TREE-RING DATING OF WHITE OAK (*QUERCUS ALBA*) SAMPLES FROM THE HIGGINS HOUSE IN MOOREFIELD, WEST VIRGINIA

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FINAL REPORT SUBMITTED TO:

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Abstract

The Higgins House, located in Moorefield, West Virginia, is a clapboard-sided, two-story, steeple-notched log building. Historical documentation indicates that the log house was likely constructed between 1786 and 1788 by Robert Higgins, a captain in the Revolutionary War. I used tree-ring dating methods to identify the absolute felling dates of 21 samples from white oak (*Quercus alba*) logs in the Higgins House. All 21 samples were internally crossdated using standard dendrochronological dating techniques and were combined to create a mean ring-width chronology for the building. I then used four local and regional oak (*Quercus* spp.) reference chronologies to assign calendar dates to the floating Higgins House chronology. All four of the regional reference chronologies provided a consistent calendar date assignment which was then tested statistically. Of the 21 samples, 12 had confirmed terminal rings (representing a live edge) and indicated two distinct felling years: 1790 and 1827. Eleven samples appeared to be associated with the 1790 felling year and ten samples appeared to be associated with the 1827 felling year. The felling date of 1790 is consistent on both floors of the two-story log building and corroborates historical documentation indicating that the log house was originally constructed by Robert Higgins after 1786. However, the felling date of 1827 is also consistent on both floors and suggests that at some point in time the log house was deconstructed and reconstructed for currently unknown reasons. It is beyond the scope of tree-ring dating to understand how and why the felling years of 1790 and 1827 are found throughout the building, however, these dates may help narrow down periods of interest in historical documentation that will point to the 'how' and 'why' of this historical mystery. Further investigation in historical records may provide information to corroborate these events.

Introduction

Trees put on annual growth rings and the variation in ring width each year, caused by the tree's response to environmental factors, creates unique patterns of wide and narrow rings through time. Trees that were alive during the same period and were exposed to the same environmental conditions have similar patterns in growth that can be matched through time. This process of pattern matching is used to crossdate living trees, dead trees, and historic log buildings (Figure 1). Tree-ring dating of pre-historic and historic log buildings, or dendroarchaeology, has a long history in Europe and North America. In eastern North America, dendroarchaeology has been used to date numerous historic log buildings to the year and season of inferred construction; including some well-known buildings such as Andrew Jackson's Hermitage, TN (Lewis *et al.* 2009), the home of John Sevier at Marble Springs Historic Site, TN (Slayton *et al.* 2009), and Fountain of Youth Archaeological Park, FL (Garland *et al.* 2012). Tree-ring dating enhances the historical significance of a log building by providing the year and season in which the logs were felled for construction and is particularly useful when written records are incomplete or uncertain. Accurate construction dates improve interpretations of political, social, economic, and cultural practices during construction and allow the structures to be tied to calendar dated historical documents and events. Established construction dates often confirm historic significance for many buildings and help private owners and agencies obtain historic status from the National Register of Historic Places (NRHP) (Parker and King 1998).

Setting and Historical Background

The Higgins House (Figure 2), located in Moorefield, West Virginia (39˚03'44" N, 78˚58'04" W), is a single-pen, two-story, steeple-notched log building covered in clapboard siding. Logs are fully exposed on the interior of the building (Figure 3). Historical documentation indicates that the house was likely constructed between 1786 and 1788 by Robert Higgins, a captain in the Revolutionary War. The town of Moorefield currently owns the Higgins House and the Hardy County Convention and Visitors Bureau requested to have the building tree-ring dated.

Methods

Field Methods

Before beginning the Higgins House project, I conducted an initial walk-through of the building to determine if it was a candidate for tree-ring dating. I determined that several logs displayed what appeared to be an outer edge, which is necessary to achieve the sample replication for internal (between log samples) and external (between logs and live trees) crossdating and to determine felling dates and inferred construction dates. I collected all cores using an electric drill with a specialized hollow drill bit (14 mm). I attached guide plates to the logs to prevent unnecessary scraping on the log surface during the drilling process. I collected cores from each wall and both floors, totaling 21 cores. I cored all logs on the underside and plugged all holes with wood filler and corks to inhibit water and insect damage and to reinforce the cavities created by sampling. I assigned a unique sample identifier to each core. The sample identification code I used for the Higgins House is as follows: Site (HH), the approximate cardinal direction of wall (N, E, S, W), Floor (first floor (1); second floor (2)), Log (01–08, moving from bottom to top log), and Core Number (first core (A); second core (B)); *e.g.* HHW103A, for Higgins House, West wall, 1st floor, 3rd log from the bottom, first core (A) taken from log.

Laboratory Methods

I glued all cores to 1.2 m prefabricated wooden core mounts with the cross-sectional surface facing upwards and placed clear tape over the cores to evenly adhere them to the core mounts. Once the glue had completely dried (~24 hours) I cut the core mounts to size (~15 cm) and sanded cores using an inverted belt sander and progressively finer sanding belts (100, 220, 320, and 400 ANSI-grit) to display the cellular features of the rings (Orvis and Grissino-Mayer 2002). I then hand sanded, as needed, using 600 to 1000 grit sanding paper to remove any remnant scratches or imperfections on the wood. Inspection at the cellular level confirmed that all 21 cores collected from the Higgins House were white oak (*Quercus alba*).

I assigned temporary sequential numbers to the rings of each sample, starting with 1 at the innermost complete ring and moving outward to the outermost ring. For every decadal ring (10, 20, 30, etc.), I marked one dot on the wood. For every fiftieth ring (50, 150, etc.), I marked two dots on the wood, and for every one-hundredth ring (100, 200, etc.), I marked three dots on the wood (Stokes and Smiley 1996). These arbitrary markings facilitate measuring and internal crossdating of the samples before assigning calendar dates. I then measured and recorded each ring-width of each sample, starting with the year "1001", to the nearest 0.001 mm using a sliding-stage Velmex micrometer and program Tellervo.

