

**Oxford Tree-Ring Laboratory  
Report 2013/16**

**The Tree-Ring Dating of the Angel-Ditzel Barn,  
Milford, New Jersey (HT #26)**

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Summary:

Angel-Ditzel Barn, Milford, New Jersey (40.58344, -75.15370)

(a) Barn primary structure

*Felling dates:* **Winter 1824/5, Spring 1825**

(a) Ceiling joists (5/6) 1824 (¼C, C); Posts (2/3) 1811 + 11mm, 1824 (¼C); Rail (0/1). *Site Master* 1667-1824 ADNJx1 (*t*=8.71 FORES; 8.31 EAPANN; 7.94 MD2011).

The Angel-Ditzel barn is a 50' x 30' Pennsylvania forebay bank barn incorporating the lighter German system of framing, with four bents framed with full-width tie beams and intermediate posts. Dendrochronological analysis has shown that the original structure was built from trees felled in the winter of 1824/5 through to the spring of 1825, suggesting a construction date of the spring of 1825 or shortly thereafter.

**Date sampled:** August 13, 2013

**Owner:** Ann-Marie Anderson

**Commissioners:** Larry LaFevre and Carla Cielo, Holland Township Historic Preservation Commission

**Funders:** New Jersey Historical Commission (NJHC Minigrant 2013) and Holland Township Committee

**Location:** 51 Crab Apple Hill Rd, Milford, NJ 08848

**Summary published:** [www.dendrochronology.com](http://www.dendrochronology.com)

## How Dendrochronology Works

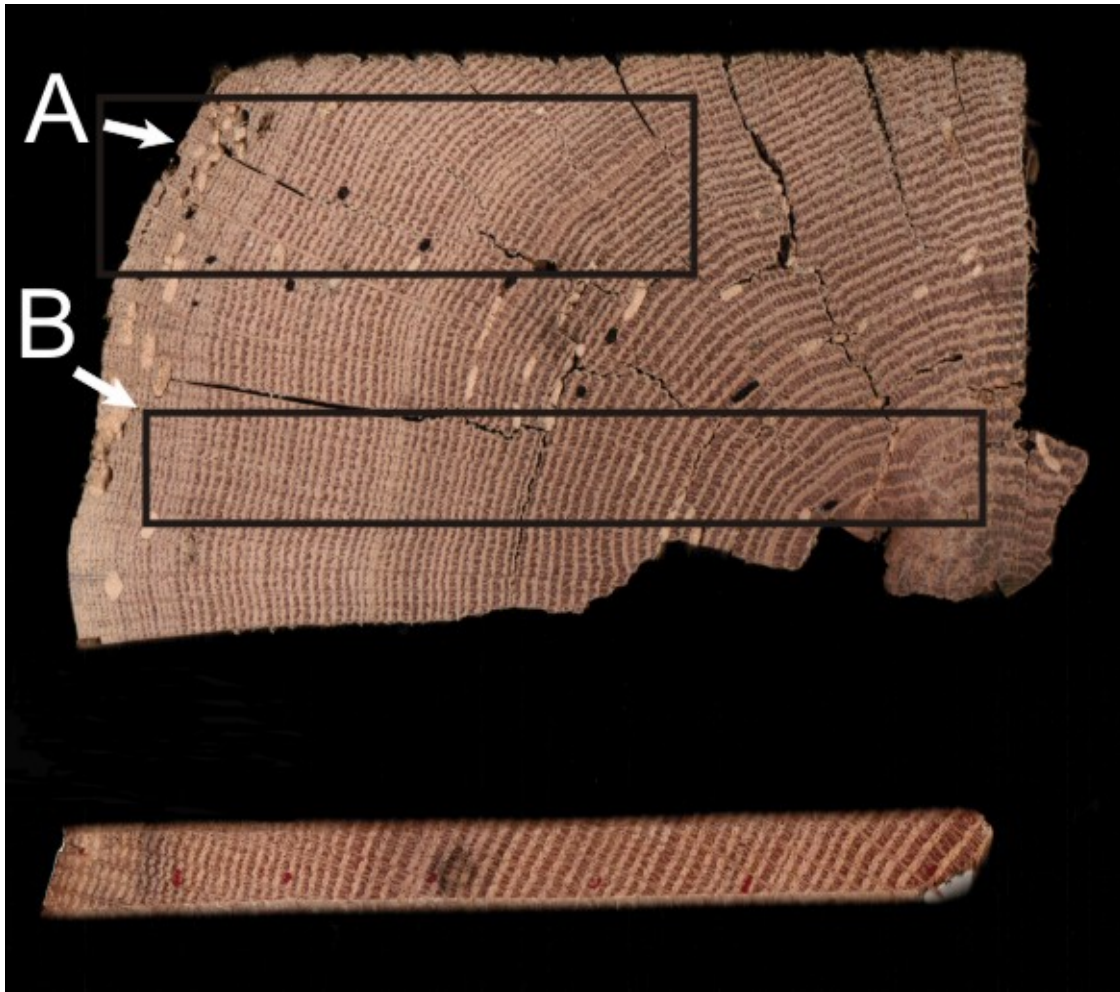
Dendrochronology has over the past few decades become one of the leading and most accurate scientific dating methods. While not always successful, when it does work, it is precise, often to the season of the year. Tree-ring dating to this degree of precision is well known for its use in dating historic buildings and archaeological timbers. However, more ancillary objects such as doors, furniture, panel paintings, and wooden boards in medieval book-bindings can sometimes be successfully dated.

