A Dendrochronological Analysis of the Mt. Bethel Baptist Meeting House, Warren, Somerset County, New Jersey.

Dr. Edward R. Cook
William J. Callahan, Jr.
December 2021

Introduction

This is the final report on a dendrochronological analysis of the Mt. Bethel Baptist Meeting House, which stands at 235 Mountainview Road, Warren, Somerset County, New Jersey 07059 (40°38'17"N 74°30'51"W). In an effort to establish a more precise chronology of the structure's history, historic architect Margaret Westfield of Westfield Architects & Preservation Consultants, acting on behalf of the tutelary Township of Warren, requested that dendrochronologists William Callahan and Dr. Edward Cook perform a tree-ring analysis of selected representative structural timbers.

Callahan visited the site on 15 November 2021, and collected samples for dendrochronological analysis. Of 11 field samples taken, all 11 were deemed methodologically and conditionally of sufficient quality for submission for laboratory analysis. The submitted samples were of oak (*Quercus* sp.) and tulip poplar (*Liriodendron* sp.).

Every effort was made on site to locate bark or waney edges on the sampled timbers in order to ascertain the absolute cutting date, or dates, of the trees used in the construction. After the completion of this analysis, the core and cut samples and their associated measurement series will be permanently archived at the Tree Ring Research Laboratory, Lamont-Doherty Earth Observatory, Columbia University, under the sample reference numbers listed in Table 1, column 1.

Dendrochronological Analysis

Dendrochronology is the science of analyzing and dating annual growth rings in trees. Its first significant application was in the dating of ancient Indian pueblos of the southwestern United States (Douglass 1921, 1929). Andrew E. Douglass is considered the “father” of dendrochronology, and his numerous early publications concentrated on the application of tree-ring data to archaeological dating. Douglass established the connection between annual ring width variability and annual climate variability which allows for the precise dating of wood material (Douglass 1909, 1920, 1928; Stokes and Smiley 1968; Fritts 1976; Cook and Kariukstis 1990). The dendrochronological methods first developed by Douglass have evolved and been employed throughout North America, Europe, and much of the temperate forest zones of the globe (Edwards 1982; Holmes 1983; Stahle and Wolfman 1985; Cook and Callahan 1992, Krusic and Cook 2001). In Europe, where the dendrochronological dating of buildings and artifacts has long been a routine professional support activity, the success of tree-ring dating in historical contexts is noteworthy (Baillie 1982; Eckstein 1978; Bartholin 1979; Eckstein 1984).

The wood samples collected from the Mt. Bethel Meeting House were processed in the laboratory by Dr. Edward Cook following well-established dendrochronological methods. The core samples were carefully glued onto grooved mounts and were sanded to a high polish to reveal the annual tree rings clearly; cut samples were similarly surfaced . The rings widths were measured under a microscope to a precision of ±0.001 mm. The cross-dating of the obtained measurements utilized a revised and modernized COFECHA computer program (Holmes 1983), which employs a sliding correlation to identify probable cross-dates between tree-ring series. In all cases, the robust non-parametric Spearman rank correlation coefficient was used for determining cross-dating. Experience has shown that for trees growing in the northeastern United States, this method of cross-dating is greatly superior to the traditional skeleton plot technique (Stokes and Smiley 1968), now disused. It is also very similar to the highly successful CROS program employed by, for instance, Irish dendrochronologists to cross-date European tree-ring series (Baillie 1982).

COFECHA is used to first establish internal, or relative, cross-dating amongst the individual timbers from the site itself. This step is critically important because it locks in the relative positions of the timbers to each other, and indicates whether or not the dates of those specimens with outer bark rings are consistent. Subsequently, one or more internally cross-dated series are compiled from the individual site samples, and these are compared in turn with independently established tree-ring master chronologies compiled from living trees and dated historical tree-ring material. All of the regional "master chronologies" are based on completely independent tree-ring samples.

