Investigation of Wood Species and Conservation Status of Wooden Seated Amitabha Buddha Triad and Wooden Amitabha Buddha Altarpiece of Yongmunsa Temple, Yecheon, Korea (Treasure)

Jaewan CHOI[1] · Junghae PARK[2] · Soochul KIM[3,†]

ABSTRACT

The Wooden Seated Amitabha Buddha Triad and Altarpiece have not been the subjects of definitive species identification and scientific analysis. In this study, visual investigation, portable X-ray fluorescence (p-XRF), species identification, and lacquer layer observations were carried out to determine the original materials and conservation status. Cracks, exfoliation and discoloration were detected during the visual investigation. The p-XRF data indicated that chrome oxide green, malachite, gold, cadmium red, cinnabar, minium, hematite, lead white, ink stick (Carbon), and copper were used for pigments and the coronet accessory. *Tilia* spp., *Abies* spp., and *Pinus* spp. were identified from both the Buddha Triad and Altarpiece. Finally, lacquer layer analyses of the base layer, lacquer layer, orange pigment layer, and gold leaf layer observed modern synthetic pigments likely used in previous conservation. As the Korean Cultural Heritage Charter and the International Charter for the Conservation and Restoration of Monuments and Sites clearly state that objects of cultural heritage must be conserved using their original materials, future conservation of these objects should utilize the data obtained in this study to employ traditional materials. Furthermore, a deterioration map diagnosis can be applied together with the obtained analysis data to understand the conservation status of and inform an appropriate and authentic conservation treatment for the Buddha Triad and Altarpiece.

Keywords: species identification, wooden buddha statue, scientific analysis, conservation science

1. INTRODUCTION

Yongmunsa Temple was built by Master Duwun in 870 A.D. according to the Royal Edict of Labor Exemption Issued to Gimryongsa Temple. In 1166 A.D., King Uijong ordered to rebuild the temple. Jehadang Pavilion, Jeokmukdang Pavilion and Beomjongnu Pavilion were rebuilt in Joseon dynasty. In 1835 A.D., Yongmunsa Temple was completely incinerated and the monks rebuilt the temple in 1840 A.D. (Dooyoung Conservation of Cultural Heritage, 2019a).

Today, Daejangjeon Hall, Bogwangmyeongjeon Hall,

Uenghyanggak Pavilion, Jingyounggak Pavilion, Myeongbujeon Hall, Uengjinjeon Hall, Hoejeonmun Gate, and Beomjongnu Pavilion are the remaining Yongmunsa Temple buildings (Fig. 1). Designated cultural heritage in Yongmunsa Temple are Daejangjeon Hall and Rotating Sutra Cases (National Treasure), Royal Edict of Labor Exemption Issued to Yongmunsa Temple (Treasure) and Wooden Seated Amitabha Buddha Triad and Wooden Amitabha Buddha Altarpiece (Treasure) (Academy of Korean Studies, 1996).

Wooden Seated Amitabha Buddha Triad (Buddha Triad) and Wooden Amitabha Buddha Altarpiece (Buddha Altarpiece) are located in Daejangjeon Hall, Yongmunsa Temple, Yecheon, Korea (Fig. 2). According to excavated relics and related documents and Royal Edict of Labor Exemption Issued to Yongmunsa Temple, Buddha Triad and Altarpiece were made in 1684 A.D. Buddha Altarpiece is located behind the Buddha Triad and sculpture techniques of both wooden sculptures are similar to each other. Especially, formation and shape of main Buddha are very similar in view of history of Buddhism art and sculpture making techniques, so same sculptor is assumed to have made the two artifacts. According to excavated relics and related documents, monk Daneung and Takmil, the most prominent sculptors of late 17th century in Joseon, made Buddha Triad and Altarpiece in 1684 A.D.

Fig. 2. Wooden Seated Amitabha Buddha Triad and Wooden Amitabha Buddha Altarpiece of Yongmunsa Temple (Treasure).

In the proximity of Yongmunsa Temple is the Daeseungsa Temple in Mungyeong (Fig. 3). Also, another Wooden Amitabha Buddha Altarpiece made by monk Daneung and Takmil is in Daeseungsa Temple. Sculpture technique and style of both Buddha Altarpieces are very similar. However, in Yongmunsa Temple, Buddha Triad still remains in front of Buddha Altarpiece. Buddha Altarpiece is a large scale wooden sculpture, and only six of them remain in Korea. Buddha Altarpiece is highly significant when studying the style of wooden Buddha sculpture in late 17th century in Joseon dynasty. In Korea, cultural heritage were classified as national treasure and

Fig. 1. Scenery of Yongmunsa Temple.
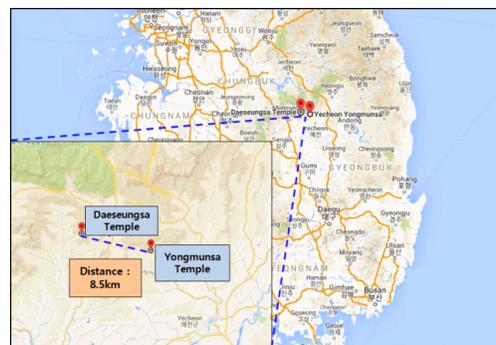
Fig. 3. Distance of Yongmunsa Temple from the Daeseungsa Temple (Google maps).

treasure (Han and Lee, 2021; Han *et al*., 2021). Because of its historic and academic values, it was designated as Treasure (Dooyoung Conservation of Cultural Heritage, 2019b).

Buddha Triad is located in front of Buddha Altarpiece, and the Amitabha Buddha is located in the center as the main Buddha. Avalokitesvara Bodhisattvas and Mahasthamaprapta Bodhisattvas are located in the side of Amitabha Buddha as attendant Buddha (Fig. 4). Also octagonal pedestal and lotus patterned pedestal remain and is expected to have been made with the Buddha Triad (Kwon, 1994).

The height and width of Buddha Altarpiece are 265.5 cm and 218 cm respectively. It is the only wooden sculptures with cloud light pattern in front of the main Buddha. Also accessory parts were attached in both side of altarpiece. This altarpiece was made by attaching twelve pieces of wooden blocks and Buddha sculpture. Amitabha Buddha was placed in the center, with the Avalokitesvara Bodhisattvas and Mahasthamaprapta Bodhisattvas placed to the sides (Fig. 5). Buddha Triad and Altarpiece were sculpted by wood. Korean lacquer, clay and ash were used for the base layer. After completing the base layer, lacquer was varnished more than 4 times and gold leaf layer was coated in the surface of Buddha sculpture. Lacquerware artifacts managed to avoid severe damage from external conditions. Also these wooden sculptures are kept in Daejangjeon Hall which protected them from external degradation factors. However, exfoliation of gold leaf layer, physical damage and polymer degradation due to temperature and humidity changes, and biological degradation from insect and

Fig. 5. Wooden Amitabha Buddha Altarpiece.

(a) (b) (c)

Fig. 4. Wooden Seated Amitabha Buddha Triad, (a) Mahasthamaprapta Bodhisattvas, (b) Amitabha Buddha, (c) Avalokitesvara Bodhisattvas.

fungi can be observed in both Buddha Triad and Altarpiece.

Research on the analysis of wooden Buddha statues in Korea has been actively conducted since the late 2000s. Wooden Vairocana Buddha in Haeinsa Temple was identified as juniper trees in through wood species identification (Park *et al.*, 2010). Buddha statues in the late Joseon Dynasty confirmed that ginko tree, pine tree, alder tree and willow tree were used through analysis (Park *et al.,* 2010). Wood species identification and scanning electron microscope – energy dispersive X-ray spectrometer (SEM-EDX) analysis were conducted on Seated Wooden Avalokitesvara Bodhisattva in Bogwangsa Temple, Andong, and confirmed that it were made of gold leaf and juniper tree (Lee, 2013). Amitabha Buddha Lotus Pedestal in the Geungnakjeon Hall of Ssang-bongsa Temple were identified as pine and ginko tree through wood species identification (Kim *et al*., 2012). Tree-ring dating was conducted on Buddha statues in Myeongbujeon Hall of Jeondeungsa Temple and analy-zed that age was 1634 to 1642, and the wood species were identified as ginkgo and pine tree (Park *et al.,* 2013). Clay Seated Vairocana Buddha Triad of Seonunsa Temple were identified as pine tree through wood species identification (Lee *et al.,* 2020).

Various studies have been conducted on the wood species and materials analysis of wooden Buddha statues, there was no ceratin scientific analysis on the Wooden Amitabha Buddha Triad and the Wooden Amitabha Buddha Altarpiece in Yongmunsa Temple, which en-compass wooden Buddha statues and wooden altarpiece (Hwang *et al*., 2020; Lee *et al*., 2021a, 2021b; Nam and Kim, 2021).

For these reason, scientific analysis was carried out for the precise diagnosis and to understand condition of Buddha Triad and Altarpiece. Visual inspection were conducted to construct deterioration map for artifacts. Also, portable X-ray fluorescence analysis (p-XRF), wood species identification and lacquer layer analysis

were carried out to figure out the original material and characteristic of wooden sculptures. These scientific analysis results and database could be applied for authentic conservation and restoration studies.

2. MATERIALS and METHODS

2.1. Subject

2.1.1. Wooden seated Amitabha Buddha Triad

Amitabha Buddha is located in center as the main Buddha. Avalokitesvara Bodhisattvas and Mahasthamaprapta Bodhisattvas are located in the side of Amitabha Buddha as attendant Buddha. The height of Buddha Triad are approximately 90 cm. Buddha Triad were made of wooden statue with lacquer, clay, ash and gold leaf. Scientific analysis were conducted to figure out the making technique.

2.1.2. Wooden Amitabha Buddha Altarpiece

Buddha Altarpiece is the only wooden sculpture with a cloud light pattern in front of the main Buddha. Also, accessory parts were attached in both sides of altarpiece. It was made by attaching twelve pieces of wooden blocks and Buddha sculptures. Amitabha Buddha was located in the center, with the Avalokitesvara Bodhisattvas and Mahasthamaprapta Bodhisattvas placed to the sides. Buddha Altarpiece were sculpted by wood and lacquer, clay, ash, gold leaf were used. The height and width are 265.5 cm and 218 cm respectively. Scientific analyses were conducted to figure out the making technique.

