TREE-RING RESEARCH, *Vol. 57(2), 2001, pp. 197–203*

DEVELOPMENT OF A WHITE OAK CHRONOLOGY USING LIVE TREES AND A POST-CIVIL WAR CABIN IN SOUTH-CENTRAL VIRGINIA

ZACHARY J. BORTOLOT, CAROLYN A. COPENHEAVER,[1] ROBERT L. LONGE and JAN A. N. VAN AARDT[2]

Department of Forestry
College of Natural Resources
Virginia Polytechnic Institute and State University
228C Cheatham Hall
Blacksburg, VA 24061, USA

ABSTRACT

A 280-year old white oak chronology was developed for south-central Virginia to verify the timber harvesting and construction dates of a cabin located on the Reynolds Homestead Research Center. A plaque on the cabin stated that the logs were harvested in 1814. However, the outer rings of the logs dated to 1875 and 1876. From the land-use history of the area, the cabin was most likely constructed to house tenant farmers after the Civil War. Most of the periods of below average growth identified in the 280-year chronology were related to drought events. Correlations between the radial growth of the white oak with temperature and precipitation data from a local weather station were examined. Precipitation had more influence on radial growth than temperature, and significant correlations ($p = 0.05$) existed between radial growth and precipitation from the previous September, the current April, and the current June.

Keywords: dendroarcheology, Virginia Piedmont, *Quercus alba*, dendrochronology.

INTRODUCTION

Timber was the most common construction material available to European settlers in the eastern United States. Wood was used extensively in the construction of tools, wagons, and buildings. The timber sources were primarily local due to the costs and time associated with timber transport (Whitney 1994). Wood was cited as the primary building material as late as 1883, with as many as nine-tenths of all houses in the northern and middle states (within 240 km from the ocean) being built entirely of wood (Perlin 1989). A rise of $37 million in market supply of unsawed lumber from 1850 to 1860 also indicates the tremendous importance of wood as both framing and mechanical material (Marsh 1864).

Dendrochronologists have used samples from wooden constructions dating to the early European settlement of North America for a number of applications. The tree-ring patterns from wooden structures have served to identify construction dates, determine the provenance of wood used in construction, reconstruct historical climate patterns, and determine the historical frequency of disturbance events (Stahle 1979; Robinson 1985; Bonzani *et al.* 1991; Nielson *et al.* 1995; Krause 1997; Therrell 2000).

Oak (*Quercus* sp.) has been used extensively to study climate trends throughout the world (Estes 1970; Bednarz and Ptak 1990; D'Arrigo *et al.* 1997). White oak (*Quercus alba* L.), one of the longest-lived oak species in North America (Rogers 1990), has traditionally been used in dendroclimatology studies in the eastern United States. White oak ring width has been shown to be significantly related to temperature and precipitation (Estes 1970; Duvick and Blasing 1981; Jacobi and Tainter 1988; Cleaveland and Duvick 1992; LeBlanc 1993). The responsiveness of oak radial

[1]Corresponding author: e-mail ccopenhe@vt.edu
[2]Authors are identified alphabetically

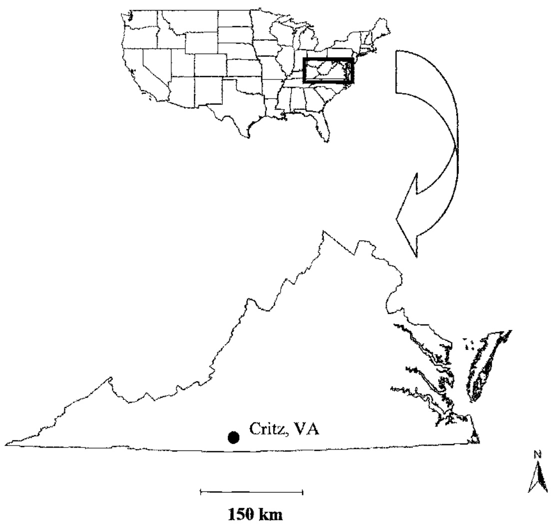

Figure 1. The Reynolds Research Center is located in Critz, Virginia. The site is the birthplace of the founder of the R. J. Reynolds Tobacco Company.

growth to climate depends upon seasonality, other climatic parameters, and edaphic conditions. Climate has the strongest effect on radial growth in oaks during the summer months and at xeric sites (Estes 1970; Duvick and Blasing 1981; Jacobi and Tainter 1988).

