

## Article

# The World's Oldest Book Printed by Movable Metal Type in Korea in 1239: The Song of Enlightenment

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**Abstract:** Four nearly identical versions of an ancient printed book, the Song of Enlightenment with Commentaries by Buddhist Monk Nammyeong Cheon (南明泉和尚頌證道歌), were examined by image analysis and comparisons to identify whether they are the identical versions or different versions in terms of printing techniques. Two out of four versions have been designated as Korean treasures and the other two versions are currently being examined for designation as Korean cultural properties. One of two Korean treasures has been spotlighted as a potential movable metal type printing book prior to the *Jikji* printed in 1377, as recognized by the UNESCO Memory of the World program. Heated debates over the printing techniques and printing dates have overwhelmed Korean historians for more than 50 years. Due to the subjective nature of the evaluation, it was hard to reach a unanimous decision. Finding objective new evidence is needed to end this heated debate. We found very clear evidence showing that one version is significantly different from the others and was likely printed using movable metal type in September 1239. It is the oldest extant book printed using metal type, 138 years prior to the printing date of *Jikji*.

**Keywords:** early history of printing; movable metal type printing; woodblock printing; image analysis; image-based dating



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## 1. Introduction

The oldest known printing material using movable metal type in the world is *Baegun Hwasang Chorok Buljo Jisimcheyojeol* (白雲和抄錄佛祖直指心體要節) published by Heungdeoksa Temple (興德寺) in Cheongju in 1377, during the Goryeo dynasty, and is registered in the UNESCO Memory of the World program [1–9]. It is usually referred to as its abbreviated name, *Jikji* (直指). According to ancient Korean literature, *Sangjeong Gogyeum Yemun* (詳定古今禮文) is estimated to have been printed between 1234 and 1241, and is possibly the first movable metal type printing [1–4,7–9]. However, it has not been recognized as such due to the lack of the real printed version. No copies have survived. Meanwhile, there are four printed versions (possibly different editions, using different printing methods) of *Nammyeong Cheon hwasangsong jeungdoga* (南明泉和尚頌證道歌, Song of Enlightenment with Commentaries by Buddhist Monk Nammyeong Cheon), which contains the postscript of Jinyang-gong Choi Yi (崔怡), a powerful ruler of the Goryeo (高麗) dynasty in Korea. The postscript was dated to September 1239, [1–4,10–15].

Among them, the two classified in Korea as national cultural treasures (寶物) versions (possibly different) were on 30 May 1984 (Samseong version (三省本)) and 29 June 2012 (Gongin version (空印本)), respectively [16,17]. In Korea, there have been heated debates among historians and experts over printing techniques and printing date on cultural heritage works for more than 50 years [4,10–15]. One group believes both versions are woodblock printing works dating from the Goryeo dynasty (918–1392) after September 1239. They even determined that both versions were printed using the same woodblocks during the Goryeo dynasty. However, historians strongly believe that the Gongin version was printed much later, perhaps in the mid Joseon (朝鮮) dynasty (1392–1897), due to the

poor quality based on paper and printed characters [4,10–15]. This opinion was adopted by the Cultural Heritage Administration of Korea during the Korean Treasure status designation [10–15]. However, other historians claim the poor quality of paper and printed characters is evidence of movable metal type printing. They even insist that the Gongin version was printed using movable metal type in September 1239 [8–10]. If this is the case, this version would be the first printing using movable metal type as it would pre-date the printing of *Jikji* by 138 years [1–9]. All these debates are based on subjective personal opinions and visual inspection. No agreement can be reached without objective and scientific evidence.

Recently, the other two versions (Daegu version (大邱本) and Banyasa Temple version (般若寺本)) have undergone, or are in the process of undergoing, designation as cultural properties. The prevailing opinion is that all four printing versions were printed using the same woodblocks at different times. During the process of classifying another version (Daegu version) as a cultural property, it was revealed that the prayer or epilog (跋文), written by Kim Su-on (金守溫) and dated as June 1472, was removed [11,12]. There is also an argument [13] that the printing date for all versions should be restated as 1472 or later, which is the beginning of the Joseon dynasty (1392–1897), from the originally stated date around 1239 in the Goryeo dynasty (918–1392). The printing dates for the previously designated Korean Treasures have been restated to be later than 1472. There is a 233-year gap from the previous estimated printing date of 1239 for at least one version (Samseong version). This is a good indicator calling into question the credibility of subjective judgments based on visual inspection and individual experience of historians and cultural property designations of committee members.

The claim that one of the four printing versions (Gongin version) is the oldest printing version using movable metal type has been consistently raised over the past 50 years [10–12,14,15]. It is time to address this claim. Since we now have information on four nearly identical versions available, it should be possible to find more objective evidence and determine the printing techniques and dates. In this paper, the high-resolution photographs of the four versions of *Nammyeong Cheon hwasangsong jeungdoga* (南明泉和頌證道歌, Song of Enlightenment with Commentaries by Buddhist Monk Nammyeong Cheon) are compared using specially developed image analysis software (PicMan).

**Key words:** The song of Enlightenment (南明泉和頌證道歌), different printing versions, image comparison, printing order, printing period, printing method

## 2. Materials and Methods

### 2.1. The Song of Enlightenment

The Song of Enlightenment (traditional Chinese: 證道歌; simplified Chinese: 证道歌; pinyin: Zhèngdào gē; Wade–Giles: Cheng-dao ke; Japanese: Shōdōka; Korean: 증도가), is a Chan (traditional Chinese: 禪; simplified Chinese: 禅; pinyin: Chán; pinyin: Chán; Japanese: 禅, romanized: Zen; Korean: 선, romanized: Seon; meaning mediation or mediative state) discourse, written sometime in the first half of the 8th century is usually attributed to the Zen Master Yongjia Xuanjue (永嘉禪師, 675–713) [18–21]. It also is translated as Song of Awakening and Song of Freedom. The true authorship of the work is a matter of debate, with a number of elements in the writing suggesting either the text has been substantially changed over time or Yongjia Xuanjue was an unlikely author [22]. The first commentaries appeared in the 11th century during the Song (宋) dynasty (960–1279). This work has remained popular through the centuries and is still often memorized in Zen practice [23].