2.2. Method

2.2.1. Visual inspection

Deterioration map of Buddha Triad and Altarpiece were made by visual inspection (National Research Institute of Cultural Heritage, 2010). Deterioration con-ditions were classified as wood and gold leaf layer crack,

exfoliation, pigments stain, orange varnish, and avian excreta.

2.2.2. Surface pigment and accessory analysis

p-XRF was used to analyze pigment, material and restoration parts of Buddha Triad and Altarpiece. p-XRF irradiates the X-ray on the sample, exciting it to exhibit fluorescence, from which quantitative component analysis can be carried out. Since irradiated X-ray hits the surface of object, the atom is excited and discharges distinct X-ray beams. With this mechanism, component analysis is possible (National Research Institute of Cultural Heritage, 2018; Skoog *et al*., 2008). Before p-XRF analysis, calibration were performed using calibration check coin. p-XRF (Delta, Innov-X system, USA) data were collected in 10–40 kV of voltage and 10–50 μA of current condition. Analysis was carried out with soil and alloy mode of 15 seconds for each beam, total 30 seconds.

2.2.3. Identification of wood species

Identification of wood species is carried out to identify wood species of Buddha Triad and Altarpiece. Wood samples were carefully taken from inconspicuous area of sculptures.

Identification of wood species is carried out by creating slices of samples of 20–30 μm width with a razor blade (ST-300, Dorco, Seoul, Korea) and microtome blade (YL-MBA35, YLS, Guri, Korea) for the cross, radial and tangential sections. The created slices are dyed in safranin (1%, aqueous solution) for 2 minutes and washed thoroughly before being placed on the slide glass. To complete the preparat, glycerine (50%, aqueous solution.) is used to mount the sample with cover glass and slide glass. Optical microscope (Eclipse Lv 100, Nikon, Tokyo, Japan) is used to identify the anatomical characteristics of wood species. The wood species are determined according to the standards set by Korean wood anatomy references and International Association

of Wood Anatomists (IAWA): List of Microscopic Features for Identification (Kim and Choi, 2016; Kim, *et al.*, 2016b; Kwon *et al.*, 2020; Lee, 1997a, 1997b, 1997c, 2003; National Folk Museum of Korea, 2004; National Research Institute of Cultural Heritage, 2015, 2016a; Park, 2006). Final confirmations are made by comparing with the samples from Conservation Laboratory for the Wooden Cultural Heritage, Korea.

2.2.4. Lacquer layer analysis

For the layer observation, lacquer layer analysis was carried out to find out the lacquer technique of Buddha Triad and Altarpiece. In disassemble process of sculpture, lacquer layer analysis sample were collected.

Cross section direction was confirmed using microscope and the sample was fixed on a silicon frame to be cured using epoxy resin. The cured epoxy resin was cut using a micro cutting machine and a slice of 20–30 μm width was crafted using a polishing paper (Choi and Kim, 2018). This slice was placed on the slide glass, and mounting medium was inserted and covered with a cover glass to create a preparat for lacquer layer observation, which was observed using an optical microscope.

3. RESULTS and DISCUSSION

3.1. Visual inspection

Visual inspection of Buddha Triad and Altarpiece were carried out. Naked eye observation and documentation were carried out to create deterioration map of sculptures (Fig. 6–8).

Amitabha Buddha of Buddha Triad had cracks around the legs and the center of the face (Fig. 9). The gold leaf layer is assumed to have cracked as the base wood expanded and contracted according to the environment and relative humidity (Fig. 10). Also, for the front side, a long crack was found from the neck to the abdominal area. Furthermore, overall gold leaf layer was lifted or
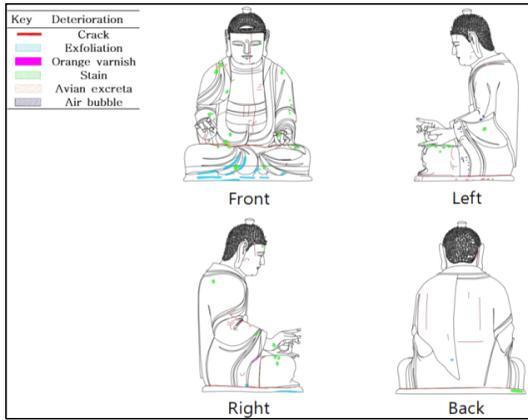
Fig. 6. Deterioration map of Amitabha Buddha.
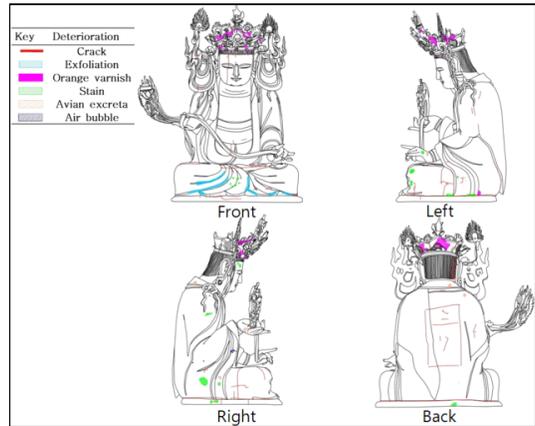
Fig. 8. Deterioration map of Mahasthamaprapta Bodhisattvas.
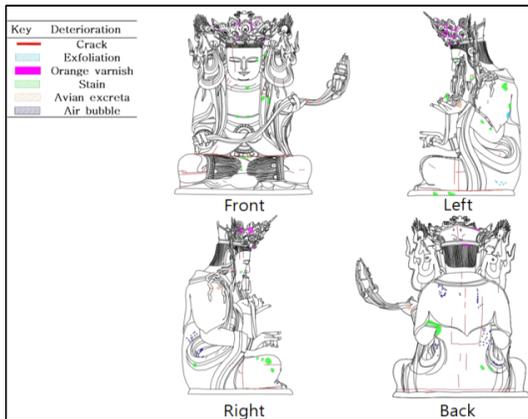
Fig. 7. Deterioration map of Avalokitesvara Bodhisattvas.

Fig. 9. Cracks from the gold leaf layer.

peeled, exposing the lacquer layer.

In the case of Avalokitesvara Bodhisattvas, cracks occurred mainly where the wooden sculpture parts were constructed. Also, exfoliation of gold leaf layer was confirmed near the cracks, and exfoliation was also visible near delicate areas such as accessory or edge of clothing.

Mahasthamaprapta Bodhisattvas of Buddha Triad was also cracked mainly on the face along with minor cracks overall. Moreover, exfoliation of gold leaf layer was

severe around the right leg. In addition, pigment stain, orange varnish, bubbles during gold leaf coating, and avian excretion were observed (Fig. 11−13). Such various damages and deterioration were marked in detail in the deterioration map.

As for the Buddha Altarpiece, crack was found overall for the central main Buddha, which is Amitabha Buddha along with attendant Buddha to the sides (Fig. 14). Crack was found near the lower part of lotus pattern and exfoliation of gold leaf layer was observed near the cracked area (Fig. 15−19).

Traditional Korean pigment mixes natural adhesion

Fig. 10. Exfoliation from the gold leaf layer.

Fig. 12. Orange color varnish.

Fig. 11. Restoration with the modern materials.

Fig. 13. Air bubble from the gold leaf layer.

such as cowhide glue or fish glue, but the pigment layer discolors as time passes because such adhesion dissolves. The discoloration occurred overall for the entire Wooden Amitabha Buddha Altarpiece (Lee, 2015). Also, parts of the wooden sculptures were also missing. Coronet accessory of Mahasthamaprapta Bodhisattvas and other accessory of West Guardian King were damaged and lost.

Moreover, areas that were restored using modern materials were confirmed. Generally, Korean lacquerware use lacquer as adhesion for the gold leaf layer, but restored parts using orange pigment and synthetic resin. Also yellow pigments were observed in gold leaf layer.

Deterioration map was made for each artifacts using the visual investigation results, facilitating the visual understanding of damage conditions. Crack, gold leaf layer exfoliation, degradation of pigment, orange pigment assumed to be recently applied, restored areas that use modern materials and avian excretion were confirmed. The conservation status of Buddha Triad and Altarpiece is determined to be highly vulnerable. Furthermore, the artifact is exposed to external environment, requiring Integrated pest management or regular monitoring for safe maintenance.

3.2. Surface pigment and accessory analysis

p-XRF were carried out for the two main purpose; pigment components analysis and accessory material analysis.
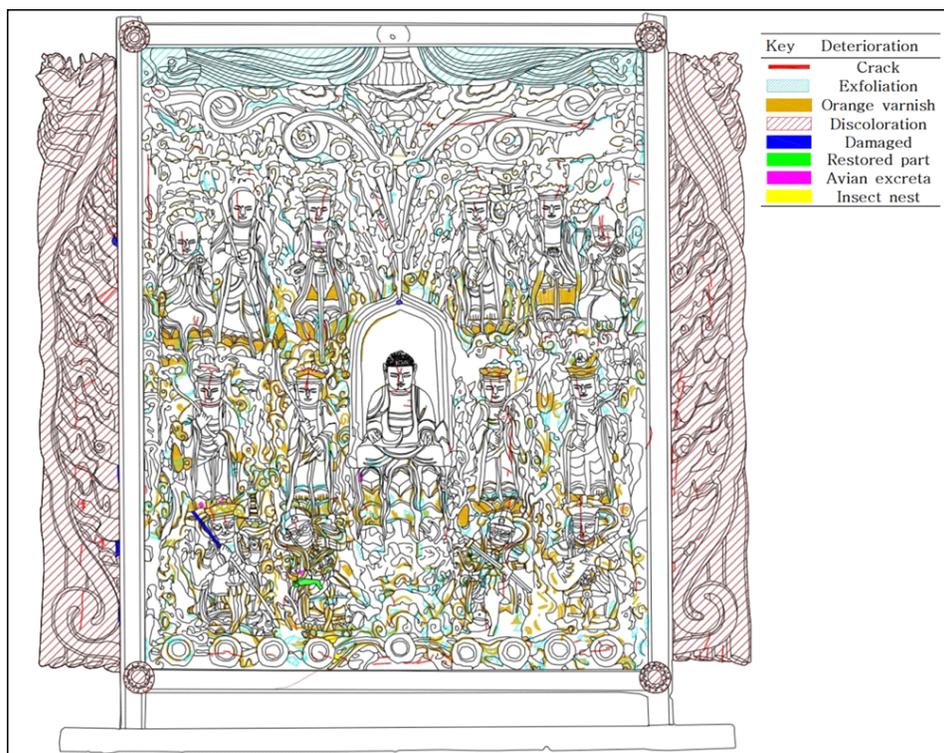
Fig. 14. Deterioration map of Wooden Amitabha Buddha Altarpiece.

