Dendrochronological Analysis of The Pavilion at Fort Ticonderoga, Ticonderoga, Essex County, NY

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Introduction

This is the final report on the dendrochronological analysis of the structure known as The Pavilion at Fort Ticonderoga, located in Ticonderoga, Essex County, NY 12883 (43º50'30"N, 73º23'15"W). The site is owned and maintained by the Fort Ticonderoga Association. In an effort to describe the construction history of this building, William Brandow of J.G. Waite Associates, Architects, Albany NY, acting on behalf of the Fort Ticonderoga Association, requested that dendrochronologists William Callahan and Dr. Edward Cook perform a tree-ring analysis of selected structural timbers.

Together with Mr. Brandow and Mr. Christopher Fox, Curator of Collections at Fort Ticonderoga, Callahan visited the site on 18, 19, 20, 21 November 2013 and collected core samples for the dendrochronological analysis of the timbers. A total of 39 field samples were taken, and of these 34 were of sufficient quality for submission for laboratory analysis. Of the submitted samples 19 were of pine (Pinus sp.) and 15 samples were of hemlock (Tsuga 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.

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 The Pavilion 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.

For the The Pavilion study, species specific, regional composite master chronologies from living trees and historical structures from central NY, the Adirondacks and near-lying regions were referenced primarily. All dating results were verified finally by comparison with other independent dating masters from surrounding areas in New England and the Mid-Atlantics. In each case, the datings as reported here were confirmed as correct.

Results and Conclusions

The results of the dendrochronological dating of The Pavilion timbers are summarized specifically for each species in **Tables 1 & 2** and **Figures 1 & 2**. A total of 19 pine and 15 hemlock samples were analyzed in the laboratory, with all 34 samples providing firm dendrochronological dates. The aforementioned 5 samples collected but not submitted to the laboratory for analysis had either significant physical degradation and/or too few rings for statistically viable analysis.

To achieve these datings required attention during the laboratory analysis to the previously recorded structural context of the samples (see **Tables 1 & 2, columns 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. Careful effort was made on-site to confirm, in the absence of the bark itself, the absolute presence of waney edge on the outermost sampled ring of the timbers. Yet due to the in situ condition of the materials and, especially, the anatomical properties of conifers, it must be considered that there exist in any specific instance a possibility of misevaluation.

The strength of the cross-dating of the samples is indicated by the Spearman rank correlations in the seventh column (“CORREL”) of **Tables 1 & 2**. 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 34 samples that cross-dated well between themselves, and also dated well against the local historical dating master (see **Tables 1 & 2**, **column 6**), 8 pines and 12 hemlocks had field-evaluated bark edge at the time of laboratory analysis. Furthermore, 2 additional pine timbers appeared to be bark edged but with lesser certainty.

The degree of congruency in the achieved datings within the site's individual structural units strongly indicates two major construction phases that developed The Pavilion into its general existing configuration, although neither phase can be conclusively assigned a single construction date based solely on the results of the dendrochronological testing. From the results it seems evident also that not all structural elements were under construction simultaneously:

an "earlier phase" that concluded in the final years of the decade of the 1820's (construction apparently completed circa 1829), as indicated by the chronological alignment of bark-edged timbers in various locations throughout the site;

a "later phase" that concluded in the final years of the decade of the 1830's (construction apparently completed circa 1837), as indicated by the alignment of bark-edged timbers in various locations throughout the site.

The strength of the cross-datings of the compiled Pavilion pine and hemlock site masters with both the pine and the hemlock regional master chronologies is an indication that most if not all of the timbers were taken from near-lying forests. Furthermore, close *in situ* inspection of the timbers indicated that many of these materials were initially utilized soon after cutting, in keeping with historical woodworking and carpentry techniques. Demonstrable evidence of previously existing structures at these locations is not obvious in the examined material, but cannot be excluded as a possibility. Although not evidenced directly in the materials, re-use of timbers in subsequent construction phases cannot and should not be excluded; speculatively, secondary usage seems very likely given the scattered assortment of dates revealed amongst tested timbers in the various structural units.

Table 1. Dendrochronological dating results for white pine samples taken from the Ticonderoga Pavilion, Ticonderoga, New York. For WANEY, +BE means the bark edge was present and thought to be recovered at the time of sampling; +BE(?) means the bark edge evaluation was judged likely but uncertain; -BE means that the bark edge was not recovered or was completely missing on the timber. 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.

