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TREE-RING RECORDS OF NEAR-YOUNGER DRYAS TIME IN CENTRAL NORTH AMERICA—PRELIMINARY RESULTS FROM THE LINCOLN QUARRY SITE, CENTRAL ILLINOIS, USA

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ABSTRACT. The abrupt millennial-scale changes associated with the Younger Dryas (YD) event ("chronozone") near the dawn of the Holocene are at least hemispheric, if not global, in extent. Evidence for the YD cold excursion is abundant in Europe but fairly meager in central North America. We are engaged in an investigation of high-resolution environmental changes in mid-North America over several millennia (about 10,000 to 14,000 BP) during the Late Glacial–Early Holocene transition, including the YD interval. Several sites containing logs or stumps have been identified and we are in the process of initial sampling or re-sampling them for this project. Here, we report on a site in central Illinois containing a deposit of logs initially thought to be of YD age preserved in alluvial sands. The assemblage of wood represents hardwood (angiosperm) trees, and the ring-width characteristics are favorable to developing formal tree-ring chronologies. However, 4 new radiocarbon dates indicate deposition of wood may have taken place over at least 8000 ^{14}C yr (6000–14,000 BP). This complicates the effort to develop a single floating chronology of several hundred years at this site, but it may provide wood from a restricted region over a long period of time from which to develop a sequence of floating chronologies, the timing of deposition and preservation of which could be related to paleoclimatic events and conditions.

INTRODUCTION

The warming from Late Glacial to Early Holocene was interrupted by an abrupt cold excursion known as the Younger Dryas (YD) event ("chronozone") at about 12,900 to 11,600 cal BP (Mayewski et al. 1993). There is abundant evidence of this event in Europe, but there is less evidence and clarity of its effects in North America, even though events in central North America (melting of the continental ice sheet) may well have been responsible for triggering the YD by slowing thermohaline circulation (Broecker et al. 1989). The Younger Dryas has left a variety of inter-related physical, geochemical, and biological evidence around the world (e.g. Kudrass et al. 1991; Roberts et al. 1993; Denton and Hendy 1994; Goslar et al. 1995; Björck et al. 1996; Benson et al. 1997; Mikolajewicz et al. 1997) from which its characteristics are being pieced together, perhaps with lessons for future world climate change.

We are interested in the YD conditions as expressed in tree-ring growth and characteristics in the Upper Midwest area of North America, focusing on sites where preserved wood samples exist (Figure 1), dispersed over a 4000-radiocarbon yr period (about 10,000 to 14,000 BP) that includes the 1300-yr YD event. One central goal of this project is to develop annual-resolution tree-ring width chronologies from available samples and estimate their variance associated with sample size and sample length. Once chronologies are established with confidence, high-resolution ^{14}C and stable-isotope chronologies will also be developed to infer additional climate/global change/carbon cycle information.

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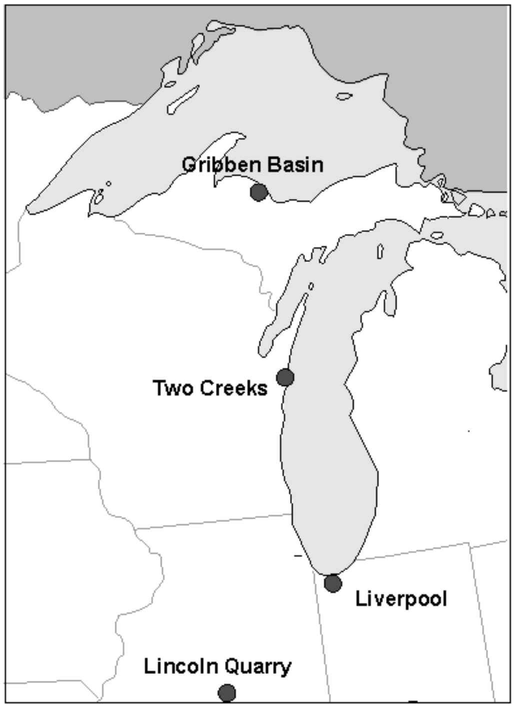

Figure 1 Map of sites from which samples have been recently obtained in this project

