Tree-ring analysis of the Boreas Ponds log cabin in North Hudson, New York

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INTRODUCTION

The Boreas Ponds log cabin is located about 0.7 miles south of the southern end of Boreas Ponds in the town of North Hudson in Essex County, NY (latitude 44.000 N and longitude 73.942 W). The reported history of the site[3] suggests that the clearing at the cabin originated after the War of 1812 as one of a series of horse pastures and worker camps that were placed every 10 miles along the nearby Port Henry to Sackets Harbor military road, with the cabin having been built in 1836. The surrounding lands were purchased by Finch, Pruyn, and Company in November 1891 and the forest cut for softwood sawlogs from 1892 to 1899. Pictures from 1900 show several buildings and barns at the site and from 1900 to 1933 the camp was used for fishing and hunting parties. In 1937 there was a larger barn, log camp, and blacksmith shop in the clearing, and the surrounding forests were lumbered again for softwood pulpwood from 1937 to 1949.

The purpose of this research project was to use tree-ring crossdating (dendrochronology) to determine the cutting dates of logs used to build the cabin. When the outermost rings of logs are intact, such dates can establish to the year and potentially to the season when the trees were cut and so thereby constrain the likely building date of the structure. Furthermore, microscopic examination of the tree-ring samples can also establish the genus and potentially the species of the wood and so provide additional information regarding to the origins of the structure.

Dendrochronology background

Trees that grow in seasonal climates such as the northeastern United States will produce annual growth rings (Figure 1). In conifers (e.g. pine, spruce, hemlock), growth is fast in the spring and so the tree will add earlywood (wide, thin-walled cells) around the outer circumference beneath the bark. Growth slows in the late summer and fall and so latewood (narrower, thicker-walled cells) is produced before the tree becomes dormant for the winter. In ring-porous angiosperms (e.g. oak, ash), the earlywood contains many large vessels or pores that diminish in size and frequency in the latewood, while in diffuse-porous angiosperms (e.g. birch, maple) the pores are spread evenly throughout the year and annual ring boundaries can be harder to discern.

The anatomical characteristics of tree rings enable many taxa to be distinguished based on microscopic examination of carefully prepared samples. For example, pines typically have large pores in most rings, spruces have infrequent small pores, and hemlocks lack pores entirely. While some samples can be readily distinguished to the species-level, others can only be identified to groupings within a genus of anatomically indistinguishable species (e.g. the white oak group contains at least nine oak species found in the eastern United States). In this latter case, knowledge of the tree species native to the area can often narrow the options to one or two likely candidate species.

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[3] Documents from Finch Pruyn and the Nature Conservancy, provided by Charles Vandrei, NYS DEC, 5/16/ 2016.

Trees produce wide annual rings in good growth years and narrow annual rings in poor years. Climate is usually the dominant control on whether a growth year is good or not, and trees of the same species in the same area will tend to respond to climate in similar ways. This means that ring width patterns of trees of the same species in an area that are alive at the same time can be matched. This is called crossdating and it enables tree ring samples from old buildings to be dated with annual precision (Figure 2). Crossdating between different species is also sometimes possible if the two species respond to climate in similar ways. Longer tree ring sequences are better for crossdating than short records because the uniqueness of the year-to-year growth pattern increases with sample length. Stokes and Smiley (1968) and Baillie (1982) provide good introductions to the methods of crossdating and dendrochronology, and to the interpretation of crossdates from historical timbers.

SAMPLING AND ANALYSIS

Sampling at the Boreas Ponds log cabin was done on May 17th, 2016. The cabin had three doors and seven windows (Figure 3), and paneling in the interior rooms meant that sampling of the logs of the cabin walls would be easiest from the exterior of the structure. Bark was present on many of the logs and logs forming the north wall were generally in better condition (i.e. more solid and less splintered) than those forming the south wall. The roof appeared to be relatively new and the interlocking of the logs at the cabin corners made it unlikely that any of the lower tiers of logs had been replaced (Figure 4).

Core samples were collected using a 5.15 mm (0.2 inches) diameter hand-driven increment borer. Cores were taken through bark or a waney edge close to bark (Figure 5) so as to include the outermost rings and were angled to reach the innermost rings at the center of each log. A total of 21 cores were collected from 17 logs, of which five (logs A-E) were in the north wall, seven (logs F-L) were in the east wall, four (logs M-P) were in the south wall, and one (log Q) was in the west wall (Figures 6 to 8). After sampling, core holes were backfilled with caulk and finished flush with the waney edge with a stainable wood filler.

In the SUNY Cortland tree-ring laboratory, core samples were glued into wooden splints and sanded with increasingly finer sandpapers (up to 1500 grit) to expose the wood cell structures. Taxa were identified by examination of the cross-sectional surfaces under a binocular microscope and with reference to keys in Brown et al. (1949) and Hoadley (1990). Ring-widths were measured to the nearest 0.001 mm using a Velmex linear encoder system and PJK software (P. Krusic, unpublished). Sample crossdating was done visually by core-to-core comparisons under a microscope and using line graphs in CORINA software (Pohl, 1995), and checked statistically using COFECHA software (Holmes, 1983). The final master chronology for the cabin samples was developed with ARSTAN software (Cook, 1985) using splines with 50% frequency response of 32 years for standardization, a biweight robust mean for calculating the mean chronology signal, and with the Residual chronology retained for crossdating with other tree-ring chronologies from the region.

RESULTS

Taxonomic identification

All 17 logs were identified as being of the spruce genus (*Picea*). Red spruce (*P. rubens* Sarg.), black spruce (*P. mariana* (Mill.) BSP), and white spruce (*P. glauca* (Moench) Voss) are all present in the Adirondack region today and these three species cannot be reliably distinguished from one another using wood samples alone (Brown et al., 1949; Hoadley, 1990). However, red spruce is abundant in the Boreas Ponds area and so is the most likely species to have been used for building this cabin. This interpretation is supported by the bark found on some of the logs as well as by the ring width patterns of the samples that are consistent with growth in a well-drained setting, which is the typical habitat of red spruce.

Crossdating and log dates

The first step of the crossdating process was to match ring-width patterns of the samples with each other. A total of 34 ring width series were used in this step; 21 series from the original core samples plus an additional 13 series that were from cores that extended 60 or more rings past the center of their respective logs. This internal crossdating process was very successful with 33 of the ring width series matching strongly with each other. The one exception was series W35B1 which was too broken-up to provide reliable data. The 33 crossdated series all correlated with the master chronology of the dataset at well above the 99% confidence level in a 1-tailed t-test, meaning that there is less than a 1% chance that any individual series has been erroneously matched with the others. The high quality of the crossdates was also evident in the strong visual match of the series with each other in both core-to-core comparisons under a microscope and in on-screen comparisons of line graphs (Figure 9). Furthermore, all of the samples that had well-preserved outer rings ended in about the same year, which is what would be expected if the original trees had all been cut at the same time in order to build the cabin.

