Oxford Dendrochronology Laboratory
Report 2010/29

The Tree-Ring Dating of Christ Church, Weems, Lancaster County, Virginia

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Summary:

LANCASTER, Weems: Christ Church (37° 40' 50" N; -76° 25' 23" W)

Felling dates: **Autumn 1731** and **Winter 1731/2**

Struts (3/4) 1731(39C), 1717(H/S), 1695; Purlin 1730(26½C); Principal rafters 1716(8), 1695(H/S); Diagonal tie 1728(12); curved ribs (0/2). *Site Master* 1514-1731 CCV (t = 9.23 PIEDMONT; 9.16 MONTP; 7.03 EYREHALL).

Christ Church is an exceptionally fine cruciform-plan brick church with walnut joinery, traditionally thought to have been constructed during the early 1730s by Robert 'King' Carter. Ten timbers were sampled, eight from the structural timbers comprising the roof, and two from the curved ribs supporting the ceiling below. All but three of the timbers dated, and a 218-year site master was constructed. The trees were from the virgin woodland and were very slow grown. Only two of the dated timbers retained complete sapwood allowing precise felling dates of autumn 1731 and winter 1731/2 to be determined. Similar heartwood/sapwood boundaries on timbers without bark edge suggests that these too were coeval.

Date sampled:	7th & 16th October 2008
Owner:	Foundation for Historic Christ Church
Commissioner:	Colonial Williamsburg Foundation
Historical Research:	Carl Lounsbury

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August 2010

How Dendrochronology Works

Dendrochronology has over the past 20 years become one of the leading and most accurate scientific dating methods. Whilst 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. Fundamental to understanding of how dendrochronology works is the phenomenon of tree growth. Essentially, trees grow through the addition of both elongation and radial increments. The elongation takes place at the terminal portions of the shoots, branches, and roots, while the radial increment is added by the cambium, the zone of living cells between the wood and the bark. In general terms, a tree can be best simplified by describing it as a cone, with a new layer being added to the outside each year in temperate zones, making it wider and taller.

An 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 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, 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-coloured early wood vessels and the dense, darker-coloured late wood.

Other species of tree are known as diffuse-porous, and this group includes the tulip, or yellow-poplar (*Liriodendron tulipifera L.*). Unlike the ring-porous trees, the spring vessels consist of a very small spring vessels which 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 utilises 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 which 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 colour change and the blocking of the spring vessels with tyloses, the waste products of the tree's growth. The heartwood is generally darker in colour, 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 colour 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.

Methodology: The Dating Process

All timbers sampled were of oak (*Quercus* spp.) from what appeared to be primary first-use timbers, or any timbers which might have been re-used from an early phase. Those timbers which looked most suitable for dendrochronological purposes with complete sapwood or reasonably long ring sequences were selected. *In situ* timbers were sampled through coring, using a 16mm hollow auger. Details and locations of the samples are given in the summary table.

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. Whilst it may not be the best statistical indicator, Student's (a pseudonym for W S Gosset) *t*-value has been widely used amongst British dendrochronologists. The cross-correlation algorithms most commonly used and published are derived from Baillie and Pilcher's CROS programme (Baillie and Pilcher 1973), although a faster version (Munro 1984) giving slightly different *t*-values is sometimes used for indicative purposes.

Generally, *t*-values over 3.5 should be considered to be 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 3's with one or two 4's, 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 which are geographically near to the sampling site are given more weight than an individual site or sample from the opposite end of the country.

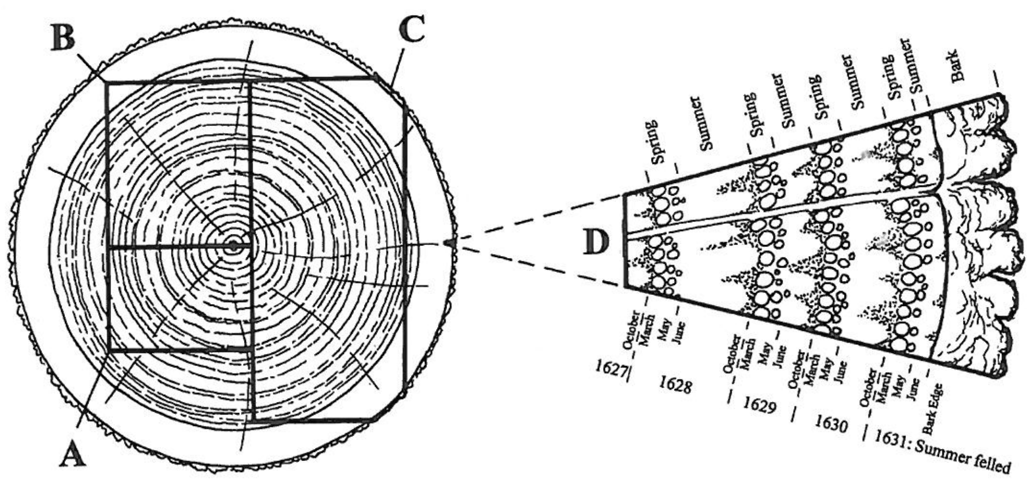
It is general practice to cross-match samples from within the same phase to each other first, combining them into a site master, before comparing with the reference chronologies. This has the advantage of averaging out the 'noise' of individual trees and is much more likely to obtain higher *t*-values 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. 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). A version of this and other programmes were written in BASIC by D Haddon-Reece, and re-written in Microsoft Visual Basic by M R Allwright and P A Parker.

