DENDROCHRONOLOGICAL DATING OF WOOD FROM THE FOUNTAIN OF YOUTH PARK SITE (8SJ31), ST. AUGUSTINE, FLORIDA, U.S.A.

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ABSTRACT

The city of St. Augustine, Florida holds particular historical significance as the oldest continuously occupied European community in the continental United States. Settled in 1565, it holds great educational, historical, and anthropological interest for current researchers. Recent archaeological excavations produced two large (ca. 20 cm diameter) posts from the Fountain of Youth Park site. Our objective in this project was to use tree-ring dating to determine the outermost dates of the two posts. Sample 8SJ31-2741 was pine (likely longleaf pine) and contained tree rings that were successfully crossdated using the Lake Louise reference chronology from southern Georgia to AD 1620–1668. Sample 8SJ31-2766 was a bald cypress sample that we could not crossdate using a nearby reference chronology from the Altamaha River in southern Georgia. Based on the troublesome ring characteristics on this sample, dating of this sample is not currently possible.. This project demonstrates the feasibility of dating wood extracted from sites from the historic Spanish-era period in the southeastern U.S.

Keywords: dendrochronology, dendroarchaeology, tree rings, St. Augustine, Florida, construction history, Fountain of Youth

1. INTRODUCTION

The science of dendroarchaeology uses tree-ring dating techniques to determine when a tree was harvested to establish the year (or years) of construction for a structure that is composed of wood (Bannister 1962; Dean 1978). Using existing reference tree-ring chronologies developed in the Southeast, structures of historical significance can be accurately dated (Mann

2002; DeWeese Wight and Grissino-Mayer 2004; Slayton *et al*. 2009; Henderson *et al*. 2009; Lewis *et al*. 2009). These reference chronologies are housed in the International Tree-Ring Data Bank at the National Climatic Data Center in Asheville, North Carolina. In the southeastern U.S., dendroarchaeology has been most successful at determining the years of construction for historic period structures rather than prehistoric structures because often the latter do not have well preserved rings or the type of wood that is conducive to dating techniques (Grissino-Mayer and van de Gevel 2007). Recent advances, however, are providing evidence that prehistoric sites and structures can eventually be dated (Koerner *et al*. 2009), although considerably more laboratory effort is required when attempting to date floating tree-ring sequences that are sometimes many hundreds of years in length.

In general, the practice of dendroarchaeology in the southeastern U.S. has lagged behind other important practices because tree-ring dating has long been thought not to be possible in the humid southeast where decay rates are especially strong (Grissino-Mayer 2009). In addition, few laboratories have ever existed in the southeast capable of performing dendroarchaeological analyses. As recent as the early 1980s, researchers recognized that the potential existed for dating timbers from prehistoric and historic sites in the southeast, but this potential was never realized despite its promise (Stahle and Wolfman 1985). Dendroarchaeological studies conducted in the southeastern U.S., especially in the last 10 years, have accelerated because (1) a growing network of tree-ring sites provides reference chronologies for dating tree-ring sequences from historic structures, (2) historical agencies are becoming more aware of the possibility of successfully dating historic structures, and (3) a proliferation of laboratories in the Southeast provides guidance and analytical capabilities that greatly increase the probability of successfully dating timbers from historic structures. These recent studies have not always supported the reported construction date for a particular structure, even those dates reported in the National Park Service's National Register of Historic Places (Grissino-Mayer and van de Gevel 2007, 2009; Grissino-Mayer *et al*. 2009; Mann *et al*. 2009; Henderson *et al*. 2009). Nonetheless, these studies are proving valuable by providing a level of historical accuracy not previously achievable (Grissino-Mayer 2009).

2. SITE BACKGROUND

The city of St. Augustine was originally settled by Spanish explorer Pedro Menéndez de Avilés in 1565 in collaboration with Phillip II, the King of Spain. Menéndez was under strict orders by the crown to eliminate the French Huguenot outpost at Fort Caroline on the St. Johns River. The French Huguenots were a real threat to the Spanish empire in the Caribbean, South America, and Central America (Deagan 1985). Menéndez took the French outpost and ordered the survivors of Fort Caroline killed. With this victory, he established La Florida as a Spanish holding.

Menéndez believed that many rewards and riches would accumulate from the founding and governorship of La Florida; however, this was not the case due to the absence of precious metals and minerals (Lyon 1976; Deagan 1985). Another contributing factor was the lack of intensive agriculture by La Florida's native population which was of very low density and highly dispersed (Deagan 1985). In spite of La Florida's lack of wealth, "St. Augustine was supported for its strategic value in maintaining the defenses and economic functions of the Caribbean and New Spain colonies" (Deagan 1985). The Straits of Florida and the Bahama Canal could be protected from St. Augustine which insured safe passage of ships travelling from New Spain to Spain.