The second step of the crossdating process was to match the master ring-width chronology of the Boreas Ponds data (AHPCSP1) with other spruce chronologies from the region. Three other such datasets were available; a chronology from living red spruce growing about 13 miles to the northeast at Roaring Brook in Keene Valley (ITRDB[4] NY009; E. Cook, unpublished), a

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[4] International Tree-Ring Data Bank (ITRDB) dataset; see Online Software and Data section of this report.

chronology composed of spruce collected from historical buildings in the town of Willsboro about 36 miles to the northeast (WHPC1; Barclay and Rayburn, 2014), and a chronology from living red spruce growing at Camels Hump in Vermont about 56 miles to the east-northeast (ITRDB VT001; T. Siccama, unpublished). The strongest match was with the closest dataset, the red spruce from Keene Valley, and this indicated that the Boreas Ponds master chronology extended from 1704 to 1891 (Figure 10). Statistically this match had a Pearson correlation coefficient (r) of 0.406, which is significant at the 99.9% confidence level, and this match was much stronger than any other crossdate position in the 1619 to 1978 timespan of the Keene Valley dataset (i.e. sliding the Boreas Ponds chronology backwards or forwards in time did not result in any other likely matches). Pearson correlation coefficients between the Boreas Ponds chronology at the 1704-1891 placement with the Willsboro historical and Camels Hump living spruce chronologies were respectively at 0.367 and 0.258, both of which are also statistically significant at the 99% confidence level. Collectively these results give very high confidence to the 1704-1891 crossdate of the Boreas Ponds master chronology.

The final step of the crossdating process was to determine the first and last years of growth of each of the 17 logs sampled (logs A to Q). This was done by transferring the results from crossdating of the master chronology back to the individual series comprising the Boreas Ponds dataset to place each of the component ring-width series correctly in time, and then dates of these series were compiled to determine the first and last years of recorded growth for each log. Incomplete or badly damaged rings had not been measured but were included in the final ring tallies where they could be counted with confidence. Quality of the outer ring dates were rated using the criteria and scale of Barclay and Rayburn (2014).

Final results (Table 1) show that the oldest log was a tree that began growing in or before 1703. The last year of growth recorded by any of the logs was 1891, with seven logs with well-preserved outer rings ending in this year. An additional nine logs have last years of recorded growth in the years leading up to 1891, but these all had less well preserved outermost rings and had likely lost a few rings to abrasion or weathering prior to being sampled.

DISCUSSION

These results clearly show that the logs used to build the cabin were cut in the late fall or winter of 1891 or before growth began in the spring of 1892. Felling of trees was often done in the wintertime in this region in the 19th century because logs could be easily moved over the frozen landscape on sleds (Keller, 1980). The slight variability of the outermost ring dates, with some samples having finished growth for 1891 and others seemingly ending earlier in the year or in the few years prior to 1891, is most likely due to weathering and loss of the outer millimeter or two (about 1/10th inch) of logs rather than the trees having been cut over an extended period of years.

There is no evidence to support a building date of 1836 or earlier for the cabin. Rather, the winter 1891-2 date corresponds with the purchase of the lands by Finch, Pruyn, and Company in November 1891. It appears that one of the first actions by these new owners was to build the cabin, perhaps for use as a bunkhouse, kitchen or mess hall (or perhaps all three), prior to lumbering operations from 1892 to 1899. If there was an older cabin on the site then it was either torn down and replaced by this cabin or otherwise removed at some other time.

The strong crossdating of the Boreas Ponds ring-width series with each other indicates that the logs were all cut from trees close to one another. Most likely they were a stand of red spruce that were felled to make the clearing, or perhaps were close by if the clearing had been made earlier. This strong internal crossdating is similar to that of the Keene Valley red spruce chronology which is comprised of living trees that were growing near to each other, and is a little stronger than the internal crossdating of the Willsboro historical spruce chronology which is comprised of trees that grew across a wider area of the headwaters of the Boquet River.

SUMMARY

- A tree-ring study was completed of an old log cabin just to the south of Boreas Ponds in Essex County, NY, in order to determine the likely construction date of the structure.
- Core samples were collected from 17 logs that form the walls of the cabin.
- The wood of all the core samples was identified as being spruce (*Picea*), and was most likely red spruce (*Picea rubens*) which is abundant in the area.
- Ring-width series from the samples crossdated strongly with each other, indicating that the trees cut for the logs had likely grown close to each other.
- A tree-ring master chronology for the site crossdated strongly with other spruce chronologies in the region, enabling exact dates to be determined for the logs.
- The logs used to build the cabin were cut in the winter of 1891-2 and the cabin was most likely built at that time or soon thereafter.

ACKNOWLEDGEMENTS

We thank Charles Vandrei (NYS DEC) for bringing this project to our attention and for facilitating and helping with field sampling. The assistance of Jamie Vornlocher (SUNY New Paltz) with field sampling is also gratefully acknowledged. Freely available software and datasets from the dendrochronology community made this project possible. Travel funding was provided by NYS DEC.

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Pohl, R. 1995. CORINA, A User's Guide. Cornell University, Ithaca, NY.

Stokes, M.A. and T.L. Smiley, 1968. An introduction to tree-ring dating, The University of Arizona Press, Tucson, Arizona, 73 pp.

ONLINE SOFTWARE AND DATA

Columbia University, Lamont-Doherty Earth Observatory, Tree-Ring Lab.: *PJK*, *COFECHA,* and *ARSTAN.* <http://www.ldeo.columbia.edu/tree-ring-laboratory/resources/software>

Cornell University, Cornell Tree-Ring Laboratory. *Corina* software. <http://dendro.cornell.edu/corina/corina.php>

NOAA National Climatic Data Center, Paleoclimatology, International Tree-Ring Data Bank. <http://www.ncdc.noaa.gov/data-access/paleoclimatology-data/datasets/tree-ring>

FIGURES

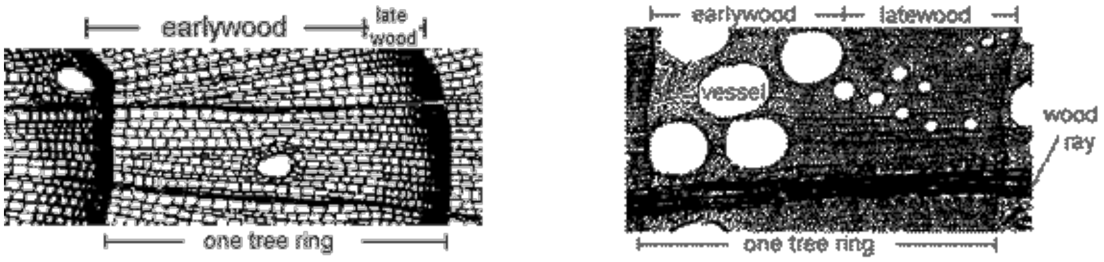


Figure 1. Tree rings of a conifer (left) and a ring-porous angiosperm (right). Growth is from left to right. Images from the University of Arizona, Laboratory of Tree Ring Research <http://www.ltrr.arizona.edu/about/treerings>.