I used the software program COFECHA to statistically crossdate the undated tree-ring series (sequential ring-width measurements from a sample), by comparing ring-width patterns from all series with one another. Correlation coefficients were calculated for 50-year segments with 25-year overlaps for each series. This provided initial internal dating that I then visually verified and used to correct dating errors, such as rings skipped during measuring. After internal crossdating was verified (*i.e.* sequential ring widths of all series were highly statistically correlated), I then compared the undated tree-ring series with local and regional tree-ring chronologies from the International Tree-Ring Data Bank (ITRDB) and my personal collection to assign absolute calendar dates to each ring. I selected four oak reference chronologies (Table 1, Figure 4) for external crossdating because of their proximity to the building, similar topography, and/or span of chronology.

I used COFECHA to assign calendar dates to the undated series by comparing them with the reference chronologies. To assign a calendar date to a series, multiple reference chronologies had to suggest the same dating adjustment, and multiple segments within a series had to have the same recommended dating adjustments. For example, in at least two reference chronologies most segments of one series had to show the same dating adjustment of "+700" before I considered it a possible inner ring date for the series. For segments and series where dating adjustments were not conclusive, I also referred to the wood to determine if there were any ring-width discrepancies for individual series.

After I assigned the suggested calendar dates to the series, I used the program ARSTAN (Cook 1985) to detrend each series using a negative exponential curve, which removes age-related growth and internal trends ("noise") from the individual series. I then reran the resulting chronology through COFECHA as a dated series against the reference chronology to verify dating accuracy. If the chronology was dated accurately, COFECHA assigned a dating adjustment of "0" to each segment tested. If all segments were assigned a "0" with a high correlation, I accepted the chronology as absolutely dated. As one last method of verification, I graphically compared the resulting absolutely dated chronology with the reference chronologies for agreement of ring-width variability through time. Corroboration of statistical, visual, and graphical results helps to ensure dating accuracy (Grissino-Mayer 2001), which is imperative when assigning calendar dates to floating ring-width series.

After I assigned calendar dates to all tree rings, I inspected the outer rings to determine terminal ring attributes for each core. To help evaluate felling dates, I used the following standard symbols (Bannister 1962, Nash 1999):

- B: Bark is present, indicating a completely intact outer ring (a certain felling date).
- r: The outermost ring is continuous and intact, but no bark is present (considered a felling date). Patination and beetle galleries, occurring at the interface of xylem and phloem just under bark, are indications of an intact ring.
- v: The date is within a few years of felling date, based on the presence of sapwood (a near felling date). The external surface of weathered logs will crumble when cored, causing the outermost rings to be lost.
- vv: External rings have been lost due to weathering or breaking, and there is no sapwood present to indicate how many rings are missing (a non-felling date).
- ++: Breaks, rot, and weathering on the exterior of core required a ring count from the crossdated section (an estimated near felling date).

Results and Discussion

All 21 cores collected from the Higgins House were confidently internally crossdated (Table 2). The critical correlation value is 0.328, meaning there is 99% confidence in dating assignments with correlation values above this critical correlation value. The mean inter-series correlation for the 21 crossdated tree-ring series is 0.607, indicating high confidence. The average mean sensitivity (a measure of year-to-year variability in ring widths) is 0.200 (relatively sensitive), and the average number of rings (*i.e.* how many years the tree grew before it was felled) is 104.5 years. Of the 84 50-year segments tested by COFECHA, four segments (4.8%) had A or B flags to indicate potential dating errors. Two error flags were from the outer rings of series HHE204A and were both "A" flags, meaning that dating correlations were low, but there was no better placement for the segments. The other two error flags were from the outer rings of series HHS105A. One was an "A" flag, and the other was a "B" flag, which indicated better placement of a 50-year segment. However, all other segments had high correlations in their position, which suggests outer rings of the sample may have had anomalous growth. I reviewed all error flags and associated rings and determined that outer growth was slightly abnormal, but inner rings were consistent with other samples and did not indicate misdated series. Overall, the summary statistics indicate successful internal crossdating (Table 3). A mean ring-width chronology was then created for the Higgins House (HH) (Figure 5).

Statistical comparisons of the 21 white oak samples with the four local and regional tree-ring chronologies yielded consistent dating adjustments. The regional chronologies all suggested a dating adjustment of "+666" for the undated HH chronology. After making dating adjustments and again comparing the dated series with the reference chronologies, all four chronologies yielded overall correlations above the critical correlation value (0.328) (Table 4), suggesting successful external crossdating. Of the four reference chronologies, SCQ had the highest inter-series correlation (0.675) with the Higgins House, followed by RVQ (0.537), WV011 (0.463), and WV012 (0.355) (Table 4). This is an expected result, as SCQ is the closest reference chronology to the Higgins House (~ 10 miles), while WV011 (~ 120 miles) and WV012 (~ 140 miles), both with lower correlations, are much further away from the Higgins House (Figure 4). RVQ, also highly correlated with the Higgins House chronology, is a combination of historic log building chronologies from the Ridge and Valley physiographic province, and thus represents the overall region that the Higgins House is located within. WV012 had the lowest correlation with the Higgins House and three error flags, however, the error flags were not in all 50-year segments, suggesting there were some dissimilarities in the chronologies that are likely due to the distance and geographic differences of the two sites. Graphical comparisons of the Higgins House tree-ring chronology with dating adjustments suggested by the reference chronologies demonstrate consistent similarities in ring-width patterns through time (Figure 6). Crossdating anchored the floating Higgins House (HH) chronology from 1667 to 1827 CE.