During the Mt. Bethel Meeting House study, species specific, regional composite master chronologies from living trees and historical structures from northern and central New Jersey state, and other near-lying regions, were referenced primarily. All dating results were verified finally by subsequent comparison with other independent dating masters from surrounding regions. In each case, the datings as reported here were confirmed as correct.

Results and Conclusions

To achieve these datings required attention during analysis to the previously recorded structural context of the samples (see **Table 1**, column 3). The contextual association of samples from within the structure, the redundancy of the indicated relative cross-datings, and the eventual existence of bark/waney edges demonstrating cutting year provides the essential constraints necessary for establishing cross-dating, both within a site and with absolute chronological masters. The strength of the cross-dating of the samples is indicated by the Spearman rank correlations in the seventh column ("CORREL") of **Table 1**. These statistical correlations, produced by the COFECHA program, indicate how well each sample cross-dates with the mean of the others in the group. The individual correlations vary slightly in statistical strength, but all are in the range that is expected for correctly cross-dated timbers from buildings in the eastern United States.

The outermost ring on a waney, bark-edged sample identifies the absolute cutting year. Absence of the bark edge (interchangeably called the wane) on a sample indicates that the outermost extant ring is not the year of cutting, but some identifiable year preceding the cutting. In the absence or loss of wane, field observations of wood anatomical factors often permit close approximation of the number of missing rings, and thereby reasoned estimation of the cutting date. In particular the presence of sapwood, a physiologically active wood found immediately within the bark on the outer portion of the trunk, is an indication that the original wane was near.

For instance, several of the cellar timbers were judged to have bark/wane when initially examined, which was subsequently lost in varying degrees during extraction due to surface degradation, yet leaving some sapwood rings. This presence is an indication that the original yet now absent bark-edge had been near, commonly within 15 ± 5 years. Such surface loss (generally extending for less than an inch, equivalent 15 ± 5 years) is not unusual when timbers have been exposed to damp conditions for decades or even centuries. In no case here was the depth of loss estimated post-sampling to be more than circa 3/4 of an inch from the wane edge, in other words falling within the estimated usual depth of sapwood. Importantly in context, it is not evidence that these timbers have lost their structural bearing integrity.

The results of the dendrochronological dating of the timbers collected from the Mt. Bethel Meeting House are summarized in **Table 1** and **Figures 1&2**. A total of 11 samples from 11 timbers were analyzed in the laboratory: 6 tulip poplar (*Liriodendron* sp.), and 5 oak (*Quercus* sp.). All 11 provided absolute dates. Of the 11 dated samples, 3 had bark/wane indicating the precise cutting year: 2 tulip poplar, 1 oak. All of the other 8 samples had outermost extant rings lying chronologically congruent with the indicated cutting year; field notes indicate that several of these had bark and/or wane present at the start of sampling, lost due to surface degradation during extraction, and the oak samples all showed at least residual sapwood.

In aggregate, the evidence of the datings of the tested material from both the attic and the cellar suggests a singular construction phase for those building sections. Completed ring growth for the year 1760 indicates that the tulip poplars collectively were harvested during growth dormancy of 1760/61, i.e that the trees were cut after 1760 growth ended and before 1761 growth started, approximately between November 1760 and February 1761. The collective datings of the cellar oaks reveal a similar harvesting pattern, with sample 07 revealing a felling date of 1759-60 and the dates for samples 08-11, once adjusted for the outer rings lost during sample extraction, falling into the same approximate date range. See **Table 1,** column 6.

Initial usage of these materials took place not long after harvesting, for inspection of the timbers indicated that most if not all were worked very soon after cutting, in keeping with historical woodworking practices and carpentry techniques. However, it must be remembered that re-usage of timbers is possible without leaving any clear evidence of subsequent preparatory workings, and that other construction phases prior to or subsequent to the dates identified by this investigation cannot be excluded absolutely and should be considered when purporting the site's construction history. In this particular case, some local traditions propose that the Meeting House was built elsewhere and disassembled and moved to its present location some years later.