In south-central Virginia, a recent arson event allowed us to destructively sample white oak logs from a cabin on the Reynolds Homestead Research Center. A plaque on the front of the cabin states, "The logs in this cabin are from the original home of the grandparents of the founders of the R. J. Reynolds' tobacco company." R. J. Reynolds' grandfather, Abraham Reynolds, built a log cabin at this site in 1814. In this study, we combine logs salvaged from the burned cabin with white oak cores from living trees in the same vicinity to address the following study objectives: (1) determine the year of harvest for the logs used in the construction of the cabin to verify whether the logs originated from the 1814 cabin built by Abraham Reynolds; (2) develop a white oak chronology for south-central Virginia from the cabin logs and live trees; and (3) identify the influence of climate on tree-ring growth in white oak in south-central Virginia.

STUDY SITE

The Reynolds' family originally purchased land in Patrick County, Virginia, near the town of Critz (36°38′N and 80°16′W), in 1814 when Abraham Reynolds purchased 20 ha and built a log cabin (Patrick County Deed Book 4, pg. 89). Abraham Reynolds continued to purchase land in the area and by 1839 he owned 589 ha (some co-owned with his son, Hardin W. Reynolds) (Tilly 1970) and used most of his lands for tobacco production (Patrick County Historical Society 1999). By 1843, Abraham Reynolds' original log cabin had been replaced as the family's residence by a 2-story brick house. According to the plaque on the sampled cabin, the original Abraham Reynolds' cabin was disassembled and the logs were used to construct another cabin, approximately 1 km from the original location. In 1969, Nancy S. Reynolds donated 287 ha and the buildings (including the aforementioned cabin) to Virginia Polytechnic Institute and State University to create the Reynolds Homestead Research Center (Figure 1). In 2000, an arsonist destroyed the roof and upper logs of the cabin built from the logs of the original Abraham Reynolds cabin. The bottom logs of the cabin were charred, but most remained structurally intact.

The Reynolds Homestead Research Center (RHRC) is located within Virginia's piedmont physiographic province and at an elevation of 340 m. The average annual precipitation is 131 cm and the mean annual temperature is 14°C (the average January minimum is −1.4°C and the average July maximum is 29.2°C). During the Civil War, large sections of land used for tobacco production were abandoned (Tilly 1970) and these areas are now forested with chestnut oak (*Quercus prinus* L.), pitch pine (*Pinus rigida* Mill.), scarlet oak (*Quercus coccinea* Muenchh.), sourwood (*Oxydendrum arboreum* L.(D. C.)), Virginia pine (*Pinus virginiana* Mill.), and white oak. Although most of the trees at the RHRC are second growth, several older white oaks were located at the base of a small slope around a spring that was formerly the site of a post office.

METHODS

Dendrochronology Methods

A chainsaw was used to cut disks from 13 logs in the front and rear walls of the cabin. One face of all disks was cut a second time with a band saw to provide a level surface for sanding. The disks were sanded with coarse sand paper using a belt sander and then a random orbital sander was used to sand the disks with progressively finer grits until the individual cell structures could be easily seen under a microscope. The ring widths of the sanded disks were measured to the nearest 0.002 mm using the Unislide "TA" Tree Ring Measurement System (Velmex Inc, Bloomfield, New York). After measurement, the raw ring widths were crossdated to create a floating chronology using the COFECHA program available in the Dendrochronology Program Library (DPL) (ftp://ftp.cricyt.edu.ar/users/dendro/). We made skeleton plots of the cabin disks to assist with interpretation of the COFECHA results (Stokes and Smiley 1968). Several of the cabin disks had been severely damaged by insects that had created burrows in the outer few centimeters of the log. In some instances, the burrows were so damaging to the structure of the wood that it was impossible to follow consecutive rings in the outer few centimeters of the log. With these logs, we only identified rings when we were able to clearly distinguish consecutive rings. Therefore, outermost ring dates of these logs underestimate the date of cutting.