Outer Ring Felling Dates

Of the 21 crossdated cores, four displayed bark (B), eight had an intact outermost (terminal) ring (r) but did not have bark, and nine were weathered and/or possibly lightly hewn and were missing a complete live (outermost ring when felled) edge (v) (Table 2). One of the samples with a complete live edge was also broken (++) in the heartwood region and possibly missing rings in the break, so dating assignments beyond the break (to the pith) were not possible due to the low ring count. The 12 crossdated cores with intact outermost rings (B, r) indicate two distinct felling years: 1790 and 1827. Of the 21 sampled logs, 11 represent the 1790 felling year and 10 represent the 1827 felling year. For logs felled in 1790, three were felled in the early growing season, four were felled in the late growing season, and four were weathered on the outer edge but had outer ring dates (not felling dates) between 1787 and 1789, indicating that they were likely also felled in 1790. Additionally, most logs felled in 1790 began growing in the 1670s – 1680s. For logs felled in 1827, five were felled in the late growing season and five were weathered on the outer edge but had outer rings dates (not felling dates) between 1801 and 1819, indicating that they were likely also felled in 1827. Additionally, most logs felled in 1827 began growing in the 1700s – 1730s. The two exceptions to this are HHS105A and HHW104A, which have inner ring dates of 1667 and 1671, respectively. However, the felling year of 1790 is generally associated with a tree cohort from the 1670s – 1680s, and the felling year of 1827 is generally associated with a tree cohort from the 1700s – 1730s. Coring locations and associated outer ring dates are reported in Figures 7–10.

There appears to be no obvious pattern between dates and locations of the logs as logs felled in 1790 and 1827 are represented on both floors (Figures 7–10). Generally, if there are two felling dates associated with a building, the earlier felling date (here 1790) is associated with lower logs, and the later felling date (here 1827) is associated with upper logs. For example, logs from the first floor of a two-story building have outer ring dates of 1790, while logs from the second floor have an outer ring date of 1827, suggesting the cabin was expanded into a two-story house. Or perhaps logs from the first floor and part of the second floor are associated with the earlier felling date (e.g. a lofted one-story cabin), and the top several log courses are associated with the later felling date, demonstrating that the cabin roof was raised to accommodate a full second floor. In the Higgins House, there is no such obvious order, suggesting the house was deconstructed and reconstructed at some point in time.

While touring the house, I noted several locations where former window and door holes were refilled with log and/or brick. I purposefully avoided sampling in those areas, excluding one core (HHS203A), assuming they would provide more modern felling dates as the building was reconfigured for modern needs. Interestingly, HHS203A was felled in 1790 and represents the original construction of the house. Additionally, I noted several locations in which logs were charred, indicating smoke and/or fire damage that was not near the hearth. However, all charred logs that I sampled dated to the 1827 felling period, suggesting that if there was fire damage, it occurred after 1827. Overall, the locations of logs felled in 1790 and 1827 offer no clear pattern from a construction standpoint and lead me to presume that the building was deconstructed and reconstructed for unknown reasons. It is beyond the scope of tree-ring dating to understand how and why the felling years of 1790 and 1827 are found throughout the building, however, these dates may help narrow down periods of interest in historical documentation that will point to the 'how' and 'why' of this historical mystery.

Conclusions

Internal and external crossdating of the 21 white oak samples from the Higgins House was successful. Of the 21 dated samples, 12 (57%) had an intact terminal ring and represented two felling dates; 1790 and 1827. Eleven of the sampled logs represent the felling date of 1790 and ten represent the felling date of 1827. The felling of logs in 1790, determined through tree-ring dating, corroborates historical documentation indicating that the log house was constructed shortly after Robert Higgins purchased the property in 1786. What occurred to the building following its original construction in 1790 remains a mystery, however, the tree-ring evidence presented here suggests that additional logs were felled in 1827, perhaps as renovation and/or reconstruction of the house occurred. What exactly occurred after 1827 and why logs felled in 1790 and 1827 are both dispersed throughout the two-story building is beyond the scope of tree-ring dating. Further investigation in historical documentation may provide information to corroborate these events.

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Table 1. Old-growth (*) and historic (†) oak (white oak, *Quercus alba* (QUAL); mix of oak species, *Quercus* sp. (QUSP)) reference chronologies from the International Tree Ring Data Bank and my personal collection that were used to date samples from the Higgins House. RVQ is a combination of historic log building chronologies from the Ridge and Valley physiographic province; latitude and longitude are approximated for the area represented. SCQ is a log cabin south of Moorefield, WV with a felling date of 1784.

ID	Span	Species	State	Lat.	Long.	Citation
RVQ†	1604 – 1876	QUSP	West Virginia	38.70	-79.38	de Graauw, *unpublished*
SCQ†	1591 – 1784	QUAL	West Virginia	38.91	-79.02	de Graauw, *unpublished*
WV011*	1670 – 2013	QUSP	West Virginia	38.21	-80.94	Cockrell *et al.*, 2017
WV012†	1631 – 1867	QUAL	West Virginia	37.55	-80.69	Cockrell *et al.*, 2017

Table 2. Twenty-one samples collected from the Higgins House. Species (white oak, *Quercus alba* (QUAL)). Innermost Year Measured (IY M), Outermost Year Measured (OY M), Outermost Year (OY, possibly unmeasured). Visual Attributes (B: bark intact; r: rounded (live) edge intact; v: outer edge not intact, near felling date; vv: outer edge not intact, not near felling date; ++: break in core, estimated felling date). Season (early (E), late (L), undetermined (U)).

Sample ID	Species	IY M	OY M	OY	Season	Visual Attributes
HHE104A	QUAL	1689	1789	1790	E	r: considered absolute felling date
HHE105A	QUAL	1778	1827	1827	L	r, ++: inside undated, live edge intact
HHE204A	QUAL	1689	1790	1790	E	r: considered absolute felling date
HHE205A	QUAL	1738	1827	1827	L	B: absolute felling date
HHN106A	QUAL	1679	1789	1790	L	r: considered absolute felling date
HHN107A	QUAL	1732	1817	1817	U	v: weathered - burn/char
HHN108A	QUAL	1701	1812	1812	U	v: weathered - burn/char
HHN203A	QUAL	1681	1789	1790	L	r: considered absolute felling date
HHN205A	QUAL	1679	1786	1787	U	v: hewn end
HHN206A	QUAL	1733	1827	1827	L	B: absolute felling date
HHS104A	QUAL	1673	1790	1790	L	r: considered absolute felling date
HHS105A	QUAL	1667	1809	1810	U	v: burn/char on weathered outer edge
HHS106A	QUAL	1675	1788	1789	U	v: weathered, outline of 1789 earlywood
HHS203A	QUAL	1678	1789	1790	L	r: considered absolute felling date
HHS205A	QUAL	1681	1789	1790	E	r: considered absolute felling date
HHW104A	QUAL	1681	1800	1801	U	v: weathered - burn/char
HHW106A	QUAL	1678	1789	1789	U	v: outline of 1790 earlywood present
HHW108A	QUAL	1700	1819	1819	U	v: weathered end
HHW205A	QUAL	1738	1827	1827	L	B: absolute felling date
HHW206A	QUAL	1740	1827	1827	L	B: absolute felling date
HHW207A	QUAL	1685	1788	1789	U	v: weathered end

Table 3. Summary Statistics for internal (between samples) crossdating of samples from the Higgins House.