Table 1. Dendrochronological dating results for the wood samples taken from the Mt. Bethel Meeting House, Somerset County, New Jersey. For WANEY, +BE means the bark edge was present and thought to be recovered at the time of sampling; -BE means that the bark edge was not recovered or was completely missing on the timber. If –BE, SP refers to the likelihood that sapwood rings are present. If so, the outer date will be close to the cutting date. All correlations are Spearman rank correlations of each series against the mean of all of the others of the same species. If the outermost recovered +BE ring is completely formed, it is indicated as "comp", meaning that the tree was felled in the dormant season following that last year of growth. "Incomp" means that the outermost ring was not fully formed, meaning that the tree was felled during the spring/summer growing season.

ID	SPECIES	DESCRIPTION	WANEY	RINGS	DATING	CORREL
MBMHNJ 01	Tulip Poplar	Attic beam, 7th from east wall	+BE?	167	1594 1760 comp	0.636
MBMHNJ 02	Tulip Poplar	Attic beam, 6th from east wall	+BE?[a]	165	1593 1757	0.542
MBMHNJ 03	Tulip Poplar	Attic beam, 5th from east wall	+BE?[a]	153	1607 1759	0.516
MBMHNJ 04	Tulip Poplar	Attic beam, 4th from east wall	+BE?[a]	169	1588 1756	0.571
MBMHNJ 05	Tulip Poplar	Attic beam, 3rd from east wall	+BE	158	1603 1760 comp	0.564
MBMHNJ 06	Tulip Poplar	Attic beam, 2nd from east wall	+BE[a]	141	1614 1754	0.537
MBMHNJ 07	White Oak	Cellar, north side crawl space, beam, 2nd from east wall	+BE	121	1639 1759	0.529
MBMHNJ 08	White Oak	Cellar, north side crawl space, beam, 4th from east wall	-BE, +SP?[b]	101	1639 1739	0.550
MBMHNJ 09	White Oak	Cellar, north side crawl space, beam, 5th from east wall	-BE, +SP[b]	81	1659 1739	0.452
MBMHNJ 10	White Oak	Cellar, north side crawl space, beam, 6th from east wall	-BE, +SP?[b]	56	1675 1730	0.588
MBMHNJ 11	White Oak	Cellar, beam by access door, south side of summer beam	+BE[c]	80	1659 1738	0.535

[a]Bark edge (BE) present at start, but possible some rings were lost at the start of coring.
[b]Bark edge (BE) present at start, but bark and some sapwood rings lost due to severe powder post degradation
[c]Bark edge (BE) present at start, but multiple loose outer pieces and some rings lost; severe sapwood suppression

Table 1. Dendrochronological dating results for all samples taken from the Mt. Bethel Meeting House located near Warren, Somerset County, New Jersey. For interpreted felling dates of the trees used for construction, +BE means that the bark edge was present and believed to be recovered at the time of sampling; -BE means that the bark edge was not recovered or was completely missing on the timber. If –BE, +SP refers to the likelihood that sapwood rings are present. If so, the outer date will be close to the cutting date. All correlations are the Spearman rank correlations of each series

