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Dendrochronological dating of the Graves Mill grist mill, Madison County, Virginia, USA☆

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ABSTRACT

Historical dendroarchaeology uses annual tree-ring widths varied by climate to crossdate structures of potential historical significance. In the Southeastern U.S. Piedmont specifically, crossdating these structures can lead to a broader historical interpretation during and after the colonial era. Our study used historical dendroarchaeology to date the Graves Mill grist mill located in Madison County along the western edge of the Virginia Piedmont. The mill and mill site reflect a regional trend in eighteenth century land use as agriculture transitioned from tobacco to wheat production in response to demand from international markets, as well as the adverse impact of tobacco cultivation on piedmont soils. Mills in this region have also been subject to flooding events from storms, with events recorded in the colonial era to a recent record flood in 1995, as well as re-building with changes in mill technologies through time. In an effort to date this structure as part of its restoration, and to verify the repeatability of this dating, ring widths from six timbers from the upper stories were analyzed independently at tree-ring laboratories at the University of Tennessee, Knoxville and Rider University. Both laboratories identified an 1816 cutting date for these samples, supporting documentary evidence that the mill likely underwent modifications over time after it was initially constructed in the eighteenth century. The consistent crossdating of these samples highlights the usefulness of dendrochronology as a research tool in the Southeastern U.S. for interpreting historical structures and their surrounding historical context.

1. Introduction

Across the Southeastern United States, dendrochronology has become an important approach for interpreting the past construction of historic structures using cutting dates from wood (Grissino-Mayer, 2009). In the Piedmont province of the Southeastern U.S., the availability of soil moisture and solar radiation under a canopy strongly affects tree growth (Kozlowski, 1949; Druckenbrod et al., 2005). The variation in these two environmental factors largely controls the width of a tree ring for each year in a time series of tree growth (Cook, 1987). Subsequently, measuring the widths of tree rings from wood in historical structures enables crossdating of tree-ring width measurements against accurately dated reference chronologies, recognizing that these trees are responding to a common climate signal. Given adequate statistical confidence (usually $p < 0.0001$), crossdating these samples can determine the years associated with each ring. If bark or a waney edge (the smooth wood surface after removal of bark and phloem over time) is present on a sample, this allows determination of the year in which a tree was harvested for construction. Multiple samples from various locations within a structure more definitively establish the construction date of a historic structure. In addition to greater statistical replication, multiple samples provide more information on a structure's construction history as building materials can be re-used from older structures and parts of a structure may be built at different times. This approach has led to the dating of log structures across the southeast (e.g., Mann et al., 2009; Slayton et al., 2009; Schneider et al., 2015) as well as within the South-

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eastern Piedmont specifically (e.g., Bortolot et al., 2001; Wight and Grissino-Mayer, 2004; Henderson et al., 2009).

Towards the end of the eighteenth century, agricultural land use in piedmont Virginia transitioned from an economy based on tobacco to one based on wheat (Neiman, 2008). This transition was driven in part by the impact of tobacco production on soil fertility and erosion (Ambers et al., 2006; Nelson, 2008) and the increased demand internationally for wheat (Hunter, 2002). By 1790, wheat would supplant tobacco as the leading export of the United States (Gilbert, 1977 cited in Hunter, 2002). Grist mills ground wheat into flour typically for a toll and were an important asset for Virginia communities because they were an advancement over the previous hand-powered methods (Peterson, 1935). Grist mills became frequent across the Piedmont as well as elsewhere in eastern North America, serving as reminders of past land use and settlement patterns (Copenheaver et al., 2007), but leaving geomorphological and hydrological impacts in streams that continue to the present (Walter and Merritts, 2008).

The Graves Mill grist mill and associated buildings are cited as uncommon examples of remaining early construction in this region and also a place of historical social significance as a gathering point for the community as a voting precinct, in addition to other community functions through the twentieth century (National Register Information System No. 06000754). The mill is located along the Rapidan River (earlier known as the Stanton River) within the foothills of the Virginia piedmont adjacent to the Blue Ridge Mountains and is listed on the National Register of Historic Places. Photos of the structure ca. 1940 and prior to its recent renovation show a three-story structure (Fig. 1). Historical information on this grist mill has also been accessioned at the Library of Virginia (Collection No. 45458). The application for the National Register of Historic Places stated that the first mill on the site was constructed ca. 1745 and that Thomas Graves petitioned to build a mill on the Stanton River in 1797, likely building a five-story grist mill on the original foundation ca. 1798. A 1936 Works Progress Administration report recorded that the mill had been renovated from a five-story to a three-story structure in 1921, but that the grist mill had not been used to produce flour for 50 years at that time and that the wooden overshot was replaced about 45 years prior during its conversion to a corn mill (Tunison, 1936). A report by a millwright (Ogden, 2006) found that Graves Mill contains an English drive system on the first floor, likely installed in the mid-nineteenth century, but that the large-timber Hurst frame holding this drive system also showed evidence of an earlier Ellicott drive that could have been constructed as early as the late eighteenth century. Machine-stamped nails retrieved and inspected from the upper stories indicated a second period of construction, most likely in the early 1800s (Wells, 1998).