We have sampled or obtained samples from 4 sites thus far (Figure 1): Gribben Basin (Upper Peninsula Michigan), the classic Two Creeks site (east-central Wisconsin), Liverpool (northwest Indiana), and Lincoln Quarry (central Illinois). The first 3 of these sites are characterized by spruce (conifer) arboreal flora, all including trees in original growth position. This paper, however, focuses on the Lincoln Quarry site, where a deposit of logs preserved in alluvial sands was discovered at a limestone quarry in central Illinois in the 1980s, for which 2 ^{14}C dates indicating a possible late YD age already existed (10,439 ± 70 BP [ISGS-4397] and 10,160 ± 80 BP [ISGS-4400], unpublished). Our efforts with additional dating, wood identification, and ring-width characteristics have advanced understanding of the wood deposit and its potential for paleoclimate reconstruction.

METHODS

The Lincoln Quarry site is a few km west of the town of Lincoln, Illinois (40°08.272′N, 89°26.858′W), in the Holocene floodplain of Salt Creek. The valley lies in the Illinois Till Plain. End moraines from the last glaciation, also drained by Salt Creek, occur about 20 km to the east. One of us (SWL) visited the quarry on August 10, 2001, and obtained access to available wood. The wood is preserved in gravel-bearing sandy alluvium typically 5 to 10 m thick, sandwiched by 1- to 5-m-thick silty overbank deposits above and mid-Wisconsin deposits below, including the wood-bearing Robein Member of the Roxana Silt that dates at about 26,000 BP. The Quaternary deposits occur above Pennsylvanian limestone.

Specifically, the samples had been excavated out of Yard 10, the area most recently quarried. The original ISGS dates were from wood sampled several years earlier, when the active operation was in a different quarry yard. The wood from Yard 10 was piled on the eastern edge of the excavation, so we do not know the specific location or depth proveniences of the pieces. A few logs were emerging from the walls of the pit 3–4 m below the surface, but because of safety concerns, we were not able to sample them. We sampled about 30 logs or log fragments in this deposit.

The samples were largely waterlogged, so to reduce cracking, we allowed them to dry out slowly over several months while wrapped in several layers of newspaper. Disks and slices were cut from the dry wood and surfaced to 400 grit. Tree-ring width series were measured with a Henson measurement system (0.01-mm precision) for each cross-section, the total number of rings of which exceeded 45 yr. The tree-ring series were examined for crossdating using the COFECHA program (Holmes 1983) and overlapping plots (TSAP program by RINNTECHenn Co., www.rinntech.com). The main statistics of tree-ring series were calculated with the ARSTAN® program (Cook 1985). Subsamples were taken for wood species identification and for ^{14}C dates.

For ^{14}C dating, 10-yr wood samples were obtained from the inner 50 rings of 4 specimens, ground, and processed to holocellulose. The cellulose samples were combusted to CO_2 with CuO in sealed quartz tubes and then converted to graphite and analyzed on the tandem accelerator mass spectrometer at the University of Arizona NSF Accelerator Facility.

RESULTS AND DISCUSSION

Age

Although the 2 ^{14}C dates (ISGS) obtained before our study were indicative of a late Younger Dryas age, the 4 dates we obtained from Yard 20 showed a wide age range from 6320 to 14,120 BP (Table 1). One of the dates at 9520 BP is most similar to the previous 2 dates, falling about 700 cal yr after the Younger Dryas.

This range of ages is consistent with an alluvial origin and with episodic deposition of the sand, gravel, and wood. Additional studies are necessary to characterize the sediment associated with the logs to determine the periodicity of the flooding, and distance to adjoining paleo-riparian environments, the presumed source of the logs. Our study was hampered by the unstable quarry walls that did not allow close examination of the sediment. If more was known about the stratigraphic distribution and distance from the stream of individual wood samples, it may be possible to make inferences about the size of these floods, which together with the dates might reveal new details about paleoclimate.