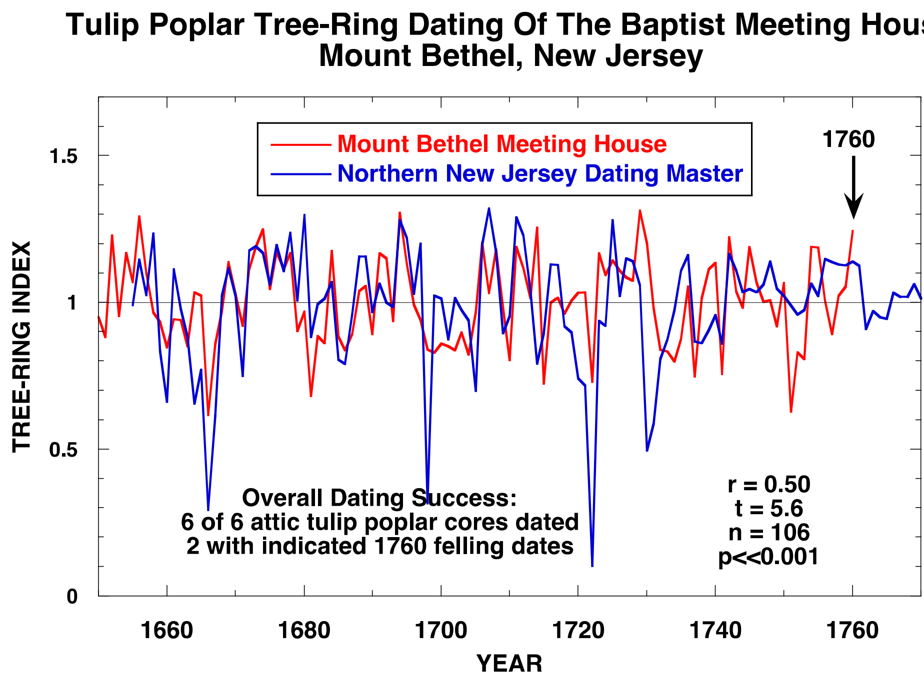


Figure 1. Comparison of the composited tulip poplar chronology from the attic timbers of the Mt. Bethel Meeting House, Warren, New Jersey against an independent, historical tulip poplar master chronology from northern New Jersey. The cross-dating indicated here is strong (t=5.6), indicating that the sampled timbers used in the attic section were felled during growth dormancy 1760/61.

The Spearman rank correlation between the series (t=5.6) associated with the correlation between the Mt. Bethel Meeting House compiled tulip poplar series and a regional tulip poplar historical master chronology (r=0.50) is strongly secure (p<<0.01) for a 106-year overlap. For that reason, the dates presented here for the sampled tulip poplar elements of the structure are robustly valid, and the statistical chance of the cross-dates being incorrect is exponentially far less than 1 in 1000.

The "r-factor" is the Spearman rank correlation coefficient, a measure of relative statistical agreement between two groups of measurements or data. It can range from +1 (perfect direct agreement) to -1 (perfect opposite agreement). The "t-value" is Student's distribution test for determining the unique probability distribution for "r", i.e. the likelihood of its value occurring by chance alone. As a rule, a t=3.5 has a probability of circa 1 in 1000, or 0.001, of being invalid. Higher "t" values as in this case indicate exponentially increasing, stronger statistical certitude.