A historical and ongoing risk to grist mills was the threat of structural damage to the mill by floods, or freshets, as they were frequently termed in colonial Virginia. For example, in a letter to Thomas Jefferson on Oct. 4, 1795, George Washington also spoke of regional mill damage when referring to the recent weather of August and September:

> The Rains have been very general, and more abundant since the first of August than ever happened in a summer within the memory of man. Scarcely a mill dam, or bridge between this and Philada. was able to resist them; and some were carried away a second, and even a third time (Washington, 1795).

These particular events were also recorded by James Madison and his father at their Montpelier plantation further downstream along the Rapidan River. In their meteorological diaries, the August 24, 1795 entry recorded a "Great Fresh in the upper part of the Rappidann (Rapidan) & Robinson" and "thunder clouds & rain at night" (Madison, 1793–1796). Combined with the outbreak of war in Europe, the weather in the mid-Atlantic led to high prices for grain (Hunter, 2002) two years before Thomas Graves petitioned to build his mill, perhaps serving as his motivation for its construction.

As a motivation for this study, tree-ring dating of the Graves Mill grist mill would not only verify the age of this structure, but could also place it within this larger historical economic and environmental context. Additionally, this project provided an opportunity to verify cutting/construction dates obtained from dendrochronology by involving tree-ring scientists at two universities (The University of Tennessee, Knoxville and Rider University in Lawrenceville, New Jersey) who independently participated in crossdating these samples. Baillie (2014) discussed how crossdating should be repeatable between labs, but published comparisons have generally been limited to re-evaluations of previous results in this region (e.g., Henderson et al., 2009). Lastly, the acquisition of tree-ring samples from historical structures in turn strengthens the replication and past extent of reference chronologies in the Virginia piedmont.

2. Methods

Graves Mill is located in Madison County at 29 Graves Road, in the town of Graves Mill, Virginia (Fig. 2). The structure had been disassembled in preparation for restoration as some of the beams were failing structurally from insufficient maintenance. During a site visit by Dr. Druckenbrod and Mr. Doug Graves (a descendant of the family who originally built the mill), several oak beams were selected that featured bark or waney edges with a high number of rings for sampling. Mr. Graves cut cross-sections from seven of these beams. These samples (referred to as GRAVE-A through G) were shipped to the Laboratory of Tree-Ring Science (LTRS) at the University of Tennessee, Knoxville for initial processing and crossdating. Beams from the first floor, including those that supported the mill works, were not sampled because they were to be re-used in the restoration of the structure and did not have bark or waney edges.

Once at the LTRS, each section was sanded using progressively finer sandpaper beginning with ANSI 100-grit (125–149 μm) and ending with ANSI 400-grit (20.6–23.6 μm) (Orvis and Grissino-Mayer, 2002). Hand-finishing with ANSI 1200-grit (4.5–6.5 μm) was used to further polish the sections for visual acuity. We used a binocular stereozoom microscope at standard 10X magnification to initially mark all rings with standard dot notation (Stokes and Smiley 1996; Speer 2010) beginning with the first innermost complete ring labeled as ring "1." All rings were then measured to 0.001 mm accuracy using a Velmex measuring stage and digital display coupled with MEASURE J2X software.

Next, we used the computer program COFECHA to perform segmented time-series correlation analyses (Holmes, 1983; Grissino-Mayer, 2001) on the undated series to place each series in proper temporal alignment with all other series. Log transformations, spline-fitting, and autoregressive modeling were applied in the COFECHA software to remove low-frequency trends and highlight year-to-year variation (Grissino-Mayer, 2001). We analyzed 40-year segments lagged by 20 years to ensure that most if not all segments crossdated with the same calendar segment from the other series. In the Southeastern U.S., we use a minimum interseries correlation coefficient of 0.40 to indicate that a series has been crossdated correctly relative to other series.

Absolute dating was accomplished by crossdating the undated tree-ring series against a composite regional reference chronology created from five separate white oak tree-ring chronologies from Virginia and one white oak chronology from Kentucky, all extracted from the ITRDB (Grissino-Mayer and Fritts, 1997). In addition, these data sets were supplemented with a recently developed