In March 2001, 20 white oak trees were cored from a stand near the original Abraham Reynolds' log cabin site. Two cores were taken per tree at 0.3 m above ground and at 180° angles from each other. All trees were cored perpendicular to the slope to avoid sampling reaction wood (Fritts 1976). In order to increase the length of the white oak chronology only dominant and co-dominant white oaks were sampled. All tree cores were air dried and glued to wooden core mounts. The cores were hand-sanded with progressively finer grits of sandpaper until the cellular structure of the wood could be seen under a microscope (Phipps 1985). All cores were visually crossdated using narrow indicator rings as reference points (Yamaguchi 1991). The tree cores were then measured to the nearest 0.002 mm using the Unislide "TA" Tree Ring Measurement System. After measurement, the raw ring widths were crossdated a second time with the COFECHA program.

Dating the Floating Chronology

The plaque on the cabin led us to believe that the outer rings on the logs should date to approximately 1814. However, the chronology we developed from white oak trees on the RHRC only dated back to 1821. Therefore, we initially dated the floating chronology using COFECHA with a crossdated white oak chronology from the Blue Ridge Parkway in south-central Virginia, developed by E. A. Cook, and available from the International Tree-Ring Data Bank (http://www.ngdc.noaa.gov/paleo/ftp-treering.html). After the outer rings on the cabin logs were dated to 1876 and 1875 with the Blue Ridge Parkway tree-ring chronology, we skeleton plotted the white oak cores from the RHRC and created a master chronology to independently verify the cabin dates with skeleton plots from the cabin disks. Additionally, we tried to verify the date of cabin construction by researching historical records at the Patrick County Court House in Stuart, Virginia, and by looking through the historical records available at the RHRC.

Master Chronology Development

After the dates of the log cabin were established, the raw ring widths of the disks and the cores were standardized. The growth patterns of the majority of trees did not fit an inverse-J shape; therefore, we detrended the raw ring widths of all cores and disks with a spline curve (50% of the frequency response for 30% of the length of the series) using the ARSTAN program available from the Dendrochronology Program Library. After detrending, all series were averaged to form a master chronology. The standard master chronology (based on the averaged, standardized series) had high autocorrelation; therefore, we opted to use the residual chronology (based on the average residuals from autoregressive modeling of the detrend-

Table 1. Chronology information from logs taken from a cabin at the Reynold's Forestry Research Center in Patrick County, Virginia. The series correlation comes from the COFECHA cross dating program and the master chronology was developed from live trees cored near the cabin site. Sound logs had no rot, fire damage, or beetle burrows; however, other logs were damaged in the outer portion of the log, which resulted in an underestimation of the harvest date.

Cabin Log	Inner Ring	Outer Measurable Ring	Autocorrelation	Series Correlation with Master Chronology	Condition of Log Surface
1	1756	1872	0.481	0.25	beetle burrows present
2	1769	1875	0.551	0.45	sound
3	1749	1876	0.519	0.40	sound
4	1740	1862	0.832	0.50	beetle burrows present
5	1738	1857	0.835	0.57	beetle burrows present
6	1742	1875	0.783	0.44	sound
7	1740	1862	0.522	0.52	beetle burrows present
8	1741	1842	0.830	0.31	fire damaged
9	1723	1875	0.827	0.18	sound
10	1720	1866	0.686	0.48	beetle burrows present
11	1781	1876	0.705	0.50	sound
12	1748	1869	0.760	0.55	beetle burrows present
13	1739	1871	0.747	0.40	beetle burrows present

ed raw ring widths) because the ARMA (autoregressive moving average) process removes the autocorrelation in the calculation of the residual chronology. The residual chronology removes most of the low-frequency information from the chronology, which would make it inappropriate for examining long-term climatic trends. However, because the residual chronology was being used to examine year-to-year climatic relationships, it was still an appropriate standardization method.

