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Dendrochronological Dating of Coffin Woods from Hoamdong, Chungju, Korea[1]

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ABSTRACT

The objective of this study was to date coffin woods of a grave of husband and wife, using the tree rings, which were excavated from Hoamdong, Chungju city in the central area of South Korea. The species of coffin woods was Japanese Red Pine (*Pinus densiflora* S. et Z.), one of the major conifers growing in Korea. The husband coffin was dated as A.D. 1628. Due to the absence of bark in the wife's coffin, the number of sapwood rings was estimated to obtain the cutting date. The cutting date of wife's one was estimated to be A.D. 1651±10. The Jeogori Jacket for women, which was found in the husband coffin, indicates that the husband died earlier than the wife, as the tree-ring dates suggested.

Key words: Dendrochronology, *Pinus densiflora*, coffin, growth ring, absolute date.

INTRODUCTION

Annual rings of many tree species can be used to date old buildings and archeological sites by using dendrochronological methods. In Korea, Japanese red pine (*Pinus densiflora* S. et Z.; also known as 'sonamu' in Korean) chronologies extend to A.D. 1200 and have been used for mainly dating historic buildings and furniture (Park et al. 2007a; Park et al. 2007b).

The coffin woods of Japanese red pines were recently excavated from various archaeological sites, and a few cases of dendrochronological dating on coffin woods (the 17^{th}-18^{th} centuries) have been reported (Park et al. 2006a, 2006b). Most coffins were obtained from the graves with plaster cover (usually, thicker than 20cm) which were used to protect wooden coffins from robbery as well as attacks from the devils and potential hazards such as animals and tree roots. Graves with plaster-covered coffins were known to be popular in the 17^{th} century, i.e., the middle of Chosun Dynasty (A.D. 1392-1910) of Korea (Park 2005). Here, we report the results of tree-ring dating of plaster-covered coffins which were excavated from a grave of husband and wife in Chungju, Korea.

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MATERIALS AND METHODS

During the period of excavation of the Hoamdong site in Chungju city, in the central area of South Korea, one grave was found by Chungju Museum in April 2003 (Fig. 1 and Fig. 2; Chungju Museum 2005). The grave housed both wife's and husband's coffins together. Each one possessed two coffins as there was a double (inner and outer) coffins as shown in Fig. 3. Samples from eleven panels, which were used to make the coffins, were collected for dating.

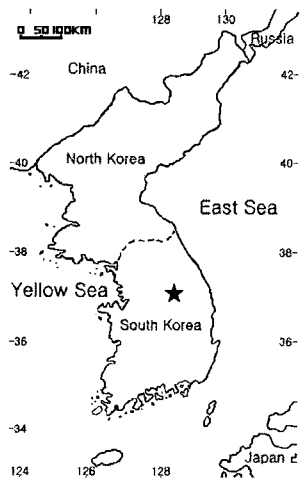


Fig.1. The location of study site (star mark: Chungju city).

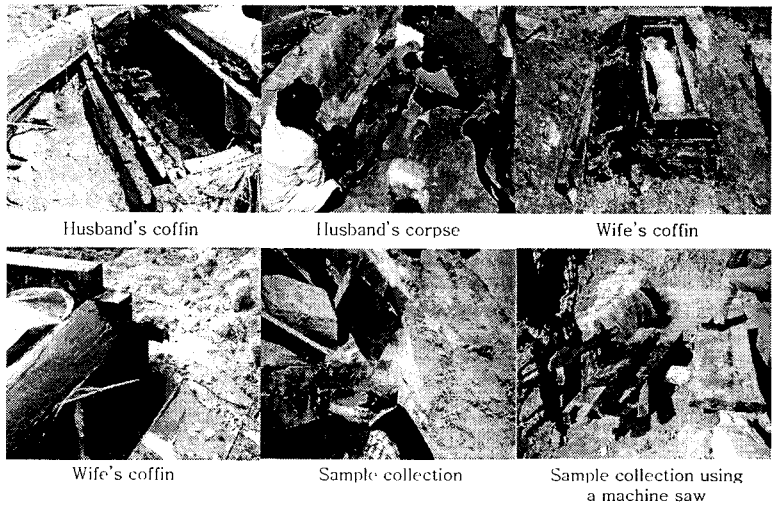


Fig.2. The wife's and husband's coffins of the Hoamdong grave, Chungju.