The science of dendrochronology is based on a combination of biology and statistics. In temperate zones, a tree puts on a new layer of growth underneath the bark every year, with the effect being that the tree grows wider and taller as it ages. Each annual ring is composed of the growth which takes place during the spring and summer and continues until about November, when the leaves are shed and the tree becomes dormant for the winter period. For the two principal American oaks, the white and red (*Quercus alba* and *Q. rubra*), as well as for the black ash (*Fraxinus nigra*) and many other species, the annual ring is composed of two distinct parts: the spring growth or early wood, and the summer growth, or late wood. Early wood is composed of large vessels formed during the period of shoot growth which takes place between March and May, before the establishment of any significant leaf growth. This is produced by using most of the energy and raw materials laid down the previous year. Then, there is an abrupt change at the time of leaf expansion around May or June when hormonal activity dictates a change in the quality of the xylem, and the summer growth, or late wood, is formed. Here the wood becomes increasingly fibrous and contains much smaller vessels. Trees with this type of growth pattern are known as ring-porous, and are distinguished by the contrast between the open, light-colored early wood vessels and the dense, darker-colored late wood.

Other species of tree, such as tulip poplar (*Liriodendron tulipifera* L.), are known as diffuse-porous. Unlike the ring-porous trees, the spring vessels consist of very small spring vessels that become even smaller as the tree advances into the summer growth. The annual growth rings are often very difficult to distinguish under even a powerful microscope, and one often needs to study the medullary rays, which thicken at the ring boundaries.

Dendrochronology utilizes the variation in the width of the annual rings as influenced by climatic conditions common to a large area, as opposed to other more local factors such as woodland competition and insect attack. It is these climate-induced variations in ring widths that allow calendar dates to be ascribed to an undated timber when compared to a firmly-dated sequence. If a tree section is complete to the bark edge, then when dated a precise date of felling can be determined. The felling date will be precise to the season of the year, depending on the degree of formation of the outermost ring. Therefore, a tree with bark that has the spring vessels formed but no summer growth can be said to be felled in the spring, although it is not possible to say in which particular month the tree was felled.

Another important dimension to dendrochronological studies is the presence of sapwood and bark. This is the band of growth rings immediately beneath the bark and comprises the living growth rings which transport the sap from the roots to the leaves. This sapwood band is distinguished from the heartwood by the prominent features of color change and the blocking of the spring vessels with tyloses, the waste products of the tree's growth. The heartwood is generally darker in color, and the spring vessels are usually blocked with tyloses. The heartwood is dead tissue, whereas the sapwood is living, although the only really living, growing, cells are in the cambium, immediately beneath the bark. In the American white oak (*Quercus alba*), the difference in color is not generally matched by the change in the spring vessels, which are often filled by tyloses to within a year or two of the terminal ring. Conversely, the spring vessels in the American red oak (*Q. rubra*) are almost all free of tyloses, right to the pith. Generally the sapwood retains stored food and is therefore attractive to insect and fungal attack once the tree is felled and therefore is often removed during conversion.



**Figure 1.** A cross-section of an oak timber with sapwood rings on the left-hand side (above). The boxes illustrate conversion methods resulting in **A**) a precise felling date and **B**) a *terminus post quem* or felled-after date. Also pictured is a core showing complete sapwood (below).

### **Methodology: The Dating Process**

All ten timbers sampled were of white oak (*Quercus alba*). All samples were from what appeared to be primary first-use timbers. Timbers that looked most suitable for dendrochronological purposes—those with complete sapwood or reasonably long ring sequences—were selected. *In-situ* timbers were sampled through coring, using a 16 mm hollow auger. Details and locations of the samples are given in the summary tables.