Arbitrary Years	Samples	Segments Tested[a]	Segments Flagged[a]	Interseries Correlation	Mean Sensitivity
1001 – 1161	21	84	4	0.607	0.200

[a] Number of segments tested in COFECHA and flagged for inconsistent growth.

Table 4. Correlation analysis from COFECHA for regional chronology comparison with internally dated samples from the Higgins House, with suggested maximum outer ring date of 1827. * "A" flags represent segments of low correlation, but with no other suggested placements and "B" flags represent segments with low correlations and possible locations of better placement. There are no correlations to report for the comparison with SCQ during the periods 1775 – 1824 and 1800 – 1849 because the SCQ chronology ends in 1784 CE.

Site	Correlation	50-year segment tested						
		1650 – 1699	1675 – 1724	1700 – 1749	1725 – 1774	1750 – 1799	1775 – 1824	1800 – 1849
RVQ	0.537	0.53	0.51	0.59	0.63	0.57	0.53	0.54
SCQ	0.675	0.58	0.63	0.81	0.80	0.80	---	---
WV011	0.463	0.49	0.45	0.59	0.52	0.41	0.40	0.38
WV012	0.355	O.13B	0.21B	0.50	0.42	0.20B	0.51	0.47

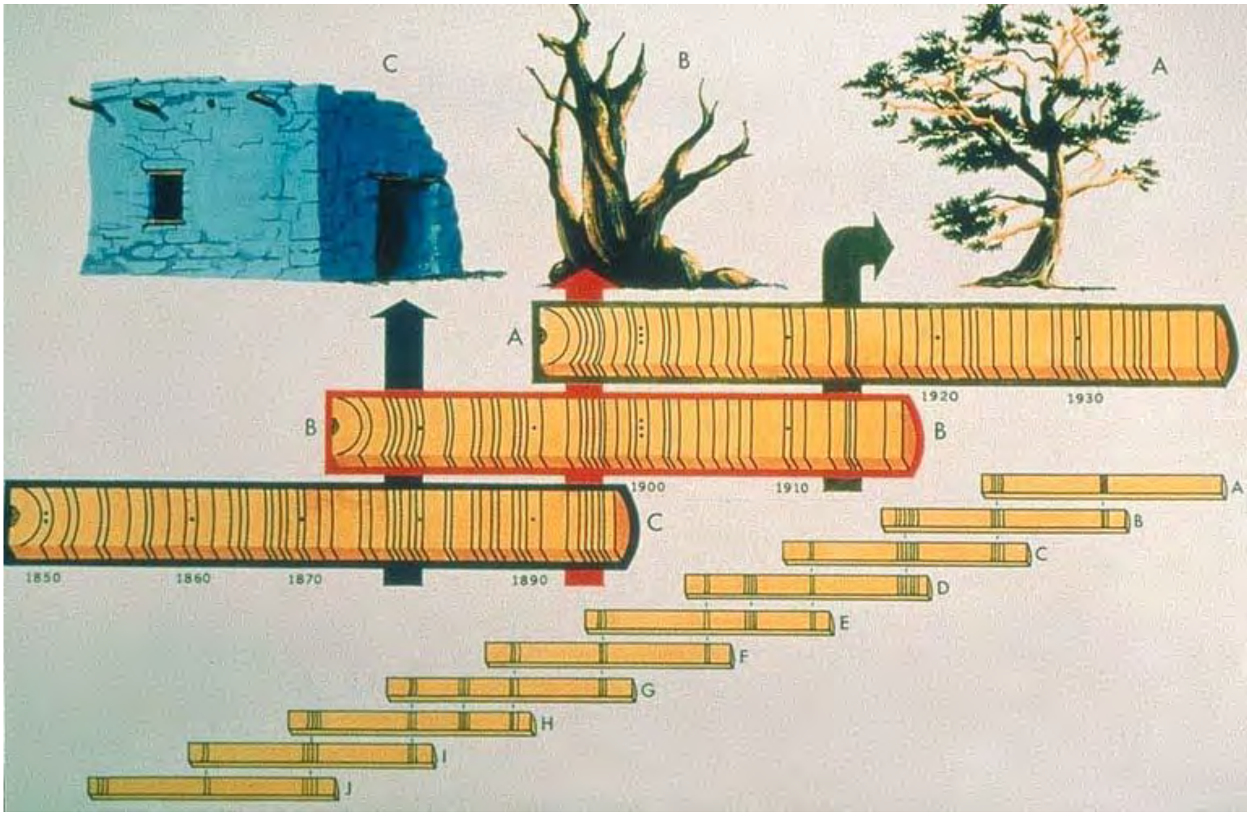

Figure 1. Patterns of tree ring-width variability are used to provide annual dates to historic structures by comparing them with living and dead trees. Courtesy of NOAA Paleoclimatology Program.

Figure 2. The Higgins House, view of the south wall. Photo: K. de Graauw

Figure 3. Logs are fully exposed on the interior of the Higgins House. View of first floor east wall (hearth) and south wall (to right).

Figure 4. Locations of the Higgins House (HH) and the four regional reference chronologies (RVQ, SCQ, WV011, and WV012) used to assigned calendar dates to the logs.