It is written in combinations of three-character and seven-character sentences. Full text in Chinese [20] and various versions of English translations are available [21–23]. There are 105 three-character sentences and 214 seven-character sentences. Total number of sentences is 319. It consists of 1813 ( $105 \times 3 + 214 \times 7 = 1813$ ) Chinese characters.

## 2.2. The Four Versions of The Song of Enlightenment (南明泉和尚頌證道歌)

There are four nearly identical old books of *Nammyeong Cheon hwasangsong jeungdoga* (南明泉和尚頌證道歌, Song of Enlightenment with Commentaries by Buddhist Monk Nammyeong) in Korea. As the title of the book implied, a Buddhist Monk Nammyeong added comments and remarks to the original 319 sentences. There is a preface by a Buddhist Monk Wú yōng (吳庸) Tiān yòng (天用) dated July 1077 from Kuò cāng (括蒼) in Zhejiang Province (浙江省) in China in front of the main text by the main author Fǎ quán (法泉), a postscript dated 10 July 1076 and a postscript by a Buddhist Monk Zhù kuàng (祝況) in Kuò cāng (括蒼) in Zhejiang Province (浙江省) in China. At the very end, there is one more post script in smaller characters describing reasons for printing the book dated beginning of September 1239 by Jinyang-gong (晉陽公) Choi Yi (崔怡), a powerful ruler of the Goryeo (高麗) dynasty in Korea. According to his statement, the book has been an essential textbook for Zen practice, but it is no longer available. Thus, he recruited workers for casting movable metal type fonts to make the book available for a long time. His statement was written in Chinese as shown below.

夫南明證道歌者 實禪門之樞要也 故後學參禪之流 莫不由斯而入升堂觀娛矣  
然則 其可 閉塞 而不傳通呼 於是募工 重彫鑄字本 以壽其傳焉  
時己亥九月上旬 中書令晉陽公 崔 怡 謹誌

Since Chinese was not his native language, some expressions may not be perfect or natural as a native Chinese could have written 782 years ago, in 1239. The translation of his statement, in particular one Chinese character 彫 which means carving or engraving, became the center of debate. The translation result may also be interpreted as recruiting woodblock workers to re-engrave using an existing print by movable metal type.

Many Korean historians first saw a version (the Samseong version (三省本)) with characteristics of woodblock print and interpreted 重彫鑄字本 as the proof of the re-engraved replica of movable metal type version. Later, three other versions, with the identical content (including the Choi Yi's post script) and format, with different printing and paper quality were discovered, over an approximately 50-year period. The author reinterpreted the phrase (重彫鑄字本) as the re-engraving of molds for metal type cast after finding characteristics of movable metal type printing from one of four versions, the Gongin version (空印本).

The book consists of 44 folding leaves, 88 pages. The last page was left blank. Two pages were printed on one side of the sheet and folded. The part folded inward is blank and the part folded outward is the printed side. Then, the folded sheets were bound together. All pages except for page 78 have 8 vertical lines. Page 78 has only 7 vertical lines. Each vertical line has 15 characters. Some vertical lines rarely have 14 or 16 characters.

Details of characteristics of all four versions are summarized in Table 1. Two books of the Samseong version (三省本) and Gongin version (空印本) were designated as Korean Treasure No. 758-1 and No. 758-2 on 30 May 1984 and 29 June 2012, respectively [15,16]. The official name for the designated versions are; Nammyeong Cheon hwasangsong jeungdoga (南明泉和尚頌證道歌, Song of Enlightenment with Commentaries by Buddhist Monk Nammyeong Cheon) 1984 and 2012. Figure 1 shows the cover images and their physical dimensions. Even though the size of the books are different, printed images look almost identical in size, by visual inspection, with respect to content, arrangement of characters and style of characters. The other two versions, Daegu version (大邱本) and Banyasa Temple version (般若寺本) under consideration for designation as Korean cultural properties are also different in physical dimension and appearance.

**Table 1.** Characteristics of four different versions of the Song of Enlightenment (南明泉和頌證道歌, Song of Enlightenment with Commentaries by Buddhist Monk Nammyeong Cheon).

Version Symbol	Formal Name	Korean Treasure Status	Remarks
A	Samseong Version (三省本)	Designated on 30 May 1984	Initially recognized as a printed book from woodblock re-engraved from movable metal type between 13th~14th century in Goryeo dynasty. During the Cultural Heritage Designation Examination of the Daegu version, the printing date has been restated as 1472 or later. No old Hangeul characters found in the text. Recognized as a replica version of the Samsung version printed much later in the Goryeo dynasty (14th~15th century) using the identical woodblocks. Later, the printing date has been restated as significantly after 1472, the printing date of the Daegu version.
B	Gongin Version (空印本)	Designated on 29 June 2012	There have been debates on the possibility of movable metal type printing in 1239, the Goryeo dynasty, since 1970s. Many old Gugyeol (口訣) <sup>1</sup> symbols were hand written in the main text. No old Hangeul characters found in the text. The lightest ink color among all versions. During the designation process, it was revealed that the prayer or epilog (跋文), written by Kim Su-on (金守溫) and dated as June 1472, was removed.
C	Daegu Version (大邱本)	Application denied in 2017 due to intentional removal of pages	The factual printing date of June 1472 can be used to date all other versions. Many Gugyeol (口訣) symbols and old Hangeul (Korean Characters invented and promulgated in September 1446) were hand written in the main text. The first leaf (page 1 and 2) is missing. All pages are darkened by oxidation and aging.
D	Banyasa Temple Version (般若寺本)	Application in progress	The contents are exactly the same as other versions. Similar to the Gongin version, many old Gugyeol symbols were hand written in the main text. No old Hangeul characters found in the text.