The dry samples were sanded on a linisher, or bench-mounted belt sander, using 60 to 1200 grit abrasive paper, and were cleaned with compressed air to allow the ring boundaries to be clearly distinguished. They were then measured under a x10/x30 microscope using a travelling stage electronically displaying displacement to a precision of 0.01mm. Thus each ring or year is represented by its measurement which is arranged as a series of ring-width indices within a data set, with the earliest ring being placed at the beginning of the series, and the latest or outermost ring concluding the data set.

As indicated above, the principle behind tree-ring dating is a simple one: the seasonal variations in climate-induced growth as reflected in the varying width of a series of measured annual rings is compared with other, previously dated ring sequences to allow precise dates to be ascribed to each ring. When an undated sample or site sequence is compared against a dated sequence, known as a reference chronology, an



indication of how good the match is must be determined. Although it is almost impossible to define a visual match, computer comparisons can be accurately quantified. While it may not be the best statistical indicator, Student's (a pseudonym for W S Gosset)  $t$ -value has been widely used among dendrochronologists. The cross-correlation algorithms most commonly used and published are derived from Baillie and Pilcher's CROS program (Baillie and Pilcher 1973).

Generally,  $t$ -values over 3.5 should be considered significant, although in reality it is common to find demonstrably spurious  $t$ -values of 4 and 5 because more than one matching position is indicated. For this reason, dendrochronologists prefer to see some  $t$ -value ranges of 5, 6, or higher, and for these to be well replicated from different, independent chronologies with local and regional chronologies well represented. Users of dates also need to assess their validity critically. They should not have great faith in a date supported by a handful of  $t$ -values of 3s with one or two 4s, nor should they be entirely satisfied with a single high match of 5 or 6. Examples of spurious  $t$ -values in excess of 7 have been noted, so it is essential that matches with reference chronologies be well replicated, and that this is confirmed with visual matches between the two graphs. Matches with  $t$ -values of 10 or more between individual sequences usually signify having originated from the same parent tree.

In reality, the probability of a particular date being valid is itself a statistical measure depending on the  $t$ -values. Consideration must also be given to the length of the sequence being dated as well as those of the reference chronologies. A sample with 30 or 40 years growth is likely to match with high  $t$ -values at varying positions, whereas a sample with 100 consecutive rings is much more likely to match significantly at only one unique position. Samples with ring counts as low as 50 may occasionally be dated, but only if the matches are very strong, clear, and well replicated, with no other significant matching positions. This is essential for intra-site matching when dealing with such short sequences. Consideration should also be given to evaluating the reference chronology against which the samples have been matched: those with well-replicated components that are geographically near to the sampling site are given more weight than an individual site or sample from far away.

It is general practice to cross-match samples from within the same phase to each other first, combining them into a site master, before comparing with the reference chronologies. This has the advantage of averaging out the "noise" of individual trees and is much more likely to obtain higher  $t$ -values and stronger visual matches. After measurement, the ring-width series for each sample is plotted as a graph of width against year on log-linear graph paper. The graphs of each of the samples in the phase under study are then compared visually at the positions indicated by the computer matching and, if found satisfactory and consistent, are averaged to form a mean curve for the site or phase. This mean curve and any unmatched individual sequences are compared against dated reference chronologies to obtain an absolute calendar date for each sequence. Sometimes, especially in urban situations, timbers may have come from different sources and fail to match each other, thus making the compilation of a site master difficult. In this situation samples must then be compared individually with the reference chronologies.

Therefore, when cross-matching samples with each other, or against reference chronologies, a combination of both visual matching and a process of qualified statistical comparison by computer is used. For this study, the ring-width series were compared on an IBM compatible computer for statistical cross-matching using a variant of the Belfast CROS program (Baillie and Pilcher 1973).

### **Ascribing and Interpreting Felling Dates**

Once a tree-ring sequence has been firmly dated in time, a felling date, or date range, is ascribed where possible. For samples that have sapwood complete to the underside of, or including, bark, this process is relatively straight forward. Depending on the completeness of the final ring, i.e. if it has only the early wood formed, or the latewood, a *precise felling date and season* can be given. Where the sapwood is partially missing, or if only a heartwood/sapwood transition boundary survives, then the question of when

the tree was felled becomes considerably more complicated. In the European oaks, sapwood tends to be of a relatively constant width and/or number of rings, and it is possible to estimate the approximate number of sapwood rings that are missing from any given timber.