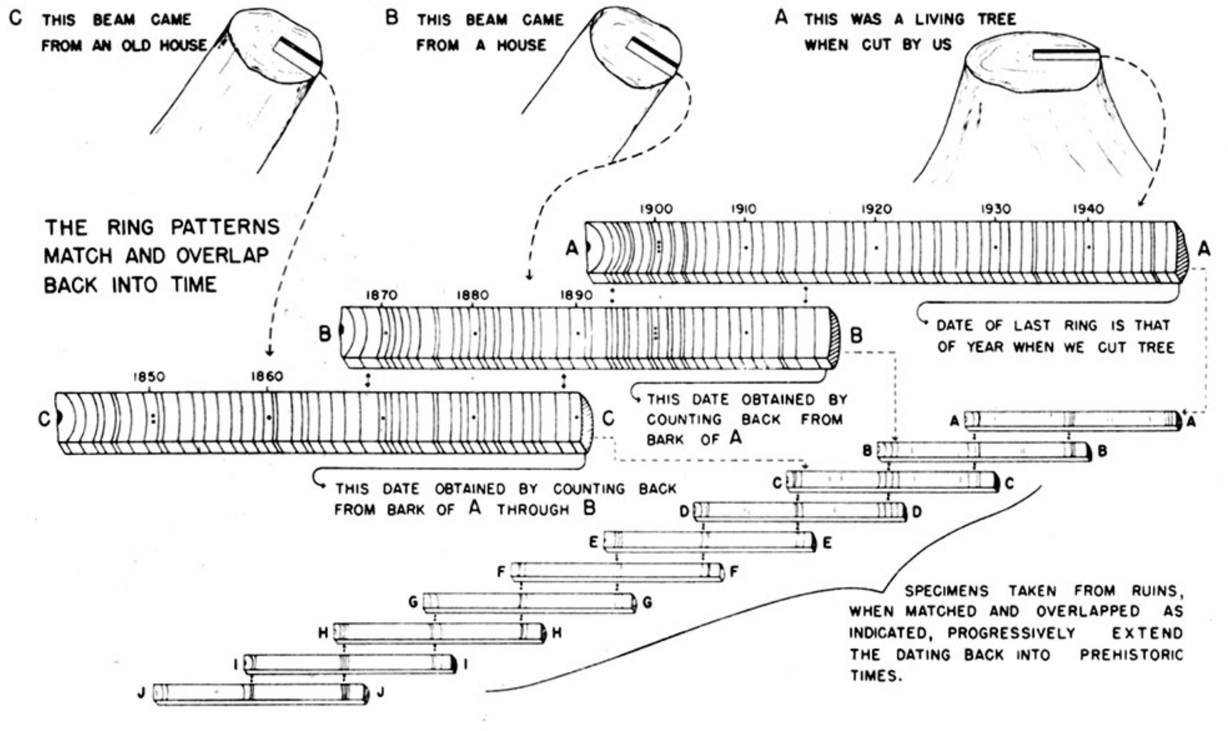


Figure 2. Tree-ring crossdating. From Stokes and Smiley (1968). Further information on the principles of tree ring crossdating can be found online at the University of Arizona, Laboratory of Tree Ring Research <http://tree.ltrr.arizona.edu/lorim/basic.html>.

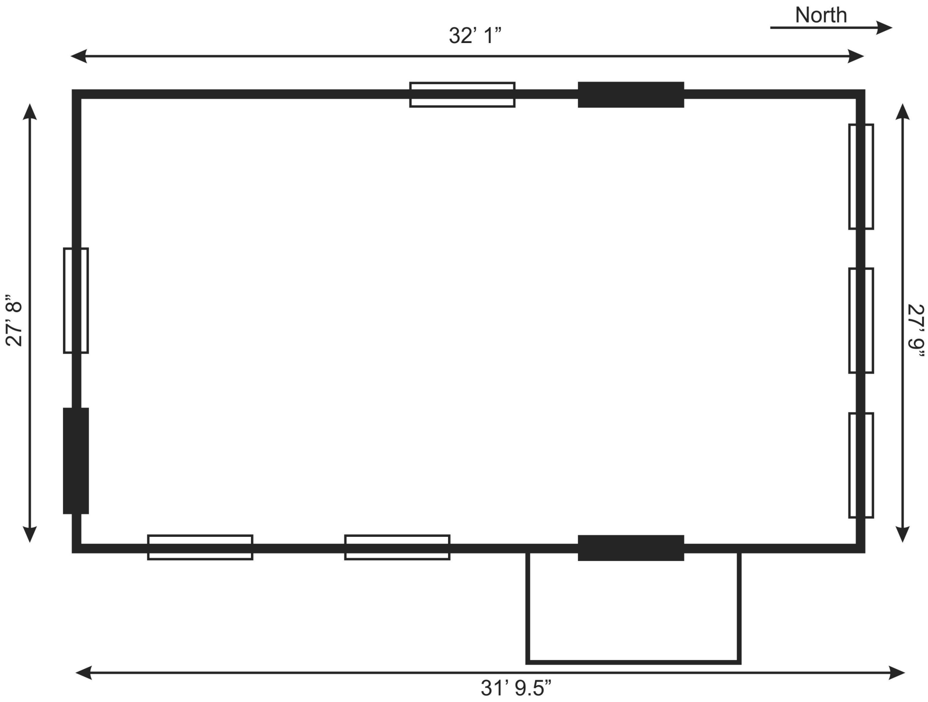


Figure 3. Layout and dimensions of the Boreas Ponds log cabin. Black blocks are doors, open blocks are the seven windows, and the extension on the east side is an open porch.

Figure 4. Sampling of the east wall at the northeast corner of the cabin. Note the newer-appearing wood above the upper tier of logs and the interlocking of logs in the corner of the cabin walls.

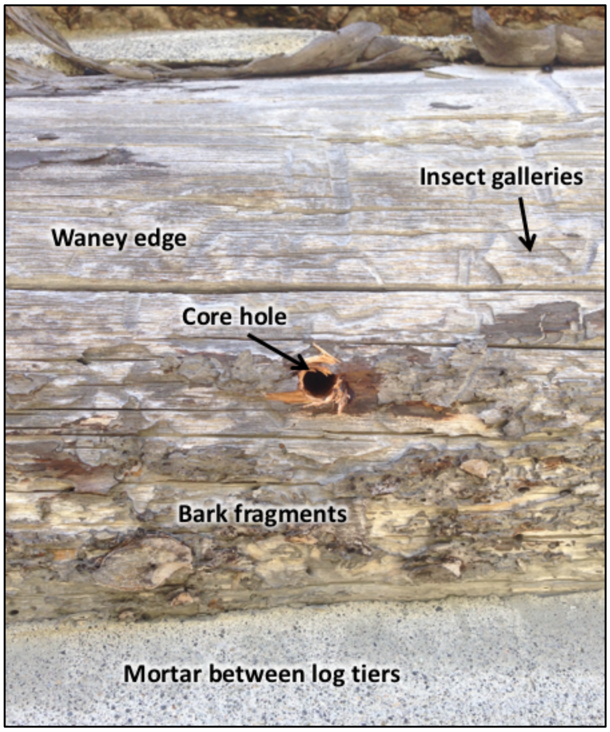


Figure 5. Outer surface of a sampled log. The waney edge is the curved surface where the bark is gone but the outermost surface appears to be intact. Insect galleries are commonly found just beneath the bark.