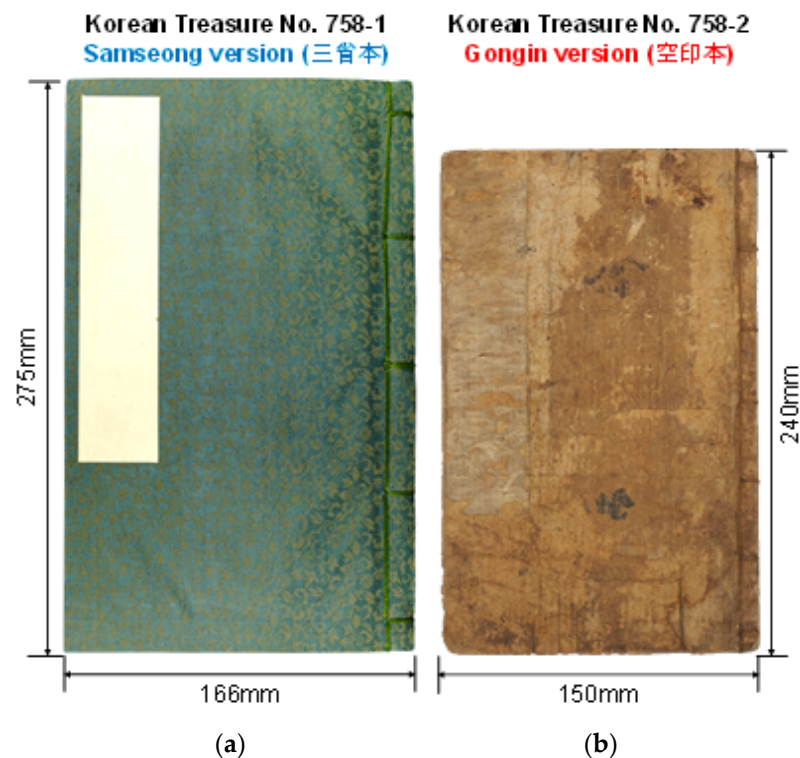
<sup>1</sup> Gugyeol (口訣) symbols: graphical system dating from the time of Silla (新羅, BC 57–AD 935) used until the 19th century, consisting of borrowing the sounds of Chinese characters to transcribe grammatical morphemes.

To avoid the use of repeated descriptions of the long book title, the version name such as A: Samseong version (三省本), B: Gongin version (空印本), C: Daegu version (大邱本) and D: Banyasa Temple version (般若寺本) will be used afterwards.

### 2.3. The Controversy over the Four Versions of The Song of Enlightenment

There has been heated debate on the printing methods and printing dates of the two Korean Treasures, Samseong version (三省本) and Gongin version (空印本), since the discovery of the Gongin version (空印本) by former owner and collector, Park, in 1969 [10]. Park insisted that his version, the Gongin version (空印本), is the original printed version using movable metal type in 1239, as described in the postscript by Choi Yi (崔怡). It was even before the *Jikji*, the UNESCO Memory of the World, was recognized as the oldest extant metal movable type printed book. Many renowned Korean bibliographers have opposed Park's claim. This was partially because the Samseong version (三省本) was familiar to them and it was determined to be a woodblock printed version from the previously available movable metal type printed version as described in the postscript by Choi Yi. The Samseong version (三省本) clearly shows characteristics of woodblock printing such as woodblock texture, missing strokes due to the partial break off from

engraved characters on the woodblock, probable engravers' names appearing on each folding leaf, and so on.



**Figure 1.** The Korean Treasure No. 758-1 and No. 758-2, The Song of Enlightenment (南明泉和頌證道歌). (a) Samseong version (三省本) and (b) Gongin version (空印本).

When they inspected the Gongin version (空印本) with the knowledge of the Samseong version (三省本), they instantly thought that it was the much later version printed using the same woodblocks, because the quality of paper and printing was much worse than what they already knew. If the Gongin version (空印本) were introduced first, without exposure to the Samseong version (三省本), their impression and conclusion might have been different. They were unknowingly biased at the time of judgment. Once the judgment has been made, it is difficult to overturn without new convincing evidence. Fortunately, we have found two more almost identical books in recent years. By inspecting all four versions very closely, we should be able to gain more insights into the printing method, printing data and role of persons whose names were engraved in each leaf. Instead of visual inspection and form, very subjective opinions, image comparisons using image processing/analysis software were used to highlight differences between four versions and make objective decisions with convincing evidence.

There are three major controversies regarding the two Korean Treasures.

- Printing method;
- Printing date or order;
- Roles of people whose names were engraved.

#### 2.4. Image Comparisons Using Image Analysis Software (PicMan)

Image comparison and analysis of all four versions were carried out page-by-page and character-by-character using image analysis software (PicMan from WaferMasters, Inc., Dublin, CA, USA). PicMan software has been developed and used for automatic analysis of digital images in semiconductor, materials science, nanotechnology, food industry, biology and medical image analysis, including colorimetric applications [14,24–28]. The key differentiation factor of PicMan from other commercial image manipulation or editing

software is the ability to perform quantitative analysis and to export analysis data in image formats as well as the numerical format in CSV (comma separate values) so that the exported data can be used as source data for further numerical analyses. By quantifying characteristics of image data in many different formats, subjectivity and person-to-person error can be eliminated.

New applications in conservation and restoration of cultural heritages, paper foxing, color analysis, image comparison and damage mapping examples on painting cultural heritages have been reported in recent years [14,24–28]. For this study, several new functions such as image overlap, image subtraction, image division, outline generation, transparency and coloring selected areas, were added for ease of use and numerous image comparisons and analyses.

### 3. Results

The image comparisons were carried out page-by-page and character-by-character for all versions. The similarities and differences were examined and characteristics of each version were summarized to answer the following three questions:

- Are all versions printed from identical woodblocks?
- What is the likely sequence of printing?
- What is the role of the name of individuals in each page?

By answering these three questions, the long debates over the controversy can finally be ended. Convincing evidence is required to acquire consensus on this age-long, heated and open question on the Song of Enlightenment.