Unfortunately, it has not been possible to apply an accurate sapwood estimate to either the white or red oaks at this time. Primarily, it would appear that there is a complete absence of literature on sapwood estimates for oak anywhere in the country (Grissino-Mayer, *pers comm*). The matter is further complicated in that the sapwood in white oak (*Quercus alba*) occurs in two bands, with only the outer ring or two being free of tyloses in the spring vessels (Gerry 1914; Kato and Kishima 1965). Out of some 50 or so samples, only a handful had more than 3 rings of sapwood without tyloses. The actual sapwood band is differentiated sometimes by a lighter color, although this is often indiscernible (Desch 1948). In archaeological timbers, the lighter colored sapwood does not collapse as it does in the European oak (*Q rober*), but only the last ring or two without tyloses shrink tangentially. In these circumstances the only way of being able to identify the heartwood/sapwood boundary is by recording how far into the timber wood boring beetle larvae penetrate, as the heartwood is not usually susceptible to attack unless the timber is in poor or damp conditions. Despite all of these drawbacks, some effort has been made in recording sapwood ring counts on white oak, although the effort is acknowledged to be somewhat subjective.

As for red oaks (*Quercus rubra*) it will probably not be possible to determine a sapwood estimate as these are what are known as “sapwood trees” (Chattaway 1952). Whereas the white oak suffers from an excess of tyloses, these are virtually non-existent in the red oak, even to the pith. Furthermore, there is no obvious color change throughout the section of the tree, and wood-boring insects will often penetrate right through to the center of the timber. Therefore, in sampling red oaks, it is vital to retain the final ring beneath the bark, or to make a careful note of the approximate number of rings lost in sampling, if any meaningful interpretation of felling dates is to be made. Similarly, no study has been made in estimating the number of sapwood rings in chestnut oak, tulip-poplar, black ash, or any of the pines.

Therefore, if the bark edge does not survive on any of the timbers sampled, only a *terminus post quem* or *felled-after* date can be given. The earliest possible felling date would be the year after the last measured ring date, adjusted for any unmeasured rings or rings lost during the process of coring.

Some caution must be used in interpreting solitary precise felling dates. Many instances have been noted where timbers used in the same structural phase have been felled one, two, or more years apart. Whenever possible, a group of precise felling dates should be used as a more reliable indication of the construction period. It must be emphasized that dendrochronology can only date when a tree has been felled, not when the timber was used to construct the structure under study. However, it is common practice to build timber-framed structures with green or unseasoned timber and therefore construction usually took place within twelve to eighteen months of felling (Miles 1997).

### **Details of Dendrochronological Analysis**

The results of the dendrochronological analysis for the buildings under study are presented in a number of detailed tables. The most useful of these is the summary **Table 1**. This gives most of the salient results of the dendrochronological process, and includes details for each sample, such as its species, location, and felling date, if successfully tree-ring dated. This last column is of particular interest to the end user, as it gives the actual year and season when the tree was felled, if bark or bark edge is present. If bark edge is not present, it gives a *terminus post quem* or date after which the timber was felled. Often these *terminus post quem* dates begin far earlier than any associated precise felling dates. This is simply because far more rings have been lost in the initial conversion of the timber. If the sapwood was complete on the timber but some was lost during coring, an estimated date range can sometimes be given.

It will also be noticed that often the precise felling dates will vary within several years of each other. Unless there is supporting archaeological evidence suggesting different phases, all this would indicate is either stockpiling of timber, or of trees that had been felled or died at varying times but were not cut up until the commencement of the particular building operations in question. When presented with varying precise felling dates, one should always take the latest date for the structure under study, and it is likely that construction will have been completed for ordinary vernacular buildings within twelve or eighteen months from this latest felling date (Miles 1997).

**Table 2** gives an indication of the statistical reliability of the match between one sequence and another. This shows the  $t$ -value over the number of years overlap for each combination of samples in a matrix table. It should be born in mind that  $t$ -values with less than 80 rings overlap may not truly reflect the same degree of matching and that spurious matches may produce similar values.

First, multiple radii have been cross-matched with each other and combined to form same-timber means. These are then compared with other samples from the site and any which are found to have originated from the same parent tree are again similarly combined. Finally, all samples, including all same timber and same tree means, are combined to form one or more site masters. Again, the cross-matching is shown as a matrix table of  $t$ -values over the number of years overlaps. Reference should always be made to **Table 1** to clearly identify which components have been combined.

**Table 3** shows the degree of cross-matching between the site master(s) and a selection of reference chronologies. This shows the state or region from which the reference chronology originated, the common chronology name, the publication reference, and the years covered by the reference chronology. The number of overlapping years between the reference chronology and the site master is also shown together with the resulting  $t$ -value. It should be noted that well replicated regional reference chronologies, which are shown in **bold**, will often produce better matches than individual site masters or indeed individual sample sequences.