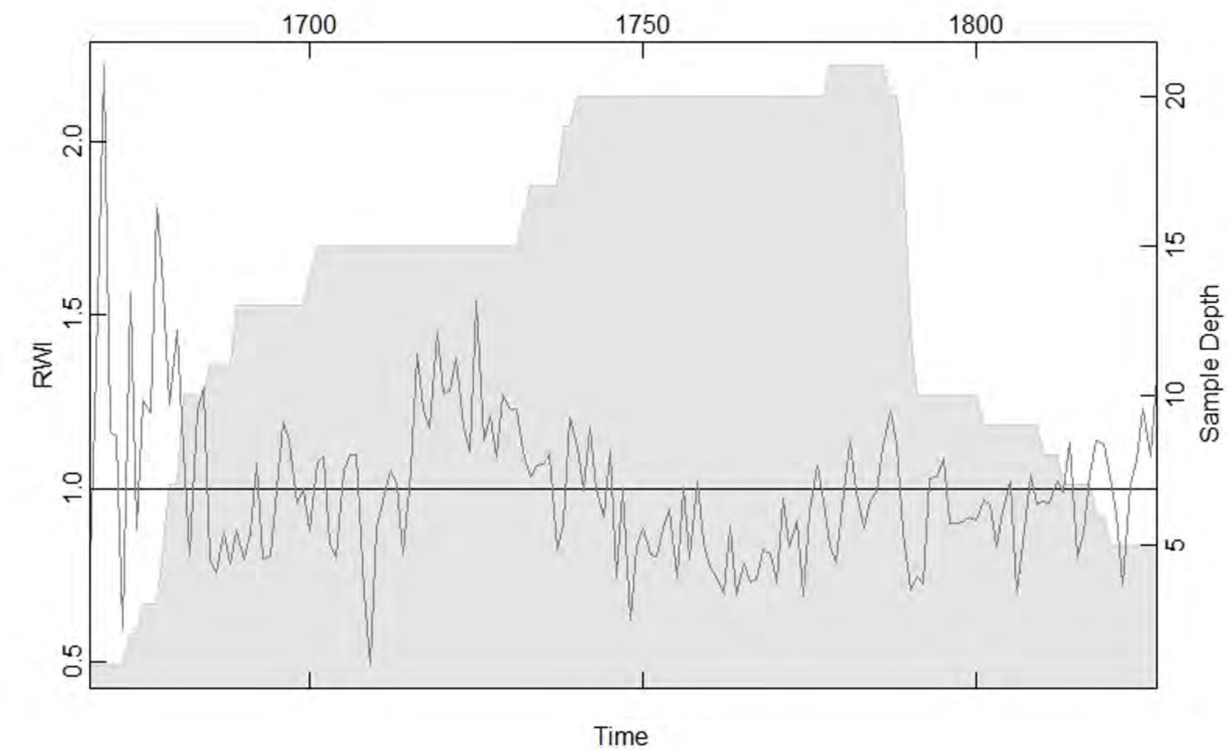

Figure 5. Mean ring width (RWI) chronology (black line) and sample depth (grey area) of the 21 white oak (*Quercus alba*) series from the Higgins House.