Wood Species

The condition of collected timber varied, but preservation was good overall. A few samples were exceptionally well preserved, and contained pith and even fragments of bark. One ash log (LQ-1) showed flattening to an elliptical cross-section, presumably resulting from the weight of overlying sediment. The 14,000 BP date of the sample is consistent with the time when the continental ice sheet would have just retreated northward near the Illinois-Wisconsin border (Hansel and Johnson 1992). No other samples are flattened.

Unlike many of the slightly older wood deposits occurring in the Upper Midwest which contain mostly conifers, primarily spruce, such as the Two Creeks site (Broecker and Farrand 1963; Leavitt and Kalin 1992), the wood from Lincoln Quarry was all from hardwoods, including *Quercus*, *Fraxinus*, *Morus*, *Carya,* and *Ulmus* (Table 1).

Table 1 Wood identification and tree-ring characteristics of Lincoln Quarry samples.

Sample ID	Nr of rings	Species[a]	^{14}C age	Lab nr	Cal BP (1 σ)
LQ-1	104	*Fraxinus*	14,120 ± 120	AA-49148	16,400–17,500
LQ-2	76	*Fraxinus*	9520 ± 120	AA-49149	10,550–11,200
LQ-3	68	*Morus**			
LQ-4		*Carya**			
LQ-5	103	*Quercus*, red or white			
LQ-6	62	*Juglans cinerea*			
LQ-7		*Acer*, soft			
LQ-8		*Quercus*, white group			
LQ-9		*Prunus**			
LQ-10		*Morus**			
LQ-11	54	*Ulmus**			
LQ-12		*Ulmus* sp.			
LQ-13	73	*Quercus*, red or white			
LQ-14		*Morus**			
LQ-15		*Morus**			
LQ-16	52	*Morus**			
LQ-17	69	*Juglans cinerea*			
LQ-18	48	*Morus**			
LQ-19	60	*Ulmus**			
LQ-20	65	*Juglans cinerea*			
LQ-21	60	*Juglans cinerea*			
LQ-22	46	*Celtis**			
LQ-23	56	*Platanus*			
LQ-24	204	*Quercus*, white group			
LQ-25	156	*Quercus*, white group	6320 ± 100	AA-49150	7000–7450
LQ-26	67	*Morus**			
LQ-28		*Platanus**			
LQ-29	111	*Carya*	8926 ± 81	AA-49151	9860–10,200

[a] * = wood identification not certain. [Common name key: *Quercus*=oak; *Ulmus*=elm; *Fraxinus*=ash; *Carya*=hickory; *Prunus*=cherry; *Morus*=mulberry; *Celtis*=hackberry; *Platanus*=sycamore; *Juglans cinerea*=butternut; *Acer*, soft=silver maple, red maple, or boxelder]

The oldest of the dated samples at 14,120 ^{14}C yr BP is *Fraxinus* (ash). The Two Creeks wood dates to about 11,800 BP and is all spruce (Leavitt and Kalin 1992), but Two Creeks occurs much farther north than Lincoln Quarry. In Illinois, *Fraxinus nigra* was common in the late glacial forest (Jacobson et al. 1987; Curry et al. 1999; Williams et al. 2001). *Quercus* and *Carya* at 9000 to 6000 ^{14}C yr BP are consistent with the pollen evidence for the common occurrence of these trees in Illinois at this time (King 1981) which fit other regional macrofossil evidence for these species. Submerged trees in Lake Michigan, 25 km east-southeast offshore at Chicago (Chrzastowski et al. 1991), and buried trees at Kenosha in the southeastern corner of Wisconsin (Schneider et al. 1977) confirm that *Quercus* and *Carya* were firmly entrenched in the region several hundred km north of Lincoln Quarry by 6000 to 8000 BP.

Ring Widths

The logs and wood fragments in our collection had 35 to nearly 200 rings (approximate tree ages are given under the "Nr of rings" column in Table 1). About 80% of the specimens have fewer than 100 yr (distribution of ages in Figure 2), but generally, when trees have ages greater than 50 yr, the potential for crossdating to build tree-ring chronologies is enhanced.