Another important purpose of the St. Augustine colony was the conversion of the Florida Indians to Catholicism. The establishment of the mission (Nombre de Dios) in 1565 was meant to aid in this conversion. The mission also served another purpose. It functioned as the mechanisms for the organization of tribute (Deagan 1985). Originally, Menéndez established a mandatory tribute from the Florida Indians and this continued until the early 18th Century. This tribute was usually paid in corn, animal skins, and labor and this resulted in the discontinuous presence in St. Augustine of non-local Indians (Deagan 1985).

In 1934, excavations began at the Fountain of Youth Park Site (8SJ31) in St. Augustine, Florida after a gardener planting orange trees unearthed human burials, as well as structural features that were later determined to be post molds. Later excavations in the 1950s at the mission settlement of Nombre de Dios in the Fountain of Youth Park Site unearthed additional possible structural features that included a well-defined linear trench. This trench was perhaps a narrow defensive ditch, known as Feature 85. Beginning in 1976 and lasting until the present, archaeological investigations continued at the Fountain of Youth Park Site conducted first by the Florida State University field school and then by the University of Florida field school. Dr. Kathleen Deagan directed the University of Florida fieldwork. Work within the park focused on the 16th Century Spanish occupation period. These excavations have unearthed thousands of artifacts, including Native American ceramics, tools, and weaponry and a vast assemblage of artifacts from the Menéndez Era settlement, including ceramics, tools, fasteners, military items and weaponry, household items, personal items, and clothing (Deagan 2009).

Only recently, however, has intact wood been excavated from the Fountain of Youth Park Site and preserved using well established conservation techniques such as the use of polyethylene glycol (PEG). PEG ensures that the waterlogged wood will remain structurally sound (Brunning 1995; Bleicher 2008). Two waterlogged posts were recently extracted from the site by the University of Florida field school assisted by the Florida Museum of Natural History, labeled 8SJ31-2741 and 8SJ31-2766. Both posts exhibited ends cut with a metal axe (Figure 1) although the cut end on 8SJ31-2766 appeared better preserved. Both posts were sent intact to Dr. Henri Grissino-Mayer, Director of the Laboratory of Tree-Ring Science at The University of Tennessee. The objectives of this research were to: (1) carefully evaluate both wood samples during the pre-processing stages and determine whether dendrochronological dating would be possible, and (2) if so, crossdate the ring patterns against previously established reference tree-ring chronologies in regional proximity to the Fountain of Youth Park Site. If crossdating is successful, the period of years represented by the dated rings would establish a *terminus post quem*, i.e. the earliest year in which the structure could have been built and subsequently occupied (Bauch and Eckstein 1970; Baillie 1995; Miles 1998).

3. METHODS

3.1 Laboratory Methods

We began processing the wood by first wrapping the samples in 2.5 inch strapping tape to ensure the stability of the fragile wood. We then carefully sawed a ca. 4 cm thick section from the cut end of each of the two posts using a band saw (Figure 2). We then fastened both cut sections onto a peg board table. We sanded each section with a Makita belt sander using progressively finer sandpaper, beginning with ISO P-80 grit (177–210 μm) and finishing with ISO P-400 grit (20.6–23.6 μm) (Orvis and Grissino-Mayer, 2002). To insure maximum visibility, we then hand sanded the finished surface on each with 800 grit (9.8–12.3 μm) finishing film. All steps of this wood preparation were digitally photo-documented.

3.2 Measurement

To begin the dating process, we used a stereozoom boom-arm microscope to identify three radial transects across the sanded surface of each section that contained the maximum number of rings. We carefully examined the entire outer edge of each section to search for possible bark or inner phloem that would provide cutting dates and therefore a possible year of construction. Each radial transect was marked with a black felt-tipped marker. We then began counting from the inner-most complete ring beginning with the relative year 1 and continued until the end of the transect was reached. Each 10th ring was marked with a single dot and the 50th ring with two dots (Speer 2010). We then scanned the surface of each section using an Epson 10000 XL scanner at 1200 dpi using WinDendro software, a tree-ring analysis system that operates off high-resolution scanned images of wood and tree rings (see e.g. Smith and Larocque 1998; Brelsford 2003). We then measured the widths of all identified tree rings to 0.001 mm precision (Tables 1A and 1B) once the WinDendro software automatically identified the tree-rings using its proprietary edge detection algorithm (Figures 3 and 4). If the software misidentified a ring boundary (which is common in scanner-based tree-ring technology), we manually corrected the misidentification using the true rings previously marked on the wood surface with the black marker. WinDendro saves all ring measurements in Tucson Decadal Format as required by international convention through the International Tree-Ring Data Bank.