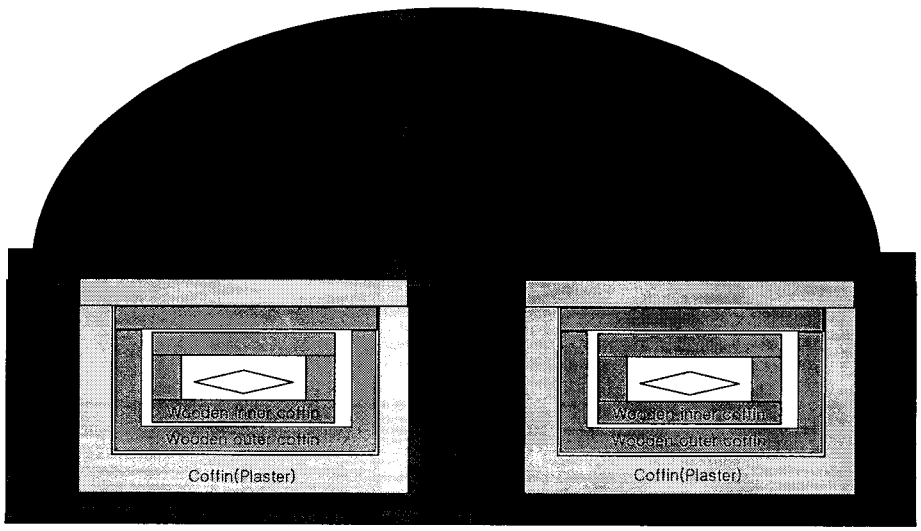
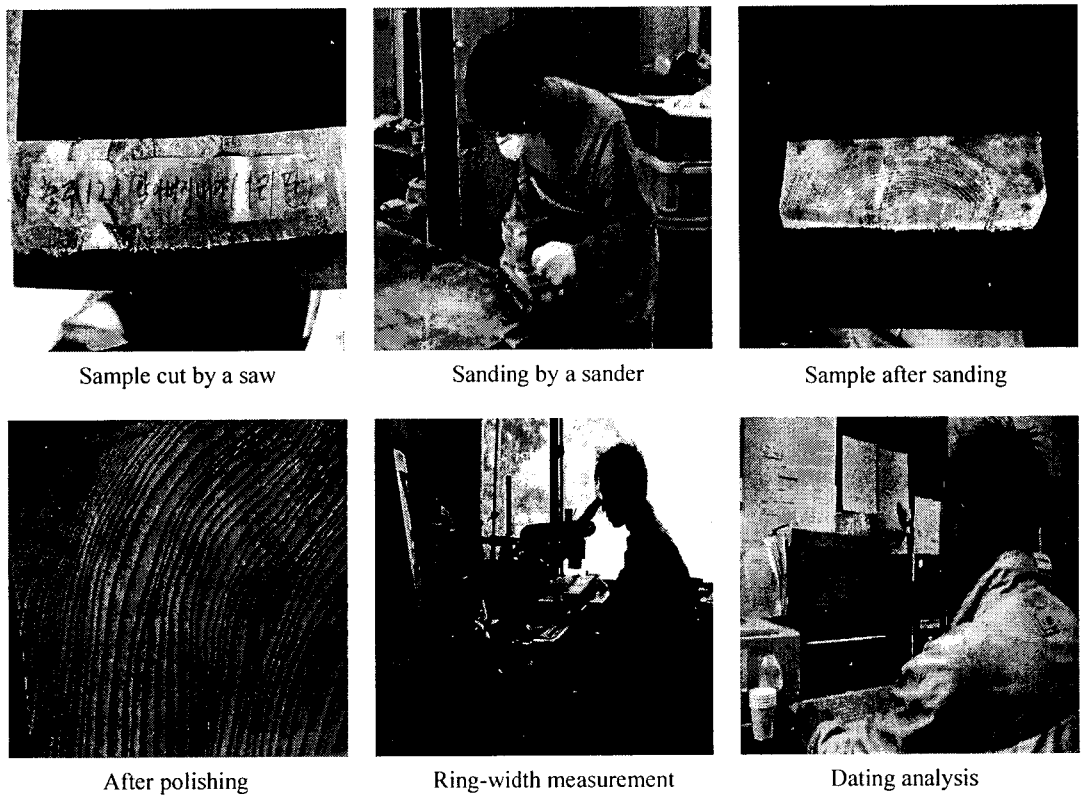


Fig.3. A diagram of the hoamdong grave with double-layered coffins (the diamond in the inner coffin represents the corpse).