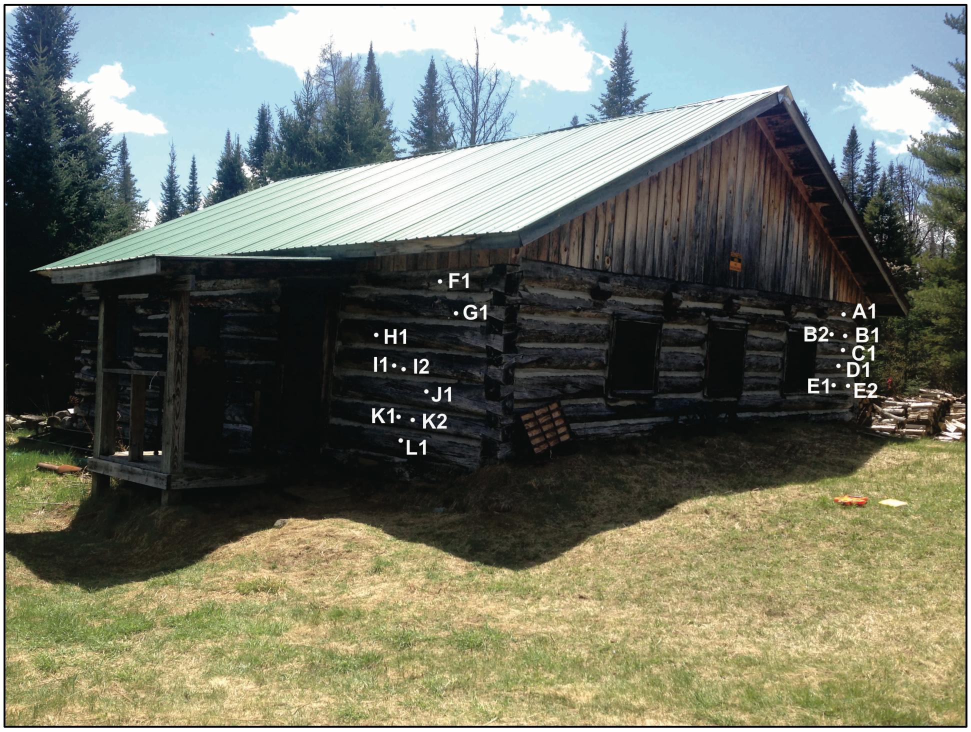


Figure 6. Sample locations on the north (A-E) and east (F-L) sides of the cabin.

Figure 7. Sample locations (M-P) on the south side of the cabin.

Figure 8. Sample location (Q) on the west side of the cabin.

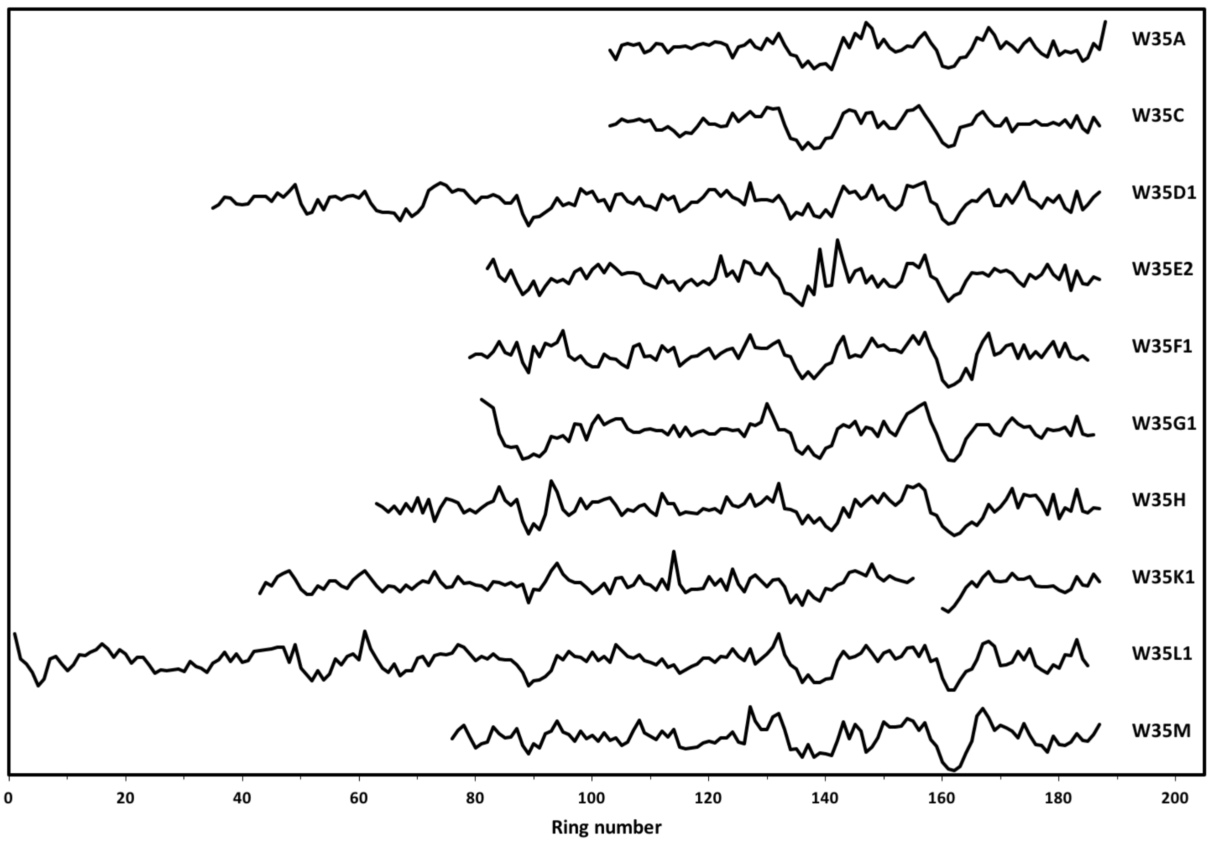


Figure 9. Crossdating of selected ring-width series. Growth trends have been removed and series are crossdated relative to each other. Average correlation between all 33 crossdated series is 0.644.

