Dendrochronological Analysis of Indian King Tavern, Haddonfield, Camden County, New Jersey

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Introduction

This is the final report on the dendrochronological analysis of the structure known as the *Indian King Tavern*, 223 Kings Highway East, Haddonfield NJ 08033 (39º53'56"N, 75º01'51"W). The Indian King Tavern Museum is a New Jersey Historic Site administered by the Division of Parks and Forestry of the New Jersey Department of Environmental Protection. In an effort to describe the construction history of this building, dendrochronologists William Callahan and Dr. Edward Cook performed a tree-ring analysis of selected structural timbers.

Together with project leader Ms Penelope Watson of Watson & Henry Associates, 12 North Pearl Street, Bridgeton, New Jersey, 08302, Callahan visited the site on 24 June and 11 November 2011, and collected core samples for the dendrochronological analysis of the timbers. Of the 34 field samples taken, 28 were of sufficient quality for submission for laboratory analysis, 25 of oak (Quercus sp.) and 2 of pine (Pinus sp.), and 1 of cedar. 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.

This January 2012 report provides supplementary data and analysis and replaces in its entirety the previous report of August 2011

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 Indian King Tavern were processed in the Tree-Ring Laboratory by Dr. Edward Cook following well-established dendrochronological methods. The core samples were carefully glued onto grooved mounts and all were sanded to a high polish to reveal the annual tree rings clearly. The rings widths were measured under a microscope to a precision of ±0.001 mm. The cross-dating of the obtained measurements utilized the 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). 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. 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, the internally cross-dated series are each compared with independently established tree-ring master chronologies compiled from living trees and dated historical tree-ring material. All of the "master chronologies" are based on completely independent tree-ring samples.

In the Indian King Tavern study, species specific, regional composite master chronologies from living trees and historical structures from the Philadelphia and near-lying regions were referenced primarily. All dating results were verified finally by comparison with independent dating masters from surrounding areas in New York state, New Jersey, northern Virgina, and central and eastern Pennsylvania. In each case, the datings as reported here were verified as correct.

Results and Conclusions

The results of the dendrochronological dating of the Indian King Tavern timbers are summarized in **Tables 1** and **Figures 1**. A total of 25 oak samples, 2 pine and 1 cedar samples were analyzed in the laboratory, with 22 oak and 0 conifer samples providing firm dendrochronological dates. The 6 additional samples collected but not submitted to the laboratory for dating had varying degrees of degradation or had too few rings for statistical viability.

To achieve these datings required attention during analysis to the previously recorded structural context of the samples (see **Table 1**). 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.

Of the 22 oak samples that cross-dated well between themselves, and also dated well against the local historical dating masters (see **Table 1**, column 6), 14 had field verified bark edge at the time of laboratory analysis. The undated conifer samples produced no statistically viable datings. The 3 oak samples that remained undated (IKTHNJ05, 27, 28) were short ring series disrupted with patches of reaction wood, interpreted in the laboratory as environmentally stressed growth not fatal to the trees. Unfortunately, this disruption of the growth made reliable dating of such short series unattainable.

The degree of congruency in the achieved oak datings from the various areas of the structure strongly indicates at least three major (re)construction phases for the Tavern: 1741, 1811, and 1832. Close *in situ* inspection of the oak timbers indicated that these materials were initially utilized soon after cutting, in keeping with historical woodworking and carpentry techniques. Possible re-use and re-location of the timbers in subsequent construction phases, although not directly evidenced in the materials, cannot be excluded absolutely.

Samples IKTHNJ18, 19, 23 & 26, flooring elements from both the 2nd and 3rd storeys, were all cut in 1739 or 1740. Three of these four timbers strongly evidenced wane/bark-edge, while the fourth (IKTHNJ23) appeared to be waney but was noted in the field as uncertain yet likely. Moreover, two samples (joists IKTHNJ24 & 25, dated to 1715 & 1719 respectively) joined and associated with a summer beam (IKTHNJ23, dated to 1740) on the south side of the 2nd storey, though themselves lacking wane edge, provide positional and chronological corroborative evidence for a 1741 dating of this section. See **Table 1** for precise locational details.

