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USING TREE-RING GROWTH PATTERNS TO DATE THE CONSTRUCTION OF A NINETEENTH CENTURY DOGTROT HOUSE IN POSEY COUNTY, INDIANA

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ABSTRACT. Dendroarchaeology is a sub-field of dendrochronology (tree-ring science) that deals with the sampling of historically constructed buildings to tap the tree-ring information found within their timbers. Dendroarchaeological studies provide an accurate and reliable means of determining the construction date of a building through a process called crossdating (matching the pattern of small and large tree rings in samples with unknown dates to samples with rings of known age). Crossdating is a highly reliable method for dating wood of unknown age, and dendroarchaeological techniques have proven to be powerful and effective research tools. The goal of this investigation was to provide a possible construction date for the Grayson dogtrot house located in a museum setting in New Harmony, Indiana. Dogtrots are a type of folk housing popular throughout the southern United States, but rare in Indiana. Tree-ring analysis of the tulip poplar timbers in the house suggests that it was built after the initiation of the 1852 growing season, and the results of this study will be used in the interpretation of this unique architectural resource.

Keywords: Dendrochronology, dendroarchaeology, tree-rings, tulip poplar, vernacular architecture

INTRODUCTION

Dendrochronology is the study of tree rings that have been dated to their precise year of formation. Analysis of the growth patterns observed in tree-ring chronologies (series of accurately measured and dated tree rings and their widths) can be extremely informative when exploring a wide variety of phenomena. Dendrochronological techniques have been used, for example, to study the timing of insect outbreaks, forest stand dynamics, forest fires, and the influence of climate on tree growth. Dendrochronological investigations are not limited to the study of tree rings found solely in living trees. Dendroarchaeology, a subfield of dendrochronology, focuses on the study and analysis of tree rings found in the timbers of historically constructed buildings and artifacts.

The tree-ring record preserved in the timbers of historically constructed buildings provides a unique opportunity to study historic tree growth (Stahle 1979; Therrell 2000). Through the accurate dating of the tree rings found in such timbers, dendroarchaeologists are able to create extended tree-ring chronologies that can be used for a variety of studies and purposes. For example, tree rings obtained from historically constructed buildings have been used for reconstructing and studying climate (e.g., precipitation, drought severity, and temperature) for periods lacking instrumental records, studying local human impacts (e.g., settlement), determining the construction date of historic buildings, and managing historic properties (e.g., Stahle 1979; Therrell 2000; Bortolot et al. 2001; Towner et al. 2001; Thun 2005).

European colonization and the subsequent clearing of forests in eastern North America have greatly hampered the creation of long-term tree-ring chronologies using living trees (Stahle 1979). However, by using the tree-ring patterns found in the timbers of historically constructed buildings, which often contain old-growth timber, it is possible to reach farther back in time than with methods using only living trees (Senter 1938; Stahle 1979). Therefore, the use of historic buildings is essential for the creation of informative, long-term regional tree-ring chronologies. Such chronologies can be useful for studying past tree and forest growth patterns. Please see Rubino (2014, in this issue) for a detailed description of dendro-

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chronological and dendroarchaeological analysis in Indiana.

Grayson House.—The Grayson dogtrot house is located near the intersection of North and West Streets in the historic town of New Harmony, Indiana. The village was founded on the Wabash River by German Harmonists in 1814 and later became a short-lived utopian experiment when industrialist Robert Owen purchased the town in 1825. The house is displayed with a collection of other log structures that were moved to the museum location. Unfortunately, very little is known about the house. An examination of building notes and newspaper articles located in the New Harmony offices of the Indiana State Museum and Historic Sites suggest that the house has no historic connection to the town's founding. It was moved from a location on what is now Indiana Highway 68 in the 1960s to be used as a pottery studio by the University of Evansville. It was purchased and restored in 1977 by Historic New Harmony, a partnership between the University of Southern Indiana and the Indiana State Museum and Historic Sites (Indiana State Museums and Historic Sites 2013). Interpretive signage at the cabin identifies it as the Macluria Double Log Cabin with a 1775 construction date. However, State Historic Site files attribute the cabin to the Grayson family. Unfortunately, neither of these family names could be located in historic census data or plat maps for Harmony and Robb Townships (the location of Indiana Highway 68 between New Harmony and Poseyville). We refer to it here as the Grayson House to be consistent with the site's interpretive materials. A construction date of 1775 was attributed to the house. Based on the region's settlement patterns, this date seemed much too early, thereby making the house a worthy candidate for dendroarchaeological study.