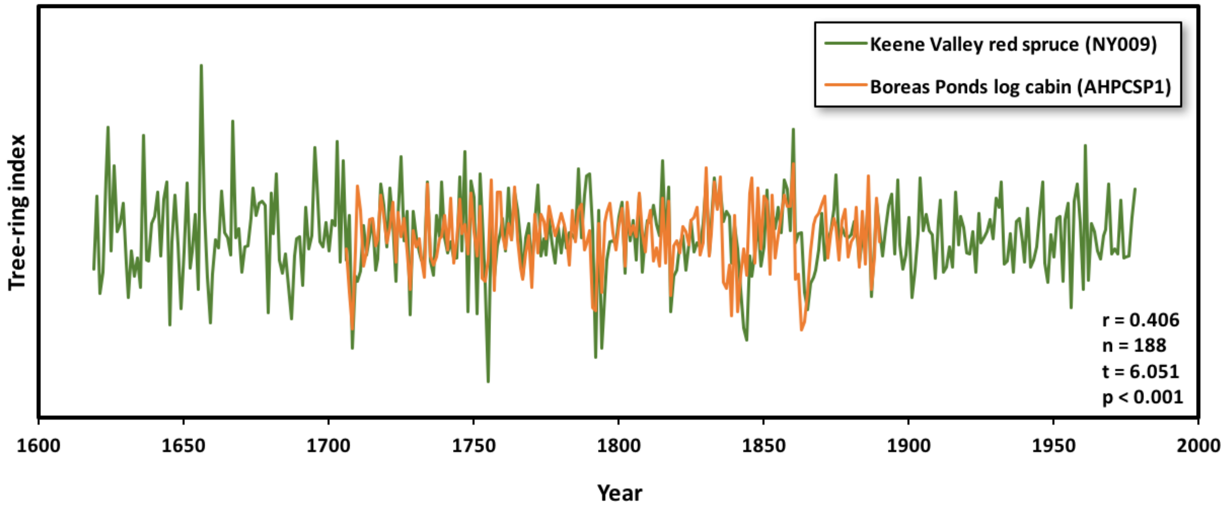


Figure 10. Match of Boreas Ponds master chronology with a chronology from living red spruce growing in Keene Valley. The crossdate is both visually and statistically strong.

TABLES

Table 1. Results for spruce logs from the Boreas Ponds log cabin.

Log id.	No. of cores	No. of series	Data for log based on all component series			
			Inner rings	First ring	Last ring	Outer rings
W35A	1	1	Hit pith	1805	1891	A_l
W35B	2	2	Close	1770	1877	D
W35C	1	1	Close	1805	1891	A_l
W35D	1	2	Close	1737	1891	A_l
W35E	2	4	Close	1781	1891	A_l
W35F	1	2	Close	1781	1889	B
W35G	1	2	Close	1783	1890	B
W35H	1	1	Close	1765	1891	A_e
W35I	2	3	Close	1759	1885	C
W35J	1	2	Close	1717	1888	C
W35K	2	4	Hit pith	1745	1891	A_e
W35L	1	2	Hit pith	1703	1889	B
W35M	1	1	Close	1771	1891	A_l
W35N	1	1	Close	1741	1882	C
W35O	1	2	Close	1746	1887	B
W35P	1	2	Close	1737	1883	C
W35Q	1	2	Close	1714	1889	B

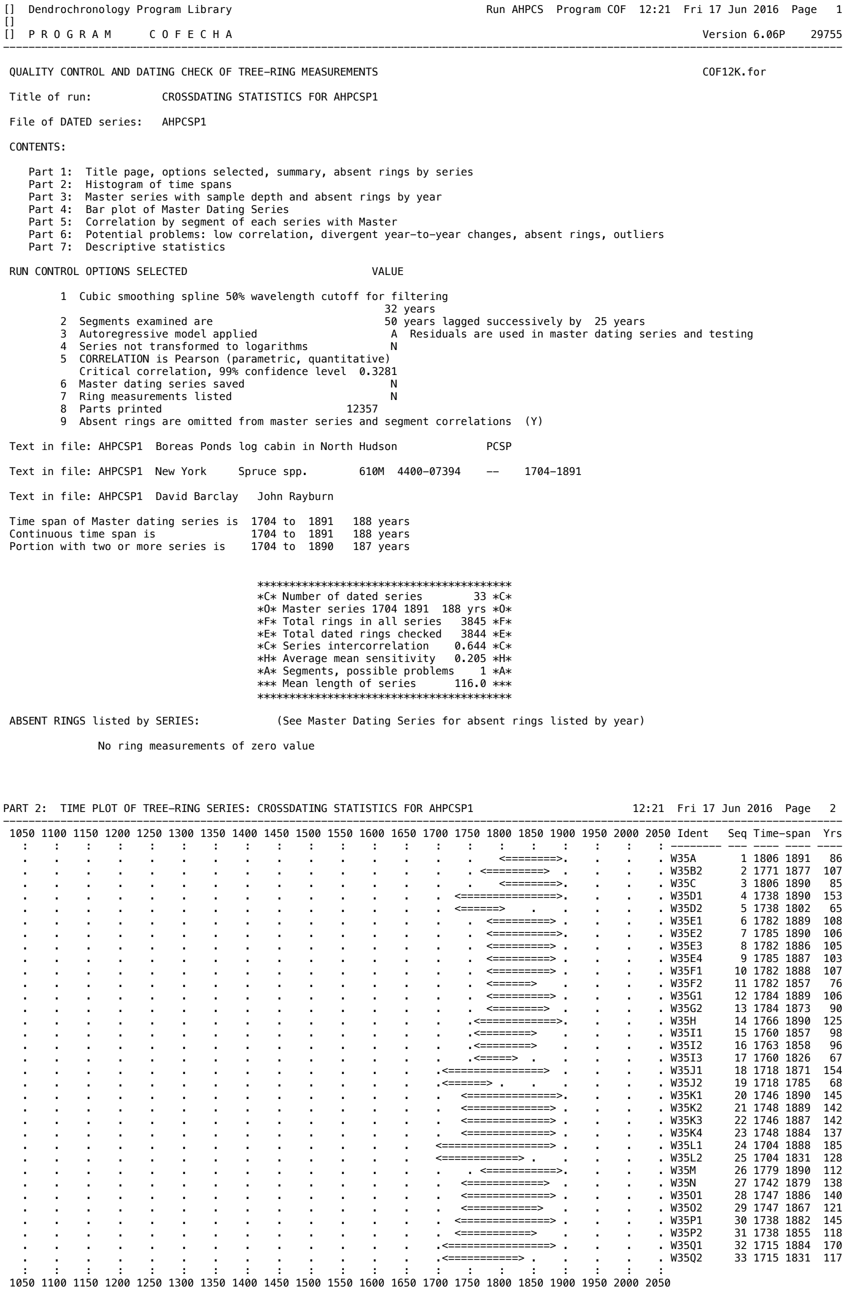
No. of cores is the total number of cores physically collected from each log, while no. of series is the total number of ring width series with 60 or more rings measured from each log. Some cores passed through the log center and continued beyond, and so provided two series that had sufficient rings for crossdating.