Cellar samples IKTHNJ08, 09, 10, 12, 13 & 14, all with bark edge, have a cutting date of 1810. Cellar sample IKTHNJ11 lacked wane but its outermost extant ring dated to 1805. Furthermore, sample IKTHNJ04, a lath-hanger extending into the attic, also dated to 1810. Speculatively, this construction phase, likely beginning in 1811, could indicate local economic conditions in the years just prior to the outbreak of hostilities with Great Britain in 1812. Two samples from the 3rd storey (IKTHNJ20 & 21, dated to 1805 and 1810) may be associated with this construction phase, but alternately may be timbers from the 1832 construction. See **Table 1** for precise locational details.

Samples IKTHNJ16, 17 & 22 indicate a third construction phase beginning in 1832. Samples IKTHNJ17 & 22 are summer beams, and thus essential timbers supporting multiple structural elements. Of particular curiosity is sample IKTHNJ16, a dated joist from an outlying section of the cellar. Although unsupported by other dated materials from this area, it may be speculated that this anomalous dating may represent an extension of the cellar conducted during the 1832 construction phase. Additionally, as mentioned in the preceding paragraph, two samples from the 3rd storey (IKTHNJ20 & 21, dated to 1805 and 1810) may be associated with this phase rather than with the earlier 1811 phase, though sample IKTHNJ21 was evidentially cut in 1810, lending more weight to an assumption that they in fact belong to the earlier 1811 phase. See **Table 1** for more precise details.

The datings of two oak joists from the east attic area (IKTHNJ02 & 03, neither with bark edge) significantly pre-date the other materials. These datings could represent materials from an earlier structure incorporated fully into the existing building, or perhaps the re-use of materials either from the Tavern in an earlier configuration or at some time removed from another structure. It is impossible to determine from the results of the present dendrochronological analysis which of these potential explanations is correct. No other corroborating dates were achieved in any area, nor were any dates from the other materials chronologically similar. However, it is reasonable to assume, based on standard carpentry techniques, the timber dimensions and an awareness of the normal life span of oaks, that it is extremely unlikely that these attic samples could be contemporary with the other materials. No more than perhaps 50 years growth, and probably less, can be absent from the extant outer faces of these joists. Perhaps an additional analysis of the Tavern, one that samples otherwise inaccessible internal structural timbers from other sections of the site, could provide evidence to reconcile the discrepancy.

Table 1. Dendrochronological dating results for oak samples taken from the Indian King Tavern, Haddonfield, 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 in the absence of the bark-edge. If so, the outer date may 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. "Inc" 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
IKTHNJ01	Pine	East attic, summer beam	+BE	264	No Date	-.--
IKTHNJ02	Oak	East attic, joist, 3rd from west wall, north side	-BE, -SP	93	1560 1652	0.48
IKTHNJ03	Oak	East attic, joist, 2nd from west wall, south side	-BE, -SP	125	1519 1643	0.55
IKTHNJ04	Oak	East attic, "lathe hanger", between joist 5&6, south side	+BE	89	1722 1810 Comp	0.50
IKTHNJ05	Oak	East attic, joist, 9th from west wall	-BE, -SP	80	No Date	-.--
IKTHNJ06	Cedar	East attic, rafter, 3rd from west wall, south side	+BE	150	No Date	-.--
IKTHNJ07	Pine	East attic, rafter, 4th from west wall, north side	+BE	140	No Date	-.--
IKTHNJ08	Oak	Cellar001, joist, 7th from north wall	+BE	63	1748 1810 Comp	0.57
IKTHNJ09	Oak	Cellar001, joist, 6th from north wall	+BE	60	1751 1810 Comp	0.67
IKTHNJ10	Oak	Cellar001, summer beam by stair	+BE	100	1711 1810 Comp	0.54
IKTHNJ11	Oak	Cellar005, joist, 8th from west wall	-BE, SP	65	1741 1805	0.70
IKTHNJ12	Oak	Cellar005, chimney girt, 3rd joist from west wall	+BE	89	1722 1810 Comp	0.52
IKTHNJ13	Oak	Cellar005, northeast corner, 3rd "remnant" from north	+BE	51	1760 1810 Comp	0.60
IKTHNJ14	Oak	Cellar005, northeast corner, 2nd "remnant" from north	+BE	54	1757 1810 Comp	0.57
IKTHNJ15	Oak	Cellar005, northeast corner, 1st "remnant" from north	+BE	55	1756 1810 Comp	0.54
IKTHNJ16	Oak	Cellar004, joist, in center of space	+BE	57	1774 1830 Comp	0.38
IKTHNJ17	Oak	3rd floor, room 306, north summer beam	+BE	94	1738 1831 Comp	0.58
IKTHNJ18	Oak	3rd floor, room 308, joist 2nd west of chimney girt	+BE	105	1636 1740 Comp	0.61
IKTHNJ19	Oak	3rd floor, room 308, chimney girt	+BE	199	1541 1739 Comp	0.45
IKTHNJ20	Oak	3rd floor, room 301A, joist under landing, associated with #21	BE?? SP??	123	1683 1805	0.55
IKTHNJ21	Oak	3rd floor, room 301A, joist under landing, associated with #20	BE?	112	1699 1810 Comp	0.35
IKTHNJ22	Oak	2nd floor, room 206, north summer beam	+BE	112	1720 1831 Comp	0.54
IKTHNJ23	Oak	2nd floor, room 206, joist, 3rd from east, south side of north summer beam	BE?	152	1589 1740 Comp	0.39