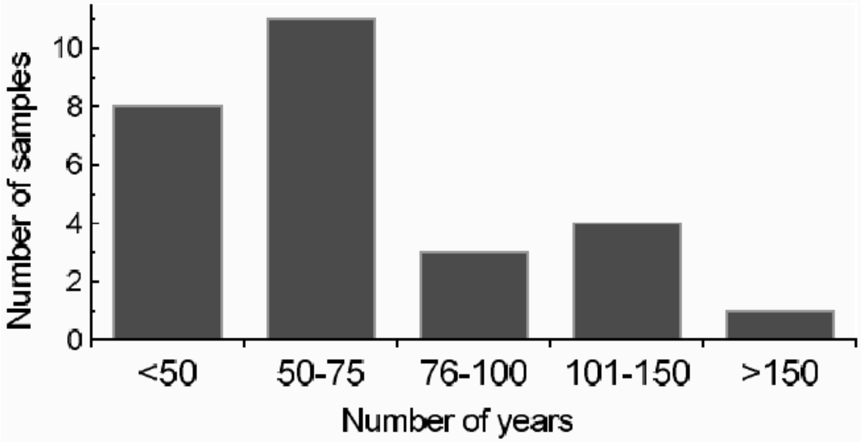

Figure 2 Age distribution of Lincoln Quarry specimens based on number of rings

The raw ring widths and best-fit growth curves of samples that contain pith show a variety of patterns (Figure 3). Some trees, such as LQ-2, 4, 29, and 25, exhibit growth patterns of growth suppression (small rings) early in life, perhaps from competition in a closed-canopy environment. Others, however, such as LQ-6, 1, 20, and 17, grew rapidly in their early years, indicating more open canopy conditions.

By removing age-growth curves from the raw ring widths, it will be eventually possible to develop ring-width indices for use in developing site chronologies. Based on the ^{14}C dating, however, it might be necessary to develop a tree-ring chronology for each of the time periods during which there was presumably an influx of wood. As of now, however, we have not been able to detect any outward physical characteristics that would allow us to group wood samples into the 4 time periods indicated by the ^{14}C dates, although species themselves may be diagnostic for time and may hint at provenience. In the worst case, the wood from the same time cluster could come from a large area, and more than 4 time clusters may exist. Floodplain deposits from Iowa (Chumbley et al. 1990; Baker et al. 1992) and Missouri (Guyette et al. 2003) have yielded wood and macrofossils from throughout the Holocene, and the same situation may exist for Salt Creek in Illinois. Fortunately, with some radiometric dating control (or perhaps species-related dating indicators), a strong response of tree growth to regional climate would help guarantee crossdating of samples even if their source area is large. If so, there is the potential for a single long chronology and certainly for a long series of chronologies over perhaps 8000 ^{14}C yr in central Illinois.

General statistics for tree-ring width measurements (Table 2) indicate that radial growth of trees is quite different. It might be caused by environmental and stand conditions as well as species identities and the young age of trees. *Fraxinus* trees possess the slowest rate of growth and low variance for both the 17,000 and 11,000 cal BP dates. Average tree-ring width is less than 1 mm. *Morus* trees have the highest rate of growth with average tree-ring width around 3 mm. Almost all trees have high autocorrelation (Table 2). This suggests dependency of growth of current year on growth conditions of previous year and, in some cases (*Quercus*, *Morus*, *Fraxinus*, and *Carya)*, 2 previous years.

Particularly promising is that within species groups (see Table 2), the specimens seem to be crossdatable. For example, within *Quercus*, *Juglans*, and *Ulmus* groups there are significant correlation coefficients between overlapped series (Table 2). Five crossdated series of *Quercus* comprise a 204-yr, high-variance chronology (standard deviation is 0.25). The *Juglans* tree group

