (Topper, Williamson, Boyd-Ledford, Thunderbird). The sample encompasses the major known sites. Documenting Clovis and immediate post-Clovis use of quarry sites in the Southeast has not been done quickly or easily, but reflects decades of collection and excavation by avocational and professional archaeologists.

Figure 6. Location of Clovis Quarry Sites Examined in the Southeast.

Site	Site No.	State	Clovis	Immediately Post Clovis	Type of Site	References
Carson-Conn-Short	40Bn190	TN	39 Clovis points 16 Preforms 216 Blade cores	5 Cumberland points 10 Unfluted preforms	Quarry, Workshop, Habitation	Norton & Broster 2008
Wells Creek	40Sw63	TN	18 Clovis points 16 Point fragments 209 Preforms	1 nipple preform?	Workshop, Habitation	Dragoo 1973
Sinclair	40Wv111	TN	Clovis points, Preforms, Blades	Redstone, Beaver Lake	Quarry, Workshop	Broster & Norton 2009
Adams	15Ch90	KY	4 Clovis points 153 Bifaces 555 Blades 140 Blade Cores & Frags.	None	Workshop, Habitation	Sanders 1990 Gramly & Yahnig 1991 Yahnig 2004
Boyd-Ledford	15Ch236	KY	Clovis	Some Cumberland	Quarry, Workshop, Habitation	Freeman et al 1996, Yahnig 2004
Roeder	15Ch482	KY	Blade Technology	None	Quarry, Workshop, Habitation	Freeman et al 1996, Yahnig 2004
Ezell	15Ch483	KY	Blade Technology 30 Blade Cores	None	Quarry, Workshop, Habitation	Freeman et al 1996, Yahnig 2004
Williamson	44Dw1	VA	100+ Clovis points Blades	2 Redstones	Quarry, Workshop, Habitation	McCary 1951, Mulvihy 2003, Peck 2004, Hill 1997
Thunderbird	44Wr11	VA	6 Clovis points Preforms	2 Instrument-assisted points	Workshop, Habitation	Gardner 1974, Johnson 1996
Topper	38Al23	SC	4 Clovis points Preforms Blades	1 Instrument-assisted point	Quarry, Workshop, Habitation	Goodyear & Charles 1984 Goodyear and Steffy 2003 Goodyear, Miller, Smallwood 2007
Big Pine Tree	38Al143	SC	2 Clovis points Preforms Blades	None	Workshop, Habitation	Goodyear 1999

Table 1. Clovis and Immediate Post-Clovis Assemblages at 11 Quarry Locations in the Southeastern United States.

Analysis Results (3): Summed Probability Analyses

To further test a North American population decline following Clovis, we used an analytical method based on radiocarbon dating that involves calibrating relevant 14C determinations and combining the probabilities, also known as summed probabilities distribution analysis (SPA) (Rick 1987; Housley et al. 1997). Major peaks and troughs in the trends are assumed to be proxies for human population magnitude, i.e., more 14C dates generally mean more people, and conversely, fewer dates mean fewer people. As with any analytical tool, SPA has drawbacks, notably collection biases, factors of sample preservation, accuracy of the dates themselves, and what individual dates represent in terms of numbers of people (e.g., Rick, 1987; Surovell and Brantingham 2007). Despite the various biases and inaccuracies, the method provides a preliminary approximation of long-term increases or declines in population levels, especially when large samples are employed. Databases employed in the analyses are referenced or noted in Table 2.

Using 14C dates from Buchanan et al. (2008), we analyzed multiple regions, including the Southeast and Great Plains. Contrary to Buchanan et al., we found an abrupt, statistically significant decline at 12.9 ka, followed 200 to 900 years later by a rebound in the number of dates. The decline at the YD onset was more than 50%, similar in magnitude to the decline in Clovis-Folsom point ratios. While calibration and sampling factors may affect the trends, this abrupt and continuing decline is large and requires explanation.

Altithermal SPA Results for North America (Figure 7)

We used the SPA technique to test whether or not a widely accepted decline in human and bison populations during the Mid-Holocene can be identified using this method (Figure 7). Available dates from the CARD (Canadian Archaeological Radiocarbon Database 2005) database were divided into four groups: the continental Northeast (Eastern Canada and the U.S. Northeast), the Eastern U.S., the Western U.S., and the continental Northwest (Alaska and Western Canada). The results clearly show that from around 9,000 to 8,800 BP, all regions of the continent show a major decline in 14C dates. In addition, a plot of available bison 14C dates (bottom plot) displays a distinct, nearly synchronous decline in summed 14C dates.

Younger Dryas SPA Results for North America (Figure 8)

Southeast: A significant 14C date decline is documented, followed by a rebound in the later YD that continued into the Holocene. The arrow marks a time near "a" after which there are 80% fewer dates (uncertainty of ~20%) for the next 200 years, a decline that compares well to the 50% decline displayed in the point frequency analysis.