Dendroclimatic Analysis

Monthly precipitation and temperature data from a local weather station in Stuart, Virginia (10 km west of the study site) were acquired from the National Oceanic and Atmospheric Administration (http://www.ncdc.noaa.gov/ol/climate/climatedata.html). Temperature data were available from 1931 to 1999 and precipitation data were available from 1925 to 1999. Any missing climate data were supplemented with data from Martinsville, Virginia (the second closest weather station) or if Martinsville data were also missing, from Mount Airy, North Carolina (the third closest weather station). The monthly average temperature and total monthly precipitation data were correlated with the white oak residual chronology to identify significant ($p < 0.05$) relationships between radial growth and climate. We correlated both the current year's climate and the previous year's climate to the residual chronology to identify lagged growth responses to climate (Fritts 1976).

RESULTS AND DISCUSSION

Cabin Construction Date

The dendrochronology results identified harvest dates for the cabin logs of 1875 and 1876 rather than the 1814 date implied by the plaque on the cabin. A number of the logs have the outer measurable ring as a year earlier than 1875 or 1876 because insects and fire damaged the outer surface of the logs (Table 1). The five logs that were sound (*i.e.* had no evidence of decay) all dated to 1875 and 1876 indicating that the cutting period extended over two years. After establishing the date of the log cutting and subsequent cabin construction, we examined the county tax records, deed descriptions, and plat maps for historical documentation of the cabin. No specific mention of the structure existed. The lack of historical documentation on log cabins is typical for Virginia (M. J. Pulice, Virginia Department of Historic Resources, personal communication).

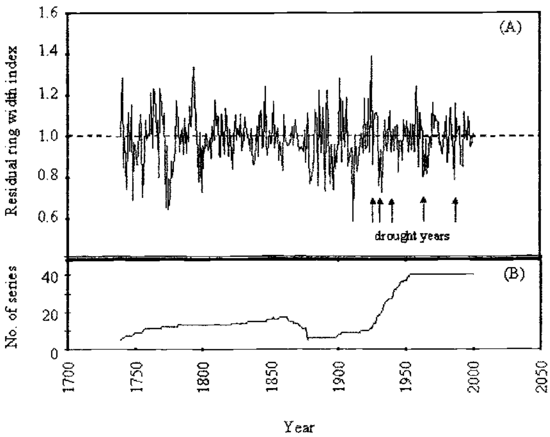

Figure 2. The 280-year master chronology is composed of disks from the cabin and cores from white oak trees. (A) The residual ring width index has a mean of 1 (indicated by the dashed line). Drought years (PDSI < -4.0 for at least one month) are indicated with an arrow. (B) The number of series in the master chronology varied as logs from the cabin overlapped with cores from the white oak trees.

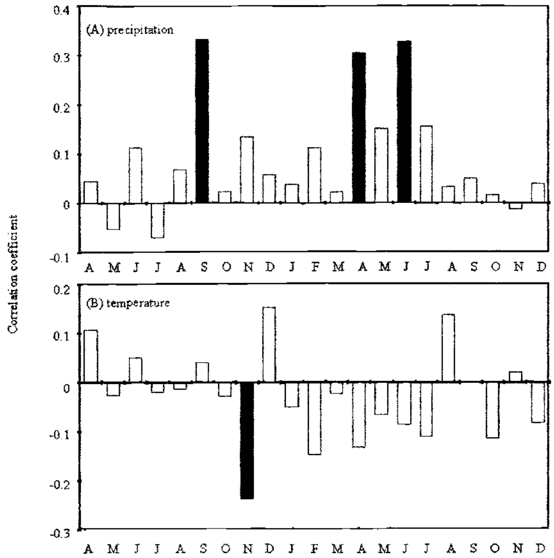

Figure 3. Correlation coefficients between the residual ring width index and (A) monthly average temperature and (B) total monthly precipitation. The dark bars indicate significant correlations ($P < 0.05$). The time span ranges from April of the previous growing season to December of the current growing season.

The construction date of the cabin suggests that the cabin may have originally served as tenant quarters. Following the Civil War, the agricultural south underwent a conversion from a slave workforce to a sharecropping workforce (Smith 1960; Michel 1991). The slave quarters at the RHRC were located near the 2-story brick house occupied by the Reynolds' family (Tilly 1970). However, tenant farmers typically were more widely dispersed over the former plantations because each family farmed their lease holding. The Reynolds Homestead Research Center had at least 10 family-sized buildings scattered throughout the former plantation (R. E. Kreh, superintendent of Reynolds Homestead Forest Resources Research Center, personal communication). From the dendrochronology research and the land-use history, we conclude that the cabin was constructed in 1876 from newly cut logs. The cabin most likely served as a residence for post-Civil War tenant farmers.