Fig. 15. Cracks from the gold leaf layer.

Fig. 16. Cracks from wooden decoration.

35 point p-XRF analysis was conducted as in Fig. 20 −23 to confirm the main components of Buddha Triad, Altarpiece and accessory parts.

The p-XRF component analysis results of Amitabha Buddha are as in Table 1. Chrome (Cr) was detected from green color pigment, implying the usage of chrome oxide green. Cadmium (Cd), sulfur (S), mercury (Hg) and lead (Pb) were detected from red color pigment, so

Fig. 17. Exfoliation from the gold leaf layer.

Fig. 18. Deterioration of pigment.

Fig. 19. Yellow color varnish.

Fig. 20. Portable X-ray flurescence (p-XRF) analysis location of Amitabha Buddha.
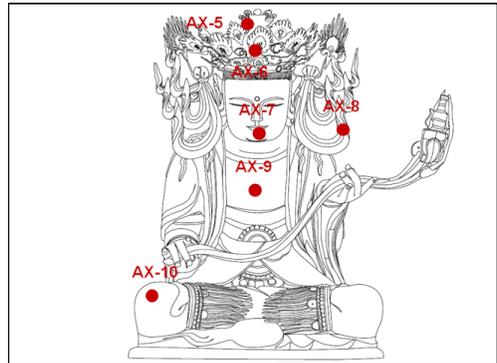
Fig. 21. p-XRF analysis location of Avalokitesvara Bodhisattvas.
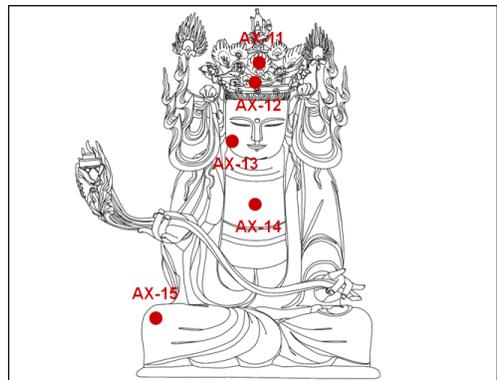
Fig. 22. p-XRF analysis location of Mahasthamaprapta Bodhisattvas.

cadmium red, cinnabar and minium is expected to have been used. Gold (Au) was detected from gold color, so gold was likely used (Jeong, 2001; National Research Institute of Cultural Heritage, 2013, 2016b).
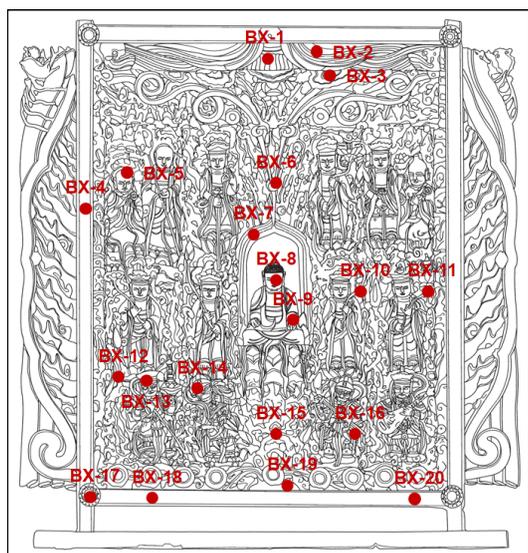
Fig. 23. p-XRF analysis location of Wooden Amitabha Buddha Altarpiece.

The p-XRF component analysis results of Avalokitesvara Bodhisattvas are as in Table 2. Copper (Cu) was detected as the main component of coronet accessory, meaning that copper was its main ingredient. Mercury (Hg), cadmium (Cd) and lead (Pb) were detected from red color pigment, implying usage of cadmium red, cinnabar, minium and Gold (Au) was detected from gold color, implying the usage of gold (Jeong, 2001; National Research Institute of Cultural Heritage, 2013, 2016a).

p-XRF component analysis results of Mahasthamaprapta Bodhisattvas were as in Table 3. Copper was detected from coronet accessory, implying it was made from copper, and Gold was detected from the gold color, implying the usage of gold (Jeong, 2001; National Research Institute of Cultural Heritage, 2013, 2016b).

p-XRF component analysis results of Buddha Altarpiece were as in Table 4. Lead (Pb) was detected from

Table 1. Portable X-ray fluorescence (p-XRF) data of Amitabha Buddha (Buddha Triad)

Serial number	Sample name	Analysis location	Main element	Expected material
1	AX-1	Green color pigment	Chrome (Cr), gold (Au)	Chrome oxide green and gold detected likely from gold leaf layer
2	AX-2	Gold	Gold (Au)	Gold
3	AX-3	Red color pigment	Cadmium (Cd), sulfur (S), gold (Au)	Cadmium red and gold detected likely from gold leaf layer
4	AX-4	Gold	Gold (Au)	Gold

Table 2. p-XRF data of Avalokitesvara Bodhisattvas (Buddha Triad)

Serial number	Sample name	Analysis location	Main element	Expected material
1	AX-5	Accessory parts	Copper (Cu)	Copper
2	AX-6	Gold	Gold (Au)	Gold
3	AX-7	Red color pigment	Cadmium (Cd), mercury (Hg), lead (Pb), gold (Au)	Cadmium red, cinnabar, minium and gold detected likely from gold leaf layer
4	AX-8	Gold	Gold (Au)	Gold
5	AX-9	Gold	Gold (Au)	Gold
6	AX-10	Gold	Gold (Au)	Gold

Table 3. p-XRF data of Mahasthamaprapta Bodhisattvas (Buddha Triad)

Serial number	Sample name	Analysis location	Main element	Expected material
1	AX-11	Accessory parts	Copper (Cu)	Copper
2	AX-12	Accessory parts	Copper (Cu), lead (Pb)	Copper and minium
3	AX-13	Gold	Gold (Au)	Gold
4	AX-14	Gold	Gold (Au)	Gold
5	AX-15	Gold	Gold (Au)	Gold

Table 4. p-XRF data of Wooden Amitabha Buddha Altarpiece

Serial number	Sample name	Analysis location	Main element	Expected material
1	BX-1	White color pigment	Lead (Pb)	Lead white
2	BX-2	Red color pigment	Mercury (Hg), lead (Pb), iron (Fe)	Cinnabar, hematite, minium
3	BX-3	Green color pigment	Copper (Cu), chrome (Cr)	Malachite, chrome oxide green
4	BX-4	Reddish brown color pigment	Lead (Pb)	Minium
5	BX-5	Green color pigment	Chrome (Cr)	Chrome oxide green
6	BX-6	White color pigment	Lead (Pb)	Lead white
7	BX-7	Red color pigment	Mercury (Hg), cadmium (Cd)	Cinnabar, cadmium red
8	BX-8	Gold	Gold (Au)	Gold
9	BX-9	Gold	Gold (Au)	Gold
10	BX-10	Reddish orange color pigment	Lead (Pb)	Minium
11	BX-11	Black color pigment	Carbon (C)	Ink stick
12	BX-12	Orange color pigment	Lead (Pb)	Minium
13	BX-13	Black color pigment	Carbon (C)	Ink stick
14	BX-14	Red color pigment	Cadmium (Cd), mercury (Hg)	Cadmium red, Cinnabar
15	BX-15	Gold	Gold (Au)	Gold
16	BX-16	Golden yellow color pigment	Gold (Au), lead (Pb)	Gold, minium
17	BX-17	Green color pigment	Copper (Cu)	Malachite
18	BX-18	Orange color pigment	Lead (Pb)	Minium
19	BX-19	White color pigment	Lead (Pb)	Lead white
20	BX-20	White color pigment	Lead (Pb)	Lead white

white color pigment, implying the usage of lead white and chrome (Cr), mercury (Hg), lead (Pb) and iron (Fe) were detected from red color pigment, implying the usage of cadmium red, cinnabar and hematite. Copper

(Cu) and chrome (Cr) were detected together for green color pigment, implying the usage of chrome oxide green and malachite. Lead (Pb) was mostly detected for orange color pigment, implying the usage of minium. Finally, main element was not detected for black color pigment, suggesting that ink stick, which is mainly composed of carbon, was used.

Pigment and material were analyzed through p-XRF. Green color pigment was malachite and chrome oxide green, gold color was gold, red color pigment was cadmium red, minium, hematite, and cinnabar, white color pigment was lead white, black color pigment was ink stick (Carbon), and coronet accessory was determined to be made of copper. Cadmium red and chrome oxide green are synthetic chemical pigment likely to be produced in modern day.

3.3. Identification of wood species

The location of species identification was six points from Buddha Triad and ten points from Buddha Altarpiece as can be seen in Fig. 24−26. Analysis of Buddha Triad showed three samples of *Tilia* spp., two samples from *Abies* spp., and one sample from *Pinus* spp. (Fig. 27−32). Samples collected from Amitabha Buddha, Avalokitesvara Bodhisattvas and Mahasthamaprapta
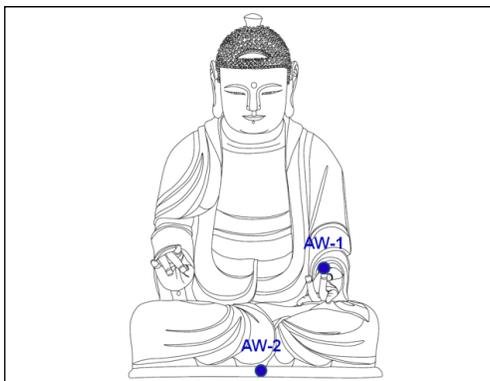
Fig. 24. Wood sample location of Amitabha Buddha.
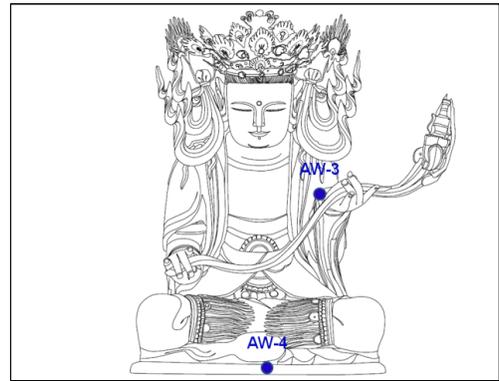
Fig. 25. Wood sample location of Avalokitesvara Bodhisattvas.
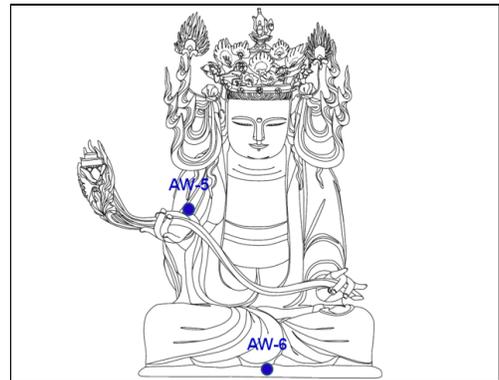
Fig. 26. Wood sample location of Mahasthamaprapta Bodhisattvas.