3.3 Crossdating

We began the process of absolute dating of the tree rings from the two samples by first dating each measured series against the other measured series on that sample. This process ensured that all rings were properly identified to minimize potential misdating problems. We then crossdated the rings on each sample using skeleton plots, a graphical plotting technique that emphasizes only the narrower tree rings because it is the narrow rings that provide the high frequency information needed to insure recognizable patterns between a floating tree-ring series and an anchored tree-ring data set (Stokes and Smiley 1968; Swetnam *et al*. 1985; Schweingruber *et al*. 1990; Speer 2010).

The graphical crossdating results were confirmed using COFECHA software, a quality computer program that uses segmented time-series correlation techniques that tests possible temporal placements of a floating tree-ring measurement series against an anchored reference tree-ring chronology (Holmes 1983; Grissino-Mayer 2001). COFECHA first removes all low frequency growth trends, such as those caused by normal physiological aging and by local or stand-wide disturbances (such as wind throw). These low frequency growth trends tend to mask the high-frequency, year to year growth patterns caused by inter-annual fluctuations in climate that provide the common signal necessary for successful crossdating (Douglas 1941; Fritts 1976; Grissino-Mayer 2001). Once the low frequency trends were removed, COFECHA removed all autocorrelation that arises in tree rings caused by biological inertia, i.e. tree growth in any particular year is physiologically influenced by stored carbon reserves from the previous year (Fritts 1976; Speer 2010). These statistical processes result in a final tree-ring chronology called a RESIDUAL chronology that is most appropriate when dating a floating tree-ring series. Crossdating is verified when the correlation coefficient between the floating RESIDUAL chronology and the anchored reference tree-ring chronology is statistically significant (usually $p < 0.001$), and corroborates the temporal placement found in the graphical crossdating. Crossdating a floating series can be only accomplished when achieved by both graphical and statistical techniques (Grissino-Mayer 2001).

To accomplish absolute crossdating, we used two nearby reference tree-ring chronologies. The first chronology was developed from longleaf pine (*Pinus palustris* P. Miller) trees collected by Dr. Henri Grissino-Mayer at the Lake Louise Biological Station located 15 km south of Valdosta, Georgia, just north of the Georgia-Florida state line off Interstate 75. These samples were obtained primarily from stumps and other pieces of remnant wood found around the periphery of Lake Louise (Grissino-Mayer *et al*. 2010). This chronology extends from AD 1421 to 1999. The second reference chronology was developed by Dr. David W. Stahle of the University of Arkansas from bald cypress (*Taxodium distichum* (L.) Rich.) trees growing along the Altamaha River in southeastern Georgia, and was used to reconstruct spring precipitation from a network of bald cypress chronologies throughout the southeast (Stahle *et al*. 1992). This data set was downloaded from the International Tree-Ring Data Bank located in Asheville, North Carolina, which had been archived as data set GA002.CRN.

4. RESULTS

After cutting sections from the post, we found that sample 8SJ31-2741 was a pine while sample 8SJ31-2766 represented some other conifer. The first sample likely represents a longleaf pine based on the presence of indistinct rings that surround the pith, indicative of the ability of longleaf pine to exist in a grass stage for up to six years. The second sample was more troublesome to identify. We consulted Hoadley (1990) to identify potential conifer species based on physical ring properties seen on the wood. The thin latewood preceded by a gradual transition from earlywood to latewood, in addition to the lack of resin ducts, conclusively identified this sample as a bald cypress. This discovery was fortuitous because the reference tree-ring chronologies we used were derived from these two species.

In our first analysis using COFECHA, we attempted to crossdate the pine sample measurements against the Lake Louise STANDARD tree-ring chronology using 35-year long segments lagged by 5 years. This analysis returned a dating adjustment of +1619 to be added to the first ring on the majority of all segments tested for the three segments (Table 2). In the second analysis, we attempted to crossdate the three pine measurement series as complete series against the Lake Louise reference chronology. This analysis also returned a systematic dating adjustment of +1619 to all measurements in the three series. The correlation for series 8SJ31-2741A was 0.49, statistically significant at the 0.001 level. The correlations for series 8SJ31-2741B and C were 0.48 and 0.53, respectively, both statistically significant at the 0.001 level (Table 3). The third analysis tested a floating chronology created from the three pine measurement series against the Lake Louise anchored chronology. This analysis returned a dating adjustment of +1619 with a correlation of 0.53, which is statistically significant at the

0.001 level (Table 4). All three analyses anchor the tree rings for pine sample 8SJ31-2741 from AD 1620 to 1668.