**Figures** include a bar diagram that shows the chronological relationship between two or more dated samples from a phase of building and any plans showing sample locations, if available.

**Publication** of all dated sites for English buildings occurs annually in *Vernacular Architecture*, but regrettably there is at the present time no vehicle available for the publication of dated American buildings. However, a similar entry is shown on the summary page of the report, which could be used in any future publication of American dates. This does not give as much technical data for the samples dated, but does give the  $t$ -value matches against the relevant chronologies, provides a short descriptive paragraph for each building or phase dated, and gives a useful short summary of samples dated. These summaries are also listed on the web-site maintained by the Laboratory, which can be accessed at [www.dendrochronology.com](http://www.dendrochronology.com). The Oxford Tree-Ring Laboratory retains copyright of this report, but the commissioner of the report has the right to use the report for his or her own use so long as the authorship is quoted. Primary data and the resulting site master(s) used in the analysis are available from the Laboratory on request by the commissioner and bona fide researchers. The samples form part of the Laboratory archives, unless an alternative archive, such as the Colonial Williamsburg Foundation in association with the Oxford Tree-Ring Laboratory, has been specified in advance.

## Sampling

The Angel-Ditzel barn is a 50' x 30' Pennsylvania forebay bank barn incorporating the lighter German system of framing. The frame has four bents, each with full-width tie beams and intermediate posts. The tie beams are squared and the posts are oriented with the longer dimension perpendicular to the ridge. The Angel-Ditzel barn is one of the few barns remaining in Holland Township that is framed with a half-lapped, half-dovetail joint at the upper tie-beam plate connection and the purlin cross tie/ purlin connection, a German detail. The center threshing bay is lined with mowstead walls on each side. An 1860 farm map shows that the associated farm was owned by John Angel at that time. (Building description provided by the Holland Township Historic Preservation Commission.)

A dendrochronological study of the Angel-Ditzel Barn was undertaken in an attempt to date the primary construction phase of the building. Ten oak timbers in total were sampled: six ceiling joists, three posts, and a rail.

Each sample was given the code **adnj** (for Angel-Ditzel, New Jersey) and numbered 1 to 10 (see table 1). The position of each sample was noted at the time of sampling (see figure 2).

## Summary of Dating

Bark edge survived on nine of the ten timbers deemed suitable for analysis. The outer wood on some of the timbers was extremely friable and therefore difficult to keep intact during coring. As a result, multiple samples were taken from two of these timbers in order to maximise the chances of retaining a complete core. Multiple samples from one of the timbers were combined to form the new individual sample sequence **adnj1**, which was used in the rest of the analysis (see table 2). The multiple samples from the other timber, **adnj7**, did not match each other and were used individually in all further analysis.

All of the timber sequences were compared with each other. Seven of the oak timbers (**adnj1**, **adnj2**, **adnj3**, **adnj4**, **adnj6**, **adnj7a2**, and **adnj9**) were found to match each other, allowing them to be combined into the 158-year oak site master **ADNJx1** (see table 2)

The site master and the remaining unmatched samples were compared with over six hundred master chronologies from the East Coast of the United States. **ADNJx1** was found to date spanning the years 1667 to 1824 (see table 3). None of the individual samples were found to match against the master chronologies and therefore remain undated.

## Interpretation

The tree-ring analysis has resulted in the successful dating of the Angel-Ditzel Barn. Seven of the ten samples have dated, six of which retained complete sapwood. The samples with complete sapwood gave precise felling dates of the winter of 1824/25 and the spring of 1825, leading to the conclusion that the primary construction phase of the barn took place in the spring of 1825 or shortly thereafter.

## Acknowledgements

Thanks are given to Ed Cook, Gordon Jacoby, and Paul Krusic of the LDEO Dendrochronology Laboratory at Columbia University, New York, and to Bill Callahan for making available both published and unpublished reference chronologies. Thanks are also due to the Holland Township Committee for their support and partial funding of the project.