Bodhisattvas were identified to be *Tilia* spp. and bottom part which is used to seal excavated relics was identified to be two samples of *Abies* spp. and one sample of *Pinus* spp. (Fig. 33−43).

Wood species identification of Buddha Altarpiece confirmed eight samples of *Tilia* spp. and two samples of *Pinus* spp. The wooden sculpture parts were crafted using *Tilia* spp. and the frame and accessory parts were likely crafted using *Pinus* spp. (Table 5).

Lime tree (Tiliaceae, *Tilia* spp.) is hard wood tree and diffuse-porous are observed from their cross section. Polygonal pores are isolated or exist in combinations of
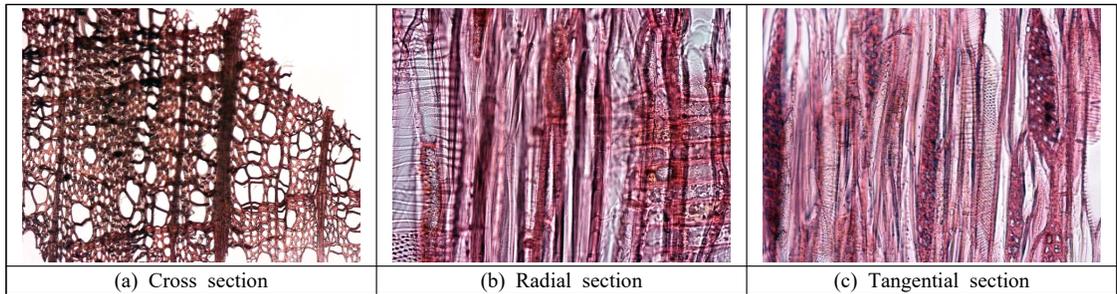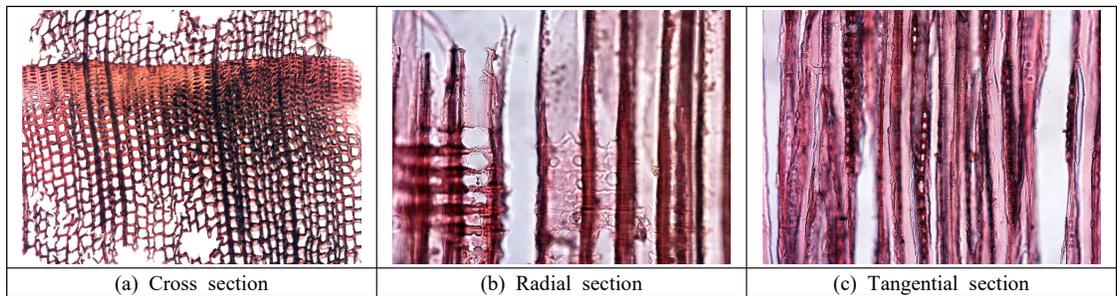
| (a) Cross section | (b) Radial section | (c) Tangential section |

Fig. 27. Micrograph of wood sample from Amitabha Buddha (AW-1).

| (a) Cross section | (b) Radial section | (c) Tangential section |

Fig. 28. Micrograph of wood sample from Amitabha Buddha (AW-2).

| (a) Cross section | (b) Radial section | (c) Tangential section |

Fig. 29. Micrograph of wood sample from Avalokitesvara Bodhisattvas (AW-3).

| (a) Cross section | (b) Radial section | (c) Tangential section |

Fig. 30. Micrograph of wood sample from Avalokitesvara Bodhisattvas (AW-4).

(a) Cross section　(b) Radial section　(c) Tangential section

Fig. 31. Micrograph of wood sample from Mahasthamaprapta Bodhisattvas (AW-5).

(a) Cross section　(b) Radial section　(c) Tangential section
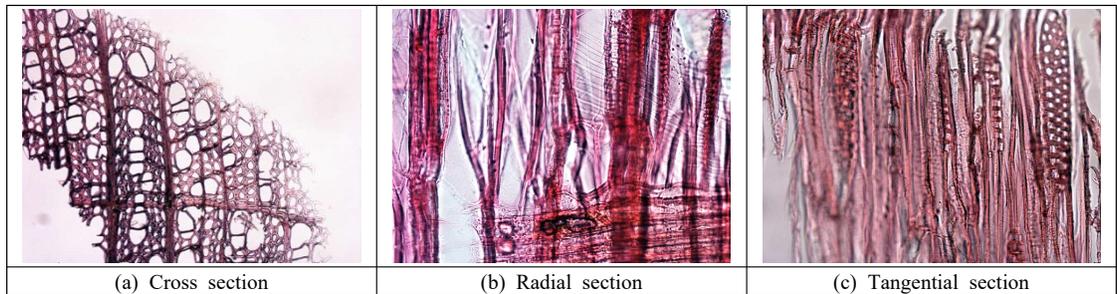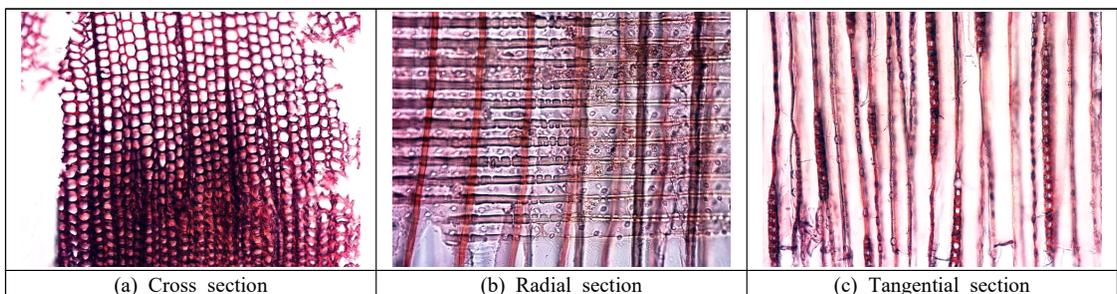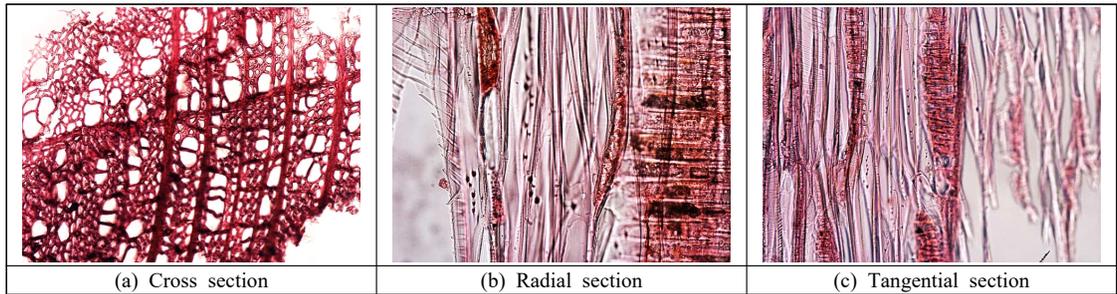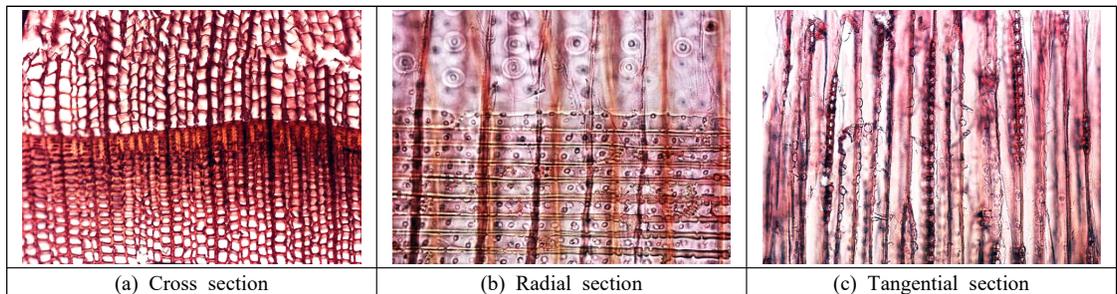
Fig. 32. Micrograph of wood sample from Mahasthamaprapta Bodhisattvas (AW-6).
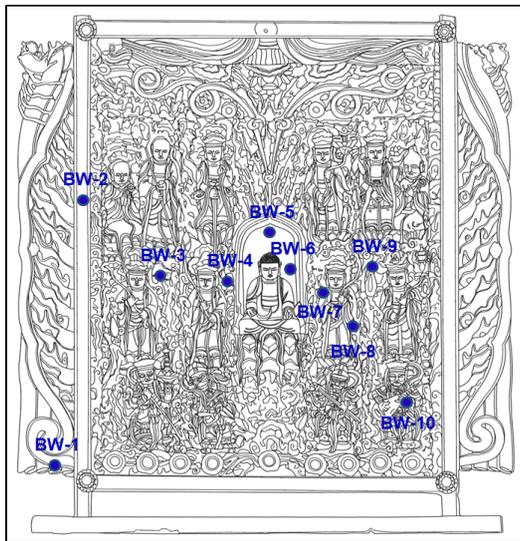
Fig. 33. Wood sample location of Wooden Amitabha Buddha Altarpiece.