IKTHNJ24	Oak	2nd floor, room 206, joist, 5th from east, south side of north summer beam	-BE, SP??	196	1520 1715	0.50
IKTHNJ25	Oak	2nd floor, room 206, joist, 7th from east, south side of north summer beam	-BE, SP?	201	1519 1719	0.61
IKTHNJ26	Oak	2nd floor, room 206, joist, 3rd from west, north side of south summer beam	+BE	114	1626 1739 Comp	0.42
IKTHNJ27	Oak	2nd floor, room 206, joist, 4th from east, north side of north summer beam, associated with #22	+BE	50	No Date	-.--
IKTHNJ28	Oak	2nd floor, room 206, joist, 7th from east, north side of north summer beam	+BE	49	No Date	-.--

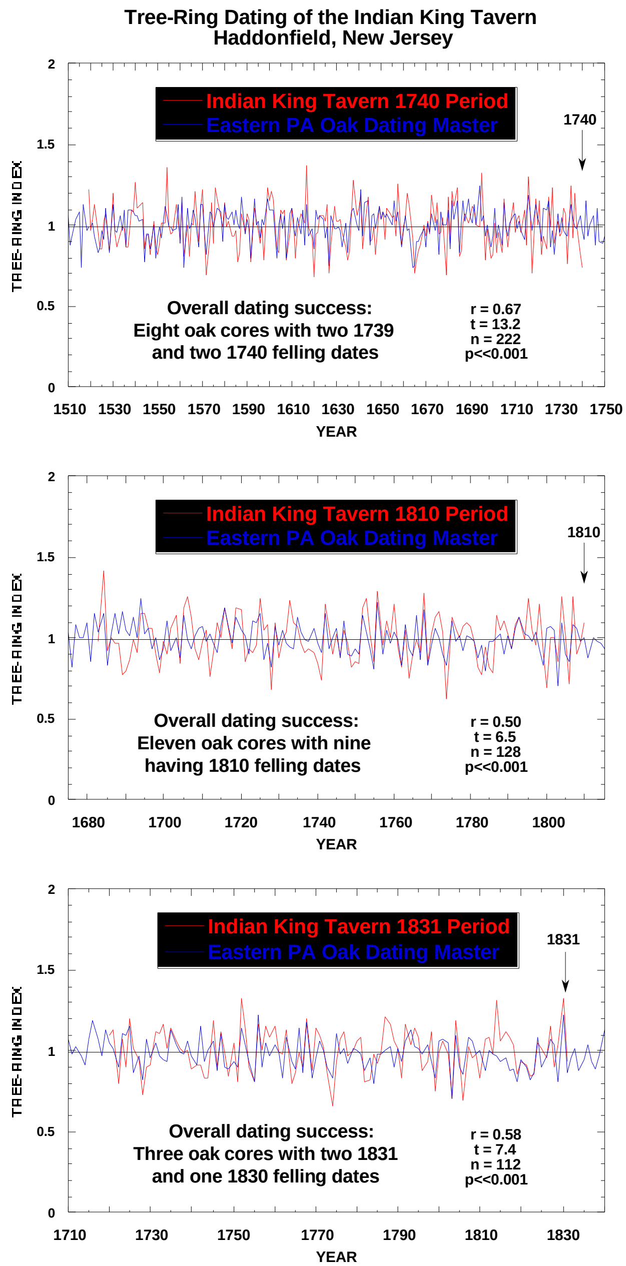


Figure 1. Comparisons of three cross-dated historical oak chronologies for the Indian King Tavern in Haddonfield, New Jersey versus an eastern Pennsylvania regional oak dating master based on oak tree-ring data from living trees and archaeological timbers. Three construction/renovation periods are indicated for the Indian King Tavern in 1741, 1811, and 1832, with each outermost year being anchored by waney edge dates. All of the Spearman rank correlations between the three series and the oak dating master are highly significant (p<<0.001) with overlaps ranging from 112 to 222 years