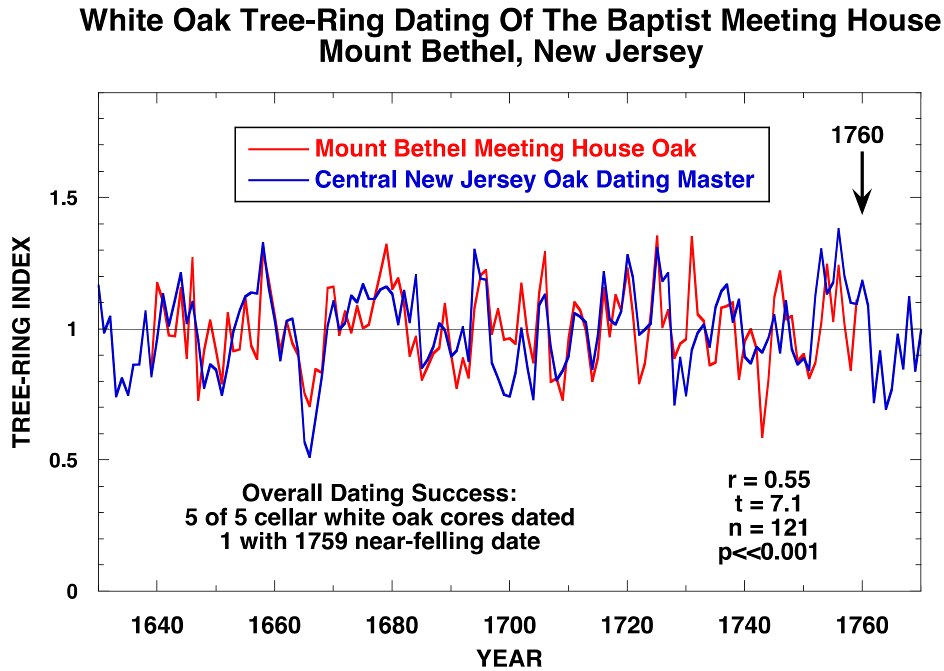
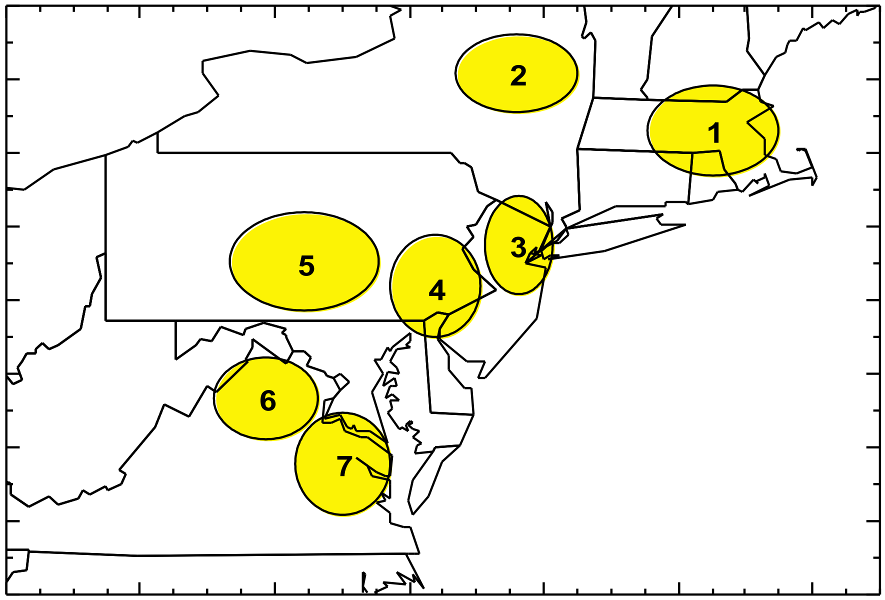


Figure 2. Comparison of the composited oak chronology from the cellar timbers of the Mt. Bethel Meeting House, Warren, New Jersey against an independent, historical white oak master chronology from central New Jersey. The cross-dating indicated here is strong (t=7.1), indicating that the sampled cellar timbers used in the attic section were felled in or slightly before 1760.