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 which 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. By determining what this range is with an empirically or statistically-derived estimate is a valuable aspect in the interpretation of tree-ring dates where the bark edge is not present (Miles 1997). The narrower this range of sapwood rings, the more precise the estimated felling date range will be.



Section of oak tree with conversion methods showing three types of sapwood retention resulting in **A** *terminus post quem*, **B** a felling date range, and **C** a precise felling date. Enlarged area **D** shows the outermost rings of the sapwood with growing seasons (Miles 1997, 42)

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 colour, although this is often indiscernible (Desch 1948). In archaeological timbers, the lighter coloured sapwood does not collapse as it does in the European oak (*Q robur*), 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 colour change throughout the section of the tree, and wood-boring insects will often penetrate right through to the centre 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 tulip-poplar or black ash, or for any of the pines.

Therefore, if the bark edge does not survive on any of the timbers sampled, then 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 emphasised 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 that construction usually took place within twelve months of felling (Miles 1997).

Details of Dendrochronological Analysis

The results of the dendrochronological analysis for the building 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, its species, location, and its 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 is present, and an estimated felling date range if the sapwood was complete on the timber but some was lost in coring, or a *terminus post quem*. Often these *terminus post quem* dates begin far earlier than those with precise felling dates. This is simply because far more rings have been lost in the initial conversion of the timber.

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 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 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 match 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) with a selection of reference chronologies. This shows the county or region from which the reference chronology originated, the common chronology name together with who compiled the chronology with publication reference and the years covered by the reference chronology. The years overlap of the reference chronology and the site master being compared are also shown together with the resulting *t*-value. It should be appreciated that well replicated regional reference chronologies, which are shown in **bold**, will often produce better matches then with individual site masters or indeed individual sample sequences. Due to the fact that chronologies are still to be developed for many parts of the eastern seaboard of America, the number of chronologies are often limited to just one or two, and this information would alternatively be presented in the summary text.

Figures include a bar diagram which shows the chronological relationship between two or more dated samples from a phase of building. The site sample record sheets are also appended, together with any plans showing sample locations, if available.

Publication of all dated sites for English buildings are routinely published in *Vernacular Architecture* annually, 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, and this hopefully 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.Oxford-DendroLab.com`. The Oxford Dendrochronology Laboratory retains copyright of this report, but the commissioner of the report has the right to use the report for his/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 ODL, has been specified in advance.

Summary of Dating

The cruciform brick church at Weems in Lancaster County had always been thought to have been built sometime in the 1730s, but it was not known for certain whether it was commenced or completed before the death of Robert 'King' Carter in August of 1732. To try and answer this question the Historic Christ Church Foundation commissioned a dendrochronological study of the roof timbers.

A total of ten timbers were sampled over a period of two days. The first sampling session produced a number of core samples but none retained the bark edge, essential for the interpretation of the construction of the building. Therefore a second day was spent taking additional samples with complete sapwood.

First, the multiple samples taken from the same timbers were compared with each other and combined where matching conclusively and the following five same-timber means were produced: **ccv2**, **ccv3**, **ccv5**, **ccv7**, and **ccv9**. These were then used in the subsequent analysis.