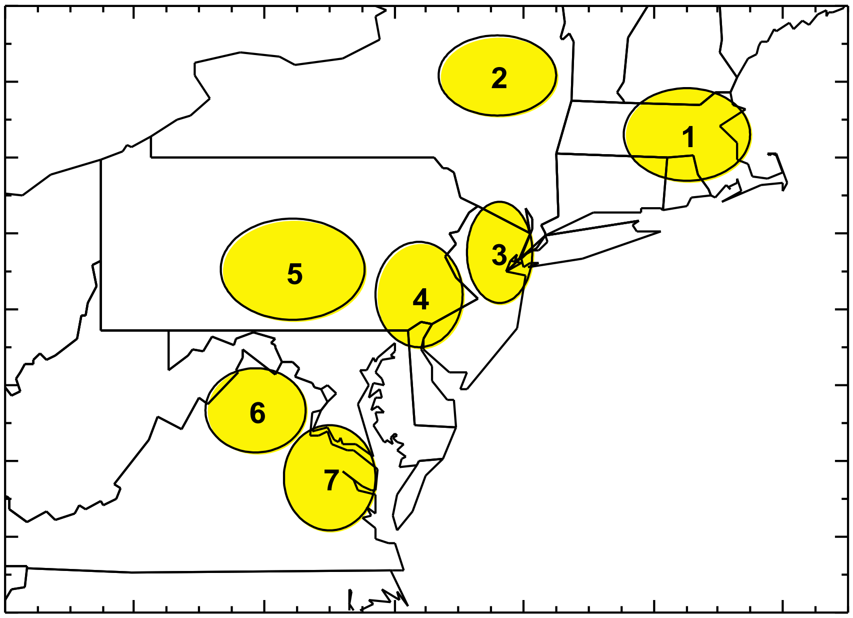
The "r-factor" is the Spearman rank correlation coefficient, a measure of relative statistical agreement between two groups of measurements or data. It can range from +1 (perfect direct agreement) to -1 (perfect opposite agreement). The "t-value" is Student's distribution test for determining the unique 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 indicate increasingly stronger statistical certitude.

The t-statistics ($t=13.2$) associated with the correlation between the 1740 series and the regional oak master chronology ($r=0.67$) is statistically significant ($p<<0.001$) for a 222-year overlap. For that reason, there can be no doubt that the dates presented here for the sampled oak elements of the Indian King Tavern are valid, and that the statistical chance of the cross-dates being incorrect is far less than 1 in 1000.