2−3. Simple perforation plates were observed and helical thickening exist in vessel wall. Diffuse-in-aggregate parenchymas were observed in cross section and ray is composed of homogeneous ray cells. Wood fibers were identified as storied structure. In these factors, wood samples were identified as lime tree (Tiliaceae, *Tilia* spp.).

Soft pine (Pinaceae, *Abies* spp.) is softwood tree and tracheids were observed in cross section without axial intercellular canal. Ray is only composed of parenchyma cell and nodular end wall were observed. Also, 1−2 rows of bordered pits were observed in longitudinal tracheid and taxodioid cross field pitting was observed in radial section. In the tangential section, uniseriate ray was observed. In these factors, wood samples were identified as soft pine (Pinaceae, *Abies* spp.).

Hard pine (Pinaceae, *Pinus* spp.) is softwood tree and tracheids and axial intercellular canal were observed in
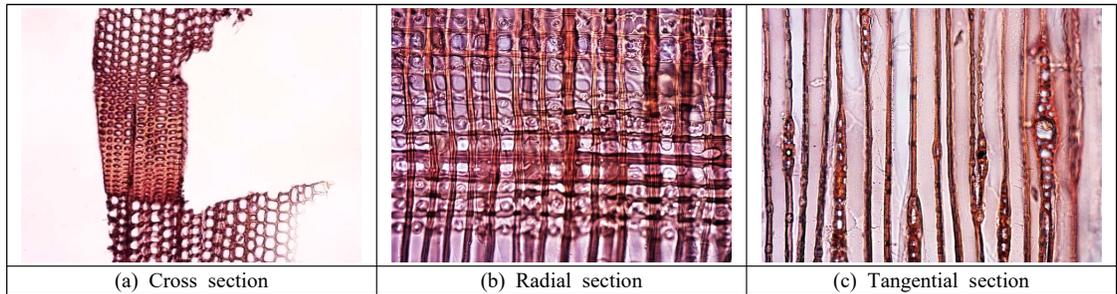
| (a) Cross section | (b) Radial section | (c) Tangential section |

Fig. 34. Micrograph of wood sample from Wooden Amitabha Buddha Altarpiece (BW-1).

| (a) Cross section | (b) Radial section | (c) Tangential section |
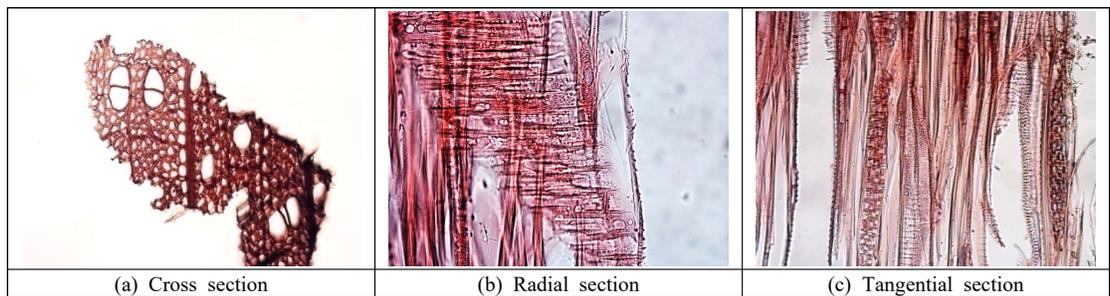
Fig. 35. Micrograph of wood sample from Wooden Amitabha Buddha Altarpiece (BW-2).

| (a) Cross section | (b) Radial section | (c) Tangential section |
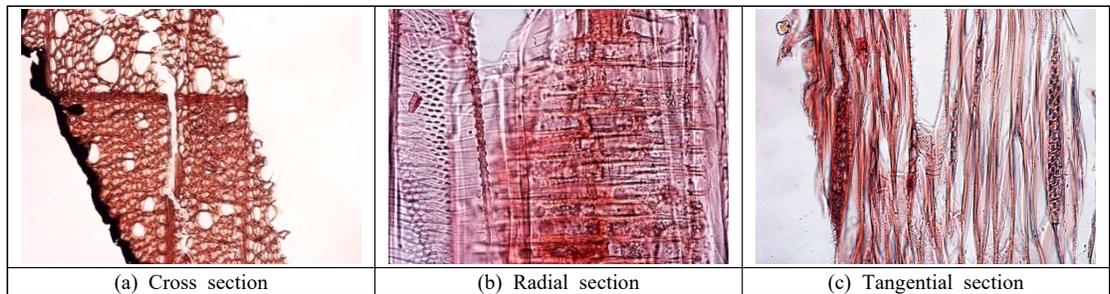
Fig. 36. Micrograph of wood sample from Wooden Amitabha Buddha Altarpiece (BW-3).
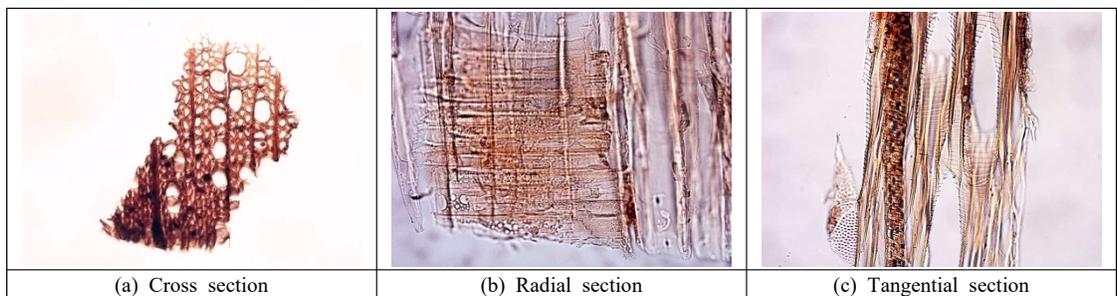
| (a) Cross section | (b) Radial section | (c) Tangential section |

Fig. 37. Micrograph of wood sample from Wooden Amitabha Buddha Altarpiece (BW-4).

| (a) Cross section | (b) Radial section | (c) Tangential section |

Fig. 38. Micrograph of wood sample from Wooden Amitabha Buddha Altarpiece (BW-5).

| (a) Cross section | (b) Radial section | (c) Tangential section |

Fig. 39. Micrograph of wood sample from Wooden Amitabha Buddha Altarpiece (BW-6).

| (a) Cross section | (b) Radial section | (c) Tangential section |

Fig. 40. Micrograph of wood sample from Wooden Amitabha Buddha Altarpiece (BW-7).

| (a) Cross section | (b) Radial section | (c) Tangential section |

Fig. 41. Micrograph of wood sample from Wooden Amitabha Buddha Altarpiece (BW-8).

| (a) Cross section | (b) Radial section | (c) Tangential section |

Fig. 42. Micrograph of wood sample from Wooden Amitabha Buddha Altarpiece (BW-9).

| (a) Cross section | (b) Radial section | (c) Tangential section |
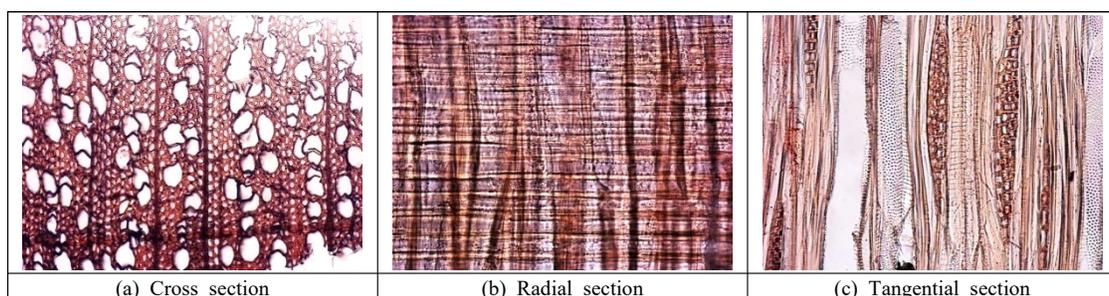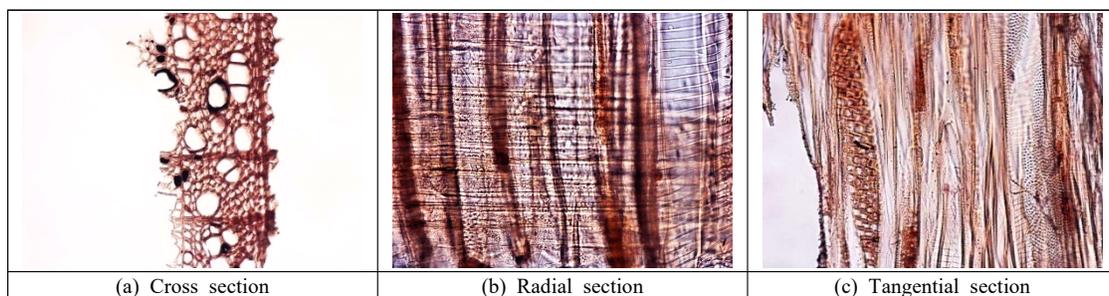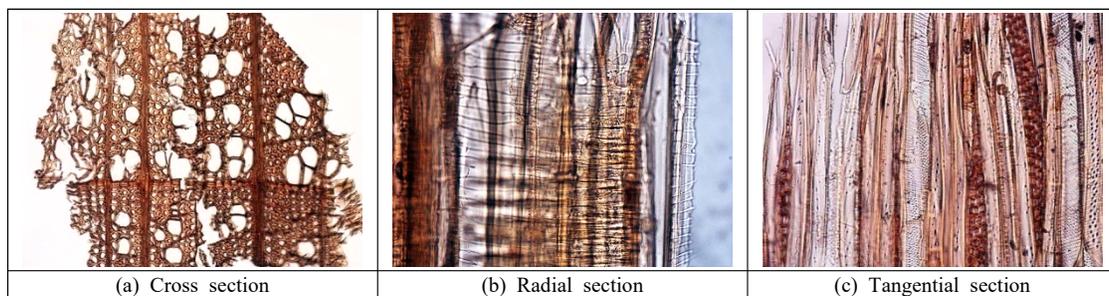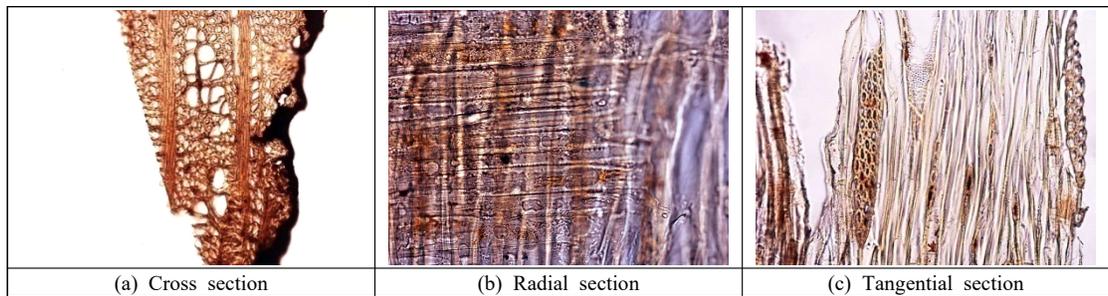
Fig. 43. Micrograph of wood sample from Wooden Amitabha Buddha Altarpiece (BW-10).