The Grayson House is a single story structure comprised of an open, central hallway flanked by two rectangular rooms. Chimneys are located at each end, and a common roof covers the entire structure (Figs. 1–3). The wide hallway runs the depth of the house, and is sometimes termed a "breezeway, passage, dogrun, or possumtrot; but it is most generally called a dogtrot" (Montell & Morse 1995). Typically, a family slept in one room and cooked in the other. The trot provided a covered outdoor living space for warm southern climates (Glassie 1968; Jordan 1985; Kniffen 1986).

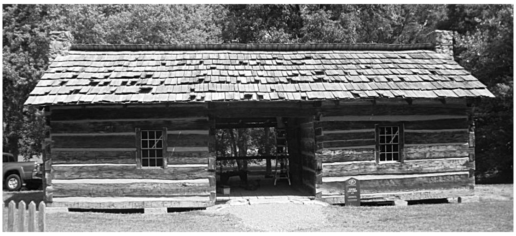

Figure 1.—Grayson dogtrot south façade. Dogtrot houses have two rectangular rooms and a central hall, all under a continuous roof. The open hall is known as a trot.

The Grayson dogtrot is made from planked logs that measure 46–61 cm (18–24 in) in height, and approximately 23 cm (8 in) in thickness. The house is seven logs in height, and modern chinking fills the spaces between the timbers. It is corner timbered with half-dovetail notching (Fig. 4). A modern porch has been added to the north façade (Fig. 3).

The dogtrot house form has European antecedents, although scholars argue whether it is descended from English, German, or Finnish and Scandinavian traditions (Glassie 1968; Jordan 1985; McAlester 1988; Roberts 1996). Early colonists brought the design to the Delaware Valley where it was carried by the wave of settlement into the American interior via the Middle Atlantic migration stream. This eighteenth and nineteenth century movement of settlers extended southwest from Pennsylvania through eastern Tennessee, then across northern Mississippi and Alabama. Settlers then brought it north into western Kentucky and the southern regions of Indiana, Illinois, and Ohio (Kniffen 1986; Roberts 1996). The open trot allowed breezes to cool the structure in southern climates and is the reason the highly functional house form was used for an extended time. While the house form is common in Appalachia and the upper South, it is rare in the Hoosier state; southern Indiana marks the northern reaches of its diffusion.

The goal of this investigation was to determine the likely construction date of the Grayson House through dendroarchaeological analysis. Construction dates for buildings can be suggested by accurately crossdating the outermost ring of an individual timbers. The outermost ring will be the year in which an