Unfortunately, our attempts to date the two bald cypress measurement series from sample 8SJ31-2766 against the Altamaha River reference chronology were unsuccessful. None of the shorter segments tested from the 69-year long series correlated significantly. We observed that the rings on the bald cypress sample displayed double bands of latewood that often wedged into a single band of latewood. The property meant that the ring widths would not be concentric around the entire circumference of the sample in that particular year. This necessary property, called circuit uniformity, is a necessary prerequisite for successful crossdating (Fritts 1976; Speer 2010). The lack of circuit uniformity means that the ring widths vary even between nearby radii on the cross-section. We observed no statistically significant correlation between the two measurement series from the bald cypress cross-section. We conclude that the potential of dendrochronological dating this bald cypress post from the Fountain of Youth Park archaeological site is minimal.

Because we were provided no information on the archaeological context from which these two samples were derived, we cannot evaluate whether the outermost date for sample 8SJ31-2741 is archaeologically meaningful. Samples sent to the Laboratory of Tree-Ring Science are sent "blind," meaning that the agency in charge of the excavation provides little to no information on the archaeological context so as not to prejudice the determination of the tree-ring dates. In other words, if we knew the date of construction or occupation of a particular site, we could unintentionally look for possible tree-ring dating adjustments that support these dates, despite our best attempts at objectivity. However, the date we obtained for pine sample

8SJ31-2741 was derived with no prior knowledge on the construction date of this particular feature.

5. CONCLUSIONS

The dating of this one pine sample represents one of the first absolute dating of any timber extracted from a Spanish-era fort and settlement in the eastern United States. This successful dating demonstrates that dendrochronological dating of wood as early as the 17th Century from archaeological sites along the east coast is possible. We recommend that additional wood samples excavated from archaeological sites in the eastern U.S. that are well preserved and contain an adequate number of tree rings routinely be sent for dendrochronological dating at an established tree-ring laboratory in the eastern U.S.

6. ACKNOWLEDGEMENTS

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Research for publication, and will have as co-authors Niki Garland, Henri Grissino-Mayer, Grant Harley, Kathleen Deagan, and Gifford Waters.

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TABLE 1A. Measurements from the three measured series for pine sample 8SJ31-2741 in Tucson Decadal Format. Each value represents the ring width in 0.001 format (e.g. "3706" = 3.706 mm). Each row contains 10 annual measurement values. "–9999" is the end of series marker.

8SJ3127A	1	3706	2401	3179	3202	3099	3021	809	3228	2444	
8SJ3127A	10	4441	3406	3774	2460	1132	1302	1631	219	614	874
8SJ3127A	20	1575	1074	1105	1715	1215	1635	375	862	1241	1071
8SJ3127A	30	654	1125	1143	1665	2098	1627	1866	1515	1182	1032
8SJ3127A	40	511	560	1185	601	1049	556	934	910	-9999	
8SJ3127B	1	4136	3776	3549	3157	2529	2772	1300	2881	2607	
8SJ3127B	10	4011	2772	4642	2429	1016	1231	1544	200	510	969
8SJ3127B	20	1364	747	1049	1612	1560	897	355	1047	1473	1193
8SJ3127B	30	541	1313	1484	1666	2051	2003	1455	1682	1360	1105
8SJ3127B	40	421	818	1397	909	1280	630	1025	1011	1087	811
8SJ3127B	50	-9999									
8SJ3127C	1	3422	2216	2667	3073	2585	3898	1329	3801	3154	
8SJ3127C	10	6198	5939	4864	2703	1523	1466	2550	153	1195	1525
8SJ3127C	20	2540	1193	1570	1369	1825	1576	734	1303	1195	819
8SJ3127C	30	777	2269	1932	1645	2560	3079	3202	3323	1846	2101
8SJ3127C	40	817	1169	2004	1163	1155	439	-9999			

TABLE 1B. Measurements from the two measured series for cypress sample 8SJ31-2766 in Tucson Decadal Format. Each value represents the ring width in 0.001 format (e.g. "2754" = 2.754 mm). Each row contains 10 annual measurement values. "–9999" is the end of series marker.