TICONDEROGA PAVILION WHITE PINE DATING RESULTS						
ID	**SPECIES**	**DESCRIPTION**	**WANEY**	**RINGS**	**DATING**	**CORREL**
FTPENY01	Pine	N pavilion attic, plate, S side	+BE(?)	85 Comp	1728 1812	0.70
FTPENY02	Pine	N pavilion attic, N/S summer beam	+BE(?)	80 Comp?	1739 1818	0.66
FTPENY03	Pine	N connector attic, "upper" plate, W side,	+BE	73 Comp	1764 1836	0.74
FTPENY04	Pine	N connector attic, "lower" plate, W side,	+BE	170 Comp	1667 1836	0.66
FTPENY12[1]	Pine	Center pavilion cellar, N/S summer beam	-BE	50 see note	1713 1762	0.66
FTPENY13	Pine	Center pavilion cellar, not in situ sill/plate (?) timber, N of central wall in crawl space	-BE	159 Comp	1626 1784	0.53
FTPENY14	Pine	Central pavilion attic, period 1, plate, N side	+BE	221 Comp	1605 1825	0.61
FTPENY15	Pine	Central pavilion attic, period 1, central summer beam	-BE	145	1668 1813	0.39
FTPENY18	Pine	Central pavilion attic, period 1, post, SE corner, W of portico	-BE	99	1612 1710	0.52
FTPENY19	Pine	Central pavilion attic, period 1, E wall plate, W of portico	-BE	107	1615 1721	0.62
FTPENY20	Pine	Central pavilion attic, period 1, W wall plate	+BE	67 Comp	1770 1836	0.43
FTPENY24	Pine	S pavilion attic, N section, period1, N/S summer beam extending under floor into S section	+BE	151 Comp	1681 1831	0.62
FTPENY25	Pine	S pavilion attic, N section, period 1, E/W plate	-BE	168	1568 1735	0.73
FTPENY26	Pine	S connector attic, N section, period 2, "upper" plate, W side	-BE	73	1741 1813	0.55
FTPENY27	Pine	S connector attic, N section, period 2, E/W wall plate, abutting S pavilion	+BE	134 Comp	1703 1836	0.64
FTPENY28	Pine	S connector attic, N section, period 1, E/W central summer beam, E segment near central summer	+BE	66 Comp	1770 1835	0.50
FTPENY30[2]	Pine	S pavilion attic, S section, period 1, plate, S side	-BE	151	1624 1775	0.69
FTPENY31	Pine	S pavilion attic, S section, period 1, plate, E side	-BE	146	1632 1778	0.73
FTPENY32[2]	Pine	S pavilion attic, S section, period1, plate, S wall	+BE	167 Comp	1664 1830	0.78

[1]Badly rotted zone in the core, only measured partially, outer date not the true felling date
[2]FTPENY30 and FTPENY32 are the same timber, cored to extend series to cutting date

Table 2. Dendrochronological dating results for eastern hemlock samples taken from the Ticonderoga Pavilion, Ticonderoga, New York. 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. 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.

TICONDEROGA PAVILION EASTERN HEMLOCK DATING RESULTS						
ID	**SPECIES**	**DESCRIPTION**	**WANEY**	**RINGS**	**DATING**	**CORREL**
FTPENY05	Hemlock	N connector attic, joist, 6th from W wall, N side of summer beam	+BE	85 Comp	1611 1695	0.33
FTPENY06	Hemlock	N connector attic, joist 7th from W wall, N side of summer beam	+BE	55 Inc	1735 1790	0.73
FTPENY07	Hemlock	N connector attic, E/W central summer beam, E side	+BE	141 Comp	1696 1836	0.72
FTPENY08	Hemlock	N connector attic, N/S central wall plate	+BE	110 Comp	1727 1836	0.62
FTPENY09	Hemlock	N pavilion attic, rafter, 3rd from E wall	+BE	154 Comp	1675 1828	0.62
FTPENY10	Hemlock	N pavilion attic, rafter, 5th from E wall	-BE	138 Comp	1619 1756	0.65
FTPENY11	Hemlock	N pavilion attic, joist, 7th from E wall	+BE	136 Comp	1623 1758	0.68
FTPENY16	Hemlock	Center pavilion attic, period 1, joist, 3rd from N wall, W side, central summer	+BE	106 Comp	1720 1825	0.66
FTPENY17	Hemlock	Center pavilion attic, period 1, joist, 4th from N wall, E side, central summer	+BE	105 Comp	1722 1826	0.34
FTPENY21	Hemlock	S pavilion attic, N section, period 1, rafter, 4th from W wall	-BE	48	1783 1830	0.82
FTPENY22	Hemlock	S pavilion attic, N section, period 1, rafter, 5th from W wall (sawn off over access door)	+BE	73 Inc	1758 1831	0.62
FTPENY23	Hemlock	S pavilion attic, N section, period 1, plank/beam extending N/S, E side of access door	+BE	79 Comp	1750 1828	0.75
FTPENY29	Hemlock	S connector attic, N section, period 2, N/S central wall plate, N of central E/W summer beam	+BE	62 Comp	1720 1781	0.73
FTPENY33	Hemlock	Center pavilion, rear wing cellar/crawl space, joist fragment not in situ	+BE	135 Comp	1703 1837	0.60
FTPENY34	Hemlock	Center pavilion, rear wing cellar/crawl space, joist fragment not in situ	-BE	77	1738 1814	0.66