Some portions of the sapwoods from the coffin woods were decayed out and mostly no complete sapwood rings were found. Wood slabs (about 2 cm in thickness) were cut with a chain saw and air-dried (Fig. 4). After sanding the surfaces of dried slabs, ring widths were measured to the nearest 0.01mm by using a measuring microscopic system. The boundary between heartwood and sapwood was marked when their colors were distinguishable.



Sample cut by a saw | Sanding by a sander | Sample after sanding

After polishing | Ring-width measurement | Dating analysis

Fig.4. Sample preparation and measurements.

Ring-width plots of individual samples were produced and these plots were used for visual comparison on a light table to crossdate each other by synchronizing the ring-width patterns (Fig. 5). The dating quality was also evaluated by statistical methods, t and G values. T value (a measure of correlation between sample and master chronologies) was calculated with correlation coefficient (r) after detrending the chronologies by 5-year moving averages (Baillie and Pilcher 1973) using the equation; $t=r\sqrt{(n-2)}/\sqrt{(1-r^2)}$, n=number of years. G values (Gleichlaufigkeit; sign agreement) were obtained from Eckstein and Bauch (1969). The final dating decision was performed using a graphic comparison between ring-width plots derived from the coffin woods and those of master chronologies from South Korea.

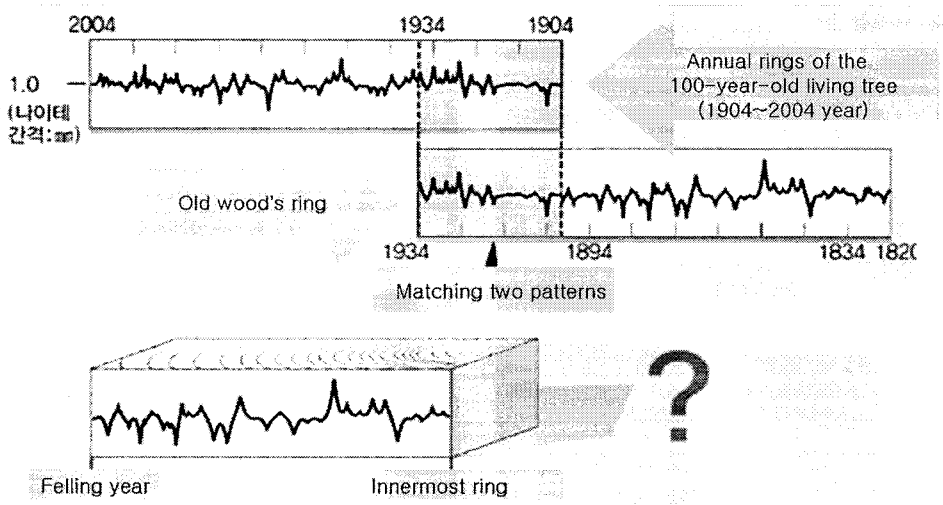


Fig.5. A schematic diagram showing the method of tree-ring dating.

RESULTS AND DISCUSSION

All coffin woods sampled were identified first as hard pines; they possessed abrupt earlywood/latewood transition, vertical and horizontal resin ducts, window like cross-field pit and the dentate thickening in ray tracheid (Fig. 6). In Korea, there are two hard pines, *Pinus densiflora* S. et Z. (Japanese red pine) and *Pinus thunbergii* Parl. (Japanese black pine). It is very difficult to distinguish between the two wood species. However, there is a minor difference; the margins of dentate thickening in *P. densiflora* are double toothed, but those in *P. thunbergii* are single toothed (Dr. Mitsuo Suzuki, personal communication). The double-toothed margin of coffin woods indicates that they are *P. densiflora* (Fig. 6). *P. densiflora* occurs naturally in Korea and Japan, although rarely in Manchuria, covering a wide ecological spectrum (Vidakovic 1991). *P. thunbergii* occurs in Japan as well as in Southern Korea. It grows mainly in coastal regions. The limited growing regions and rather short life span of *P. thunbergii* prevent the development of long tree-ring chronologies. The wood quality of these species is similar to that of *P. densiflora*.

<Cross section> <Radial section I > < Tangential section>

Fig.6. Micrographs of coffin woods (*Pinus densiflora* S. et Z.).