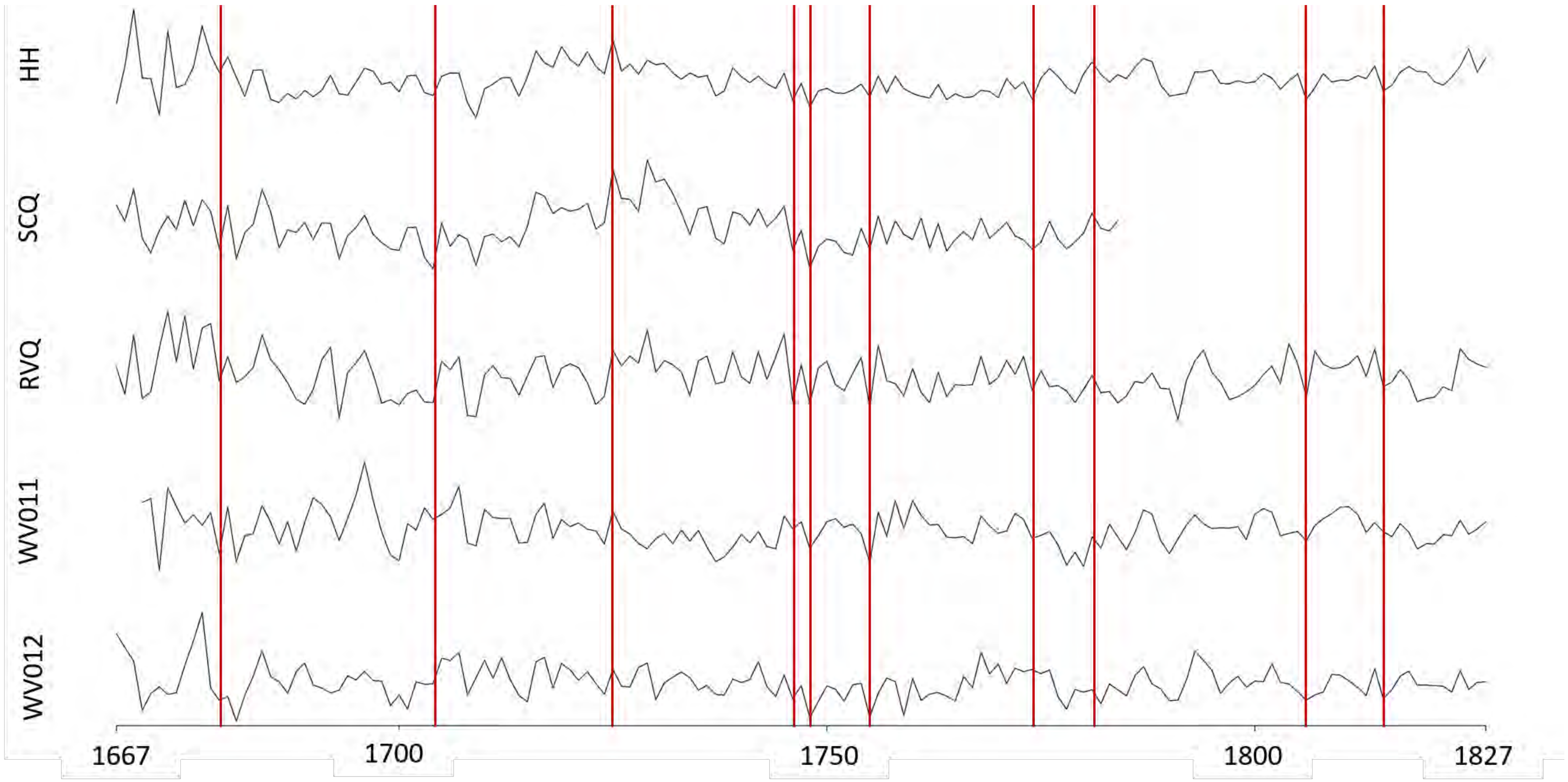

Figure 6. Graphical comparison of the Higgins House (HH) chronologies with the reference chronologies SCQ, RVQ, WV011, and WV012. Vertical red lines to emphasize select major years of agreement among chronologies.

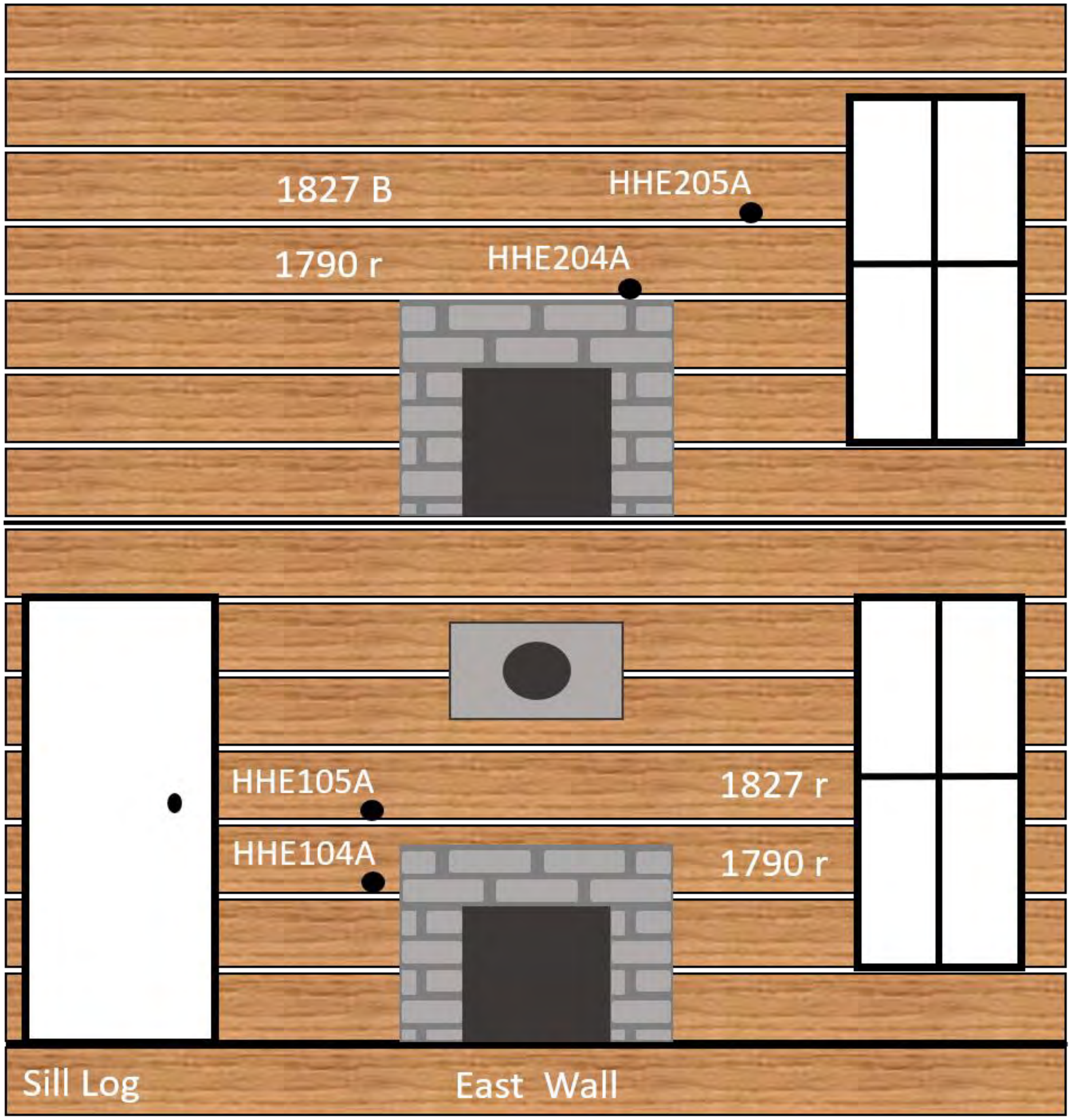

Figure 7. Coring locations and outer ring dates (with visual attribute) for all samples collected from the east wall of the Higgins House. Visual attribute code: "B" indicates bark is present, a true felling date; "r" indicates no bark is present, but there is a terminal "live" edge, considered a true felling date.