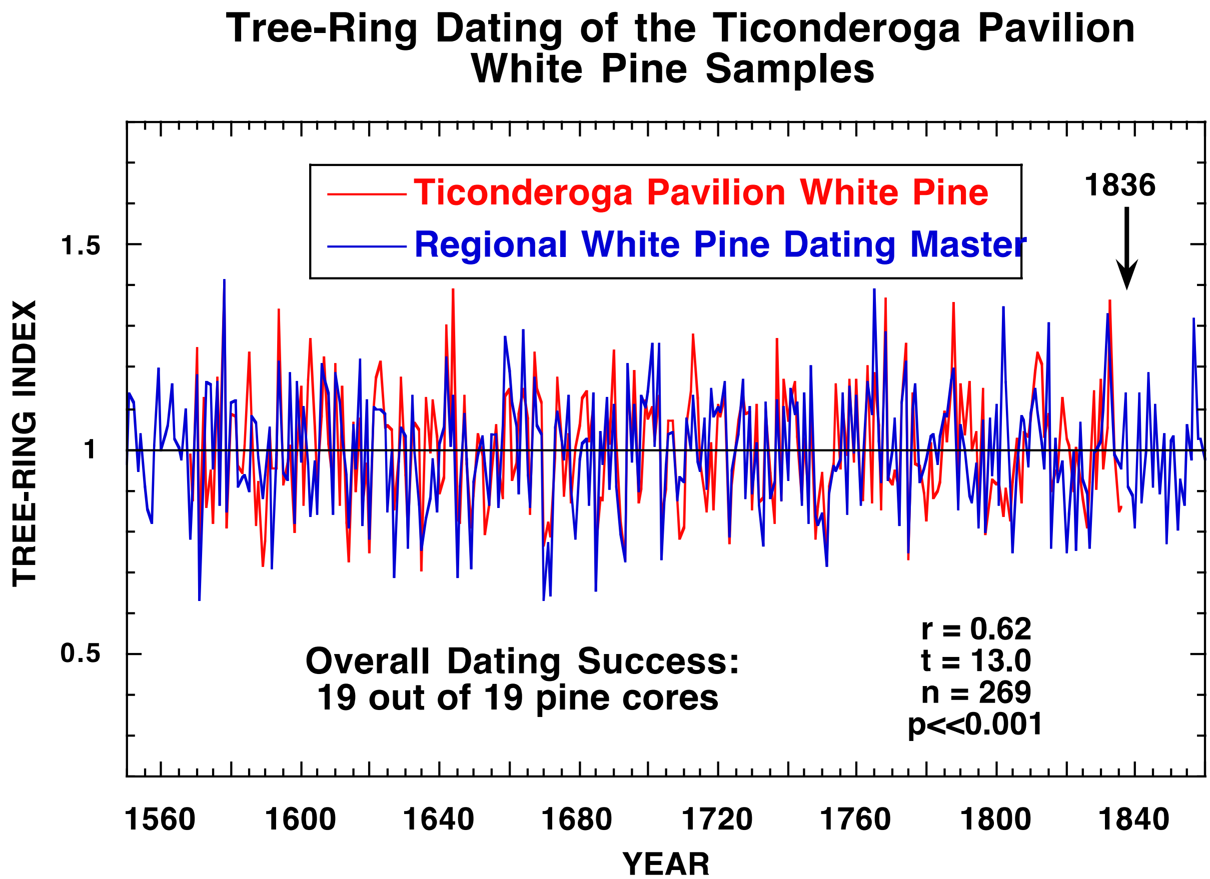

Figure 1. Comparison of the master dated series for the Ticonderoga Pavilion (red plot) versus an independent regional white pine dating master (blue plot). All nineteen collected pine samples dated successfully, with an assortment of outermost dates. See Table 1 for details. The Pavilion dated pine master has a highly significant ($p<<0.001$) Spearman rank correlation with the regional pine dating master.

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 exponentially increasing, stronger statistical certitude.

The t-statistics (t=13.0) associated with the correlation between the The Pavilion pine series and the regional pine master chronology (r=0.62) is statistically significant ($p<<0.001$) for a 269-year overlap. For that reason, there can be no doubt that the dates presented here for the sampled pine elements of The Pavilion are valid, and that the statistical chance of the cross-dates being incorrect is far less than 1 in 1000.