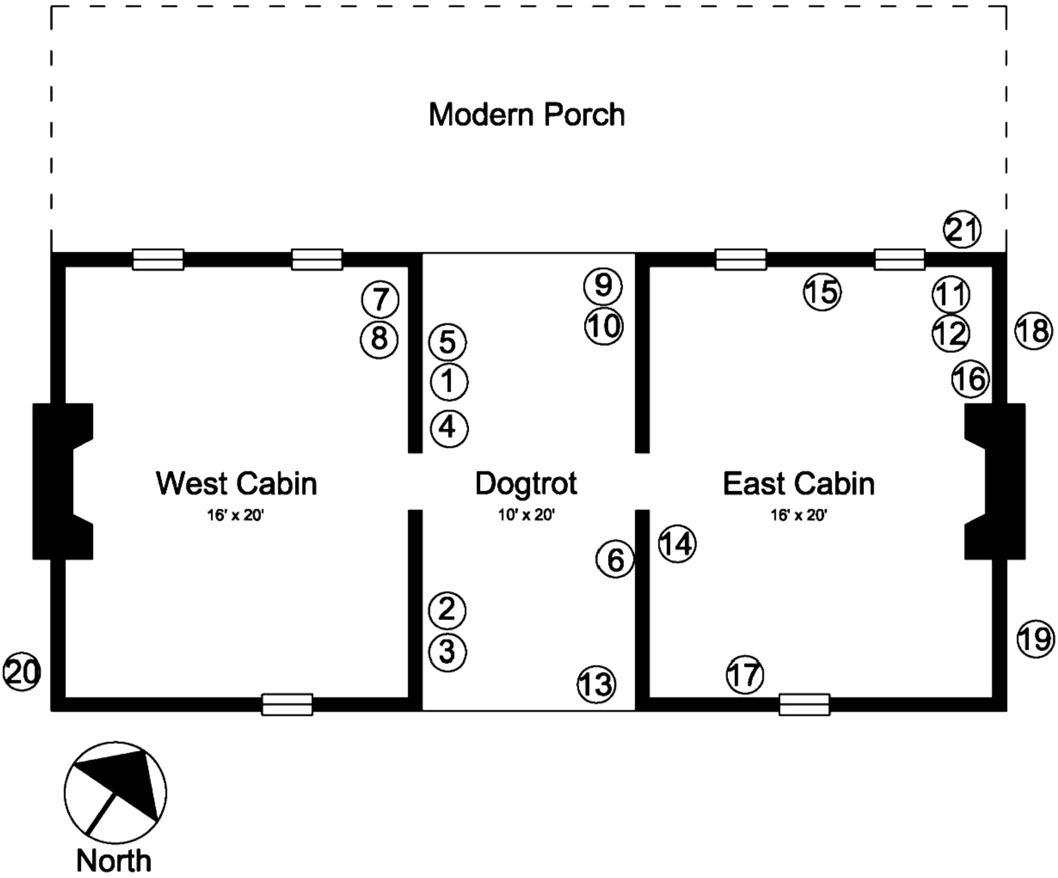

Figure 2.—Plan of Grayson dogtrot showing sampling locations. Note: measurements are given in feet, the unit most likely used by the builders of the structure. See Table 1 for details of each provenience.

individual tree died. For hypothesized construction dates to be accurate, the outermost ring of a timber must represent the last year of growth for the tree; the outermost ring must either be adjacent to bark or be associated with the wane of the piece of lumber. Wane can be identified by noting a uniform, rounded outer surface of a timber that is free of any tool marks (e.g., those created by hatchet, ax, adze, chisel, or saw). If wane is present but bark is not, the outermost ring of the timber represents the last ring formed by a tree, and the bark most likely fell off or was removed. When a

Figure 3.—Grayson house east façade showing end chimney and porch.

Figure 4.—Close up of southeast corner of the Grayson house showing half-dovetail notching.

number of timbers from a structure have similar (or comparable) death dates, one can infer a likely construction date.

METHODS AND MATERIALS

Samples were obtained from the building by coring timbers using a battery-powered drill (1.3 cm chuck) and a dry wood boring bit (Forest Research Tools, Knoxville, Tennessee). Sampling focused on wane-bearing and bark-bearing timbers since determining construction date of the house was the major goal of this investigation. Since repair and renovation are common in log buildings, sampling was performed throughout the structure so that an accurate date of initial construction could be determined (Fig. 2). Each timber in the house was carefully inspected to make certain that either bark or wane was present. Prior to coring the timber, a permanent marker was used to color the outermost surface of the wood or bark to ensure that it was kept intact during the coring process. The bit was drilled into the timber until it passed the approximate center or pith of the timber or until a void was reached.

For several timbers, multiple cores were extracted to increase sample size, to provide a better opportunity for dating if one core was undatable (e.g., extensive insect damage or wounds), and to ensure that the outermost ring did in fact represent wane. Replicate sampling of an individual timber is especially beneficial when working with tulip poplar (*Liriodendron tulipifera* L.) because it is prone to containing missing rings (missing rings result from a tree not forming a complete ring around its entire circumference or any ring at all in a given year due to injury or stressful growing conditions).

