Tree-Ring Dating of Coffin WoodsExcavated from Shinnae-dong in Seoul, Korea*1

Kwang-Hee Lee*2, Byung-Hwa Son*3, and Won-Kyu Park*4†

ABSTRACT

This study aims to date wooden coffins excavated from graves in Shinnae-dong, Seoul, South Korea, using dendrochronology. The species of woods used to make the coffins were identified as *Pinus densiflora* S. et Z., one of the major conifers in Korea. Of 12 graves, 10 were successfully dated using various red-pine chronologies of South Korea. Due to the absence of the last-formed tree ring before felling, the number of sapwood rings, used to obtain likely cutting dates, had to be estimated. The *terminus post quem* for two coffins without plaster frames were AD 1548 and AD 1571, respectively. Eight coffins with plaster frames yielded estimated dates from AD 1664 to AD 1799. The tree-ring dates indicated that the coffins with plaster frames in Shinnae-dong were constructed approximately 100 years later than those without plaster frames.

Keywords: Dendrochronology, *Pinus densiflora*, Coffin, Growth ring, Absolute date, Plaster frame

1. INTRODUCTION

Dendrochronology uses the annual rings of several tree species to date historical and archaeological structures (Stokes and Smiley, 1968; Baillie, 1982). Some tree species in Korean forests are reported to be several centuries old, and thus provide a unique opportunity to develop long tree-ring chronologies (Park *et al.*, 2001). Among them, the wood of *Pinus densiflora* S. et Z. was the most favored building material in Korea (Park and Lee, 2007). As of 2011, the *Pinus densiflora* S. et Z. chronologies from Korea extend to AD 1170 and have mainly been used for dating historic buildings and artifacts (Kim and Park, 2005; Park *et al.*, 2007 & Park *et al.*, 2010).

Recently, a number of coffins excavated from various archaeological sites were identified as being built from *Pinus densiflora* S. et Z. To date, a few cases of dendrochronological dating of wooden coffins (from the 17th and 18th centuries) in Korea have been reported (Park *et al.*, 2006a & b Park and Lee, 2009). Most of them came from graves that incorporated a plaster frame (usually, thicker than 10 cm) to protect...
the interment from robbery, attacks by devils, and physical damage from animals or tree roots.

Wood coffins kept in plaster-frame graves often preserve corpses well, and many mummies have been found under these conditions. Studies of mummies buried in plaster-frame graves have produced important information about the diseases and parasites afflicting ancient people (Shin et al., 2003; Seo et al., 2008). Additionally, the clothes of corpses in wood coffins kept in plaster-frame graves often remain intact, which is especially important given that one corpse may be wearing dozens of articles of clothing (Yim and Cho, 2004; Song, 2008). The precise dating of wood coffins is necessary for determining when those who were buried inside had lived.

Because plaster-frame graves contain few buried goods that can be used to assign dates, the archaeologists who study the graves often resort to tree-ring dating of the coffins.

The plaster-framed grave type seems to become popular in the 17\textsuperscript{th} century, in the middle of the Joseon Dynasty (AD 1392 – 1910) (Park, 2005). Few graves from before this time employed plaster frames. This study presents results from tree-ring dating of coffins, excavated from Shinnae-dong in Seoul by the Hangang Institute of Cultural Heritage. They were found in both graves with and without plaster frame. Hangang Institute of Cultural Heritage funded coffin sampling and dating to Tree-Ring Material Bank, Chungbuk National University. This research is the first tree-ring dating study of grave sites to include both plain-soil (\textit{i.e.}, without plaster frames) and plaster-frame graves.

2. MATERIALS and METHODS

Excavation by the Hangang Institute of Cultural Heritage of the Shinnae-dong site in Seoul uncovered the remains of 218 graves (Figs. 1 and 2; Hangang Institute of Cultural
Heritage, 2009). Seoul was the capital during the Joseon Dynasty, which reigned from AD 1392 to AD 1910. Of the graves recovered from this site, 125 employed plaster frames and 93 used plain-soil cover (Fig. 3). Only 12 graves yielded remains of wood coffins from which a total of 24 pieces of planks were collected (10 from graves with plaster frames, 2 from plain-soil graves). One of these graves (#2-2) contained two coffins, for a male and a female body (Fig. 4). All other graves contained a single coffin each.