8SJ3166A	1	2754	3347	2625	2722	2199	1390	1224	357	819	
8SJ3166A	10	880	1057	1160	1194	1430	1415	994	1170	1244	1646
8SJ3166A	20	2012	1765	1230	1862	2847	2204	1540	1168	2821	4178
8SJ3166A	30	1784	756	890	1675	2074	1202	1745	1616	904	1219
8SJ3166A	40	2061	1581	1615	1809	1095	1604	1137	886	1029	1838
8SJ3166A	50	977	1228	565	641	825	1113	1666	1239	954	1227
8SJ3166A	60	752	1186	666	875	676	672	832	1141	800	-9999
8SJ3166B	1	2670	3201	2008	2428	1188	1129	742	670	741	
8SJ3166B	10	618	904	907	1338	1216	1486	663	742	1627	1594
8SJ3166B	20	1124	1896	2003	1298	1748	1667	1998	2101	2155	980
8SJ3166B	30	1420	1500	1629	2244	1389	1124	1330	2963	2305	1621
8SJ3166B	40	1771	1710	1952	1424	1171	2067	1290	982	1076	948
8SJ3166B	50	1616	1339	1028	1307	1210	1110	1337	1030	1233	1014
8SJ3166B	60	887	656	732	995	627	759	519	581	535	894
8SJ3166B	70	-9999									

TABLE 2. COFECHA output showing the dating of pine sample 8SJ31-2741 against the Lake Louise master chronology in 35-year long segments. The dating adjustment "+1619" (in yellow) shows consistently for all segments on all three series.

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PART 8:  ADJUSTMENTS FOR UNDATED SERIES:                                                 18:19  Thu 01 Apr 2010  Page   0
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 Time span  1421  1799   379 years, best matches for  35-year segments lagged   5 years
 Listed in order from highest correlation

           Counted        Corr       Corr       Corr       Corr       Corr       Corr       Corr       Corr       Corr       Corr       Corr
 Series    Segment    Add  # 1  Add  # 2  Add  # 3  Add  # 4  Add  # 5  Add  # 6  Add  # 7  Add  # 8  Add  # 9  Add  #10  Add  #11
 -------- ---------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------
 8SJ3127A    1   35  1629 .58  1619 .48  1439 .43  1723 .42  1684 .41  1562 .38  1593 .38  1526 .37  1734 .36  1519 .36  1638 .35
 8SJ3127A    6   40  1629 .58  1619 .48  1562 .41  1684 .40  1723 .39  1744 .38  1593 .37  1638 .36  1451 .36  1570 .35  1492 .35
 8SJ3127A   11   45  1619 .54  1744 .52  1517 .44  1451 .43  1593 .40  1530 .38  1732 .36  1547 .36  1426 .36  1658 .35  1492 .30
 8SJ3127A   13   47  1619 .56  1744 .47  1517 .47  1658 .44  1593 .41  1451 .39  1507 .37  1686 .36  1700 .35  1732 .34  1426 .33
      4 segments  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
 Number of segments
       Add No R_av   Add No R_av   Add No R_av   Add No R_av   Add No R_av   Add No R_av   Add No R_av   Add No R_av
     +1593  4  .39 +1619  4  .51 +1451  3  .39 +1744  3  .46
 Chronological order
       Add No    Add No    Add No    Add No    Add No    Add No    Add No    Add No    Add No    Add No    Add No    Add No    Add No    Add No
     +1451  3 +1593  4 +1619  4 +1744  3
===================  ========  ========  ========  ========  ========  ========  ========  ========  ========  ========  ========
           Counted        Corr       Corr       Corr       Corr       Corr       Corr       Corr       Corr       Corr       Corr       Corr
 Series    Segment    Add  # 1  Add  # 2  Add  # 3  Add  # 4  Add  # 5  Add  # 6  Add  # 7  Add  # 8  Add  # 9  Add  #10  Add  #11
 -------- ---------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------
 8SJ3127B    1   35  1744 .50  1619 .49  1492 .47  1629 .43  1638 .43  1562 .43  1435 .37  1439 .36  1723 .36  1745 .36  1526 .36
 8SJ3127B    6   40  1619 .51  1492 .47  1570 .46  1629 .42  1562 .40  1451 .37  1745 .37  1744 .36  1593 .35  1596 .35  1529 .34
 8SJ3127B   11   45  1619 .54  1451 .45  1732 .38  1658 .37  1547 .37  1517 .37  1681 .36  1745 .35  1695 .34  1593 .34  1596 .33
 8SJ3127B   15   49  1619 .55  1681 .42  1686 .41  1658 .40  1732 .40  1596 .38  1507 .38  1696 .37  1745 .36  1593 .36  1517 .36
      4 segments  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
 Number of segments
       Add No R_av   Add No R_av   Add No R_av   Add No R_av   Add No R_av   Add No R_av   Add No R_av   Add No R_av
     +1619  4  .52 +1745  4  .36 +1593  3  .35 +1596  3  .35
 Chronological order
       Add No    Add No    Add No    Add No    Add No    Add No    Add No    Add No    Add No    Add No    Add No    Add No    Add No    Add No
     +1593  3 +1596  3 +1619  4 +1745  4
===================  ========  ========  ========  ========  ========  ========  ========  ========  ========  ========  ========
           Counted        Corr       Corr       Corr       Corr       Corr       Corr       Corr       Corr       Corr       Corr       Corr
 Series    Segment    Add  # 1  Add  # 2  Add  # 3  Add  # 4  Add  # 5  Add  # 6  Add  # 7  Add  # 8  Add  # 9  Add  #10  Add  #11
 -------- ---------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------
 8SJ3127C    1   35  1619 .54  1593 .52  1424 .48  1684 .44  1724 .44  1439 .41  1744 .40  1526 .40  1562 .39  1492 .39  1519 .37
 8SJ3127C    6   40  1619 .54  1593 .53  1562 .47  1424 .46  1492 .44  1684 .42  1448 .41  1744 .39  1724 .38  1682 .37  1642 .36
 8SJ3127C   11   45  1619 .57  1732 .49  1593 .46  1448 .38  1744 .38  1658 .38  1682 .38  1424 .33  1517 .33  1562 .32  1435 .32
      3 segments  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
 Number of segments
       Add No R_av   Add No R_av   Add No R_av   Add No R_av   Add No R_av   Add No R_av   Add No R_av   Add No R_av
     +1424  3  .42 +1562  3  .39 +1593  3  .50 +1619  3  .55 +1744  3  .39
 Chronological order
       Add No    Add No    Add No    Add No    Add No    Add No    Add No    Add No    Add No    Add No    Add No    Add No    Add No    Add No
     +1424  3 +1562  3 +1593  3 +1619  3 +1744  3
```

TABLE 3. COFECHA output showing the dating of pine sample 8SJ31-2741 against the Lake Louise master chronology using the entire length of each series rather than breaking the series into segments. Again, the dating adjustment "+1619" shows consistently for all three series.