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**Table 1:** Summary of tree-ring dating

**ANGEL-DITZEL BARN, MILFORD, NEW JERSEY**

Sample seasons and number & type ranges	Species	Timber and position	Dates AD spanning	Last Ring	No of rings	Mean width mm	Std devn mm	Mean sens mm	Felling dates/date
<b>Barn primary structure</b>									
<b>adj1a</b>	c	QUAL Joist 9 <sup>th</sup> from east wall	1689-1824	¼C	136	1.28	0.53	0.199	
<b>adj1b</b>	c	QUAL ditto	1676-1824	¼C	149	1.24	0.53	0.205	
* <b>adj1</b>		Mean of <b>adj1a1</b> + <b>adj1b</b>	1676-1824	¼C	149	1.25	0.50	0.192	Spring 1825
* <b>adj2</b>	c	QUAL Joist 10 <sup>th</sup> from east wall	1667-1824	C	158	0.99	0.36	0.196	Winter
1824/5									
* <b>adj3</b>	c	QUAL Joist 7 <sup>th</sup> from east wall	1741-1824	¼C	84	1.94	0.62	0.153	Spring 1825
* <b>adj4</b>	c	QUAL Joist 6 <sup>th</sup> from east wall	1696-1824	¼C	129	1.15	0.33	0.164	Spring 1825
<b>adj5</b>	c	QUAL Joist 3 <sup>rd</sup> from east wall	-	¼C	140	0.73	0.34	0.207	
* <b>adj6</b>	c	QUAL Joist 4 <sup>th</sup> from east wall	1732-1824	C	93	1.22	0.37	0.239	Winter
1824/5									
<b>adj7a1</b>	c	QUAL Post bent C south end	-	h/w only	86	0.63	0.24	0.224	
* <b>adj7a2</b>	c	QUAL ditto	1735-1811	11nm ¼C	77	1.00	0.30	0.188	1822-1827
<b>adj7b1</b>	c	QUAL ditto	-		70	1.23	0.33	0.112	
<b>adj7b2</b>	c	QUAL ditto	-	¼C	42	0.95	0.20	0.117	
<b>adj8</b>	c	QUAL Post bent A 1 <sup>st</sup> from north wall	-	h/w only	98	1.20	0.39	0.154	
* <b>adj9</b>	c	QUAL Post bent B 1 <sup>st</sup> from north wall	1713-1824	C	98	1.20	0.39	0.154	Winter
1824/5									
<b>adj10a1</b>	c	QUAL Rail bent C north end	-	h/w only	58	1.59	0.27	0.115	
<b>adj10a2</b>	c	QUAL ditto	-	C	8	1.59	0.51	0.127	
* <b>ADNJx1</b>			1667-1824		158	1.19	0.36	0.152	

Key: \*, †, § = sample included in site master; c = core; mc = micro-core; s = slice/section; g = graticule; p = photograph; ¼C, ½C, C = bark edge present, partial or complete ring; ¼C = spring (last partial ring not measured), ½C = summer/autumn (last partial ring not measured), or C = winter felling (ring measured); h/w only = heartwood only; nm = number of unmeasured rings; std devn = standard deviation; mean sens = mean sensitivity; QUAL = *Quercus alba* (white oak)

## Explanation of terms used in Table 1

The summary table gives most of the salient results of the dendrochronological process. For ease in quickly referring to various types of information, these have all been presented in Table 1. The information includes the following categories:

**Sample number:** Generally, each site is given a two or three letter identifying prefix code, after which each timber is given an individual number. If a timber is sampled twice, or if two timbers were noted at time of sampling as having clearly originated from the same tree, then they are given suffixes ‘a’, ‘b’, etc. Where a core sample has broken, with no clear overlap between segments, these are differentiated by a further suffix ‘1’, ‘2’, etc.

**Type** shows whether the sample was from a core ‘c’, or a section or slice from a timber ‘s’. Sometimes photographs are used ‘p’, or timbers measured *in situ* with a graticule ‘g’.

**Species** gives the four-letter species code used by the International Tree-Ring Data Bank, at NOAA. These are identified in the key at the bottom of the table.

**Timber and position** column details each timber sampled along with a location reference. This will usually refer to a bay or truss number, or relate to compass points or to a reference drawing.

**Dates AD spanning** gives the first and last measured ring dates of the sequence (if dated),

**H/S bdry** is the date of the heartwood/sapwood transition or boundary (if identifiable).

**Sapwood complement** gives the number of sapwood rings, if identifiable. The tree starts growing in the spring during which time the earlywood is produced, also known also as spring growth. This consists of between one and three decreasing spring vessels and is noted as *Spring* felling and is indicated by a ¼ C after the number of sapwood ring count. Sometimes this can be more accurately pin-pointed to very early spring when just a few spring vessels are visible. After the spring growing season, the latewood or summer growth commences, and is differentiated from the preceding spring growth by the dense band of tissue. This summer growth continues until just before the leaves drop, in about October. Trees felled during this period are noted as *summer* felled (½ C), but it is difficult to be too precise, as the width of the latewood can be variable, and it can be difficult to distinguish whether a tree stopped growing in autumn or *winter*. When the summer

growth band is clearly complete, then the tree would have been felled during the dormant winter period, as shown by a single C. Sometimes a sample will clearly have complete sapwood, but due either to slight abrasion at the point of coring, or extremely narrow growth rings, it is impossible to determine the season of felling.