Inner rings. Samples that hit the pith include the innermost rings at the center of the log and so the first ring date is the innermost ring of the tree. Samples that were close had significant curvature of the inner rings indicating that the first ring date is near to the pith.

Outer rings. Last ring dates are rated as follows (from Barclay and Rayburn, 2014):

A_e or A_l	Precise date. Bark or waney edge present and last ring date is the actual last year of growth. Subscript indicates that the last ring ends with earlywood (e) or latewood (l).
B	Close date. Quality of outer rings and consilience with other samples suggests that last ring date is within a few years of when tree died.
C	Minimum date. No clear indication that the last ring date is close to the actual death date of the tree, so date simply constrains the year of tree death to be sometime after the last year of recorded growth.
D	Suspect. Outer rings known to be lost, removed, badly decayed, or damaged.

Appendix. Crossdating quality control statistics from COFECHA.



```
[]  Dendrochronology Program Library                                       Run AHPCS  Program COF  12:21  Fri 17 Jun 2016  Page   1
[]
[]  P R O G R A M     C O F E C H A                                                                         Version 6.06P    29755
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 QUALITY CONTROL AND DATING CHECK OF TREE-RING MEASUREMENTS                                                  COF12K.for

 Title of run:           CROSSDATING STATISTICS FOR AHPCSP1

 File of DATED series:   AHPCSP1

 CONTENTS:

    Part 1:  Title page, options selected, summary, absent rings by series
    Part 2:  Histogram of time spans
    Part 3:  Master series with sample depth and absent rings by year
    Part 4:  Bar plot of Master Dating Series
    Part 5:  Correlation by segment of each series with Master
    Part 6:  Potential problems: low correlation, divergent year-to-year changes, absent rings, outliers
    Part 7:  Descriptive statistics

 RUN CONTROL OPTIONS SELECTED                            VALUE

         1  Cubic smoothing spline 50% wavelength cutoff for filtering
                                                           32 years
         2  Segments examined are                          50 years lagged successively by  25 years
         3  Autoregressive model applied                    A  Residuals are used in master dating series and testing
         4  Series not transformed to logarithms            N
         5  CORRELATION is Pearson (parametric, quantitative)
            Critical correlation, 99% confidence level  0.3281
         6  Master dating series saved                      N
         7  Ring measurements listed                        N
         8  Parts printed                            12357
         9  Absent rings are omitted from master series and segment correlations  (Y)

 Text in file: AHPCSP1  Boreas Ponds log cabin in North Hudson             PCSP

 Text in file: AHPCSP1  New York     Spruce spp.        610M  4400-07394    --    1704-1891

 Text in file: AHPCSP1  David Barclay   John Rayburn

 Time span of Master dating series is  1704 to  1891   188 years
 Continuous time span is               1704 to  1891   188 years
 Portion with two or more series is    1704 to  1890   187 years


                                        ****************************************
                                        *C* Number of dated series        33 *C*
                                        *O* Master series 1704 1891  188 yrs *O*
                                        *F* Total rings in all series   3845 *F*
                                        *E* Total dated rings checked   3844 *E*
                                        *C* Series intercorrelation    0.644 *C*
                                        *H* Average mean sensitivity   0.205 *H*
                                        *A* Segments, possible problems    1 *A*
                                        *** Mean length of series      116.0 ***
                                        ****************************************

 ABSENT RINGS listed by SERIES:            (See Master Dating Series for absent rings listed by year)

              No ring measurements of zero value



PART 2:  TIME PLOT OF TREE-RING SERIES: CROSSDATING STATISTICS FOR AHPCSP1                        12:21  Fri 17 Jun 2016  Page   2
-----------------------------------------------------------------------------------------------------------------------------------
 1050 1100 1150 1200 1250 1300 1350 1400 1450 1500 1550 1600 1650 1700 1750 1800 1850 1900 1950 2000 2050 Ident    Seq Time-span  Yrs
   :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    : -------- --- ---- ---- ----
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   .    .    .    .    .    .    .    .    .    .    .    .    .    .    . <=========>  .    .    .    . W35B2      2 1771 1877  107
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    <========>.    .    .    . W35C       3 1806 1890   85
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   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .  <==========>.    .    .    . W35E2      7 1785 1890  106
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .  <=========> .    .    .    . W35E3      8 1782 1886  105
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .  <=========> .    .    .    . W35E4      9 1785 1887  103
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .  <=========> .    .    .    . W35F1     10 1782 1888  107
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   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .<=====>  .    .    .    .    . W35I3     17 1760 1826   67
   .    .    .    .    .    .    .    .    .    .    .    .    .    .<===============>  .    .    .    . W35J1     18 1718 1871  154
   .    .    .    .    .    .    .    .    .    .    .    .    .    .<======> .    .    .    .    .    . W35J2     19 1718 1785   68
   .    .    .    .    .    .    .    .    .    .    .    .    .    .   <==============>.    .    .    . W35K1     20 1746 1890  145
   .    .    .    .    .    .    .    .    .    .    .    .    .    .   <=============> .    .    .    . W35K2     21 1748 1889  142
   .    .    .    .    .    .    .    .    .    .    .    .    .    .   <=============> .    .    .    . W35K3     22 1746 1887  142
   .    .    .    .    .    .    .    .    .    .    .    .    .    .   <=============> .    .    .    . W35K4     23 1748 1884  137