Wood slabs (approximately 2 cm thick) were cut from the planks with a chainsaw and air-dried. After sanding their surfaces, tree-ring widths were measured to the nearest 0.01 mm using a LINTAB measuring system (Rinn, 1996). When distinguishable by color, the boundary between heartwood and sapwood was marked.

The TSAP program produced ring-width plots for each sample (Rinn, 1996). Visual comparison of these plots on a monitor permitted the crossdating. The dating quality was also evaluated using Student’s t and G values. The t value (a measure for the correlation between sample and master chronologies) was calculated after detrending the tree-ring sequences using 5-year moving averages (Baillie and Pilcher, 1973). The G value (Gleichläufigkeit; percentage of sign agreement) was obtained following Eckstein and Bauch (1969). More details about the statistics for tree-ring dating were described in Park and Lee (2009). Graphic comparison between ring-width plots from the wooden coffins and of master chronologies from South Korea were used to determine the final dating.

As a result of the decay of coffin woods, no complete set of sapwood rings could be found (there was no bark or cambial face to indicate the terminal growth ring). Therefore, the number of sapwood rings had to be statistically estimated to obtain the likely cutting dates (Baillie,
3. RESULTS and DISCUSSION

All wood samples were identified first as hard pines (*diploxylon*), as they possessed an abrupt transition from earlywood to latewood, vertical and horizontal resin ducts, and window-like cross-field pitting and dentate ray tracheids (Fig. 5). In Korea, there are two hard pines, *Pinus densiflora* S. et Z. and *Pinus thunbergii* Parl. It is difficult to separate these two species based on the wood anatomy (Lee, 1997 Eom, 1999). There is a minor difference between them the margins of the dentate thickenings in the ray tracheids of *P. densiflora* are double toothed, while those in *P. thunbergii* are single toothed (Dr. Mitsuo Suzuki, personal communication). The double-toothed margins found in the coffin wood indicate that they are *P. densiflora*.

*Pinus densiflora* covers a wide ecological spectrum, is native to Korea and Japan, and is found rarely in Manchuria (Lee, 1986; Vidakovic,
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Table 1. The t and G values between coffin samples and master chronology

<table>
<thead>
<tr>
<th>Coffin No.</th>
<th>Period (A.D.)</th>
<th>Over-lap year</th>
<th>G (%)</th>
<th>Average ring width (mm)</th>
<th>Coffin No.</th>
<th>Period (A.D.)</th>
<th>Over-lap year</th>
<th>G (%)</th>
<th>Average ring width (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-37</td>
<td>1461-1546</td>
<td>86</td>
<td>66**</td>
<td>5.2***</td>
<td>1-30</td>
<td>1547-1737</td>
<td>191</td>
<td>72***</td>
<td>7.2***</td>
</tr>
<tr>
<td>1-41</td>
<td>1481-1571</td>
<td>91</td>
<td>67***</td>
<td>6.4***</td>
<td>1-29</td>
<td>1591-1718</td>
<td>128</td>
<td>74***</td>
<td>8.4***</td>
</tr>
<tr>
<td>1-38</td>
<td>1538-1646</td>
<td>109</td>
<td>65**</td>
<td>7.2***</td>
<td>2-2</td>
<td>1595-1737</td>
<td>143</td>
<td>66***</td>
<td>5.1***</td>
</tr>
<tr>
<td>1-53</td>
<td>1573-1702</td>
<td>130</td>
<td>62**</td>
<td>5.6***</td>
<td>2-2</td>
<td>1589-1749</td>
<td>161</td>
<td>74***</td>
<td>8.4***</td>
</tr>
<tr>
<td>1-57</td>
<td>1605-1733</td>
<td>129</td>
<td>62**</td>
<td>5.1***</td>
<td>1-56</td>
<td>1669-1762</td>
<td>94</td>
<td>70***</td>
<td>9.3***</td>
</tr>
</tbody>
</table>