```
PART 8:  ADJUSTMENTS FOR UNDATED SERIES:                                                                 11:41  Wed 07 Apr 2010  Page   0
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 Time span  1421  1799   379 years, best matches for  50-year segments lagged  25 years
 Listed in order from highest correlation

          Counted         Corr      Corr      Corr      Corr      Corr      Corr      Corr      Corr      Corr      Corr      Corr
 Series   Segment    Add   # 1  Add   # 2  Add   # 3  Add   # 4  Add   # 5  Add   # 6  Add   # 7  Add   # 8  Add   # 9  Add   #10  Add   #11
 -------- ---------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------
 8SJ3127A    1   47  1629 .56  1619 .49  1734 .34  1593 .33  1439 .32  1744 .32  1562 .32  1424 .32  1451 .32  1526 .32  1502 .29
===================  ========  ========  ========  ========  ========  ========  ========  ========  ========  ========  ========
          Counted         Corr      Corr      Corr      Corr      Corr      Corr      Corr      Corr      Corr      Corr      Corr
 Series   Segment    Add   # 1  Add   # 2  Add   # 3  Add   # 4  Add   # 5  Add   # 6  Add   # 7  Add   # 8  Add   # 9  Add   #10  Add   #11
 -------- ---------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------
 8SJ3127B    1   49  1619 .48  1596 .33  1686 .32  1745 .32  1696 .31  1451 .30  1574 .29  1638 .29  1629 .29  1526 .29  1570 .28
===================  ========  ========  ========  ========  ========  ========  ========  ========  ========  ========  ========
          Counted         Corr      Corr      Corr      Corr      Corr      Corr      Corr      Corr      Corr      Corr      Corr
 Series   Segment    Add   # 1  Add   # 2  Add   # 3  Add   # 4  Add   # 5  Add   # 6  Add   # 7  Add   # 8  Add   # 9  Add   #10  Add   #11
 -------- ---------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------  --------
 8SJ3127C    1   45  1619 .53  1593 .42  1424 .41  1562 .38  1682 .37  1724 .33  1684 .31  1744 .30  1526 .30  1548 .30  1463 .30
===================  ========  ========  ========  ========  ========  ========  ========  ========  ========  ========  ========
        3 undated series
```

TABLE 4. COFECHA output showing the dating of the RESIDUAL chronology created from pine sample 8SJ31-2741 against the Lake Louise RESIDUAL master chronology. Again, the dating adjustment "+1619" shows consistently indicating a form match.