Development of a White Oak Master Chronology

By combining the dated cabin disks with the white oak cores (the chronology had an average series correlation of 0.45), we were able to construct a residual master chronology that extended from 1720 to 2000 (Figure 2). The residual chronology shows periods of higher and lower variation in the residual ring-width index compared to the variation seen over most of the chronology. These periods of high variability (1750 to 1800 and 1880 to 1930) reflect the low sample depth (Figure 2B) and the subsequent increase in non-climate signal noise (Fritts 1976) rather than actual climatic changes. The master chronology exhibits periods of below-average growth in the 1960s, 1930s, 1890s and 1770s. These periods of reduced growth have been identified in other white oak chronologies from the United States and appear to be related to individual drought events (Duvick and Blasing 1981; Cleaveland and Duvick 1992; Rubino and McCarthy 2000).

Dendroclimatology

The radial growth of white oak in south central Virginia is influenced more by precipitation than temperature (Figure 3). Precipitation from the previous September and the current April and June are both positively and significantly ($p < 0.05$) correlated to radial growth. The importance of sufficient moisture for white oak early in the growing season has not been identified at other sites (Rubino and McCarthy 2000). The significant correlation between precipitation in the prior September (Figure 3) may allow for later season storage and subsequent increased growth in the following year. The importance of precipitation late in the growing season of the previous year has been identified for white oak from Ohio (Rubino and McCarthy 2000). The stronger influence of precipitation in white oak radial growth indicates that this species may be more suitable for historical reconstruction of precipitation patterns rather than temperature patterns. This may be a site-specific limitation of white oak; however, the species has been employed more frequently to reconstruct precipitation and drought indices (Duvick and Blasing 1981; Cleaveland and Duvick 1992). The only significant relationship ($p < 0.05$) between radial growth and temperature was a negative correlation in the previous November (Figure 3). This may be a spurious correlation or it may be that warmer temperatures in November could result in higher maintenance respiration expenditures during the fall and a subsequent reduced growth in the following year (Kozlowski and Pallardy 1997).

CONCLUSIONS

This study was able to successfully date the timbers from the cabin located on the RHRC in south-central Virginia. The cabin was probably constructed in 1876 from newly harvested logs rather than from logs used to construct the Abraham Reynolds' cabin in 1814. We were able to combine the cabin data with data from live white oaks to create a master chronology, extending from 1720 to 2000. Based on the master chronology and climate data, precipitation is the most important climatic factor determining radial growth in white oak in south-central Virginia.

ACKNOWLEDGMENTS

We would like to thank Lawton Grinter, Jean Lorber, Matt Neatrour, and Mike Spinney for assistance in the collection of the white oak cores and the cabin disks. We would like to thank Kimberly McGee and Connie Kreh for their assistance with researching the historical documents from Patrick County. We also owe thanks to Richard Kreh, the superintendent of the Reynolds Homestead and Forest Research Center, for allowing us to sample the cabin and for all of his assistance with the project.

REFERENCES CITED

Bednarz, Z., and J. Ptak
1990 The influence of temperature and precipitation on ring widths of oak (*Quercus robur* L.) in the Niepolomice forest near Cracow, Poland. *Tree-Ring Bulletin* 50:1–10.

Bonzani, R. M., R. C. Carlisle, and F. B. King
1991 Dendrochronology of the Pennsylvania Main Canal Lock Number Four, Pittsburgh. *North American Archaeologist* 12:61–73.

Cleaveland, M. K., and D. N. Duvick
1992 Iowa climate reconstructed from tree rings, 1640–1982. *Water Resources Research* 28:2607–2615.