Table 1. The gross characteristics of the sampled panels

Sample name			Computer I.D.	Pith	Number of tree rings present	Number of sapwood rings	Bark	Tree age
Husband	Inner Coffin	Head panel	CJGF012A	N	93	•	N	124+
	Outer Coffin	Top panel	CJGF003A	N	150	25	N	169+
		Right-side panel	CJGF010A	N	74	•	N	84+
		Bottom panel	CJGF013A	N	162	88	Y	180
		Left-side panel	CJGF014A	N	73	•	N	83+
		Bottom panel	CJGF017A	N	134	41	N	146+
Wife	Inner Coffin	Head panel	CJGM006A	Y	136	•	N	136+
		End panel	CJGM016A	Y	117	•	N	121+
	Outer Coffin	Top panel	CJGM001A	N	114	•	N	139+
		Head panel upper	CJGM007A	N	127	31	N	135+
		Head Panel under	CJGM008A	N	102	•	N	112+

Most coffin woods included more than 120 growth rings, which enabled the tree-ring dating (Tab. 1). Only one sample (CJGF013) possessed bark. A 196 year-long site (composite) chronology was made from the samples. The site chronology was cross-dated well with the master chronology of *P. densiflora* in South Korea. It dated back to A.D. 1422-1628, i.e., the latest ring dated to A.D. 1628. The t and G values between the samples and master chronologies were 8.8 and 70%, respectively. Both statistics were significant at 1% level.

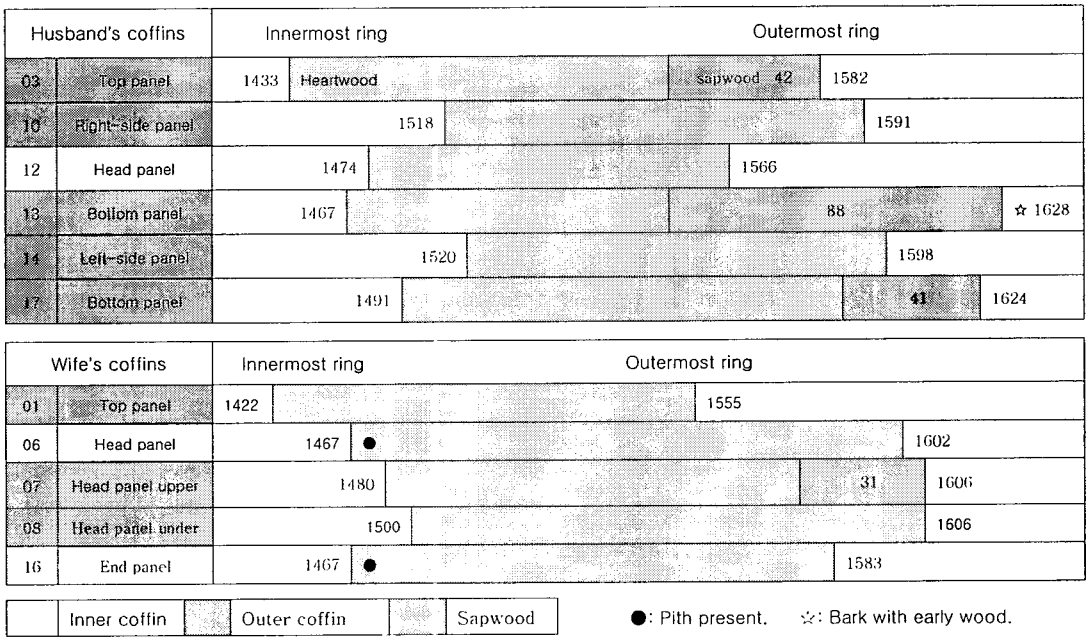


Fig.7. The results of tree-ring dating (the closed dots, star and shaded bars represent pith, bark and sapwood, respectively).

The tree-ring dates of the coffin samples from each grave are given in Fig. 7. The outmost ring of the sample, which possessed the bark (CJGF013: bottom panel of the husband's outer coffin), was dated as A.D. 1628 (Fig. 7). The outmost ring possessed only earlywood, so the cutting date of the woods for the husband's coffin was determined as the summer of A.D. 1628.

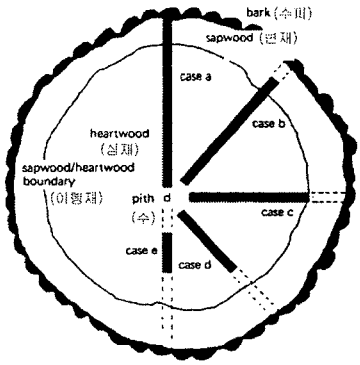


Fig.8. Estimation of the sapwood rings in wood panels (Schweingruber 1988).