```
PART 8:  ADJUSTMENTS FOR UNDATED SERIES:                                                                   11:50  Wed 07 Apr 2010  Page   0
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 Time span  1421  1999   579 years, best matches for  50-year segments lagged  25 years
 Listed in order from highest correlation

           Counted         Corr       Corr       Corr       Corr       Corr       Corr       Corr       Corr       Corr       Corr       Corr
 Series    Segment     Add  # 1   Add  # 2   Add  # 3   Add  # 4   Add  # 5   Add  # 6   Add  # 7   Add  # 8   Add  # 9   Add  #10   Add  #11
 -------- ---------    --------   --------   --------   --------   --------   --------   --------   --------   --------   --------   --------
 TEST        1   49    1619 .53   1593 .40   1682 .35   1696 .34   1836 .34   1858 .34   1526 .33   1451 .32   1517 .32   1846 .31   1925 .30
===================    ========   ========   ========   ========   ========   ========   ========   ========   ========   ========   ========
        1 undated series
```

Figure 1. Bald cypress sample 8SJ31-2766 showing the original axe cut end.

Figure 2. Pine sample 8SJ31-2741 after being sawn to reveal the interior ring structure.

Figure 3. Operating WinDendro to measure the ring widths of pine sample 8SJ31-2741 in the Laboratory of Tree-Ring Science.

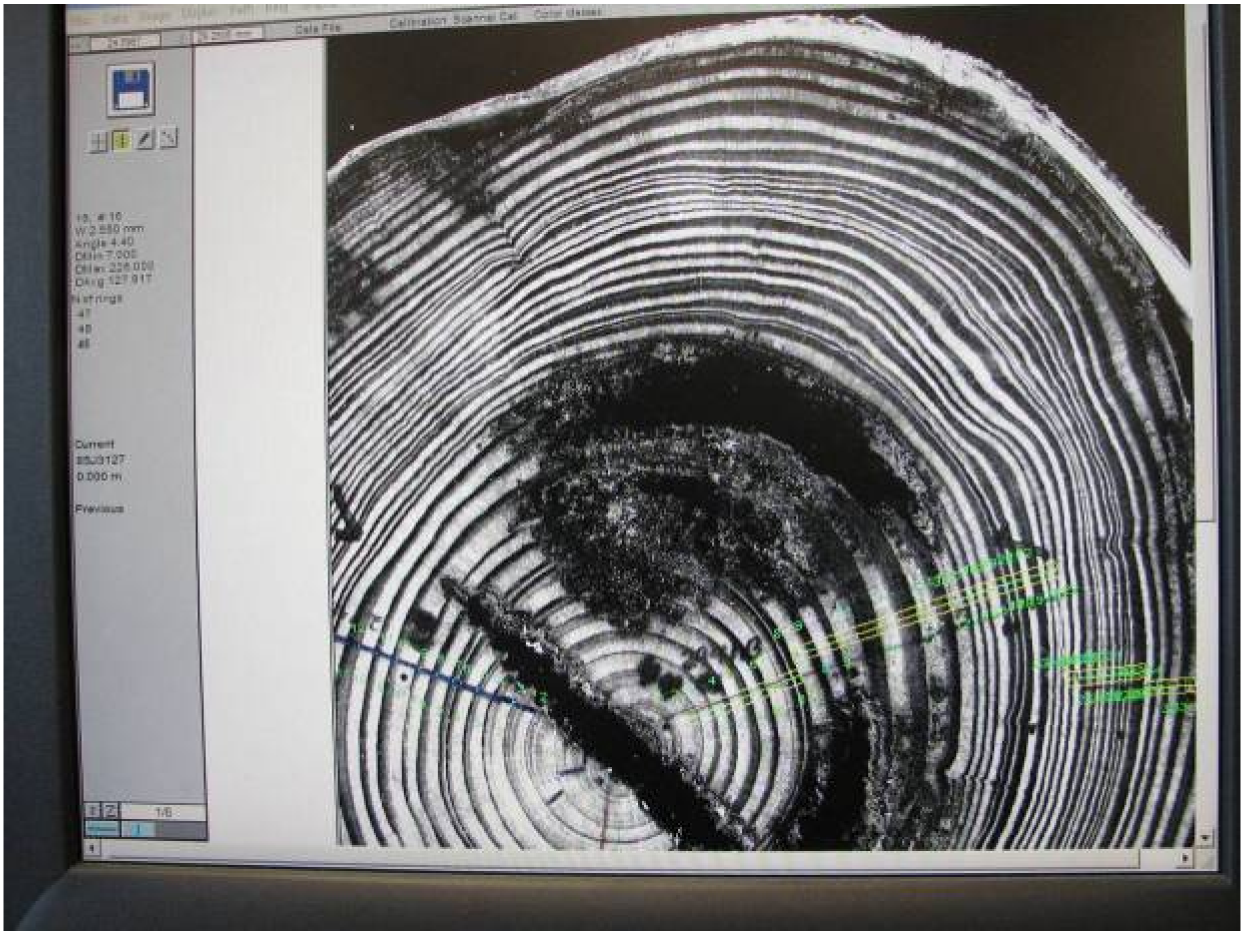

Figure 4. The WinDendro software automatically detects ring boundaries from pith to outer most tree ring.

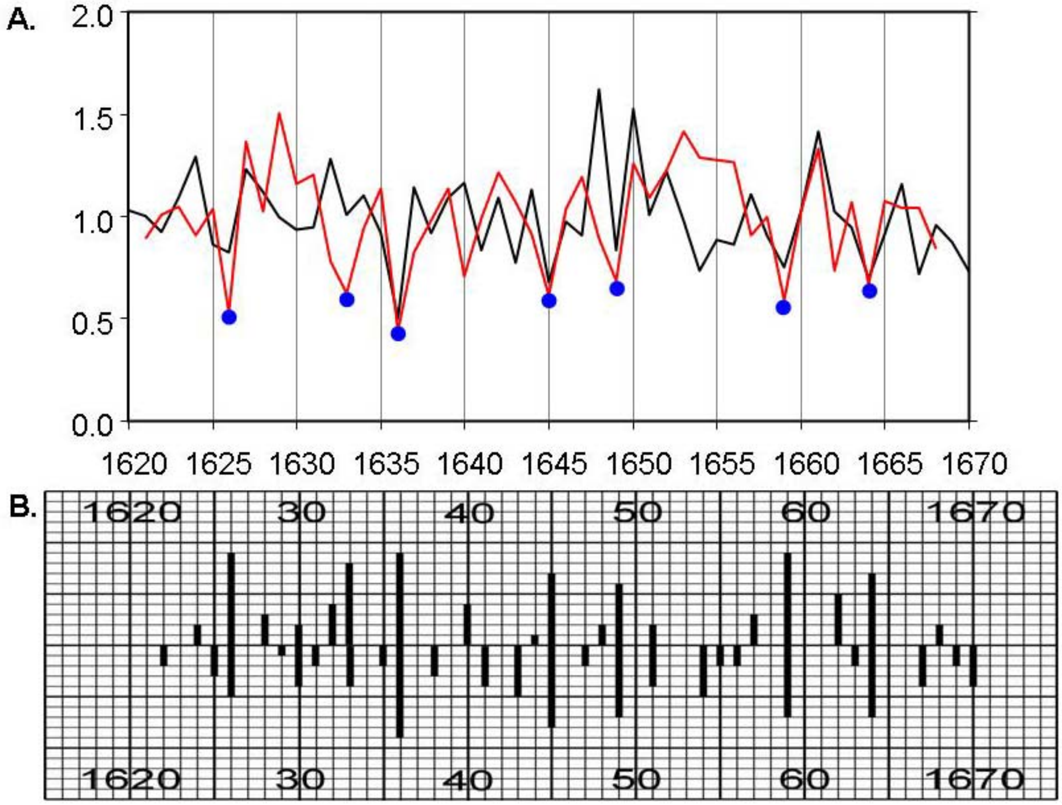

Figure 5. A. Scatter plots comparing the Lake Louise RESIDUAL chronology (black) with the RESIDUAL chronology from sample 8Sj31-2741 ($r = 0.53$, $n = 48$, $t = 4.24$, $p < 0.001$). Blue dots accentuate the unique pattern of very narrow rings common to both plots. B. Skeleton plots comparing the Lake Louise narrow rings (bottom) with those from sample 8SJ31-2741, highlighting the unique pattern of seven very narrow rings common to both series.