#### 3.1. Page-by-Page Image Comparisons

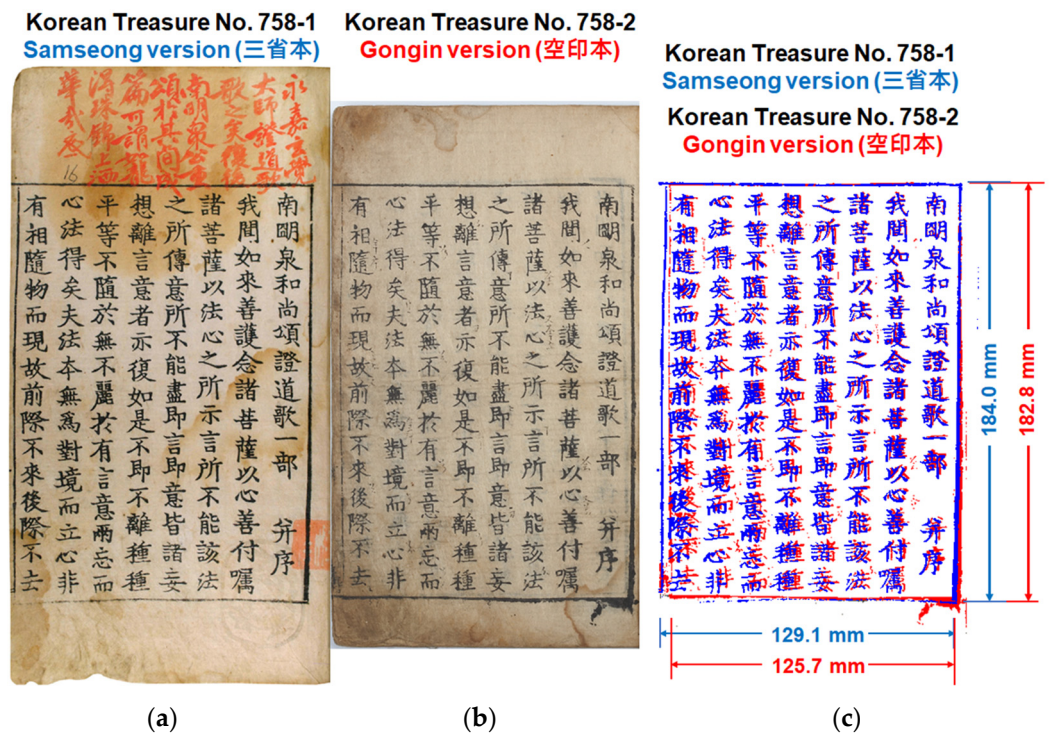
##### 3.1.1. Two Korean Treasures: Samseong Version (三省本) and Gongin Version (空印本)

As a first step, the first page (page 1) and last printed page (page 87) images of the two Korean treasures of the Samseong version (三省本) and Gongin version (空印本) were selected for image comparisons. Since both books belong to two separate museums in Korea, physical side-by-side comparisons are very difficult to arrange. Instead, high resolution photographic images were compared. To match the scale, we have used the vertical dimension of the two versions as a reference.

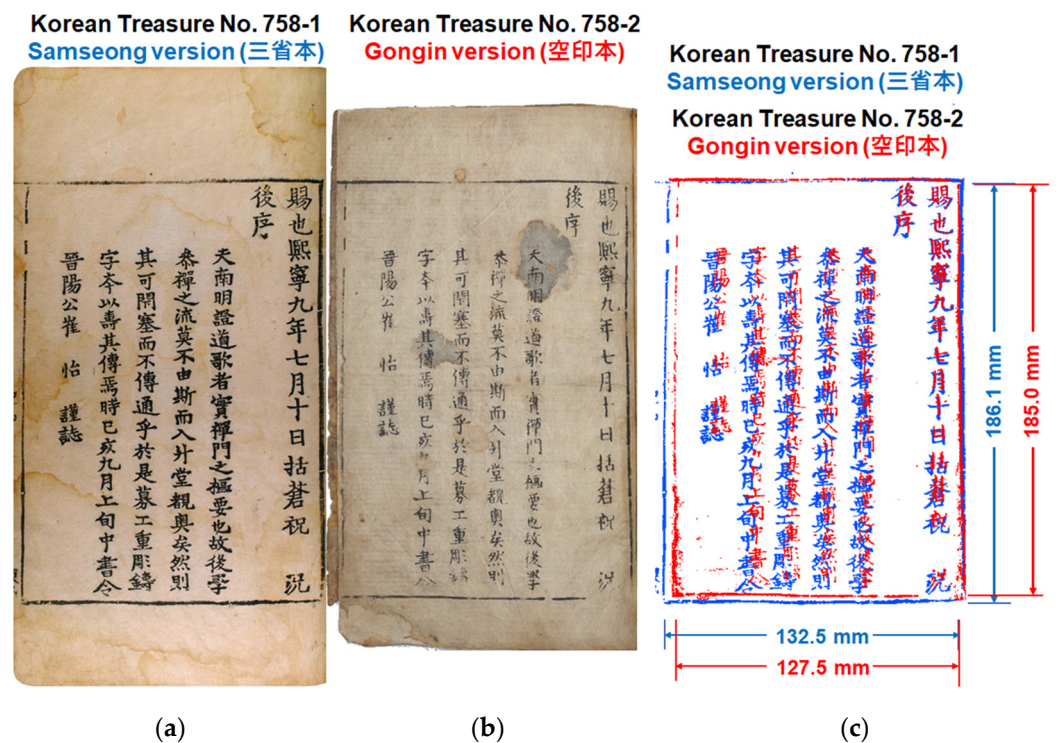
Figure 2 shows the first page images of (a) Samseong version (三省本), (b) Gongin version (空印本) and (c) superimposed images of colored characters and border lines with transparent background. To make easy comparisons, characters and border lines of the Samseong version (三省本) and Gongin version (空印本) were colored blue and red, respectively. As seen from Figure 2c, the Samseong version (三省本) was slightly wider than the Gongin version (空印本) while the vertical dimension was almost the same. The Samseong version (三省本) was found to be approximately 1.5% taller and 3.0% wider than the Gongin version (空印本). Due to the difference in aspect ratio between two versions, characters do not overlap on top of each other. If we align with one border line or characters on any vertical line, the mismatch of character positions becomes larger as the distance from the reference point is longer.

On the other hand, it is understandable that many highly experienced historians formed strong opinion about the similarity between the two versions. Even if they were able to place two versions of the books side by side, it is almost impossible to tell the difference between them. The quality of paper and character printing of the Samseong version (三省本) looks much better. Once they are exposed to this version, prior to the Gongin version (空印本) with poor appearances, one would have been strongly influenced and naturally biased. These are very natural human psychological behaviors which no one can really be blamed for. It is especially true if one turns 88 pages over and over and witnesses the same matrices of characters in similar size.

The same comparison was carried out for the last printed page (page 87). Figure 3 shows the results. The Samseong version (三省本) was found to be approximately 1.7% taller and 5.2% wider than the Gongin version (空印本).