Central North America: An SPA analysis was conducted on dates from the same twenty-one states analyzed for Folsom point frequencies. In Figure 8, the "Plains" plot reveals a decline in amplitude just after 12,900 BP at the start of the YD. The arrow indicates the beginning of an 80% decline in 14C dates extending over the next 200 years, and these SPA results support the Clovis-Folsom projectile point declines shown in Figures 4 and 5 for central North America.

Alaska: A large increase in 14C dates is evident just before the YD at "a", followed by a rapid decline in amplitude just afterward. That decline reached its lowest level early in the YD and lasted for about 900 years until the number of dates rebounded in the late YD. The arrow identifies a time in Alaska near "a" after which there are no recorded 14C dates for more than 200 years, suggesting a major bottleneck.

North America: For the entire North American continent there is a large increase in 14C dates just before the YD at "a" followed by a rapid decline in amplitude that reached its lowest level early in the YD and continued for about 900 years. The arrow marks a 200-year-long 80% decline in 14C dates, implying a serious drop in population The GISP2 temperature proxy profile Greenland matches reasonably well with the increases and declines in 14C dates.

SPA Analyses on Other Continents in the Northern Hemisphere (Figures 9-10).

European SPA Results: A drop in 14C date intensity amounting to about 35% (arrow) occurs for the 200 years following "a", with the most pronounced and deepest drop occurring after the start of the YD and lasting for 800 years before rebounding prior to the Holocene at "b".

Asian SPA results: The steepest and deepest part of an amplitude decline (arrow) occurred early in the YD at "a". The decline amounted to 80% fewer dates than in the preceding 200 years. There was a brief recovery about 600 years later in the YD.

African SPA results: Date intensity plummeted early in the YD, with dates and hence inferred population levels not increasing again for about 1300 years until the Holocene.

Middle Eastern SPA results: The 14C evidence from the Middle East during the YD is unlike those in North America, Europe, Asia, and Africa, suggesting that the region may have been a refugium.

Faunal Bottlenecks During the YD in Alaska and Across North America (Figures 11 and 12).

It is widely accepted that many genera of animals became extinct in North America in the Late Pleistocene, with the extinctions largely completed by early in the YD (e.g., Martin 1984; Grayson and Meltzer 2002). Here we examine dates for extinct and surviving species to determine what effect the YD may have had on these populations.

Alaskan SPA results. The SPA plots (Figure 11) show nearly synchronous date declines of 75% to 100% near the onset of YD (±150 years). Moose, elk, and humans all display major declines in 14C dates. Bison experienced a more severe decline, virtually disappearing from Alaska after the YD.

North American SPA results: For the continent as a whole, we compiled a SPA plot to compare 14C dates for deer (and antelope), caribou, squirrels, and shrews, as shown in Figure 12. Those dates came mostly from archaeological sites, and therefore, they may not be fully representative of overall animal population levels. In addition, the numbers of available dates are low, increasing the uncertainties. Even so, all of the plots display similar major YD-related declines in dates for surviving species.

Database Name	Total	Sample	Authors	References	Region Covered
Canadian Archaeological ^{14}C Database	14423	3190	Morlan and Betts	CARD 2009	U.S., CAN, Russia
African Database: Egypt/Sudan	890	750	Hendrickx	Hendrickx 2009	Africa: Egypt, Sudan
Near East ^{14}C Database	4907	1510	Böhner	Böhner 2009a	Near East
INQUA Palaeolithic Database	5898	640	Vermeersch	Vermeersch 2009	Europe
CalPal Neolithic Database	9715	1100	Böhner, Bradtmöller, Linstädter, Rollefson	Böhner 2009b	Mediterranean, MidEast, Europe
TOTAL ^{14}C DATES:	35833	7190			

Table 2. Databases employed in the Summed Probability Analyses.

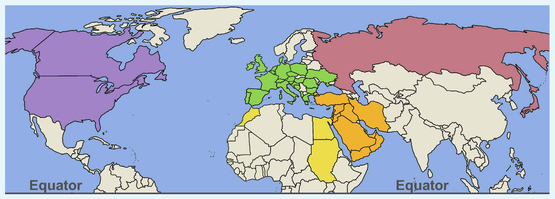

Figure 9. Regions in the Northern Hemisphere analyzed with summed probability: North America (purple); Europe (green); Africa (yellow); Middle East (orange); and Russia (red)(References in Table 2).

CONCLUSIONS

Our analyses indicate that serious human and animal population declines or bottlenecks, or alternatively population reorganizations (i.e., dramatic changes in settlement patterning) occurred with the onset of the YD cooling episode 12,900 years ago in some or all portions of North America. SPA analyses suggest similar declines occurred across much of the Northern Hemisphere, with the possible exception of the Middle East. In addition, SPA analyses indicate that such changes also occurred during the Altithermal beginning around 9,000 years ago and lasting for nearly 3000 years.

This is the first time that a continental pattern has been reported for the Altithermal or that a hemispheric demographic pattern has been proposed for the YD. We suggest these changes in climate and biota are related, that they occurred quickly and lasted for centuries, and may have resulted in human population declines of up to 30% to 50%. If a comparable episode occurred today, the results would be catastrophic.

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