Table 5. Wood species of Buddha Triad and Altarpiece

Serial number	Sample name	Sculpture	Species
1	AW-1	Buddha Triad (Amitabha Buddha)	*Tilia* spp.
2	AW-2		*Pinus* spp.
3	AW-3	Buddha Triad (Avalokitesvara Bodhisattvas)	*Tilia* spp.
4	AW-4		*Abies* spp.
5	AW-5	Buddha Triad (Mahasthamaprapta Bodhisattvas)	*Tilia* spp.
6	AW-6		*Abies* spp.
7	BW-1	Buddha Altarpiece	*Pinus* spp.
8	BW-2		*Tilia* spp.
9	BW-3		*Tilia* spp.
10	BW-4		*Tilia* spp.
11	BW-5		*Tilia* spp.
12	BW-6		*Tilia* spp.
13	BW-7		*Tilia* spp.
14	BW-8		*Tilia* spp.
15	BW-9		*Pinus* spp.
16	BW-10		*Tilia* spp.

cross section. Ray is composed of parenchyma cell and 1 row of bordered pits was observed in longitudinal tracheid. Window-like (Fenestriform) cross field pitting and dentate thickening from ray tracheid was observed in radial section. Uniseriate ray, radial intercellular canal and fusiform ray were observed in tangential section. Due to these factors, wood samples were identified as hard pine (Kwon *et al.*, 2020; Lee, 1997a, 1997b, 1997c, 2003; National Folk Museum of Korea, 2004; National Research Institute of Cultural Heritage, 2015, 2016a; Park, 2006; Park and Kim, 2004; Park *et al.*, 2018).

Wood species analysis identified that *Tilia* spp., *Abies* spp., and *Pinus* spp. were used on the wooden sculptures. Lime tree has Buddhist significance and can be easily found near Korean temples, and are often used for wooden sculptures for their high process ability (Kim *et al.*, 2016a). Soft and hard pine tree are easily found throughout Korea, and are diversely utilized for construction, wooden sculptures and furniture since ancient times to today. For these reasons, when Buddha Triad and Altarpiece were crafted in late 17th century Joseon, lime tree was mainly used for wooden sculptures and for large frameworks such as accessory parts, hard pine were used. Through this data, the original species of tree can be used for the appropriate location of the cultural heritage when conducting conservation treatment.

3.4. Lacquer layer analysis

Layer analysis of Buddha Triad was performed by collecting two samples from Amitabha Buddha, two samples from Avalokitesvara Bodhisattvas, and three samples from Mahasthamaprapta Bodhisattvas, totaling to seven (Fig. 44‒46). Lacquer layer was observed by using transmitted light, reflected light, and polarized light.

Above the base layer, pigment layer and orange pigment layer was observed at the edge of Amitabha Buddha's sleeves (AL-1) and gold leaf layer was found
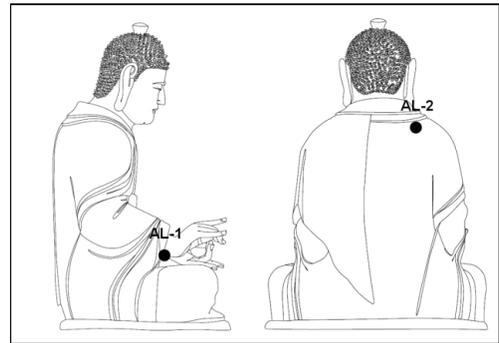
Fig. 44. Layer analysis sample location of Amitabha Buddha.
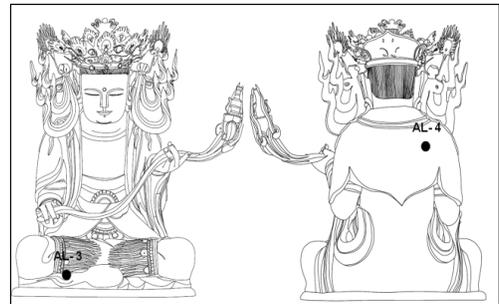
Fig. 45. Layer analysis sample location of Avalokitesvara Bodhisattvas.
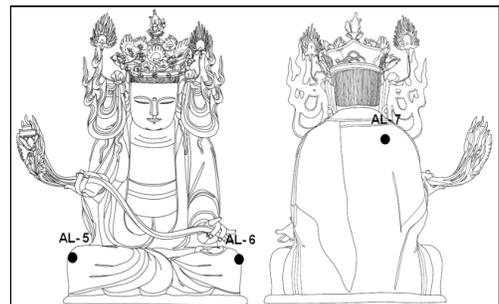
Fig. 46. Layer analysis sample location of Mahasthamaprapta Bodhisattvas.

above them. For the back side (AL-2), gold leaf layer was above the base layer, and orange pigment layer and gold leaf layer was found above it. Ash, bone-dust,

clay-dust and etc. were checked through polarized light observation, but none was found (Fig. 47, 48).

Two layers of base layer were found at the sleeve of Avalokitesvara Bodhisattvas (AL-3), and gold leaf layer was found above the orange pigment layer. Gold leaf layer was on top of the base layer for the back side (AL-4), with 2 pigment layer above them, topping with gold leaf layer. Ash, bone-dust, clay-dust, etc. were che-

cked through polarized light observation, but none was found (Fig. 49, 50).

For the knee of Mahasthamaprapta Bodhisattvas (AL-5), gold leaf layer was found above the base layer, with the orange pigment layer and gold leaf layer above them. For the other knee (AL-6), white filler formulated the base layer, with orange pigment layer and pigment layer above them with another orange pigment layer and

| Transmitted light | Reflected light | Polarized light |

Fig. 47. Micrograph of layer analysis sample from Amitabha Buddha (AL-1).

| Transmitted light | Reflected light | Polarized light |
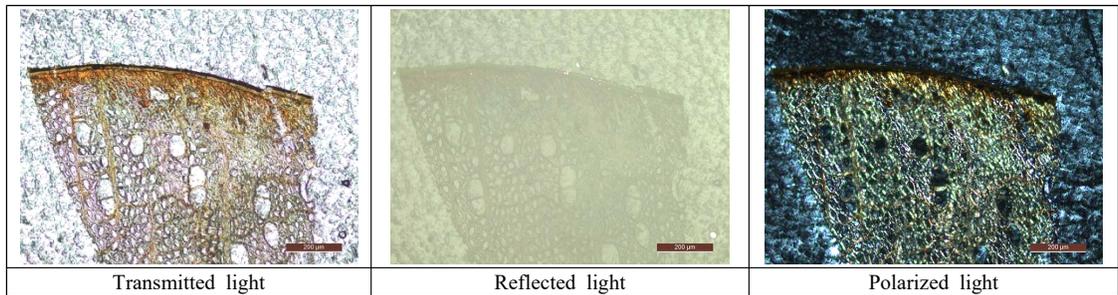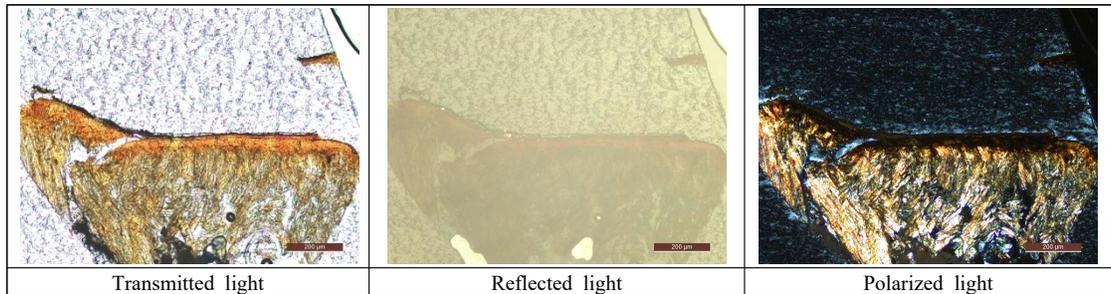
Fig. 48. Micrograph of layer analysis sample from Amitabha Buddha (AL-2).
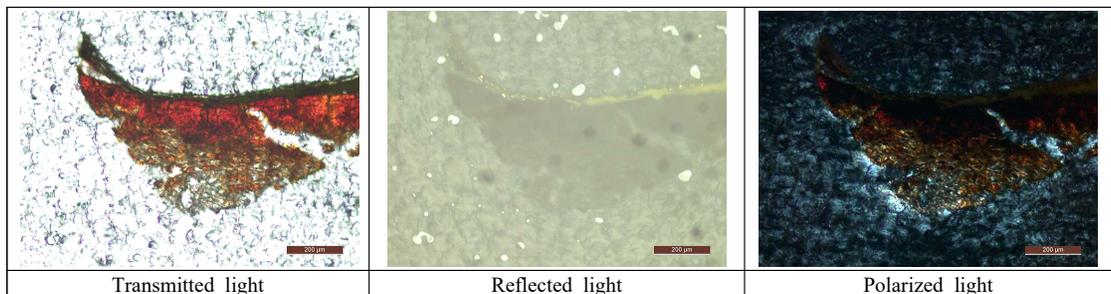
| Transmitted light | Reflected light | Polarized light |

Fig. 49. Micrograph of layer analysis sample from Avalokitesvara Bodhisattvas (AL-3).

| Transmitted light | Reflected light | Polarized light |
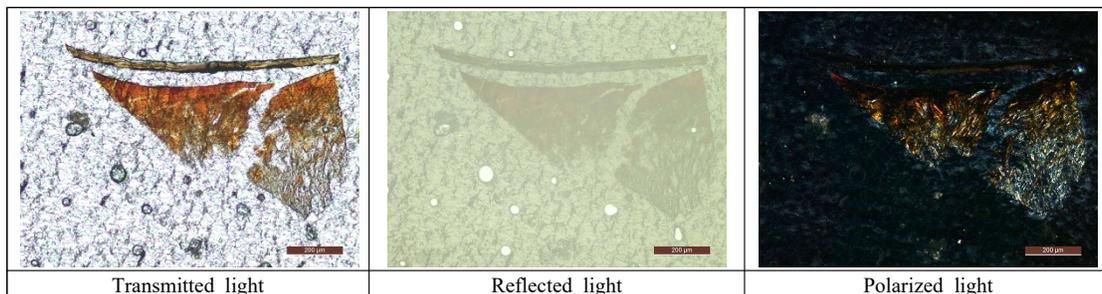
Fig. 50. Micrograph of layer analysis sample from Avalokitesvara Bodhisattvas (AL-4).

pigment layer above them again repeatedly, topping off with a gold leaf layer. For the back (AL-7), gold leaf layer was above the base layer, with two pigment layers above them, with the gold leaf layer as the final layer. Ash, bone-dust, clay-dust, etc. which can be used at the base layer were checked through polarized light observation, but none was found (Fig. 51–53).