D'Arrigo, R. D., D. K. Yamaguchi, G. C. Wiles, G. C. Jacoby, A. Osawa, and D. M. Lawrence
1997 A kashiwa oak (Quercus dentate) tree-ring width chronology from northern coastal Hokkaido, Japan. *Canadian Journal of Forest Research* 27:613–617.

Duvick, D. N., and T. J. Blasing
1981 A dendroclimatic reconstruction of annual precipitation amounts in Iowa since 1680. *Water Resources Research* 17:1183–1189.

Estes, E. T.
1970 Dendrochronology of black oak (*Quercus velutina* Lam.), white oak (*Quercus alba* L.) and shortleaf pine (*Pinus echinata* Mill.) in the central Mississipi valley. *Ecological Monographs* 40:295–316.

Fritts, H. C.
1976 *Tree Rings and Climate.* Academic Press, London.

Jacobi, J. C., and F. H. Tainter
1988 Dendroclimatic examination of white oak along an environmental gradient in the Piedmont of South Carolina. *Castanea* 53:252–262.

Kozlowski, T. T., and S. G. Pallardy
1997 *Physiology of Woody Plants.* Academic Press, San Diego, California.

Krause, C.
1997 The use of dendrochronological material from buildings to get information about past spruce budworm outbreaks. *Canadian Journal of Forest Research* 27: 69–75.

LeBlanc, D. C.
1993 Temporal and spatial variation of oak growth—climate relationships along a pollution gradient in the

midwestern United States. *Canadian Journal of Forest Research* 23:772–782.

Marsh, G. P.
1864 *Man and nature.* The Belknap Press of Harvard University Press, Cambridge, Massachusetts.

Michel, G. L.
1991 From slavery to freedom: Hickory Hill, 1850–80. In *The Edge of the South: Life in Nineteenth-Century Virginia,* edited by E. L. Ayers and J. C. Willis, pp. 107–133. University of Virginia Press, Charlottesville.

Nielson, E., G. Conley, and K. D. McLeod
1995 The use of tree-ring analysis to determine the construction date of historic buildings in southern Manitoba. *Manitoba Archaeological Journal* 5:46–59.

Patrick County Historical Society
1999 *History of Patrick County,* Virginia. Publisher??? Stuart, Virginia.

Perlin, J.
1989 *A forest journey: The role of wood in the development of civilization.* Harvard University Press, Cambridge, Massachusetts.

Phipps, R. L.
1985 Collecting, preparing, crossdating, and measuring tree increment cores. U.S. Geological Survey. Water-Resources Investigation Report 85–4148.

Robinson, W. J.
1985 A construction sequence for Hubbell trading post and residence. *The Kiva* 50:219–236.

Rogers, R.
1990 *Quercus alba* L. In *Silvics of North America,* edited by R. M. Burns and B. H. Honkala, pp. 605–613. USDA Forest Service. Agricultural Handbook 654.

Rubino, D. L., and B. C. McCarthy
2000 Dendroclimatological analysis of white oak (*Quercus alba* L., Fagaceae) from an old-growth forest of southeastern Ohio, USA. *Journal of the Torrey Botanical Society* 127:240–250.

Smith, J. D.
1960 Virginia during reconstruction, 1865–1870: a political, economic and social study. Unpublished Ph.D. thesis, University of Virginia, Charlottesville.

Stahle, D. W.
1979 Tree-ring dating of historic buildings in Arkansas. *Tree-Ring Bulletin* 39:1–25.

Stokes, M. A., and T. L. Smiley
1968 *An introduction to Tree-Ring Dating.* University of Chicago Press, Chicago. Reprinted 1996, The University of Arizona Press, Tucson.

Therrell, M. D.
2000 The historic and Paleoclimatic significance of log buildings in southcentral Texas. *Historical Archaeology* 34:25–37.

Tilly, N. M.
1970 *Reynolds Homestead 1814–1970.* Robert Kline and Company, Richmond, VA.

Whitney G.G.
1994 *From coastal wilderness to fruited plain: A history of environmental change in temperate North America from 1500 to the present.* Cambridge University Press, Cambridge.

Yamaguchi, D. K.
1991 A simple method for cross-dating increment cores from living trees. *Canadian Journal of Forest Research* 21:414–416.

Received 9 July 2001; accepted 18 February 2002.