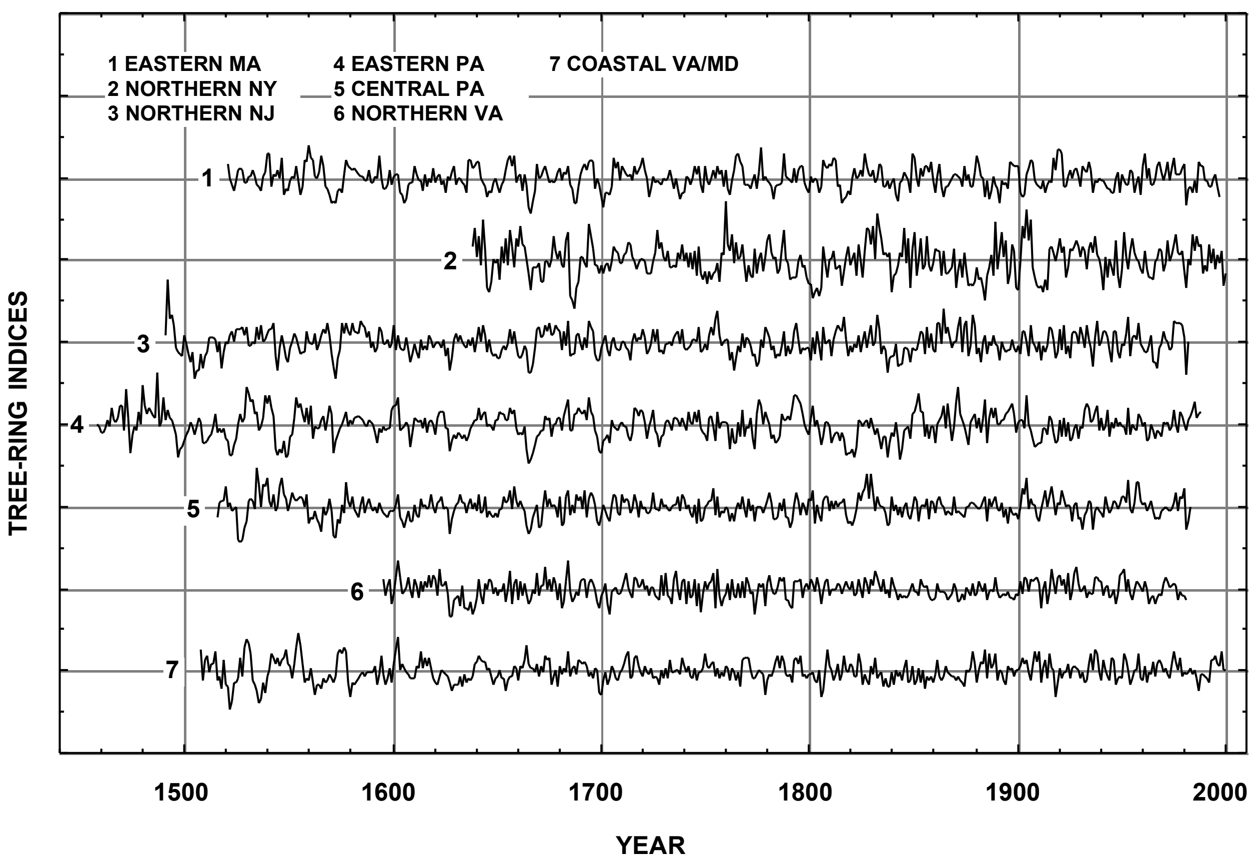
The Spearman rank correlation between the series (t=7.1) associated with the correlation between the Mt. Bethel Meeting House compiled oak series and the regional oak master chronology (r=0.55) is statistically very significant ($p<<0.001$) for a 121-year overlap. For that reason, there can be no doubt that the dates presented here for the sampled oak elements of the structure are robustly valid, and that the statistical chance of the cross-dates being incorrect is exponentially far less than 1 in 1000.

The "r-factor" is the Spearman rank correlation coefficient, a measure of relative statistical agreement between two groups of measurements or data. It can range from +1 (perfect direct agreement) to -1 (perfect opposite agreement). The "t-value" is Student's distribution test for determining the unique probability distribution for “r”, i.e. the likelihood of its value occurring by chance alone. As a rule, a t=3.5 has a probability of about 1 in 1000, or 0.001, of being invalid. Higher “t” values as in this case indicate exponentially increasing, stronger statistical certitude.

MODERN/HISTORICAL OAK CHRONOLOGIES
REGIONAL LOCATIONS OF SAMPLES



MODERN/HISTORICAL OAK TREE-RING CHRONLOGIES



Some Selected References

Baillie, M.G.L. 1982. *Tree-Ring Dating and Archaeology*. Croom Helm, London and Canberra. 274 pp.

Baillie, M.G.L. 1995. *A Slice Through Time: Dendrochronology and Precision Dating.*B.T. Batsford, Ltd., London

Bartholin, T.S. 1979. ”Provtagning för dendrokronologisk datering och vedanatomisk analys.” *Handbook i archeologiskt fältarbete, häfte 2.* 1-15 Riksantikvarieämbetets dokumentationsbyrå, Stockholm.