Cores were stored in labeled PVC pipe to protect them during transport. Each sample or core was assigned a unique identification containing three portions: a three-letter structure identification (MAC), a two digit provenience (individual timber) identification, and a letter indicating the individual series sampled from a provenience. For example sample MAC03B identifies a replicate series (B) obtained from the third provenience (03) sampled from the structure.

Cores were glued into individually labeled mounting boards so that the vessels were aligned vertically for later surface preparation, ring measurement, and dating. Each core was sanded with progressively finer grits of sandpaper (Stokes & Smiley 1968) to expose the tree-ring structure. Each core was sanded with a belt sander with ANSI 80-, 120-, 180-, and 220-grit sanding belts. A palm sander was then used with ANSI 220-, 320-, and 400-grit sandpaper (Orvis & Grissino-Mayer 2002). Each core was then hand sanded/polished with 30 and 15 micron sanding film.

Starting with the innermost (oldest) tree ring, years—not dates—were assigned to each ring using a boom dissection microscope at 40×. The innermost ring was assigned year 1, the next year 2, and so on until the outermost ring was numbered. The resulting tree-ring series were then considered to be "floating" since individual rings were assigned arbitrary years and not calendar dates (Grissino-Mayer 2001). For each floating series, a skeleton plot was manually created. Skeleton plots are prepared to graphically highlight the pattern of small and large rings in the samples (Stokes & Smiley 1968). The skeleton plots of each series were compared to each other to identify common growth patterns and potential marker years (e.g., abnormally small rings).

The ring widths of each sample were measured to the nearest 0.01 mm with a boom dissecting scope (45× magnification), VELMEX unislide measuring device (VELMEX Inc., Bloomfield, NY), ACU-RITE linear encoder (ACU-RITE Inc., Jamestown, NY), and Quick-Check digital readout device (Metronics Inc., Bedford, NH) connected to a computer. The program MEDIR (Version 1.13; Krusic et al. 1997) was used during the measurement process to create computerized ring-width series consisting of years and measurements for each sample.

The outermost ring in each series with wane was not measured since it is not possible to know if the ring was fully formed (i.e., the tree could have been harvested during the growing season). The innermost ring of most samples could not be measured since sawing, hewing, cracking, or decay does not follow a ring boundary, and the ring would be incomplete. The innermost ring of a series can be measured only if pith is present since the innermost ring would be fully present and adjacent to the pith. Measurement of an entire series is not always possible if the sample has an irregular growth pattern due to scar tissue or growth anomalies associated with branching. When such patterns were encountered, measuring was performed

Table 1.—Series information for each of the dated tulip poplar timbers sampled from the Grayson House, New Harmony, Indiana. "First" and "last" refer to the first and last years present in each of the series. If more than one sample was taken from an individual timber, the provenience description is given only once and not for each of the series. Mean and SD refer to ring widths of each series (mm). In the "Outer Ring" column, "w" = wane; "b" = bark; blank = outer ring is not the last ring formed on the log, and the death date of the timber is undeterminable. See Fig. 2 for sample locations.