**Figure 2.** The images of the first page images of Korean Treasure No. 758-1 and No. 758-2, The Song of Enlightenment (南明泉和頌證道歌). (a) Samseong version (三省本), (b) Gonggin version (空印本) and (c) their superimposed images of extracted characters in different colors.

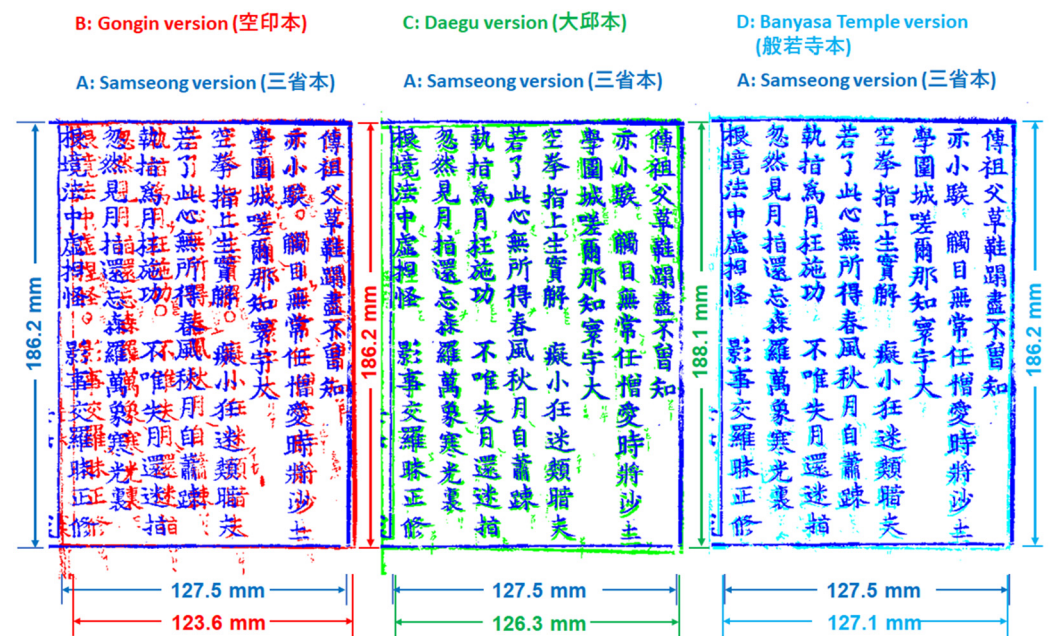


**Figure 3.** The images of the last printed page of Korean Treasure No. 758-1 and No. 758-2, The Song of Enlightenment (南明泉和頌證道歌) containing the postscript of Jinyang-gong Choi Yi (崔怡), a powerful ruler of the Goryeo dynasty, dating back to September 1239. (a) Samseong version (三省本), (b) Gonggin version (空印本) and (c) their superimposed images of extracted characters in different colors.

This page-by-page image comparison clearly answered the first question. At least, the Samseong version (三省本) and Gongin version (空印本) cannot be printed from the same woodblocks. In our experimental study of woodblock printing on traditional Korean paper (*Hanji*) only a fraction of one percent in dimensional variations is observed [24,25]. In the experiment, two operators printed five sheets of paper using the same woodblock. It is not possible to change the aspect ratio by printing using the same woodblock.

### 3.1.2. All Four Versions

A series of image comparisons of all four versions of page 71 were performed after displaying printed characters in different colors and making backgrounds transparent. Figure 4 shows the superimposed images of the series of image comparisons. All images were compared against blue colored images from A: Samseong version (三省本). Printed characters of A: Samseong version (三省本), B: Gongin version (空印本), C: Daegu version (大邱本) and D: Banyasa Temple version (般若寺本), were colored in red, blue, green and sky blue, respectively.



**Figure 4.** Comparisons of superimposed printed image of the page 71 to determine similarities and differences among different versions towards estimation of printing techniques, printing sequence and their characteristics of re-engraving craftsmanship. (A: Samseong version (三省本), B: Gongin version (空印本), C: Daegu version (大邱本) and D: Banyasa Temple version (般若寺本)).

As expected from the results shown in Figures 2 and 3, blue colored characters from A: Samseong version (三省本) do not overlap with the red colored characters from B: Gongin version (空印本) due to the aspect ratio difference. The Samseong version (三省本) turned out to be approximately 0.4% shorter and 3.3% wider.

The blue colored image from A: Samseong version (三省本) and green colored image of C: Daegu version (大邱本), were almost matched within printing variations from the same woodblocks. The blue colored image from A: Samseong version (三省本) and sky-blue colored image of D: Banyasa Temple version (般若寺本), were also almost matched within printing variations from the same woodblocks.

These super imposed image comparison results clearly demonstrate that the B: Gongin version (空印本) is significantly different from the other three versions implying that it is from a different printing block whether it is movable metal type or woodblock. In addition to the B: Gongin version (空印本), all three versions of A: Samseong version (三省本), C: Daegu version (大邱本) and D: Banyasa Temple version (般若寺本) have been

printed from the identical woodblock. This result further supports the answers to the first question that the B: Gongin version (空印本) has been printed from different printing blocks. The width of the B: Gongin version (空印本) is 3.3 to 3.9 mm (or 2.18% to 3.2%) narrower than other three versions. It is very hard to imagine that the dry paper is able to stretch or shrink in one direction during or after printing. During the printing process, ink on embossed surface of movable metal type blocks or woodblocks are transferred to the printing paper. The printing paper never becomes totally wet during the printing process after traditional Korean paper (*Hanji*) is prepared. In the author's previous experimental studies on woodblock printing using a woodblock, with a border size of 337.5 mm in the horizontal direction and 197.6 mm in the vertical direction, only showed 2.4 mm (or 0.7%) variations only in the horizontal direction among ten prints by two operators [25].

However, small imperfections such as breaks in the borders were often repeated across the pages of all versions. This leads historians to believe all four versions were printed using the same woodblocks. Figure 5 shows small cuts at the top right corner and breaks at the bottom right corner of border lines suggesting at least two versions (C: Daegu version (大邱本) and A: Samseong version (三省本)) were printed using the same woodblock. To verify the possibility of differences in printing techniques used for all versions, other evidence is necessary.