Cook, E.R. and Callahan, W.J. 1987. *Dendrochronological Dating of Fort Loudon in South-Central Pennsylvania*. Limited professional distribution.

Cook, E.R. and Callahan, W.J. 1992. *The Development of a Standard Tree-Ring Chronology for Dating Historical Structures in the Greater Philadelphia Region.* Limited professional distribution.

Cook, E.R., Callahan, W.J. and Wells, Camille 2007. *Dendrochronological Analysis of Rural Plains, Mechanicsville, Hanover County,Virginia.* Limited professional distribution..

Cook, E.R. and Callahan, W.J. 2008. *Dendrochronological Analysis of Freer-Low House,Huguenot Street, New Paltz, Ulster County,NewYork.* Limited professional distribution.

Cook, E.R. and L. Kariukstis, eds. 1990. *Methods of Dendrochronology: Applications in the Environmental Sciences*. Kulwer, The Netherlands.

Douglass, A.E. 1909. Weather cycles in the growth of big trees. *Monthly Weather Review* 37(5): 225-237

Douglass, A.E. 1920. Evidence of climate effects in the annual rings of trees. *Ecology* 1(1):24-32

Douglass, A.E. 1928. Climate and trees. *Nature Magazine* 12:51-53

Douglass, A.E. 1921. Dating our prehistoric ruins: how growth rings in trees aid in the establishing the relative ages of the ruined pueblos of the southwest. *Natural History* 21(1):27-30

Douglass, A.E. 1929. The secret of the southwest solved by talkative tree-rings. *National Geographic Magazine* 56(6):736-770.

Eckstein, D. 1978. Dendrochronological dating of the medieval settlement of Haithabu (Hedeby). In: *Dendrochronology in Europe*, (J. Fletcher, ed.) British Archaeological Reports International Series 51: 267-274

Eckstein, D. 1984. *Dendrochronological Dating (Handbooks for Archaeologists, 2).* Strasbourg, European Science Foundation.

Eckstein, D. and Bauch, J. 1969. “Beitrag zur Rationisilerung eines dendrokronologischen Verfahrens und zur Analyse seiner Aussagesicherheit.” *Forstwissenschaftliches Centralblatt* 88, 230-250.

Edwards, M.R. 1982. Dating historic buildings in lower Maryland through dendrochronology. In: *Perspectives in Vernacular Architecture*. Vernacular Architecture Forum.

Fritts, H.C. 1976. *Tree Rings and Climate.* Academic Press, New York. 567 pp.

Holmes, R.L. 1983. Computer assisted quality control in tree-ring dating and measurement. *Tree-Ring Bulletin* 43:69-78

Krusic, P.J. and E.R. Cook. 2001. *The Development of Standard Tree-Ring Chronologies for Dating Historic Structures in Eastern Massachusetts: Completion Report*. Great Bay Tree-Ring Laboratory, May 2001.

Stahle, D.W. and D. Wolfman. 1985. The potential for archaeological tree-ring dating in eastern North America. *Advances in Archaeological Method and Theory* 8: 279-302.

Stokes, M.A. and T.L. Smiley. 1968. *An Introduction to Tree-Ring Dating*. University of Chicago Press, Chicago 110 pp.

Edward Cook was born in Trenton, New Jersey, in 1948. He received his PhD. from the Tucson Tree-Ring Laboratory of the University of Arizona in 1985, and has worked as a dendrochronologist since 1973. Currently director of the Tree-Ring Laboratory at the Lamont-Doherty Earth Observatory of Columbia University, he has comprehensive expertise in designing and programming statistical systems for tree-ring studies, and is the author of many works dealing with the various scientific applications of the dendrochronological method.

William Callahan was born in West Chester, Pennsylvania, in 1952. After completing his military service he moved to Europe, receiving his MA from the University of Stockholm in 1979. He began working as a dendrochronologist in Sweden in 1980 at the Wood Anatomy Laboratory at the University of Lund, and returned to the United States in 1998. A former research associate of Dr. Edward Cook at the Tree-Ring Laboratory of Lamont-Doherty, he has extensive experience in using dendrochronology in dating archaeological artifacts and historic sites and structures.