Series	First	Last	Outer Ring	Years	Mean	SD	Provenience
MAC01A	1803	1851	w	47	0.42	0.22	West pen, east wall
MAC01B	1774	1851	b	76	0.64	0.56	
MAC01C	1738	1792		53	0.63	0.30	
MAC01D	1713	1738		24	1.52	0.57	
MAC01E	1738	1757		18	0.79	0.32	
MAC02A	1761	1851	w	87	0.57	0.51	West pen, east wall
MAC02B	1681	1761		79	1.28	0.64	
MAC03A	1772	1834		60	1.05	0.46	West pen, east wall
MAC03B	1703	1851	w	145	0.81	0.52	
MAC03C	1709	1772		62	0.67	0.32	
MAC03D	1834	1851	w	16	0.54	0.11	
MAC04I	1780	1852	w	71	0.63	0.46	West pen, east wall
MAC05A	1730	1852	w	121	0.92	0.60	West pen, east wall
MAC06A	1760	1851	w	90	1.35	0.82	East pen, west wall
MAC11A	1797	1827		29	1.86	0.78	Ceiling beam
MAC12A	1719	1812		91	1.21	0.59	Ceiling beam
MAC12I	1799	1852	w	52	0.69	0.25	
MAC14A	1770	1852	b	71	1.00	0.66	East pen, west wall
MAC14B	1808	1852	b	43	0.66	0.18	
MAC15A	1767	1808		40	2.17	1.17	East pen, north wall
MAC16A	1758	1852	b	93	1.49	1.38	East pen, east wall
MAC17B	1759	1852	b	92	1.22	1.16	East pen, south wall
MAC18A	1745	1824		76	2.07	1.22	East pen, east wall
MAC18B	1827	1852	b	24	0.90	0.45	
MAC19A	1783	1852	w	68	1.42	0.63	East pen, east wall
MAC20A	1802	1852	w	49	0.88	0.39	West pen, west wall
MAC21A	1708	1806		97	1.17	0.50	East pen, north wall

only in the region where normal growth was observed. Inclusion of incomplete rings and abnormally-formed rings in the ring-width series was avoided since the true ring width is not determinable and subsequent inclusion of such measurements would likely bias growth pattern analyses.

Calendar date assignment to individual rings in the floating series was achieved by crossdating the samples against local chronologies with known dates (see Rubino 2014, in this issue for an example). Chronologies are comprised of dated and measured tree rings created by studying numerous trees in an area. These local chronologies consist of living trees and crossdated timbers from other regional structures. Crossdating was performed by using skeleton plots and by using ring-width measurements via the computer program COFECHA (Holmes 1997). COFECHA utilizes a correlation procedure to enhance time-series characteristics (the pattern of small and large rings) in the samples. COFECHA assists in date assignment of floating tree-ring series by comparing the measured floating series to measured series with known, verified dates. Following a run of COFECHA, a list of possible calendar dates for dating each of the floating series is provided (Holmes 1997; Grissino-Mayer 2000). These tentative dates were then compared to the growth patterns observed in the skeleton plots of each sample to assist in final calendar date assignment.

COFECHA was also used to verify date assignments (i.e., quality control). COFECHA breaks each series into consecutive 50-year segments overlapping by 25 years (Grissino-Mayer 2000; Holmes 1997). The correlation of each of the segments is then checked against all other series. If a correlation coefficient for