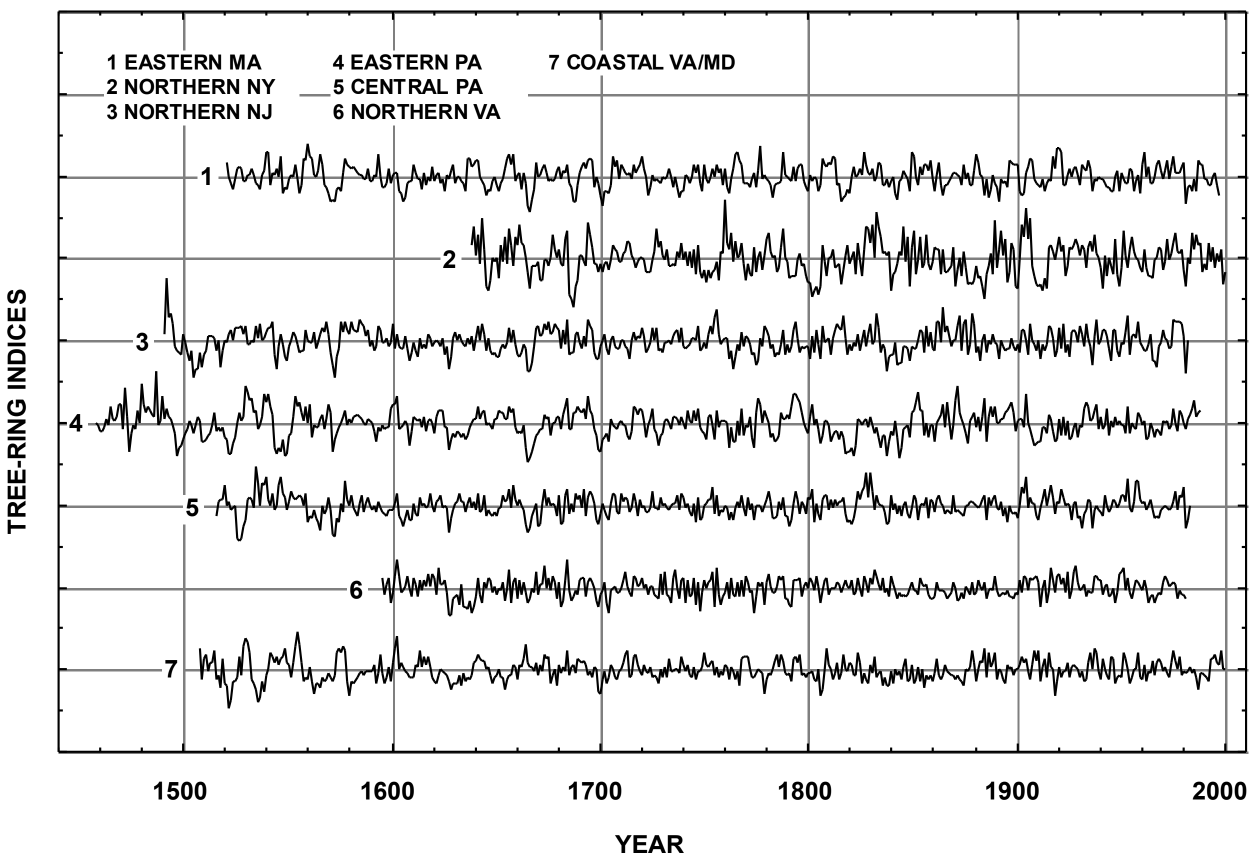
The t-statistics ($t=6.5$) associated with the correlation between the 1810 series and the regional master chronology ($r=0.50$) is statistically significant ($p<<0.001$) for a 128-year overlap. For that reason, there can be no doubt that the dates presented here for the sampled elements of the Indian King Tavern are valid, and that the statistical chance of the cross-dates being incorrect is far less than 1 in 1000.

The t-statistics ($t=7.4$) associated with the correlation between the 1831 oak series and the regional master chronology ($r=0.58$) is statistically significant ($p<<0.001$) for a 112-year overlap. For that reason, there can be no doubt that the dates presented here for the sampled elements of the Indian King Tavern are valid, and that the statistical chance of the cross-dates being incorrect is far less than 1 in 1000.

MODERN/HISTORICAL OAK CHRONOLOGIES
REGIONAL LOCATIONS OF SAMPLES



MODERN/HISTORICAL OAK TREE-RING CHRONLOGIES



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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 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 Ilse, Lancaster County, VA
Bowne House, Queens, NY
Carpenter's Hall, 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
Fawcett House, Alexandria, VA
Gadsby's Tavern, Alexandria, VA
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
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
Marmion, King George County, VA
Menokin, Richmond County, VA
Merchant's Hope Church, Prince George County, VA
Monaskon, Lancaster County, VA
Morris Jumel House, Jamaica, NY
Frederick Muhlenberg House, Trappe, PA
Old Caln Meeting House, Thorndale, PA
Old Swede's Church, Philadelphia, PA
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
Rippon Lodge, Prince William County, VA
Rochester House, Westmoreland County, VA
Rural Plains, Hanover County, VA
Sabine Hall, Richmond County, VA
Shirley, Charles City County, VA
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
Tuckahoe, Goochland County, VA
Updike Barn, Princeton, NJ
Varnum's HQ, Valley Forge, PA
Verville, Lancaster County, VA
West Camp House, Saugerties, NY
Westover, Charles City County, VA
William Garrett House, Sugartown, PA
Wilton, Westmoreland County, VA
Yew Hill, Fauquier County, VA