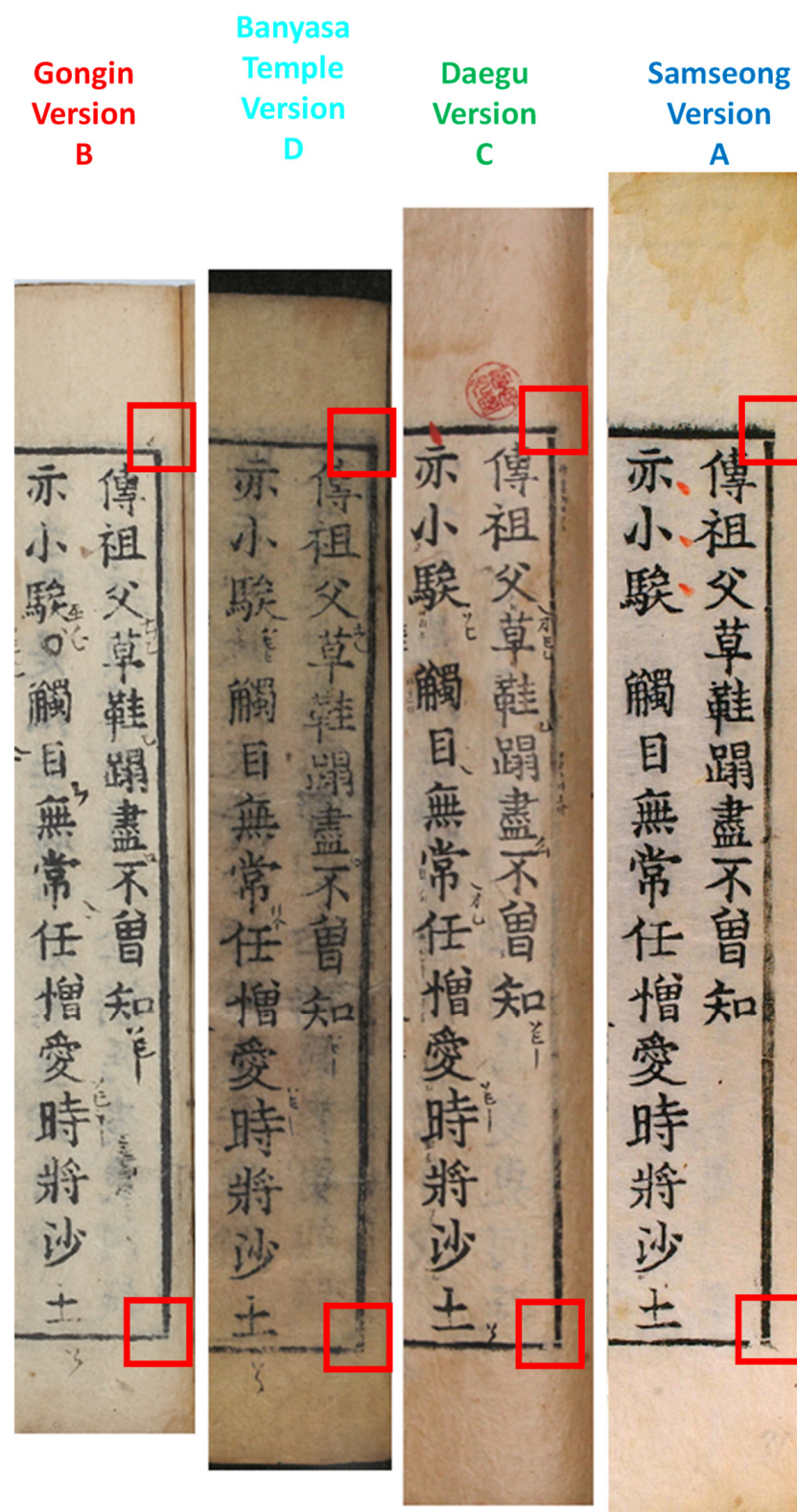
It is time to find answers to the second question by comparing images of individual characters at the same position on the same pages for all four versions.

### 3.2. Character-by-Character Image Comparison for Printing Sequence Determination

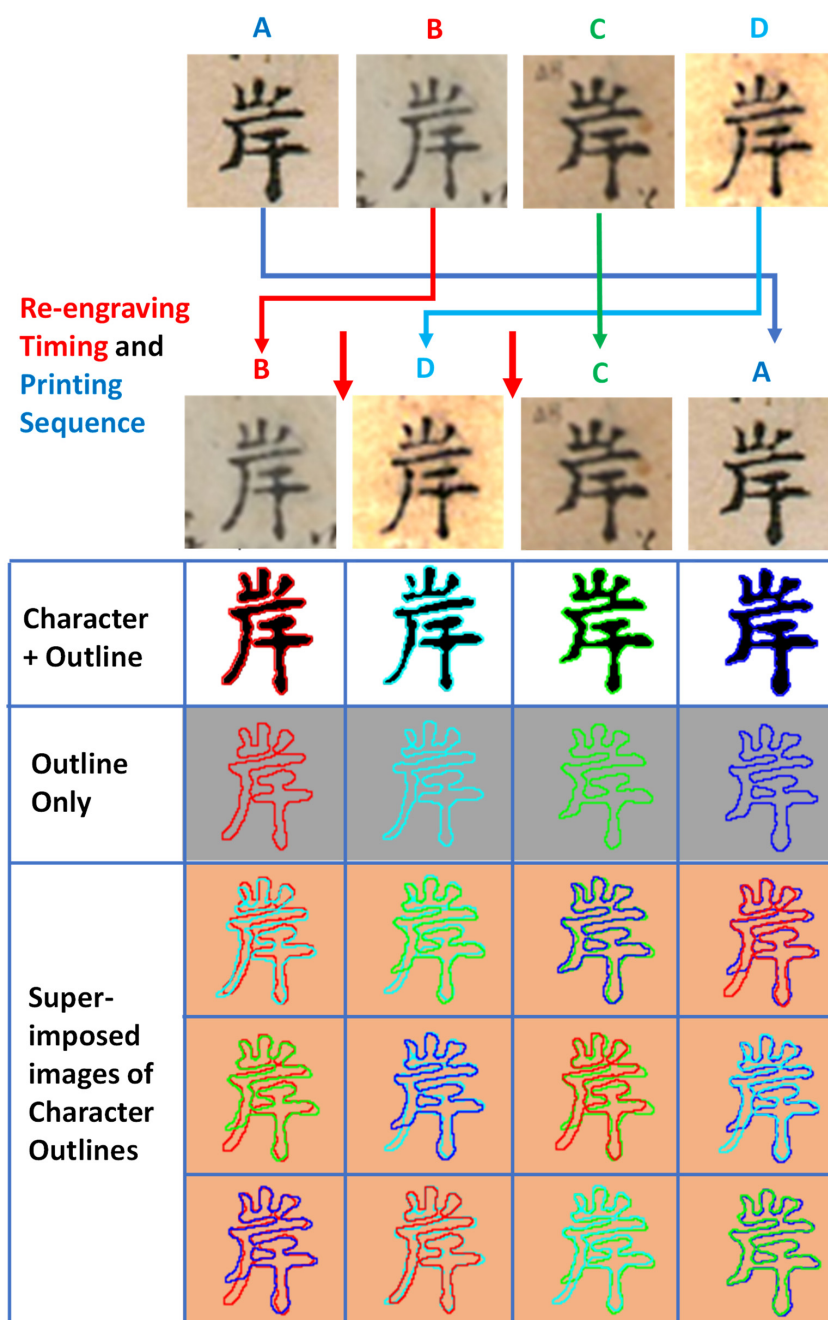
To determine the printing sequence among four different versions, images of individual characters at the same location, on the same page have to be compared. In the case of woodblocks, the condition of woodblock degrades with time, usage, and storing environment. By comparing high resolution images of printed individual characters, the condition of woodblocks at the time of printing can be estimated. Imperfect printed characters and variations in the shape of characters between versions can provide good sources of information.