** and ***: significant at the 0.01 and 0.001 levels, respectively.

<table>
<thead>
<tr>
<th>Coffins number</th>
<th>Key code</th>
<th>innermost ring</th>
<th>outermost ring</th>
</tr>
</thead>
<tbody>
<tr>
<td># 1-37</td>
<td>SNCF019A</td>
<td>1461 (86)</td>
<td>1546</td>
</tr>
<tr>
<td># 1-41</td>
<td>SNCF018A</td>
<td>1481 (91)</td>
<td>1571</td>
</tr>
<tr>
<td># 1-38</td>
<td>SNCF003A</td>
<td>1538 (52)</td>
<td>1646</td>
</tr>
<tr>
<td># 1-53</td>
<td>SNCF004A</td>
<td>1573 ● (80)</td>
<td>1702</td>
</tr>
<tr>
<td># 1-57</td>
<td>SNCF026A</td>
<td>1605 (129)</td>
<td>1733</td>
</tr>
<tr>
<td># 1-30</td>
<td>SNCF001A</td>
<td>1547 (110)</td>
<td>1658</td>
</tr>
<tr>
<td># 1-29</td>
<td>SNCF023A</td>
<td>1595 (86)</td>
<td>1680</td>
</tr>
<tr>
<td># 1-29</td>
<td>SNCF022A</td>
<td>1622 (86)</td>
<td>1707</td>
</tr>
<tr>
<td># 1-29</td>
<td>SNCF020A</td>
<td>1625 (47)</td>
<td>1718</td>
</tr>
<tr>
<td># 2-2 Female</td>
<td>SNCF015A</td>
<td>1595 (98)</td>
<td>1692</td>
</tr>
<tr>
<td># 2-2 Female</td>
<td>SNCF014A</td>
<td>1629 ● (62)</td>
<td>1737</td>
</tr>
<tr>
<td># 2-2 Female</td>
<td>SNCF006A</td>
<td>1611 (74)</td>
<td>1684</td>
</tr>
<tr>
<td># 2-2 Male</td>
<td>SNCF010A</td>
<td>1591 (103)</td>
<td>1692</td>
</tr>
<tr>
<td># 2-2 Male</td>
<td>SNCF005A</td>
<td>1623 (100)</td>
<td>1722</td>
</tr>
<tr>
<td># 2-2 Male</td>
<td>SNCF007A</td>
<td>1589 ● (103)</td>
<td>1749</td>
</tr>
<tr>
<td># 1-56</td>
<td>SNCF025A</td>
<td>1669 ● (57)</td>
<td>1762</td>
</tr>
</tbody>
</table>

Fig. 6. Tree-ring dates of 10 coffins. Dots represent pith, numbers in parentheses represent the numbers of heartwood and sapwood rings, from left to right; in the box, sapwood is gray in color.

1991). This species occupies nearly 40% of the Korea Forests, covering about 65% of the total land area (Lee, 1986). Pinus thunbergii occurs in Japan as well as South Korea. It grows mainly in coastal regions (Lee, 1986 Vidakovic 1991). The wood quality of this species is sim-
Fig. 7. Number of sapwood rings of *Pinus densiflora* versus tree age: modified from Park and Lee (2009).

Fig. 8. Cutting years of 10 coffins. Graves #1-37 and #1-41 were made of plain soil, the rest had plaster frames. Numbers to the left and right of the solid box represent the dates of innermost and outmost rings, respectively. Dotted lines to the left and right of the solid-line box represent estimated pith and bark, respectively. Error bars denote cutting years with sapwood estimation. The years without sapwood estimation are *terminus post quem* dates for cutting.
The standard deviation is approximately 10 years regardless of tree age. Because of the age-dependence of the number of sapwood rings, the presence of the pith is crucial to properly estimate tree age. Unless the pith is present, the curvature of the innermost rings is used to estimate the number of rings missing to the pith. The wood of seven graves possessed distinct difference between heartwood and sapwood and therefore could be used to estimate cutting dates (Fig. 8).