**Number of rings:** The total number of measured rings included in the samples analysed.

**Mean ring width:** This, simply put, is the sum total of all the individual ring widths, divided by the number of rings, giving an average ring width for the series.

**Mean sensitivity:** A statistic measuring the mean percentage, or relative, change from each measured yearly ring value to the next; that is, the average relative difference from one ring width to the next, calculated by dividing the absolute value of the differences between each pair of measurements by the average of the paired measurements, then averaging the quotients for all pairs in the tree-ring series (Fritts 1976). Sensitivity is a dendrochronological term referring to the presence of ring-width variability in the radial direction within a tree which indicates the growth response of a particular tree is “sensitive” to variations in climate, as opposed to complacency.

**Standard deviation:** The mean scatter of a population of numbers from the population mean. The square root of the variance, which is itself the square of the mean scatter of a statistical population of numbers from the population mean. (Fritts 1976).

**Felling seasons and dates/date ranges** is probably the most important column of the summary table. Here the actual felling dates and seasons are given for each dated sample (if complete sapwood is present). Sometimes it will be noticed that often the precise felling dates will vary within several years of each other. Unless there is supporting archaeological evidence suggesting different phases, all this would indicate is either stockpiling of timber, or of trees which have been felled or died at varying times but not cut up until the commencement of the particular building operations in question. When presented with varying precise felling dates, one should always take the *latest* date for the structure under study, and it is likely that construction will have been completed for ordinary vernacular buildings within twelve or eighteen months from this latest felling date (Miles 1997).

**Table 2:** Matrix of *t*-values and overlaps for same-timber mean and site master

Components of timber mean **adnj1**

<i>Sample:</i>	<b>adnj1b</b>
<i>Last ring</i>	1824
<i>date AD:</i>	
<b>adnj1a</b>	<u>11.73</u>
1824	136