Out of the ten timbers sampled, seven were found to match together: samples **ccv1** through **ccv6** and **ccv8**. These were therefore combined together to form the 218-ring site master **CCV**. This matched extremely well with local and regional reference chronologies and dated, spanning the years 1514-1731. Two of the timbers dated retained complete sapwood, and two felling dates were determined. The first was the north purlin at the east end (**ccv5**) which was found to have been felled in the summer/autumn of 1731, and the second timber was the south strut to the east kingpost (**ccv3**) which was found to have been felled slightly later, in the winter of 1731/2. The dates of the other five dated timbers without complete sapwood were consistent with these felling dates. Two curved ceiling ribs were also sampled (**ccv9** and **ccv10**), and despite matching together with a *t*-value of 8.0 to form the 121-year mean **ccv910**, it failed to date conclusively either with the site master or on its own.

The dendrochronology confirms the documented building history and indeed helps to refine the timing of the various construction phases. Evidently Carter had ordered brickmaking to commence as early as 1725, and by August 1726 when he wrote his will he directed '*..it is my further will that the bricks that are now made and burnt shall be appropriated to the Building of the said Brick Church or as many thereof as will perfect the building…*' Thus by 1730 when the Vestry accepted Carter's proposal to construct the new church, most if not all of the bricks were already made, and construction probably would have commenced almost of immediately. Depending on the amount of labour available, it is not unreasonable to expect between one or two years for the brickwork to reach eaves level. The timber was said to have been obtained from the glebe land, and as shown by the tree-ring dating cut from as early as late 1731 to the spring of 1732. Allowing for a two or three months to convert the timber and prefabricate the roof frame on the ground, it is conceivable the roof structure could have been erected no earlier than the summer of 1732. Carter died on the 4th of August 1732, and it is questionable as to whether or not he ever saw the roof frame erected, but an obituary published a month later stated that '*He was building a very handsome Brick Church in his own Parish, at his own Expense, which will be finished by his sons…*' Nevertheless, it is not unreasonable to surmise that by 1733 the roof would have been erected and covered in, thereby making the building watertight. Once the roof frame was erected, the next stage was to cut and fix all of the curved ribs for the vaulted plaster ceilings. These were probably not fully seasoned by the time of the plastering was completed, but it would not be unreasonable to expect this to be deferred until 1734 or early 1735 to mitigate the worst of the structural distortion of the oakwork. In any event, the church was reported to have been completed by 1735.

Acknowledgements

For the work at Christ Church, Lancaster, permission was granted by members of Historic Christ Church under the direction of Camille Bennett, the Executive Director. Robert Teagle, the Education Director and Curator, provided on-site support when the roof timbers were sampled. The dating was co-ordinated by Carl Lounsbury, who also provided much of the historical background information. Dr Ed Cook and Paul Krusic of the LDEO Dendrochronology Laboratory at Columbia University, New York, made available both published and unpublished reference chronologies. Dr Martin Bridge provided the bar diagramme.

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Table 1: Summary of Tree-Ring Dating **CHRIST CHURCH, LANCASTER COUNTY, VIRGINIA**

Sample number & type		Species	Timber and position	Dates AD spanning	H/S bdry	Sapwood complement	No of rings	Mean width mm	Std devn mm	Mean sens mm	Felling seasons and dates/date ranges
* **ccv1**	c	QUAL	SW strut to centre king post	1664-1717	1717	H/S	54	2.73	0.53	0.157	After 1709
ccv2a	c	QUAL	E principal rafter	1621-1716	1708	8	96	1.62	0.50	0.220	
ccv2b1	c		ditto	1660-1708	1708	h/s	49	1.69	0.46	0.206	
ccv2b2	c		ditto	-		20½C	20	1.41	0.30	0.236	
* **ccv2**			Mean of **ccv2a** + **ccv2b1**	1621-1716	1708	8	96	1.56	0.47	0.218	After 1730
ccv3a	c	QUAL	S strut to E kingpost	1585-1701	1700	1	117	1.15	0.31	0.176	
ccv3b	c		ditto	1674-1731	1685	46C	58	0.86	0.43	0.172	
* **ccv3**			Mean of **ccv3a** + **ccv3b**	1585-1731	1692	39C	147	1.05	0.38	0.164	Winter 1731/2
* **ccv4**	c	QUAL	E end strut to principal rafter	1514-1695			182	1.03	0.45	0.182	After 1696
ccv5a	c	QUAL	N purlin E end	1578-1702	1702	H/S	125	0.97	0.21	0.132	
ccv5b1	c		ditto	1585-1624			40	1.12	0.15	0.107	
ccv5b2	c		ditto	-			76	0.86	0.14	0.140	
ccv5b3	c		ditto	-		28	28	0.55	0.11	0.120	
ccv5c	c		ditto	1580-1730	1702	26½C	151	0.91	0.25	0.106	
* **ccv5**			Mean of **ccv5a** + **ccv5b1** + **ccv5c**	1578-1730	1702	26½C	153	0.91	0.25	0.100	Autumn 1731
* **ccv6**	c	QUAL	W principal rafter	1539-1695	1695	H/S	157	1.12	0.36	0.154	After 1696
ccv7a	c	QUAL	NW strut to centre kingpost	-		H/S	150	1.26	0.39	0.139	
ccv7b1	c		ditto	-		H/S	73	1.07	0.24	0.130	
ccv7b2	c		ditto	-		C	18	1.10	0.24	0.143	
ccv7c	c		ditto	-		18C	18	1.14	0.29	0.168	
ccv7			Mean of **ccv7a** + **ccv7b1**	-		H/S	153	1.28	0.38	0.124	
* **ccv8**	c	QUAL	NE diagonal tie	1616-1728	1716	12	113	1.70	0.45	0.154	After 1729
ccv9a	c	QUAL	3rd upper rib of S oxeye window	-		C	79	0.97	0.23	0.125	
ccv9b	c		ditto	-		11C	30	1.09	0.13	0.107	
ccv9c	c		ditto	-		C	57	0.98	0.21	0.119	
ccv9			Mean of **ccv9a** + **ccv9b** + **ccv9c**	-		11C	79	1.02	0.20	0.119	
ccv10	c	QUAL	6th lower rib from SE corner, S side	-		C	121	0.96	0.18	0.124	
ccv910	c		Mean of **ccv9** + **ccv10**	-		C	121	0.97	0.17	0.113	
* = **CCV Site Master**				**1514-1731**			**218**	**1.20**	**0.33**	**0.135**	