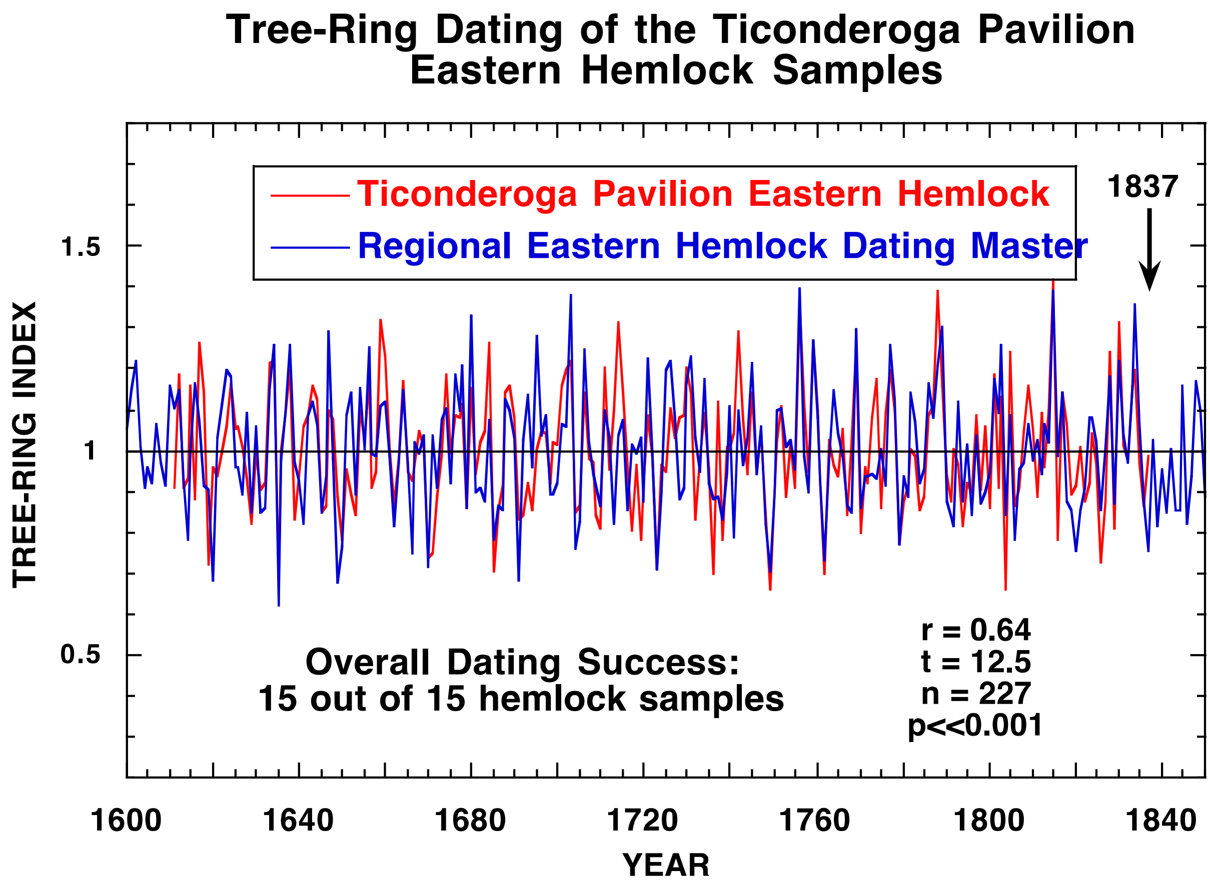

Figure 2. Comparison of the master dated series for the Ticonderoga Pavilion (red plot) versus an independent regional hemlock dating master (blue plot). All fifteen collected hemlock samples dated, with an assortment of outermost dates. See Table 1 for details. The Pavilion dated hemlock master has a highly significant ($p<<0.001$) Spearman rank correlations with the regional pine dating master.

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 exponentially increasing, stronger statistical certitude.

The t-statistics (t=12.5) associated with the correlation between the The Pavilion hemlock series and the regional hemlock master chronology (r=0.64) is statistically significant ($p<<0.001$) for a 227-year overlap. For that reason, there can be no doubt that the dates presented here for the sampled pine elements of f The Pavilion are valid, and that the statistical chance of the cross-dates being incorrect is far less than 1 in 1000.

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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 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
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 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
Sisk Cabin, Culpeper 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
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
Wilton, Westmoreland County, VA
Yew Hill, Fauquier County, VA