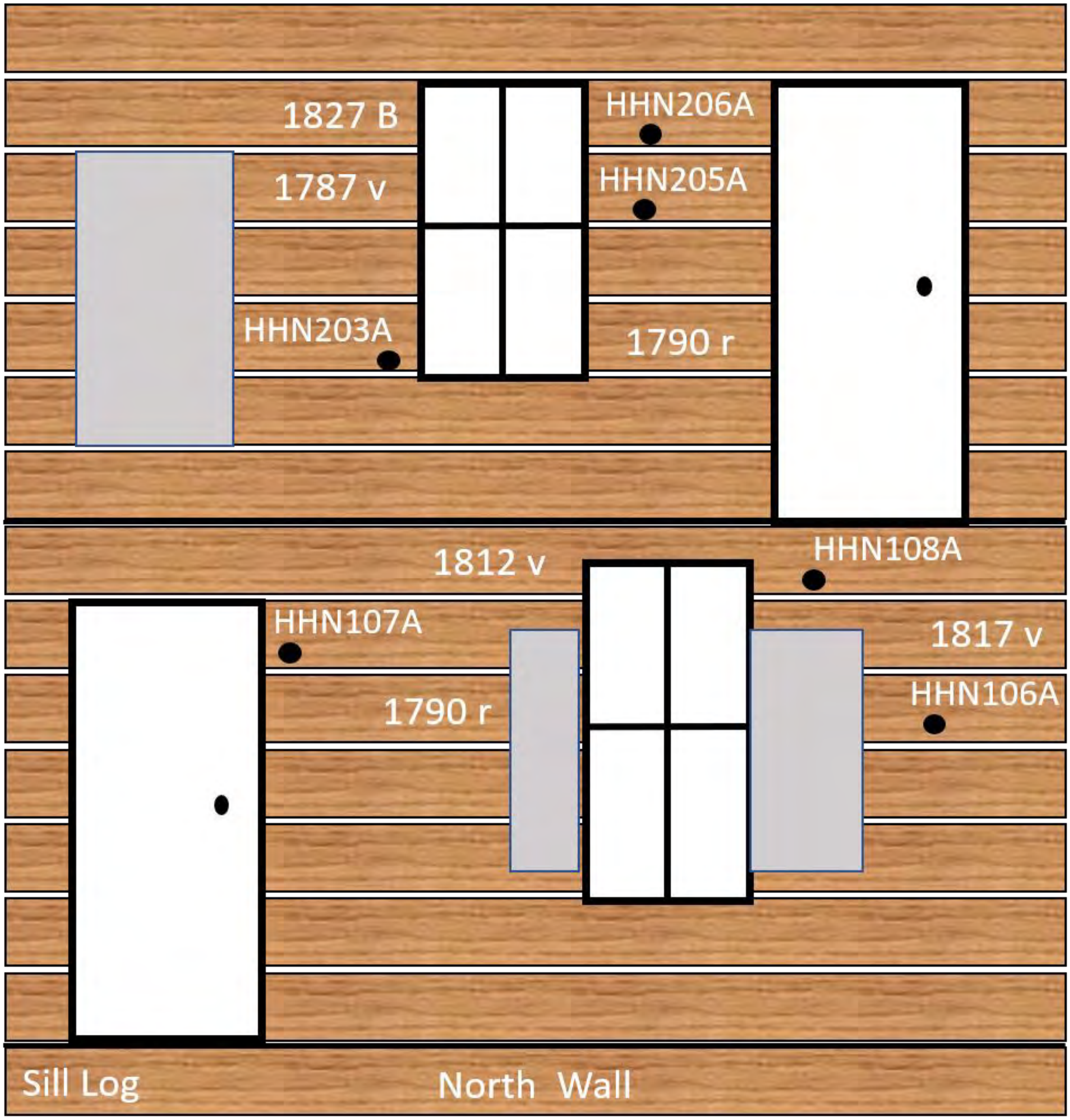

Figure 8. Coring locations and outer ring dates (with visual attribute) for all samples collected from the north wall of the Higgins House. Visual attribute codes: "B" indicates bark is present, a true felling date; "r" indicates no bark is present, but there is a terminal "live" edge, considered a true felling date; "v" indicates there is no terminal edge, likely weathered or hewn and missing outer ring(s).