In the author's previous study, a few characters with significant differences between A: Samseong version (三省本) and B: Gongin version (空印本) were reported and used as evidence for the usage of different printing blocks [13,14]. Since images of all four versions are available, images of those characters in all versions are compared. In addition, images of additional characters at random positions and characters in the same vertical line (even with significant differences) are compared among the four versions.

Figure 6 shows one of the specific characters reported in the previous study “岸” meaning shore, which appeared on page 25 of all four versions. The first row of the “岸” character images are shown in alphabetical order. Based on the author's previous study [13,14] and width difference between versions shown in Figure 4, the B: Gongin version (空印本) is significantly different from other versions. Let's hypothesize that, all other versions, except for the B: Gongin version (空印本), were presumably printed using the same woodblock. To see if this hypothesis can stand, the “岸” character from B: Gongin version (空印本) was separated from others and the order of the other three versions rearranged based on the natural flow of woodblock deterioration and re-engraving (making replicated woodblocks). The word “re-engraving” in this paper stands for “making replicated woodblock”. Woodblock printing tends to make characters thicker by repeated usage and loses strokes due to partial break off of engraved characters by wear and tear. Replacing the damaged woodblocks with new ones also makes strokes simpler. The length and angle of a stroke towards the bottom left differs between versions. This cannot be explained by normal woodblock wear or damage. Based on these differences, the other three “岸” characters from different versions are rearranged in the order of D: Banyasa Temple version (般若寺本), C: Daegu version (大邱本) and A: Samseong version (三省本) as seen in the second row.



**Figure 5.** Comparisons of printed image of page 71 to determine similarities and differences in border lines among different versions for estimation of printing techniques, printing sequence and their characteristics of re-engraving techniques. ((A): Samseong version (三省本), (B): Gongin version (空印本), (C): Daegu version (大邱本) and (D): Banyasa Temple version (般若寺本)).

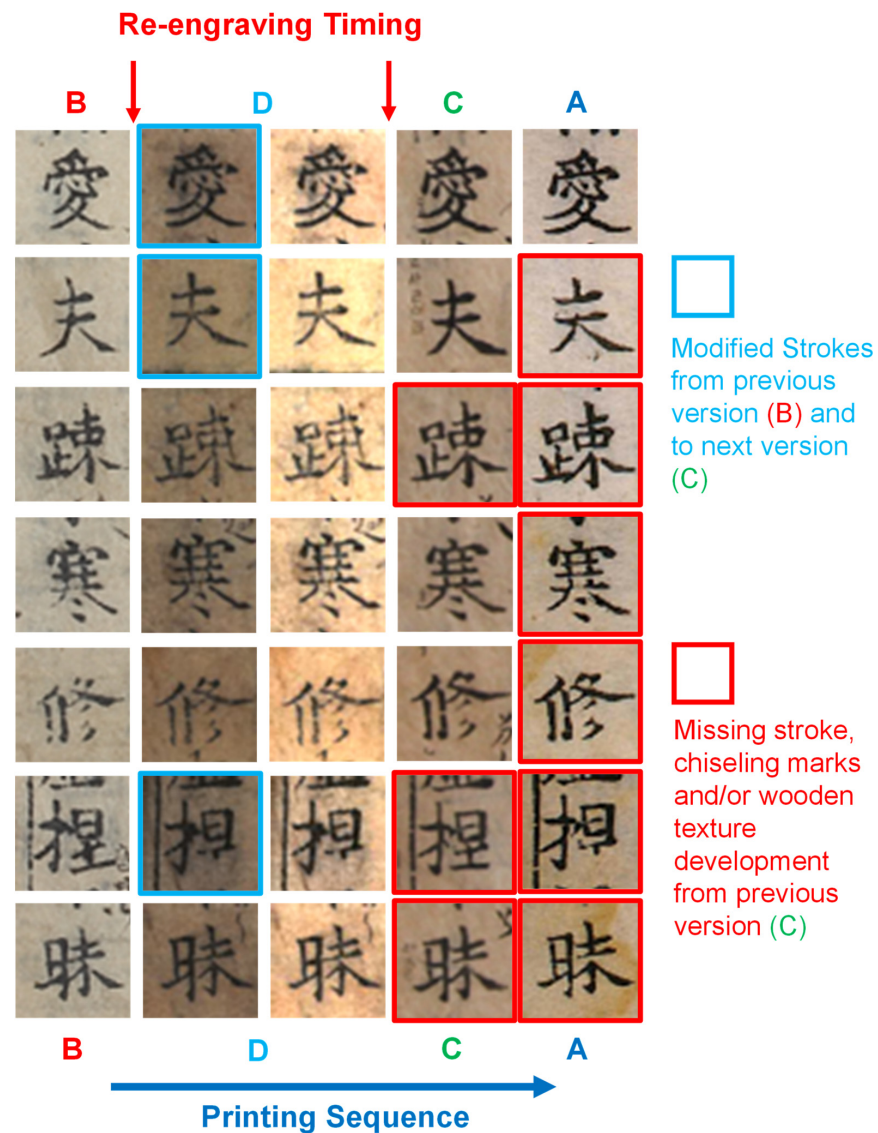


**Figure 6.** Estimated printing sequence and timing of woodblock re-engraving based on comparisons of printed image of the same character (岸) at the same location on page 25 and their characteristics of re-engraving craftsmanship. (A: Samseong version (三省本), B: Gongin version (空印本), C: Daegu version (大邱本) and D: Banyasa Temple version (般若寺本)).