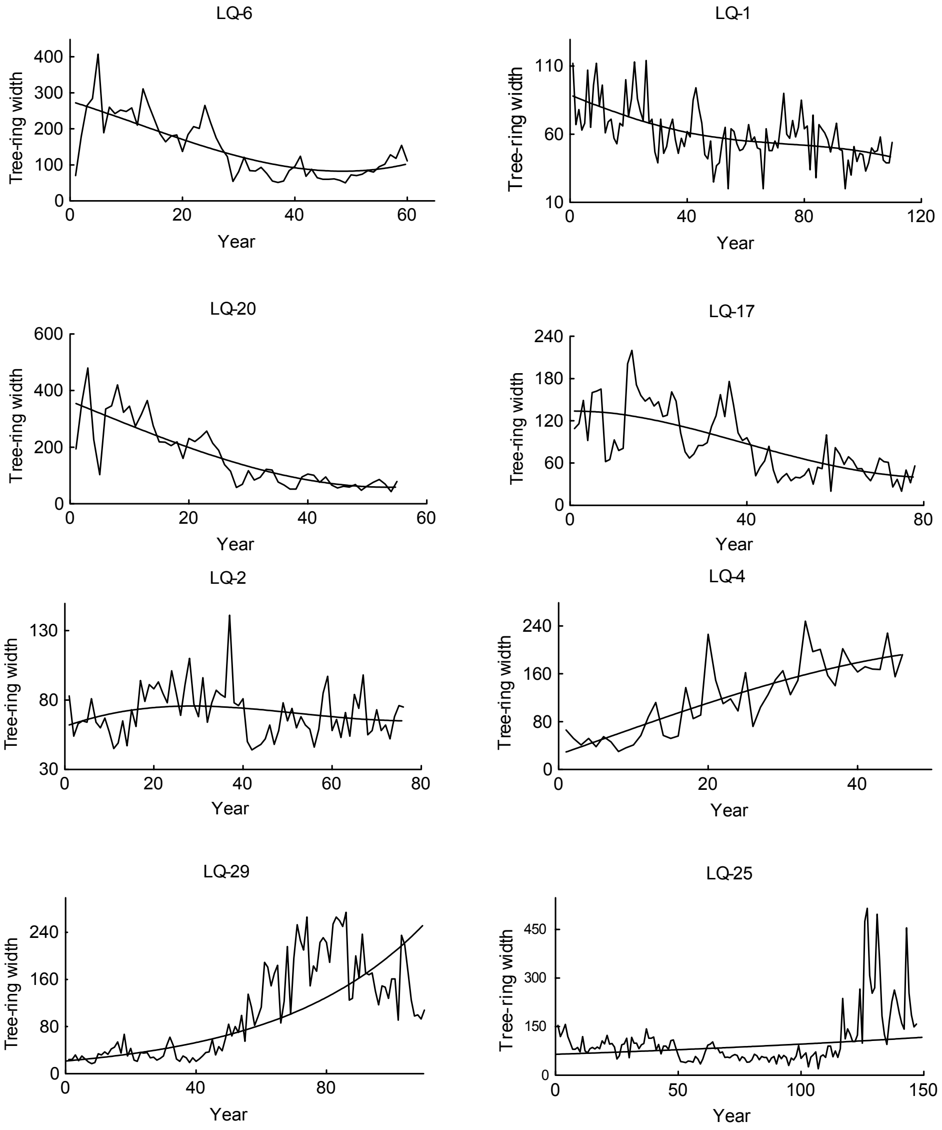

Figure 3 Examples of representative ring-width series (in mm) from Lincoln Quarry specimens

from 45 overlapped samples with length of 97 yr shows the best match (see correlations in Table 2). We also obtained a 60-yr sequence of *Ulmus* and a 75-yr sequences of *Morus*. The *Morus* series has low correlations because of tension wood and, therefore, needs to be verified with a larger sample set. We could not check the crossdating features of *Fraxinus* because two of the available series are from distinct time periods.

Even more interesting, crossdating exists *among* the *Ulmus*, *Juglans*, and *Carya* (LQ-29) series, suggesting they may be the same age. The 7 series of these species combined to make a 111-yr chronology (Figure 4). Because the Carya dates at 10,000 cal BP, the samples from the other 2 species may well be the same age, about 1600 cal yr after Younger Dryas proper.

Table 2 Statistics of measured tree-ring widths (all series >45 yr).