   .    .    .    .    .    .    .    .    .    .    .    .    .    <=================> .    .    .    . W35L1     24 1704 1888  185
   .    .    .    .    .    .    .    .    .    .    .    .    .    <============> .    .    .    .    . W35L2     25 1704 1831  128
   .    .    .    .    .    .    .    .    .    .    .    .    .    .    . <===========>.    .    .    . W35M      26 1779 1890  112
   .    .    .    .    .    .    .    .    .    .    .    .    .    .   <============>  .    .    .    . W35N      27 1742 1879  138
   .    .    .    .    .    .    .    .    .    .    .    .    .    .   <=============> .    .    .    . W35O1     28 1747 1886  140
   .    .    .    .    .    .    .    .    .    .    .    .    .    .   <===========>   .    .    .    . W35O2     29 1747 1867  121
   .    .    .    .    .    .    .    .    .    .    .    .    .    .  <==============> .    .    .    . W35P1     30 1738 1882  145
   .    .    .    .    .    .    .    .    .    .    .    .    .    .  <===========>    .    .    .    . W35P2     31 1738 1855  118
   .    .    .    .    .    .    .    .    .    .    .    .    .    .<================> .    .    .    . W35Q1     32 1715 1884  170
   .    .    .    .    .    .    .    .    .    .    .    .    .    .<===========> .    .    .    .    . W35Q2     33 1715 1831  117
   :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :    :
 1050 1100 1150 1200 1250 1300 1350 1400 1450 1500 1550 1600 1650 1700 1750 1800 1850 1900 1950 2000 2050
```

```
PART 3:  Master Dating Series: CROSSDATING STATISTICS FOR AHPCSP1                                  12:21  Fri 17 Jun 2016  Page   3
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  Year  Value  No Ab    Year  Value  No Ab    Year  Value  No Ab    Year  Value  No Ab    Year  Value  No Ab    Year  Value  No Ab
  ------------------    ------------------    ------------------    ------------------    ------------------    ------------------
                        1750  0.639  17       1800  0.222  30       1850  0.884  28
                        1751 -0.038  17       1801  0.966  30       1851  1.193  28
                        1752  0.824  17       1802 -0.369  30       1852 -0.127  28
                        1753 -0.686  17       1803  0.758  29       1853  0.889  28
  1704  2.511   2       1754 -1.548  17       1804  0.370  29       1854  0.127  28
  1705 -0.061   2       1755 -1.389  17       1805  0.526  29       1855  0.109  28
  1706 -0.266   2       1756  0.617  17       1806  0.283  31       1856  0.417  27
  1707 -1.118   2       1757 -1.137  17       1807  1.591  31       1857  1.047  27
  1708 -2.410   2       1758  0.602  17       1808  1.046  31       1858  0.903  25
  1709 -2.002   2       1759  1.399  17       1809  0.006  31       1859  1.105  24

  1710 -0.510   2       1760  0.481  19       1810  0.545  31       1860  1.993  24
  1711  0.087   2       1761 -0.039  19       1811  1.270  31       1861  0.379  24
  1712 -0.643   2       1762  0.356  19       1812 -0.284  31       1862 -0.377  24
  1713 -0.852   2       1763  0.101  20       1813 -0.612  31       1863 -1.697  24
  1714 -0.261   2       1764  1.590  20       1814 -1.537  31       1864 -2.354  24
  1715  0.122   4       1765  1.039  20       1815  0.571  31       1865 -2.298  24
  1716 -0.274   4       1766 -0.207  21       1816 -0.762  31       1866 -1.553  24
  1717 -0.012   4       1767 -1.402  21       1817  1.273  31       1867 -0.680  24
  1718  1.706   6       1768 -0.832  21       1818 -1.526  31       1868 -0.208  23
  1719  1.348   6       1769 -0.287  21       1819 -1.157  31       1869  0.245  23

  1720  0.347   6       1770 -1.682  21       1820 -0.941  31       1870  0.838  23
  1721  0.511   6       1771 -0.172  22       1821 -1.137  31       1871  1.279  23
  1722  1.362   6       1772 -0.939  22       1822 -0.258  31       1872  0.579  22
  1723 -0.436   6       1773  0.301  22       1823  0.023  31       1873  0.219  22
  1724  0.669   6       1774  0.419  22       1824 -0.317  31       1874  0.532  21
  1725  0.152   6       1775 -0.198  22       1825  0.310  31       1875  0.546  21
  1726  1.054   6       1776  0.532  22       1826  0.687  31       1876 -0.118  21
  1727  0.106   6       1777  0.618  22       1827  1.087  30       1877  0.425  21
  1728 -1.224   6       1778  0.217  22       1828  0.033  30       1878  1.105  20
  1729 -0.247   6       1779  0.547  23       1829 -0.192  30       1879 -0.100  20

  1730 -0.586   6       1780  1.034  23       1830  1.711  30       1880 -0.170  19
  1731 -0.161   6       1781  0.841  23       1831  0.425  30       1881 -0.091  19
  1732 -1.017   6       1782  0.373  27       1832  0.237  28       1882  0.839  19
  1733 -2.072   6       1783 -0.619  27       1833  1.131  28       1883 -0.686  18
  1734  0.680   6       1784  0.388  29       1834  1.107  28       1884  0.618  18
  1735 -0.410   6       1785 -0.020  31       1835  1.793  28       1885 -1.103  16
  1736 -1.370   6       1786  0.718  30       1836  0.171  28       1886  1.484  16
  1737 -1.449   6       1787  1.201  30       1837 -0.887  28       1887 -0.953  14
  1738 -1.056  10       1788  0.313  30       1838 -1.053  28       1888 -1.313  12
  1739 -0.592  10       1789 -0.005  30       1839 -2.018  28       1889  0.580  10

  1740  0.429  10       1790  0.120  30       1840 -0.770  28       1890  0.557   7
  1741 -0.271  10       1791 -1.620  30       1841 -1.882  28       1891  2.853   1
  1742  1.251  11       1792 -2.770  30       1842 -1.698  28
  1743 -0.190  11       1793 -1.172  30       1843 -1.346  28
  1744  0.009  11       1794 -2.136  30       1844 -1.622  28
  1745  1.074  11       1795 -0.897  30       1845 -0.102  28
  1746  0.360  13       1796  0.095  30       1846  1.014  28
  1747  0.354  15       1797  0.906  30       1847  0.061  28
  1748 -0.619  17       1798  0.583  30       1848  1.067  28
  1749  0.938  17       1799 -0.093  30       1849  0.339  28
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PART 5:  CORRELATION OF SERIES BY SEGMENTS: CROSSDATING STATISTICS FOR AHPCSP1                     12:21  Fri 17 Jun 2016  Page   5
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 Correlations of  50-year dated segments, lagged  25 years
 Flags:  A = correlation under  0.3281 but highest as dated;  B = correlation higher at other than dated position

 Seq Series  Time_span   1700 1725 1750 1775 1800 1825 1850
                         1749 1774 1799 1824 1849 1874 1899
 --- -------- ---------  ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- ----
   1 W35A     1806 1891                       .35  .70  .78