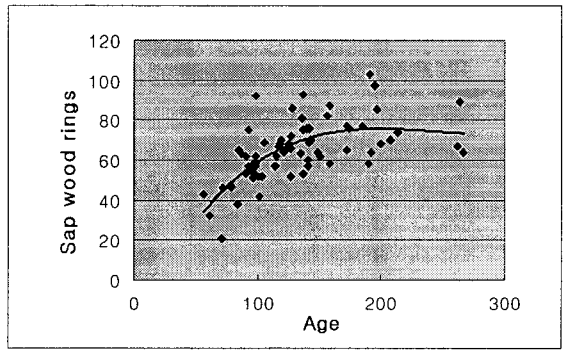


Fig.9. Number of sapwood rings in *Pinus densiflora* trees of South Korea graphed against its age (Park et al. 2007b).

All samples of wife's coffins lacked in the completion of sapwoods, i.e., had no bark or cambial surface. Therefore, sapwood estimation was used to obtain the cutting date (Fig. 8, case b). The separation of heartwood and sapwood in the samples was very difficult due to their fainted heartwood color in waterlogged coffin woods. One sample (sample #07: head panel-upper) of the wife's outer coffin had a distinct boundary. It could be used to determine the approximate cutting dates as the procedure is described below.

Critical step for determining a cutting date of the wood without bark was to estimate the sapwood portion, which was lost during the milling process of the panel. The number of sapwood rings in Japanese red pine grown in South Korea is age-dependent (Fig. 9; Park et al. 2007b). It increases with the increasing age of trees until about 170 years old and then becomes constant (75 sapwood rings). The standard deviations were about 10 years regardless of the age. The sample #07 from the wife's coffin, which rings dated to A.D. 1480-1606, included 127 rings (96 heartwood and 31 sapwood rings). Because of the age-dependent relationship in the sapwood rings, the presence of pith is crucial in the estimating process. Unfortunately, there was no pith in the sample #07 panel. Therefore, we first estimated the location of the pith from the curvature in the inner rings of the #07 panel. The distance from the pith location estimated to the innermost ring was 4cm. The mean of innermost 5 rings was 0.5cm, so 8 rings might be included between the pith and the innermost rings (Fig. 10). Then the total heartwood rings became 104 and the tree age from which the #7 panel was cut estimated at 180 years old from the age-sapwood curve (Fig. 9). Consequently, the total number of sapwood rings should have been 76 with 45 sapwood rings having been lost during the manufacturing of the coffin and/or by the decay. Finally, the estimated cutting year of the #07 sample was determined to be A.D. 1651±10 (Fig. 10).

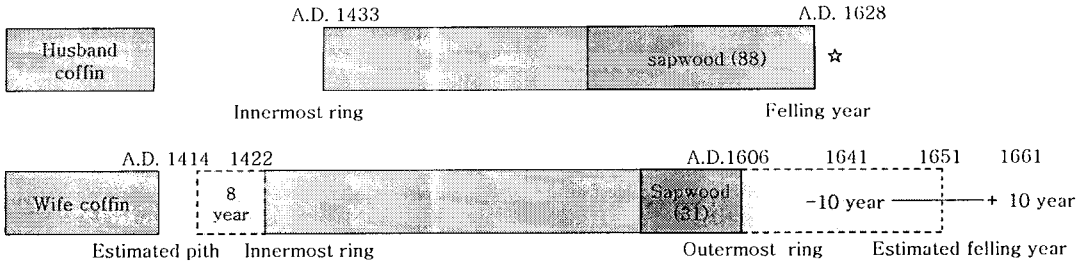


Fig.10. The summary of tree-ring dating for the husband's and wife's coffins.

The results indicated that the coffins of husband and wife were made in 1628 summer and 1651±10 respectively if the drying and storage periods for the panels or coffins were not so long. If some coffins with known dates are dated by the dendrochronological methods in the future, these periods would be clarified by measuring the lag between cutting dates and burial dates.

There were many clothes found in the Hoamdong coffins. The Jeogori Jacket for women, which was found in the husband coffin, indicates that the husband died earlier than wife, as the tree-ring dates suggested. The Jacket of wife might be inserted in the husband's coffin in order to make him happy in the heaven.

In conclusion, the results obtained from the present and previous studies (Park et al. 2006a, 2006b) confirmed that the graves with plaster-covered coffins became popular in the early 17th century.

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