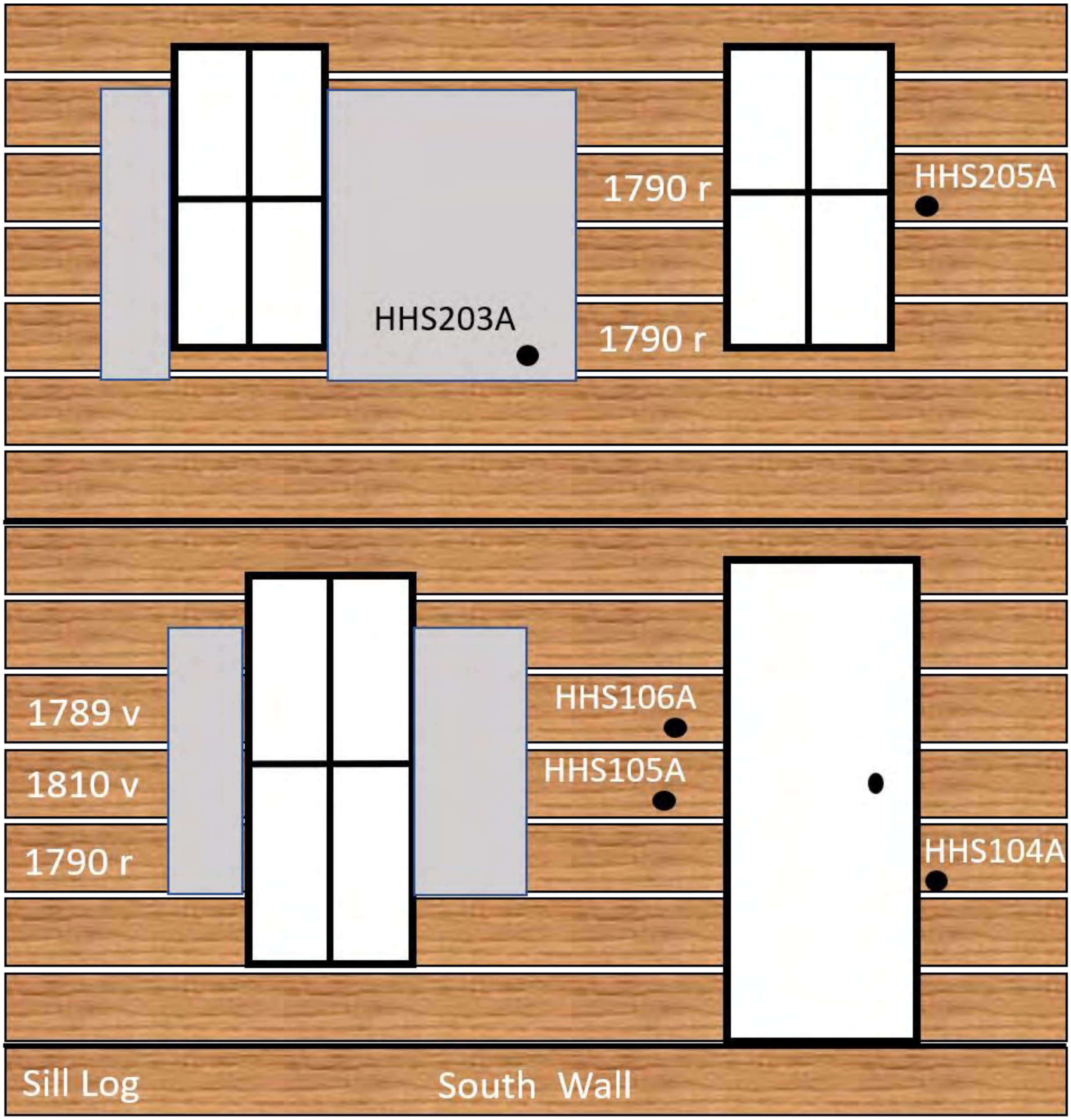

Figure 9. Coring locations and outer ring dates (with visual attribute) for all samples collected from the south wall of the Higgins House. Visual attribute codes: "r" indicates no bark is present, but there is a terminal "live" edge, considered a true felling date; "v" indicates there is no terminal edge, likely weathered or hewn and missing outer ring(s).

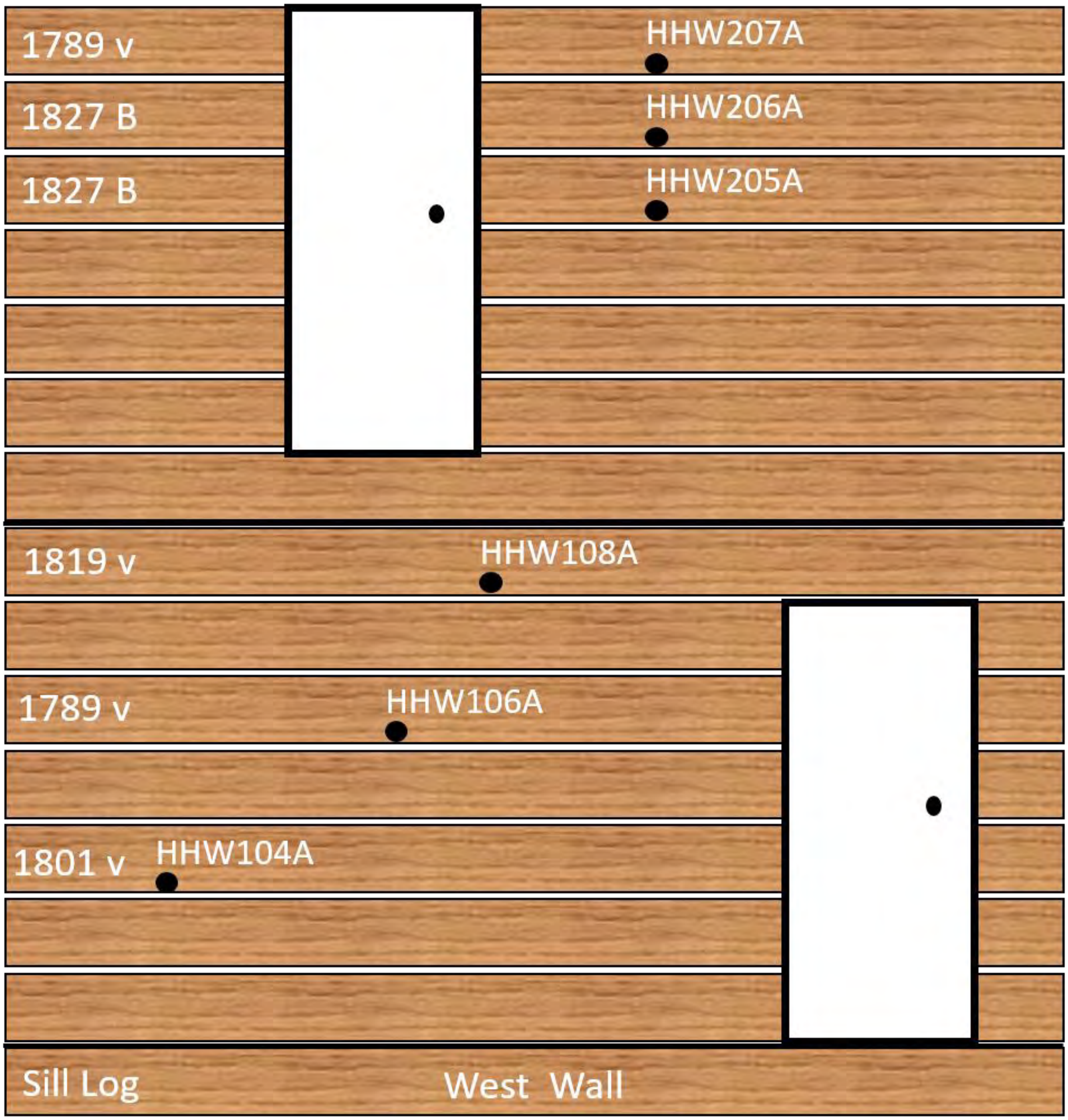

Figure 10. Coring locations and outer ring dates (with visual attribute) for all samples collected from the west wall of the Higgins House. Visual attribute codes: "B" indicates bark is present, a true felling date; "v" indicates there is no terminal edge, likely weathered or hewn and missing outer ring(s).

Dendroarchaeology Tools


#HN107A
11 • 13 • 15


HHE205A
E205


HHW104A
HHS104A
HHE104A
HHN107A

AmScope
JMN102A
RUTH WOODS DAYTON