   2 W35B2    1771 1877             .66  .66  .75  .73  .76
   3 W35C     1806 1890                       .59  .75  .67
   4 W35D1    1738 1890        .62  .74  .71  .75  .82  .61
   5 W35D2    1738 1802        .52  .62  .67
   6 W35E1    1782 1889                  .54  .60  .72  .72
   7 W35E2    1785 1890                  .54  .46  .50  .55
   8 W35E3    1782 1886                  .49  .61  .59  .70
   9 W35E4    1785 1887                  .49  .64  .68  .72
  10 W35F1    1782 1888                  .60  .69  .81  .59
  11 W35F2    1782 1857                  .66  .69  .76
  12 W35G1    1784 1889                  .54  .57  .74  .77
  13 W35G2    1784 1873                  .62  .70  .80
  14 W35H     1766 1890             .43  .46  .63  .76  .74
  15 W35I1    1760 1857             .55  .63  .71  .67
  16 W35I2    1763 1858             .42  .60  .71  .57
  17 W35I3    1760 1826             .49  .60  .65
  18 W35J1    1718 1871   .62  .62  .77  .75  .75  .81
  19 W35J2    1718 1785   .61  .61  .58
  20 W35K1    1746 1890        .59  .61  .61  .60  .44B .47
  21 W35K2    1748 1889        .70  .69  .75  .72  .45  .43
  22 W35K3    1746 1887        .58  .62  .69  .78  .80  .77
  23 W35K4    1748 1884        .63  .64  .79  .83  .79  .71
  24 W35L1    1704 1888   .66  .72  .76  .74  .80  .81  .76
  25 W35L2    1704 1831   .67  .69  .83  .70  .72
  26 W35M     1779 1890                  .70  .77  .76  .57
  27 W35N     1742 1879        .68  .70  .76  .75  .74  .74
  28 W35O1    1747 1886        .71  .71  .73  .76  .58  .50
  29 W35O2    1747 1867        .73  .73  .74  .75  .78
  30 W35P1    1738 1882        .69  .70  .72  .74  .59  .54
  31 W35P2    1738 1855        .68  .71  .72  .75  .73
  32 W35Q1    1715 1884   .55  .52  .60  .68  .65  .65  .58
  33 W35Q2    1715 1831   .55  .57  .64  .67  .73
 Av segment correlation  0.61 0.64 0.65 0.65 0.68 0.70 0.65
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PART 7:  DESCRIPTIVE STATISTICS: CROSSDATING STATISTICS FOR AHPCSP1                                12:21  Fri 17 Jun 2016  Page   4
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                                                Corr   //-------- Unfiltered --------\\  //---- Filtered -----\\
                           No.    No.    No.    with   Mean   Max     Std  Auto    Mean   Max     Std   Auto  AR
 Seq Series   Interval   Years  Segmt  Flags   Master  msmt   msmt    dev   corr   sens  value    dev   corr  ()
 --- -------- ---------  -----  -----  -----   ------ -----  -----  -----  -----  -----  -----  -----  -----  --
   1 W35A     1806 1891     86      3      0   0.499   1.48   3.08  0.836  0.931  0.194   0.64  0.269  0.004   1
   2 W35B2    1771 1877    107      5      0   0.695   1.07   2.37  0.492  0.877  0.173   0.63  0.247 -0.028   1
   3 W35C     1806 1890     85      3      0   0.610   1.19   2.48  0.458  0.889  0.167   0.72  0.263 -0.071   1
   4 W35D1    1738 1890    153      6      0   0.662   0.89   2.00  0.392  0.873  0.189   0.77  0.254 -0.012   1
   5 W35D2    1738 1802     65      3      0   0.554   1.05   1.87  0.492  0.912  0.165   0.58  0.240 -0.063   1
   6 W35E1    1782 1889    108      4      0   0.651   0.95   2.50  0.531  0.895  0.231   0.73  0.287 -0.053   1
   7 W35E2    1785 1890    106      4      0   0.552   0.87   2.07  0.443  0.852  0.246   0.86  0.313 -0.018   2
   8 W35E3    1782 1886    105      4      0   0.608   0.98   2.84  0.471  0.857  0.213   0.92  0.309 -0.006   1
   9 W35E4    1785 1887    103      4      0   0.621   1.07   2.41  0.472  0.795  0.221   0.84  0.289 -0.007   1
  10 W35F1    1782 1888    107      4      0   0.604   1.10   2.38  0.540  0.851  0.242   0.75  0.317 -0.027   1
  11 W35F2    1782 1857     76      3      0   0.689   1.07   2.71  0.670  0.886  0.223   0.88  0.314  0.011   1
  12 W35G1    1784 1889    106      4      0   0.637   1.12   2.30  0.491  0.860  0.214   1.29  0.344  0.023   2
  13 W35G2    1784 1873     90      3      0   0.684   0.94   1.93  0.459  0.876  0.255   0.72  0.312 -0.022   1
  14 W35H     1766 1890    125      5      0   0.595   1.00   1.94  0.415  0.771  0.235   0.99  0.321  0.022   2
  15 W35I1    1760 1857     98      4      0   0.610   1.34   3.02  0.593  0.941  0.139   0.54  0.196 -0.027   1
  16 W35I2    1763 1858     96      4      0   0.510   1.33   3.30  0.619  0.925  0.160   0.75  0.251 -0.032   1
  17 W35I3    1760 1826     67      3      0   0.497   1.40   3.13  0.700  0.947  0.146   0.48  0.194  0.012   1
  18 W35J1    1718 1871    154      6      0   0.722   0.70   2.11  0.392  0.855  0.211   0.89  0.333  0.011   1
  19 W35J2    1718 1785     68      3      0   0.594   0.72   1.22  0.206  0.756  0.155   0.69  0.232  0.004   1
  20 W35K1    1746 1890    145      6      1   0.560   0.64   2.16  0.416  0.935  0.200   0.91  0.192 -0.026   1
  21 W35K2    1748 1889    142      6      0   0.614   0.63   2.20  0.386  0.908  0.207   0.86  0.190 -0.002   1
  22 W35K3    1746 1887    142      6      0   0.696   0.86   2.27  0.444  0.906  0.187   0.78  0.258 -0.014   1
  23 W35K4    1748 1884    137      6      0   0.696   0.86   2.08  0.410  0.893  0.182   0.60  0.246 -0.002   1
  24 W35L1    1704 1888    185      7      0   0.730   0.72   1.95  0.375  0.892  0.202   0.87  0.263 -0.062   1
  25 W35L2    1704 1831    128      5      0   0.708   0.75   2.18  0.383  0.905  0.185   0.67  0.253 -0.085   1
  26 W35M     1779 1890    112      4      0   0.663   1.19   3.85  0.810  0.901  0.232   0.96  0.321  0.058   1
  27 W35N     1742 1879    138      6      0   0.729   0.67   1.65  0.302  0.766  0.243   0.96  0.333 -0.024   1
  28 W35O1    1747 1886    140      6      0   0.640   0.82   1.93  0.439  0.859  0.231   0.79  0.290 -0.030   1
  29 W35O2    1747 1867    121      5      0   0.761   0.94   1.81  0.386  0.796  0.227   0.79  0.308 -0.018   1
  30 W35P1    1738 1882    145      6      0   0.655   0.77   1.65  0.381  0.890  0.230   0.69  0.272 -0.028   1
  31 W35P2    1738 1855    118      5      0   0.722   0.92   1.83  0.385  0.837  0.218   0.53  0.263 -0.009   1
  32 W35Q1    1715 1884    170      7      0   0.587   0.58   1.79  0.300  0.872  0.195   0.62  0.242  0.016   2
  33 W35Q2    1715 1831    117      5      0   0.626   0.73   2.06  0.444  0.913  0.179   0.82  0.244 -0.030   1
 --- -------- ---------  -----  -----  -----   ------ -----  -----  -----  -----  -----  -----  -----  -----  --
 Total or mean:           3845    155      1   0.644   0.91   3.85  0.455  0.873  0.205   1.29  0.272 -0.016

                                              - = [  COFECHA AHPCSCOF  ] = -
```