Sample ID	Nr of rings	Mean (mm)	Standard deviation	Autocorrelation Lag 1	Autocorrelation Lag 2	Highest correlation among crossdated series[a]
Fraxinus						
LQ-1	104	0.62	0.18	0.53	0.24	—
LQ-2	76	0.71	0.18	0.40	0.23	—
Morus						
LQ-3	68	1.35	0.45	0.61	0.31	0.22
LQ-16	52	3.10	0.94	0.47	0.20	0.22
LQ-18	48	2.84	0.69	0.45	–0.13	0.33
LQ-26	66	2.90	1.44	0.80	0.12	0.26
Quercus						
LQ-5	103	0.89	0.33	0.63	0.26	0.42
LQ-8	75	0.84	0.24	0.60	0.31	0.38
LQ-13	74	0.91	0.63	0.47	–0.27	0.32
LQ-24	204	1.13	0.35	0.51	0.14	0.35
LQ-25	156	1.02	0.34	0.67	0.13	0.39
Juglans						
LQ-6	62	1.42	0.82	0.79	0.09	0.53
LQ-17	69	0.97	0.39	0.53	0.24	0.45
LQ-20	65	1.34	0.76	0.77	0.07	0.55
LQ-21	60	0.54	0.23	0.60	0.13	0.36
Ulmus						
LQ-11	54	1.21	0.45	0.50	0.04	0.39
LQ-19	60	0.92	0.35	0.63	–0.01	0.39
Misc.						
LQ-22	46	2.10	0.75	0.81	0.15	—
LQ-23	56	1.70	1.08	0.71	0.29	—
LQ-29	111	1.04	0.78	0.86	0.31	—

[a] Coefficients for tree-ring series crossdated only within the species groups.

In conclusion, we suggest that the Lincoln Quarry has good potential for reconstructing environmental changes from the Late Glacial to mid-Holocene. Complications related to unknown provenience of wood might be resolved by dendrochronology and ^{14}C dating. The results of crossdating and the new ^{14}C dates may support a hypothesis of periodic flooding contributing sediments and wood to the Salt Creek floodplain. Further collection of available wood is needed.

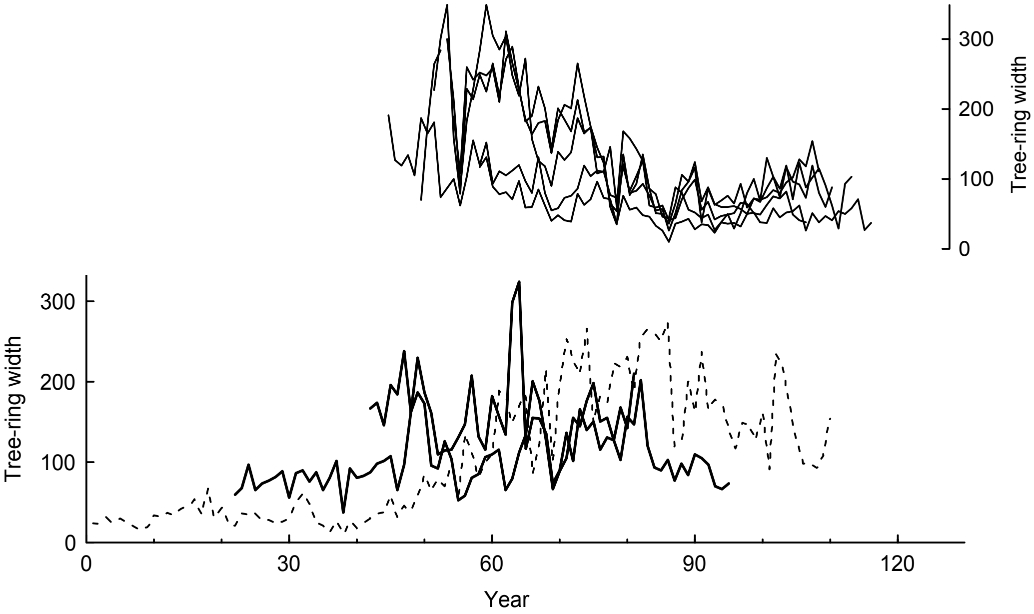

Figure 4 Example of crossdated tree-ring width (in mm) series for 3 species groups: upper 7 curves—*Juglans* (butternut), dashed line—*Carya* (hickory); lower 2 bold lines—*Ulmus* (elm).

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