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/S bdry = heartwood/sapwood boundary - last heartwood ring date; std devn = standard deviation; mean sens = mean sensitivity; QUAL = *Quercus alba* (White oak), QURU = *Q rubra* (Red 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 proceeding 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 means and site masters

Components of timber **ccv2**

Sample:	**ccv2b1**
Last ring date AD:	1708
ccv2a	11.09 49

Components of timber **ccv3**

Sample:	**ccv3b**
Last ring date AD:	1731
ccv3a	5.00 28

Components of timber **ccv5**

Sample:	**ccv5b1**	**ccv5c**
Last ring date AD:	1624	1730
ccv5a	4.08 40	6.88 123
	ccv5b1	3.77 40

Components of timber **ccv7**

Sample:	**ccv7b1**
Last ring date AD:	1709
ccv7a	3.19 70

Components of timber **ccv9**

Sample:	**ccv9b**	**ccv9c**
Last ring date AD:	1121	1121
ccv9a	3.71 30	9.40 57
	ccv9b	7.44 30

Components of mean **ccv910**

Sample:	**ccv10**
Last ring date AD:	1121
ccv9	8.00 79

Components of site master **CCV**

Sample:	**ccv2**	**ccv3**	**ccv4**	**ccv5**	**ccv6**	**ccv8**
Last ring date AD:	1716	1731	1695	1730	1695	1728
ccv1	3.70 53	4.22 54	1.93 32	3.67 54	3.43 32	4.88 54
	ccv2	5.41 96	2.57 75	5.38 96	2.09 75	5.21 96
		ccv3	5.51 111	7.50 146	4.81 111	6.45 113
			ccv4	6.19 118	1.76 157	2.92 80
				ccv5	2.98 118	5.75 113
					ccv6	2.38 80

Table 3: Dating of site master **CCV** (1514-1731) against reference chronologies at 1731

County or region:	*Chronology name:*	*Short publication reference:*	*File name:*	*Spanning:*	*Overlap:*	t-*value:*
Virginia	Piedmont Oak + Historical	*(Columbia pers comm)*	**PIEDMONT**	1488-2001	218	9.23
Maryland	Preston MD Oak	*(Columbia pers comm)*	MONTP	1508-2000	218	9.17
Virginia	Eyre Hall, Cheriton	*(Miles 2003)*	EYREHALL	1514-1806	218	7.03
Virginia	Falling Creek Archaeology Site	*(Miles and Worthington 2007)*	fct3	1518-1724	207	6.60
Virginia	Four Mile Tree oak chronology	*(Miles and Worthington in prep)*	FMTx1	1621-1742	111	5.74
Virginia	Blackwater River Baldy Cypress	*(Stahle, Cleaveland, & Hehr; World Data Bank)*	VA021	932-1985	218	5.30

Bar diagram showing dated timbers in chronological position