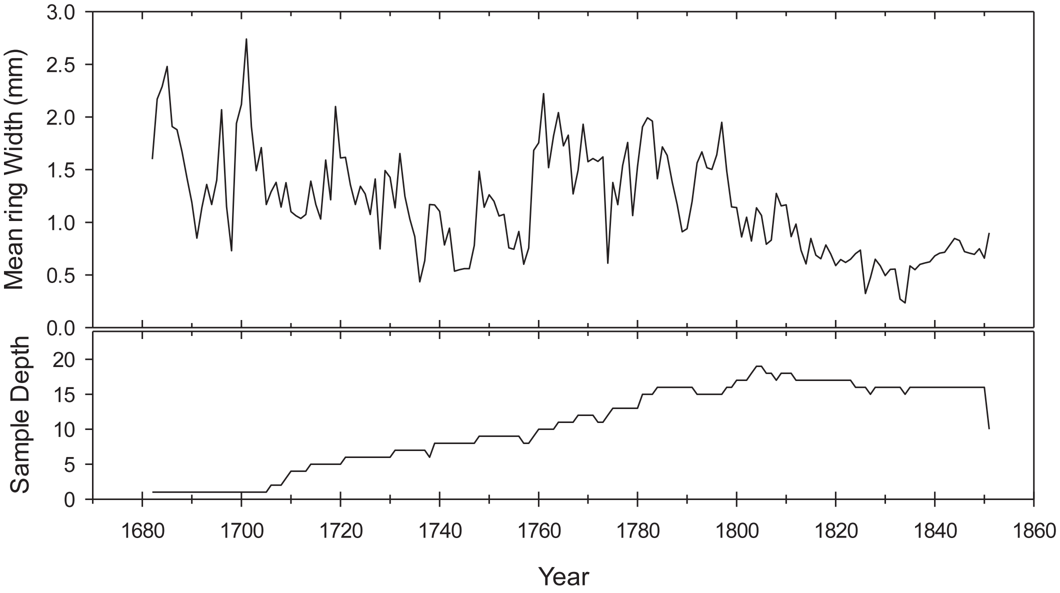

Figure 5.—Tree-ring chronology prepared from tulip poplar timbers of the Grayson House, New Harmony, Indiana. Sample depth is the number of samples that had a ring present at an individual year.

a 50 year segment has an r-value $>$ 0.33 (associated probability of 0.01) the crossdating is verified, and date assignment is likely successful.

Each timber type was identified to the lowest possible taxonomic rank (species or subgenus) using macroscopic and microscopic wood anatomy characteristics (Panshin & de Zeeuw 1980). Subsamples for wood identification were obtained by removing paper-thin sections of wood with a double-edged razor blade.

RESULTS

Samples were obtained from American (white) elm (*Ulmus americana* L.), "White" oak (*Quercus* subgenus *Lepidobalanus*), hickory (*Carya* sp.), and tulip poplar timbers. Taxonomy and nomenclature follows Gleason & Cronquist (1991). Twenty-one proveniences were sampled from throughout the structure (Fig. 2). Dates were successfully assigned to 27 samples from16 different proveniences. Confident date assignment was not possible for 5 of the proveniences due to extensive insect damage and decay that did not allow extraction of long enough cores to permit reliable crossdating or extensive growth suppressions that consisted of tree rings exhibiting little to no change in ring width from year to year (accurate crossdating necessitates ring-width variation).

Tulip poplar was the dominant timber type sampled from the structure (Table 1). Two white elm (MAC09 and MAC10), two "white" oaks (MAC08 and MAC13), and one hickory (MAC07) were also sampled; none of these crossdated. All of the tulip poplar timbers crossdated and yielded a 172 year-long chronology (1682–1851) consisting of 1774 accurately dated and measured tree rings (Table 1; Fig. 5). Mean ring width was 1.06 mm (SD = 0.63).

To determine the strength and quality of dating among the samples, each series was broken into 50 year-long segments overlapping by 25 years (e.g., 1700–1749, 1725–1774, 1750–1799, etc.). Each segment was then correlated against all other series in the chronology. Additionally, each of the complete series was correlated against all other series in the chronology. Correlation analysis was performed with the ring width measurements for each year in each of the series. Strong and significant correlations were found among the 50 year-long segments and among all series in the chronology (Table 2). These significant correlations suggest that accurate crossdating was achieved. Skeleton plots (not shown) also suggest successful crossdating among the

Table 2.—Segment (50 year-long segments overlapping by 25 years) and series correlation coefficients for crossdated tulip poplar timbers from the Grayson House. A correlation coefficient > 0.33 indicates a significant correlation ($P < 0.01$) for 50 year segments. Time span is the period for which tree rings were measured for each series.

Series	Time Span	1700–1749	1725–1774	1750–1799	1775–1824	1800–1849	1825–1874	Series *r*
MAC01A	1804–1850					0.66		0.66
MAC01B	1775–1850				0.67	0.73	0.69	0.69
MAC01C	1739–1791		0.49	0.50				0.51
MAC01D	1714–1737	0.82						0.82
MAC01E	1739–1756		0.43					0.43
MAC02A	1764–1850			0.67	0.59	0.66	0.63	0.64
MAC02B	1682–1760	0.63	0.64					0.65
MAC03A	1774–1833			0.68	0.71	0.69		0.68
MAC03B	1706–1850	0.68	0.73	0.65	0.66	0.67	0.67	0.66
MAC03C	1710–1771	0.65	0.61					0.55
MAC03D	1835–1850						0.21	0.21
MAC04I	1781–1851				0.35	0.34	0.33	0.36
MAC05A	1731–1851		0.60	0.69	0.60	0.62	0.64	0.62
MAC06A	1761–1850			0.72	0.56	0.42	0.42	0.59
MAC11A	1798–1826				0.49			0.49
MAC12A	1721–1811	0.47	0.59	0.54	0.61			0.54
MAC12I	1800–1851					0.49	0.49	0.49
MAC14A	1781–1851				0.62	0.75	0.75	0.66
MAC14B	1809–1851					0.74		0.74
MAC15A	1768–1807			0.39				0.40
MAC16A	1759–1851			0.72	0.51	0.52	0.49	0.61
MAC17B	1760–1851			0.67	0.58	0.44	0.42	0.55
MAC18A	1748–1823		0.78	0.76	0.70			0.72
MAC18B	1828–1851						0.81	0.81
MAC19A	1784–1851				0.49	0.33	0.30	0.37
MAC20A	1803–1851					0.60		0.60
MAC21A	1709–1805	0.78	0.86	0.73	0.72			0.74