Some regional historical dendrochronological projects completed by the authors:

Abraham Hasbrouck House, New Paltz, NY
Allen House, Shrewsbury, NJ
Belle Isle, Lancaster County, VA
Bowne House, Queens, NY
Carpenter’s Hall, Philadelphia, PA
Charpentier House, Philadelphia PA
Christ’s Church, Philadelphia, PA
Clifton, Northumberland County, VA
Conklin House, Huntington, NY
Customs House, Boston, MA
Daniel Boone Homestead, Birdsboro, PA
Daniel Pieter Winne House, Bethlehem, NY
Ditchley, Northumberland County, VA
Ephrata Cloisters, Lancaster County, PA
Fallsington Log House, Bucks County, PA
Ferris House, Old Greenwich, Fairfield County, CT
Fawcett House, Alexandria, VA
Gadsby's Tavern, Alexandria, VA
Garrett House, Sugartown PA
Gilmore Cabin, Montpelier, Montpelier Station, VA
Gracie Mansion (Mayor’s Residence), New York, NY
Grove Mount, Richmond County, VA
Hanover Tavern, Hanover Courthouse, VA
Harriton House, Bryn Mawr, PA
Hills Farm, Accomack County, VA
Hollingsworth House, Elk Landing, MD
Indian Banks, Richmond County, VA
Indian King Tavern, Haddonfield NJ
Independence Hall, Philadelphia, PA
John Bowne House, Forest Hills, NY
Kirnan, Westmoreland County, VA
Linden Farm, Richmond County, VA
Log Cabin, Fort Loudon, PA
Lower Swedish Log Cabin, Delaware County, PA
Lummis House, Ipswich MA
Marmion, King George County, VA
Martin Cabin, New Holland PA
Menokin, Richmond County, VA
Merchant’s Hope Church, Prince George County, VA
Millbach House, Lebanon County, PA
Monaskon, Lancaster County, VA
Morris Jumel House, Jamaica, NY
Frederick Muhlenberg House, Trappe, PA
Nottingham DeWitt House, NY
Old Barn, Madison VA
Old Caln Meeting House, Thorndale, PA
Old Parsonage, Kinderhook NY
Old Swede’s Church, Philadelphia, PA
OTB House, West Nyack, NY
Panel Paintings, National Gallery, Washington, DC
Pennock House & Barn, London Grove, PA
Penny Watson House, Greenwich, NJ
Podrum Farm, Limekiln, PA
Powell House, Philadelphia, PA
Pyne House, Cape May, NJ
Radcliff van Ostrade, Albany, NY
Reese's Corner House, Rock Hall, MD
Rippon Lodge, Prince William County, VA
Rochester House, Westmoreland County, VA
Rockett¨s, Doswell VA
Rural Plains, Hanover County, VA
Sabine Hall, Richmond County, VA
Shirley, Charles City County, VA
Sisk Cabin, Culpeper VA
Stiles Cabin, Sewickely PA
Spangler Hall, Bentonville, VA
Springwater Farm, Stockton, NJ
St. Peter’s Church, Philadelphia, PA
Strawbridge Shrine, Westminster, MD
Sweeney-Miller House, Kingston, NY
Thomas & John Marshall House, Markham, VA
Thomas Grist Mill, Exton, PA
Thomas Thomas House, Newtown Square, PA
Ticonderoga Pavilion, Ticonderoga, NY
Tuckahoe, Goochland County, VA
Tullar House, Egremont MA
Updike Barn, Princeton, NJ
Varnum’s HQ, Valley Forge, PA
Verville, Lancaster County, VA
West Camp House, Saugerties, NY
Westover, Charles City County, VA
White Plains House, King George, VA
Wilton, Westmoreland County, VA
Yew Hill, Fauquier County, VA