To explain sapwood-ring estimation, grave #2-2 (male) is described as an example. One sample (SNCF007A), dated to AD 1589–1749, included 161 rings (103 heartwood and 58 sapwood rings Fig. 6). Because the sample had 103 heartwood rings, tree age was estimated to be 177 years based on the age vs. sapwood relationship (Fig. 7). Consequently, the total number of sapwood rings should have been 74, with 16 sapwood rings lost during milling. Accordingly, the cutting year of the SNCF007A (#2-2, male) sample was estimated to be AD 1765 ± 10 (Fig. 8).

The cutting years of another five coffins possessing heartwood/sapwood boundaries (#1-38, #1-53, #1-30, #2-2 female, and #1-56) were estimated to be 1664, 1723, 1748, 1755 and 1799, respectively, with margins of error of ± 10 years (Fig. 8). The outermost rings of the other three coffins (#1-37, #1-41, and #1-53), where the heartwood and sapwood boundary was unclear, were dated to 1546, 1571, and 1733, respectively. These dates represent only the *terminus post quem* for cutting. Deteriorated woods of these three coffins prevented from any judgments about sapwood appearance.

The results indicate that the eight coffins with plaster frames were made during the 1660s to the 1790s, assuming that the drying and storage periods of the lumber for the coffins were short. The drying periods are unknown, but we assume they would have been fairly short (perhaps less than 5~10 years) because evidence suggests that coffins were made only when a death was expected (Park, 2005). One way to clarify this in the future would be to obtain samples for dendrochronological dating from coffins with known burial dates, then measure the lag between estimated cutting dates and burial dates.

The cutting dates of the two coffins (#1-37 and #1-41) without plaster frames were estimated to be after 1546 and 1571, respectively, because the heartwood and sapwood boundary was unclear (Fig. 8). Even if we consider the wood lost during milling, these coffins were dated to the 16th or early 17th centuries. The coffins with plaster frames were dated to between mid-17th to late 18th centuries, that means approximately 100 years later than those without plaster frames in the Seoul region. It is possible that time, the raw material of plaster, might not have been widely available until the 17th century due to its cost. The technology of plaster manufacturing was also not well established until the middle of the Joseon Dynasty (Park, 2005).

The coffin woods from graves without plaster frames (#1-37 and #1-41) was thinner than those from graves with plaster frames. Fewer tree rings were found in the coffin wood of the former. Average ring widths were various (0.64 ~ 1.60 mm Table 1). However, no apparent difference in the average ring width of the coffin wood found in the two grave types has been observed. Wood processing techniques could not be fully examined due to heavily cracked surface of coffin wood. However, it was interesting that only the latest coffin (#1-56) used metal nails (16~18 cm long) to fasten the planks (Hangang Institute of Cultural Heritage, 2009). Other coffins employed dovetail joints and butterfly clamps, without using nails. A previous study (Park, 2005) insisted that metal
nails were used only during the early stage of plaster-framed graves. More careful studies on the fastening method would be necessary in the future. Our study also offered a precise date for the coffin (#1-57), in which more than 50 pieces of clothes with a mummy were found (Hangang Institute of Cultural Heritage, 2009).

4. CONCLUSIONS

We could date 10 coffins of 12 graves in Shinnae-dong, Seoul, South Korea using various red-pine chronologies of South Korea. This study dates wooden coffins excavated from graves in Shinnae-dong, Seoul, South Korea, using dendrochronology. The species of wood used to make the coffins was identified as Pinus densiflora S. et Z, one of the major conifers in Korea. Of 12 graves, 10 were successfully dated using various red-pine chronologies of South Korea. Due to the absence of the last-formed tree ring before felling, the number of sapwood rings, used to obtain likely cutting dates, had to be estimated. The terminus post quem for two coffins without plaster frames were AD 1548 and AD 1571, respectively. Eight coffins with plaster frames yielded estimated dates from AD 1664 to AD 1799. The tree-ring dates indicated that the coffins with plaster frames in Shinnae-dong were constructed approximately 100 years later than those without plaster frames.

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