Buddha Altarpiece was analyzed by collecting three

pieces of small samples that were collected from Amitabha Buddha (Fig. 54).

Above the base layer, pigment layer and orange pigment layer was observed and 1–2 gold layers were found above them. Ash, bone-dust, clay-dust, etc. from base layer were checked through polarized light observation, but none was found. In the microscope observation, tradition varnish such as lacquer can be observed
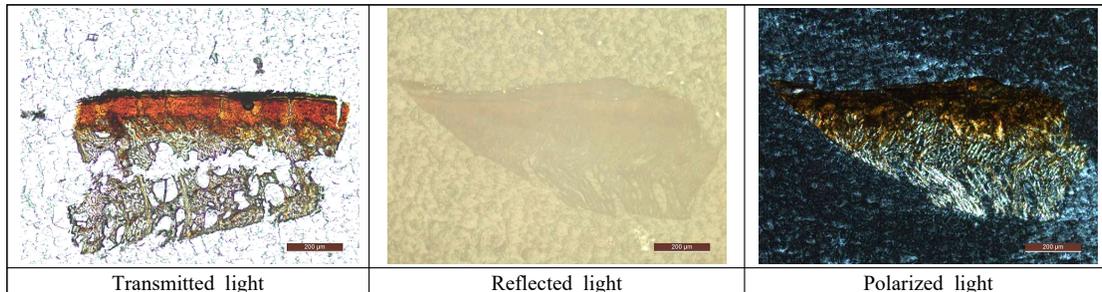
| Transmitted light | Reflected light | Polarized light |

Fig. 51. Micrograph of layer analysis sample from Mahasthamaprapta Bodhisattvas (AL-5).

| Transmitted light | Reflected light | Polarized light |
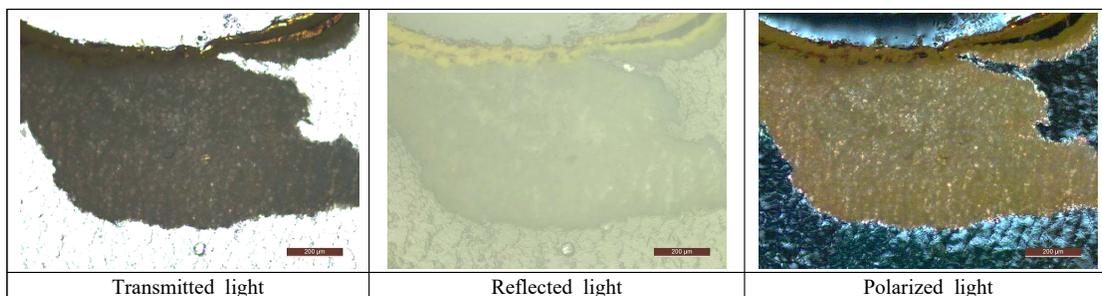
Fig. 52. Micrograph of layer analysis sample from Mahasthamaprapta Bodhisattvas (AL-6).
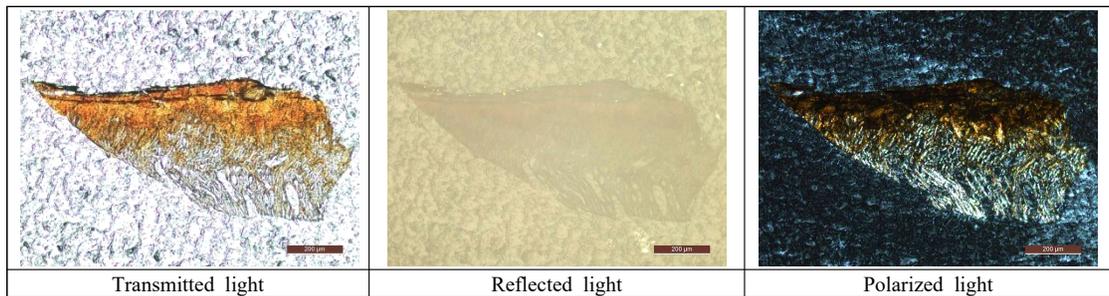
Fig. 53. Micrograph of layer analysis sample from Mahthamaprapta Bodhisattvas (AL-7).
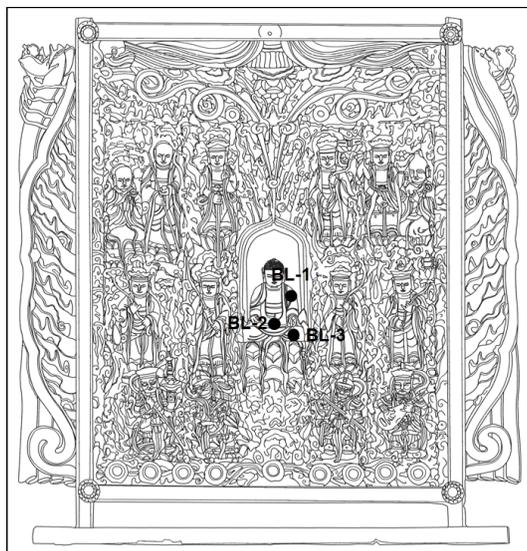
Fig. 54. Layer analysis sample location of Wooden Amitabha Buddha Altarpiece.

as light brown and brown color. However, Yellowish varnish was observed in this sample. It seems to be modern chemical varnish and polymers were used in the previous conservation work (Fig. 55−57).

Lacquer layer analysis of Buddha Triad showed that an orange pigment layer was above two lacquer layers, which were above two base layers. Also, a gold leaf layer is found above the orange pigment layer. Lacquer layer appears brown−light brown color when observed (Choi, 2017; Kim, 2007). However, the orange pigment layer found above the lacquer layer appears to be modern synthetic chemical varnish used during previous conservation works. Korean wooden Buddha sculptures are crafted by coating lacquer on the surface, plating with gold, and painting using pigment as tradition method. However, some pigments assumed to be used in modern era is analyzed from the Buddha Triad and Buddha Altarpiece. Synthetic pigment and paint were introduced
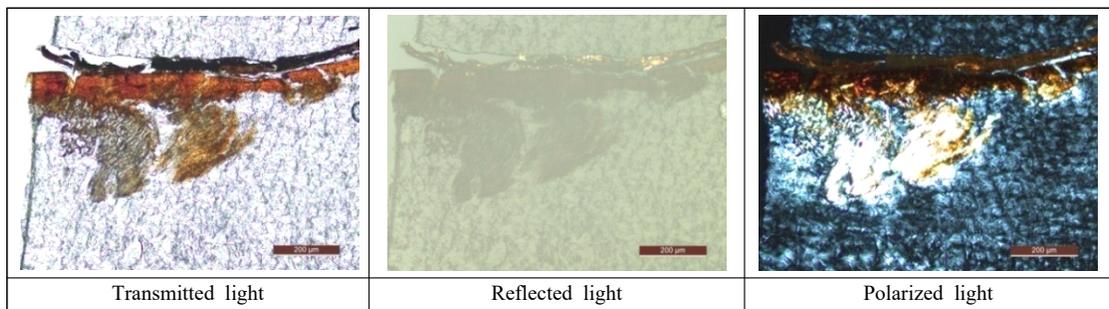
Fig. 55. Micrograph of layer analysis sample from Wooden Amitabha Buddha Altarpiece (BL-1).

| Transmitted light | Reflected light | Polarized light |
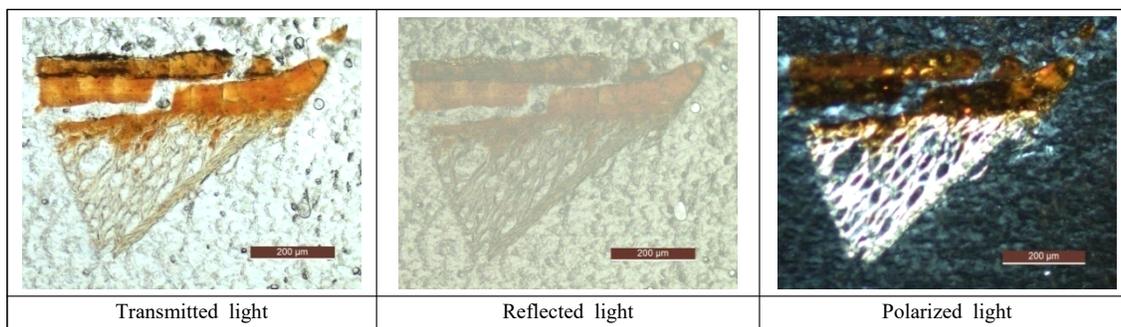
Fig. 56. Micrograph of layer analysis sample from Wooden Amitabha Buddha Altarpiece (BL-2).

| Transmitted light | Reflected light | Polarized light |
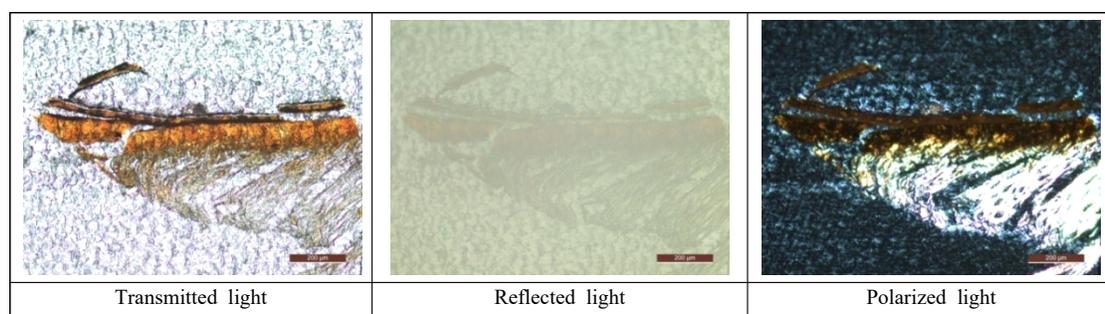
Fig. 57. Micrograph of layer analysis sample from Wooden Amitabha Buddha Altarpiece (BL-3).

in modern age, and is likely to have been used for previous conservation works. Moreover, the back of Buddha Altarpiece was indiscreetly painted with orange color pigment composed of cadmium red and minium, and areas with exfoliated gold leaf were likely painted with yellow color pigment. As a scientific analysis result show that whole part of Buddha Triad and Buddha Altarpiece were damaged by several factors.