individual timbers from the house. Crossdating was greatly aided by noting decreased growth rate (in relation to neighboring rings) in 1728, 1736, 1752, 1774, 1833 (missing ring in two of the timbers), and 1834 (Fig. 5).

Calendar date assignment to individual tree rings was performed and assessed by correlating a master chronology (a mean chronology comprised of all crossdated tree rings from the house's timbers) with local regional chronologies. The ring-width master chronology of the Grayson House correlated significantly with all other regional chronologies (Table 3). The consistent, significant correlations suggest that accurate calendar date assignment was achieved.

DISCUSSION

An 1851 or 1852 death date was found in all timbers for which a death date was determinable (i.e., bark or wane present). The timbers

Table 3.—Correlation results of 50 year-long segments (overlapping by 25 years) of the Grayson House mean master chronology with regional tulip poplar chronologies from Indiana. Correlations for 50 year-long segments are significant ($P < 0.01$) if $r > 0.33$.

Chronology	Span	1682–1731	1707–1756	1732–1781	1757–1806	1782–1831	1802–1851
Corydon	1575–1901	0.40		0.56	0.55	0.41	0.33
Jefferson County	1457–1889			0.62	0.66	0.48	0.33
Switzerland County	1613–1856	0.42	0.48	0.69	0.70	0.52	0.46
Washington County	1637–1882	0.40	0.33	0.60	0.62	0.54	0.45
New Harmony (1)	1686–1858		0.64	0.76	0.63	0.55	0.75
New Harmony (2)	1704–1885		0.49	0.81	0.74	0.65	0.66

showed uniform hewing marks and thicknesses. Also, the timbers had little or no extraneous tooling (e.g., empty mortises) suggesting that the timbers had been recycled from other buildings. Since timbers from throughout the house had similar death dates, we conclude that the house was most likely originally constructed in its current layout/format as a dog-trot house after the initiation of the 1852 growing season. We are not certain (nor is Historic New Harmony) how the 1775 construction date was assigned, but it should be corrected in light of tree-ring evidence.

Crossdating (using skeleton plots and correlation analysis) among tree-ring series was achieved in this investigation using only tulip poplar. Tulip poplar is not commonly used for dendrochronological and dendroarchaeological investigations and has been considered a species of minor importance to dendrochronology because it has been reported to only crossdate within and between trees on a site-by-site basis (Grissino-Mayer 1993). However, we found a very consistent signal (repeated pattern of small and large tree rings among samples) in the samples at both the within (all Grayson house samples) and among (regional tulip poplar chronologies) site levels using correlation analysis (Tables 2 and 3). We suggest further investigation of the potential of tulip poplar for tree-ring studies. In this investigation the samples exhibited consistent annual ring variation and sensitivity to extraneous growth factors.

For this analysis, we utilized dendrochronology within a framework of interpretive archaeology to explain historic sites to public and academic audiences (Wilkie 2009). Along with Historic New Harmony, we are working with local museums and individuals to interpret historic timber buildings in public history settings (Baas & Rubino 2012). The authors aim to continue investigating New Harmony structures, specifically Harmonist houses and community buildings.

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