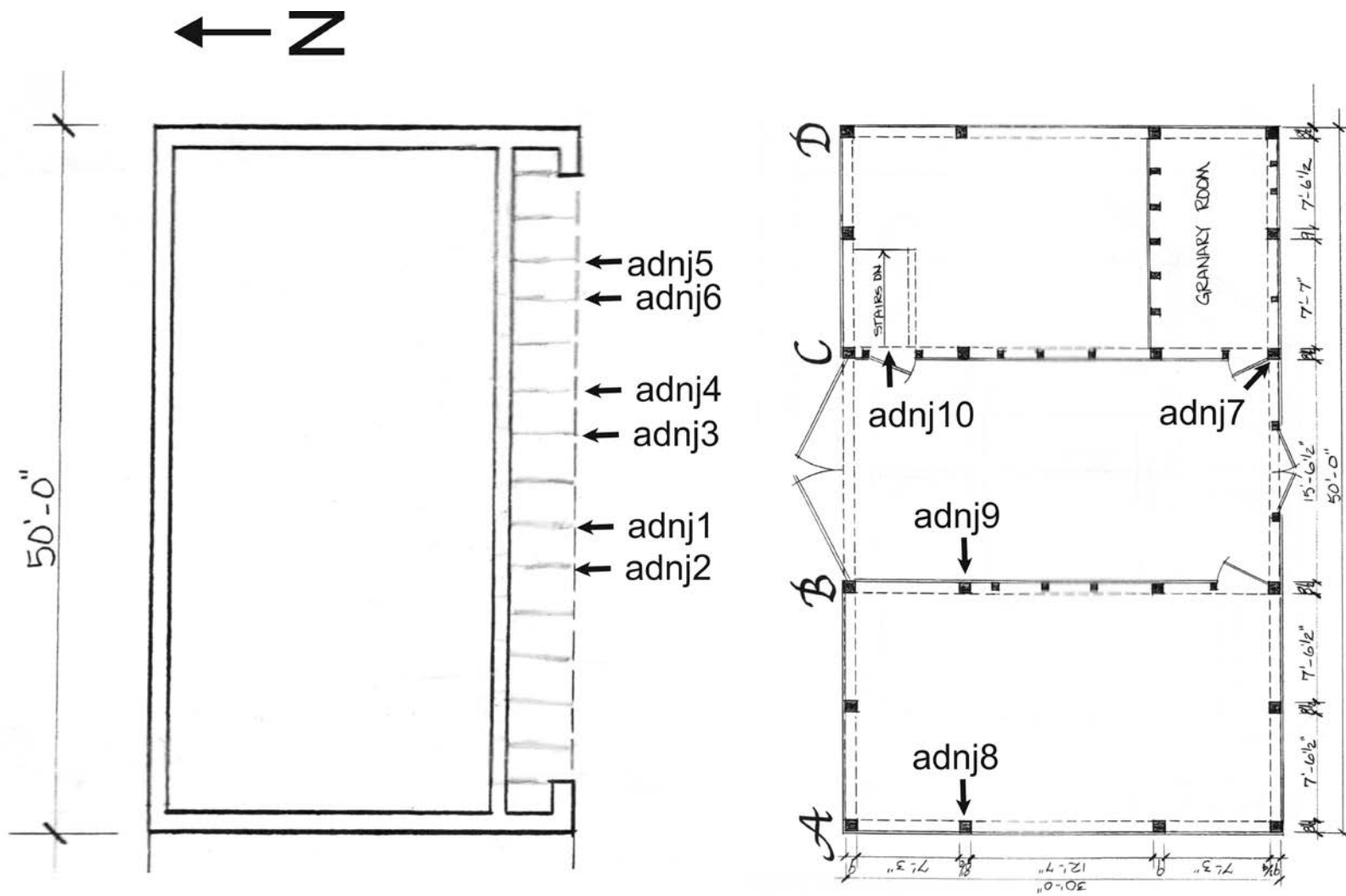
Components of site master **ADNJx1**

<i>Sample:</i>	<b>adnj2</b>	<b>adnj3</b>	<b>adnj4</b>	<b>adnj6</b>	<b>adnj7a2</b>	<b>adnj9</b>
<i>Last ring</i>	1824	1824	1824	1824	1811	1824
<i>date AD:</i>						
<b>adnj1</b>	<u>4.95</u>	<u>6.41</u>	<u>7.88</u>	<u>5.09</u>	<u>4.87</u>	<u>3.99</u>
1824	149	84	129	93	77	112
	<b>adnj2</b>	<u>4.62</u>	<u>7.08</u>	<u>4.05</u>	<u>6.02</u>	<u>4.00</u>
		84	129	93	77	112
		<b>adnj3</b>	<u>3.94</u>	<u>7.17</u>	<u>3.71</u>	<u>7.13</u>
			84	84	71	84
			<b>adnj4</b>	<u>3.13</u>	<u>5.20</u>	<u>3.43</u>
				93	77	112
				<b>adnj6</b>	<u>3.89</u>	<u>5.25</u>
					77	93
					<b>adnj7a2</b>	<u>4.72</u>
						77

**Table 3:** Dating of site master **ADNJx1** (1667-1824) against reference chronologies

<i>State or region:</i>	<i>Chronology name:</i>	<i>Short publication reference:</i>	<i>File name:</i>	<i>Spanning:</i>	<i>Overlap:</i>	<i>t-value:</i>
Pennsylvania	Morgan Homestead	Columbia unpublished	FORES	1458-1988	158	8.71
Pennsylvania	Eastern Pennsylvania Master Chronology	Columbia unpublished	<b>EAPENN</b>	1471-2003	158	8.31
Maryland	Master Chronology	Worthington 2011	<b>MD2011</b>	1536-1892	158	7.94
Virginia and Maryland	DC Area Oak Master Chronology (made from sites within a 100-mile radius of Washington DC)	Worthington 2013	<b>DC- AREA2</b>	1536-1892	158	7.61
Maryland	Eastern Shore Master Chronology #2	Worthington 2011	<b>ESHORE2</b>	1592-1836	158	7.39
Virginia	Hanover Tavern	Columbia unpublished	WATCH	1595-1981	158	6.97
Pennsylvania	Alan Seeger Natural Area, Jackson	Columbia unpublished	ALLENS	1516-1983	158	6.24
New Jersey	Richard Cain Barn, Milford	Worthington and Seiter 2013/17	RCNJx1	1550-1793	127	6.13
Pennsylvania	Philadelphia Historical Dating Master Cross Dated Oak	Columbia unpublished	<b>PHILY</b>	1480-1801	135	5.81

Chronologies in **bold** denote regional masters



**Figure 2.** Plan of first floor (left) and second floor (right) of Angel-Ditzel Barn showing sample locations





**Figure 3.** Bar diagram showing dated timbers in chronological order