4. CONCLUSIONS

Material analysis results show that sculptures were made of lime tree, soft pine and hard pine which were used to craft wooden sculpture for the prolonged period of Korea. Lacquer layer, gold leaf layer and pigment analysis result show that synthetic varnish and modern pigments were partially used. Also conservation status can be diagnosis through the visual inspection. Korean cultural heritage charter and the international charter for the conservation and restoration of monuments and sites clearly state that cultural heritages must be conserved using its original material (Choi, 2008; Lee & Do, 1998). Thus, conservation processes must replace such modern pigments and varnishes with Korean traditional materials. Therefore, conservation treatment must utilize this database and be conducted with traditional materials. Furthermore, deterioration map diagnosis for the understanding of conservation status and scientific analysis data can be applied for the appropriate and authentic conservation treatment of Buddha Triad and Altarpiece.

CONFLICT of INTEREST

No potential conflict of interest relevant to this article

was reported.

ACKNOWLEDGMENT

Not applicable.

REFERENCES

Academy of Korean Studies. 1996. Yongmunsa Temple, Encyclopedia of Korea Culture. Academy of Korean Studies, Sungnam, Korea.

Choi, J.D. 2008. The nara document on authenticity 1994. Journal of Architectural History 17: 127-133.

Choi, J.W. 2017. Analysis on paints and varnishes for conservation of lacquerware cultural heritage. M.S. Thesis, Korea National University of Cultural Heritage, Seoul, Korea.

Choi, J.W., Kim, S.C. 2018. Analysis of lacquer and CNSL using infrared spectrometer and pyrolysis-GC/MS. Journal of the Korean Wood Science and Technology 46(1): 1-9.

Dooyoung Conservation of Cultural Heritage. 2019a. Conservation Report of Wooden Seated Amitabha Buddha Triad of Yongmunsa Temple. Dooyoung Conservation of Cultural Heritage, Yecheon, Korea.

Dooyoung Conservation of Cultural Heritage. 2019b. Conservation Report of Wooden Amitabha Buddha Altarpiece of Yongmunsa Temple. Dooyoung Conservation of Cultural Heritage, Yecheon, Korea.

Han, Y., Lee, S., Choi, J., Park, C.Y. 2021. A study on classification of wood cultural resources in South Korea. Journal of the Korean Wood Science and Technology 49(5): 430-452.

Han, Y., Lee, S.M. 2021. Investigation on the awareness and preference for wood culture to promote the value of wood: I. Awareness of Wood and Cultural Experience. Journal of the Korean Wood Science and Technology 49(6): 616-642.

Hwang, S.W., Tazuru, S., Sugiyama, J. 2020. Wood identification of historical architecture in Korea by synchrotron X-ray microtomography-based three-dimensional microstructural imaging. Journal of the Korean Wood Science and Technology 48(3): 283-290.

Jeong, J.M. 2001. Korean Color and Paint of Painting, Material and Technique of Korean Painting. Hak-gojae, Daegu, Korea.

Kim, S.C. 2007. Analysis and conservation of lacquer wares from archaeological sites in Korea. Ph.D. Thesis, Chungbuk National University, Cheongju, Korea.

Kim, S.C., Choi, J.W. 2016. Study on wood species identification for Daeungjeon hall of Jeonghyesa temple, Suncheon. Journal of Korean Wood Science and Technology 44(6): 897-902.

Kim, S.C., Choi, J.W.. Lee, J.E. 2016a. Study on material characteristic of modern cultural heritage rickshaw. Journal of Conservation Science 32(1): 33-42.

Kim, S.K., Choi, J., Jeong, A.R. 2016b. Study regarding species identification for hanging paintings and hanging painting storage boxes in Joseon Dynasty. Journal of Conservation Science 32(4): 535-548.

Kim, Y.J., Son, B.H., Oh, J.A., Jo, T.G., Choi, S.I., Park, W.K. 2012. Species identification and tree-ring dating of the Lotus Pedestal of Amitabha Statue at Ssangbong-Temple in Hwasun, Korea. Journal of the Korea Furniture Society 23(1): 95-102.

Kwon, O.K., Kim, N.H., Kim, J.S., Seo, J.W., Jeong, Y.J. 2020. Wood Anatomy. The Korean Society of Wood Science & Technology, Seoul, Korea.

Kwon, S.R. 1994. Encyclopedia of Korean Temple. Ewha Womans University Press, Seoul, Korea.

Lee, C.B. 2003. Illustrated Plant Book of Korea. Hyang-munsa, Seoul, Korea.

Lee, H.H. 2015. Research trend of the analysis and restoration study on traditional pigment. Korean Journal of Cultural Heritage Studies 48(1): 132-147.

Lee, H.M., Jeon, W.S., Lee, J.W. 2021a. Analysis of anatomical characteristics for wood species identification of commercial plywood in Korea. Journal of the Korean Wood Science and Technology 49(6): 574-590.

Lee, H.S., Lee, H.H., Han, G.S. 2020. Study on the characteristics of materials and production techniques of clay seated Vairocana Buddha triad of Seonunsa temple, Gochang. Journal of Conservation Science 36(6): 562-577.

Lee, K.H., Park, C.H., Kim, S.C. 2021b. Species identification and tree-ring dating of the wooden elements used in Juheulgwan of Joryeong (Gate No.1), Mungyeong, Korea. Journal of the Korean Wood Science and Technology 49(6): 550-565.

Lee, P.W. 1997a. Characteristics and Usages of Korean Wood I. Seoul National University Press, Seoul, Korea.

Lee, P.W. 1997b. Characteristics and Usages of Korean Wood II. Seoul National University Press, Seoul, Korea.

Lee, T.N.. Do, C.H. 1998. The venice charter international charter for the conservation and restoration of monuments and sites. Journal of Conservation Science 7(2): 86-91.

Lee, W.Y. 1997c. Structure of Timber Organization of Korea Wood. Hyangmunsa, Seoul, Korea.

Lee, Y.H. 2013. Scientific analysis and conservation treatment on the seated wooden Avalokiteshvara Bodhisattva in Bogwangsa Temple of Andong. M.S. Thesis, Kongju National University, Kongju, Korea.

Nam, T.G., Kim, H.S. 2021. A fundamental study of the Silla shield through the analysis of the shape, dating, and species identification of wooden shields excavated from the ruins of Wolseong moat in Gyeongju. Journal of the Korean Wood Science and Technology 49(2): 154-168.

National Folk Museum of Korea. 2004. Species Identification and Dendrochronology of Wooden Furniture. National Folk Museum of Korea, Seoul, Korea.

National Research Institute of Cultural Heritage. 2010. Drawing Instruction of the Deterioration and Damage Map for the Stone Cultural Heritage. National Research Institute of Cultural Heritage, Daejeon, Korea.

National Research Institute of Cultural Heritage. 2013. Basic Research on Manufacturing Techniques for Traditional Korean Pigments and Non-destructive Analytical Methods. National Research Institute of Cultural Heritage, Daejeon, Korea.

National Research Institute of Cultural Heritage. 2015. Identification and Database Construction of Wooden Structural Members of Palaces and Government Office Buildings. National Research Institute of Cultural Heritage, Daejeon, Korea.

National Research Institute of Cultural Heritage. 2016a. Identification and Database Construction of Wooden Structural Members for Temples and Local Confucian Schools. National Research Institute of Cultural Heritage, Daejeon, Korea.

National Research Institute of Cultural Heritage. 2016b. Non-destructive Pigment Analysis Guide Book, X-ray Fluorescence, Tera Hertz and Visible Light Spectroscopy. National Research Institute of Cultural Heritage, Daejeon, Korea.

National Research Institute of Cultural Heritage. 2018. Scientific Analysis of Cultural Heritage. National Research Institute of Cultural Heritage, Daejeon, Korea.

Park, J.H., Oh, J.E., Hwang, I.S., Jang, H.U., Choi, J.W., Kim, S.C. 2018. Study on species identification for Pungnammun Gate (Treasure 308) in Jeonju, Korea. Journal of the Korean Wood Science and Technology 46(3): 278-284.

Park, S.J. 2006. Timber Organization and Identification. Hyangmunsa, Seoul, Korea.

Park, W.K., Kim, S.J. 2004. Species identification of wood members in the Keunjeongjeon Hall of

Kyungbok Palace. Journal of the Korean Wood Science and Technology 32(1): 88-95.

Park, W.K., Kim, Y.J., Son, B.H., Lee, K.H. 2013. Dendrochronology, species and non-destructive analysis for the statues of Myungbujeon hall at Jeondeungsa temple in Ganghwado. The Journal of Incheon Studies 1(29): 255-286.

Park, W.K., Oh, J.A., Kim, Y.J., Kim, S.K., Park S.Y.,

Son, B.H., Choi, S.I. 2010. Species of wooden Buddhist statues of the late Joseon Dynasty in Jeollado, South Korea. Journal of the Korea Furniture Society 21(1): 72-82.

Skoog, D.A., Holler, F.J.. Crouch, S.R. 2008. Principles of Instrumental Analysis, 6th edition. Cengage Learning, Boston, MA, USA.