It is interesting to see the “岸” character from the D: Banyasa Temple version (般若寺本) resembles the B: Gongin version (空印本) more closely than others. To find out whether a partial break off of stroke in the “岸” character from the D: Banyasa Temple version (般若寺本) overlaps with the “岸” characters from both the C: Daegu version (大邱本) and A: Samseong version (三省本), outlines of each “岸” characters in different colors were superimposed. Only two “岸” characters from the C: Daegu version (大邱本) and A: Samseong version (三省本) overlapped. Since the “岸” characters from A: Samseong version (三省本) is thicker, it must be the version printed using woodblock for C: Daegu version (大邱本). Thus, the woodblock was at least re-engraved (replaced) twice as indicated by

the red arrow between the “岸” characters. The printing sequence seemed to be B → D → C → A.

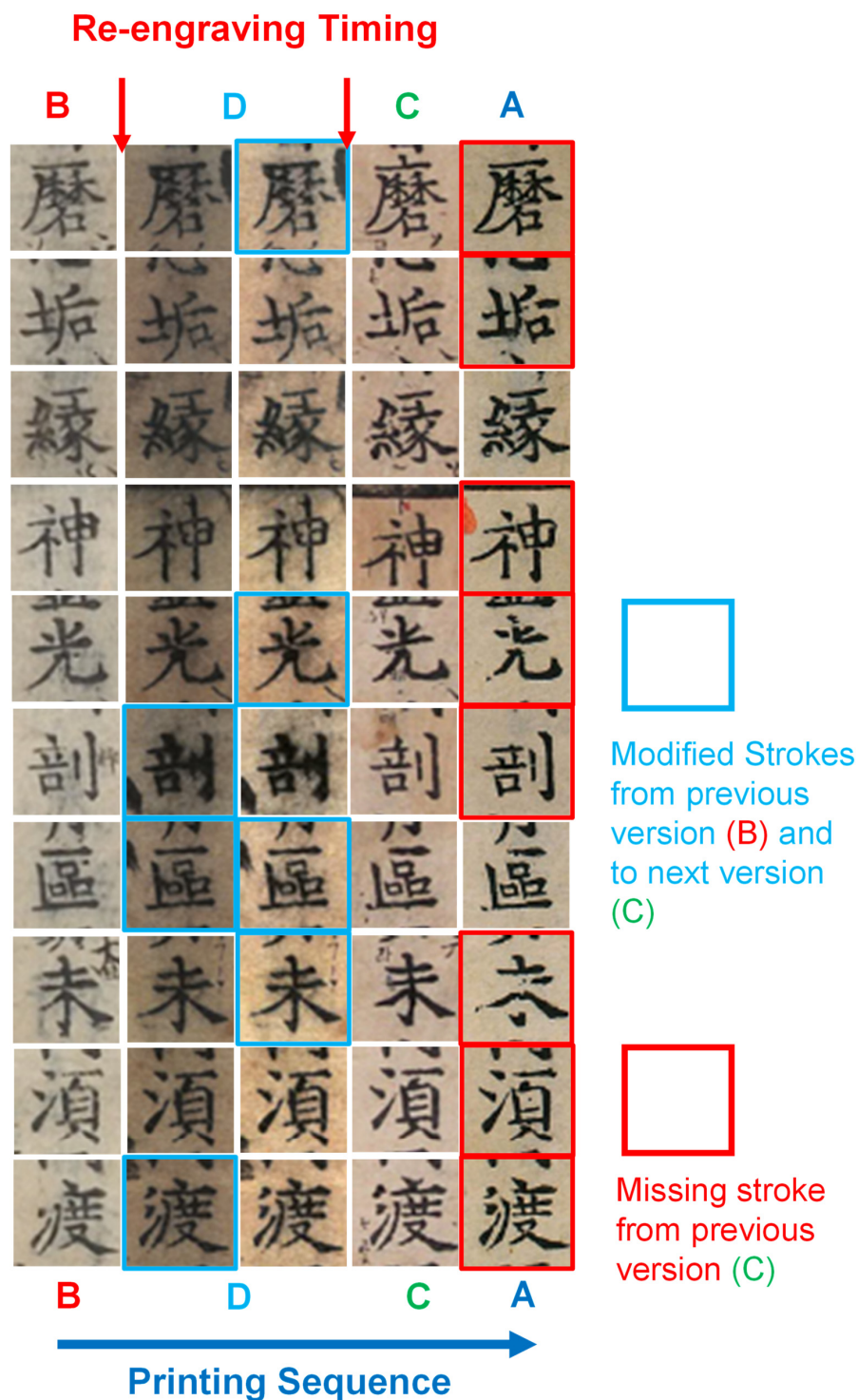
Figure 7 shows seven selected characters from various locations on page 25 from all the versions showing modified strokes during re-engraving, missing strokes, chiseling marks and/or wooden texture development by re-engraving and usage. For the characters from the D: Banyasa Temple version (般若寺本), contrast adjusted images are shown next to the original image for easy recognition of printed characters. The derived outcome of re-engraving timing of the woodblock and printing sequence remained the same as previously determined sequences.



**Figure 7.** Estimated printing sequence and timing of woodblock re-engraving based on comparisons of printed image of the same seven characters at the same location on page 25 and their characteristics of re-engraving craftsmanship of each version: (A: Samseong version (三省本), B: Gongin version (空印本), C: Daegu version (大邱本) and D: Banyasa Temple version (般若寺本)).

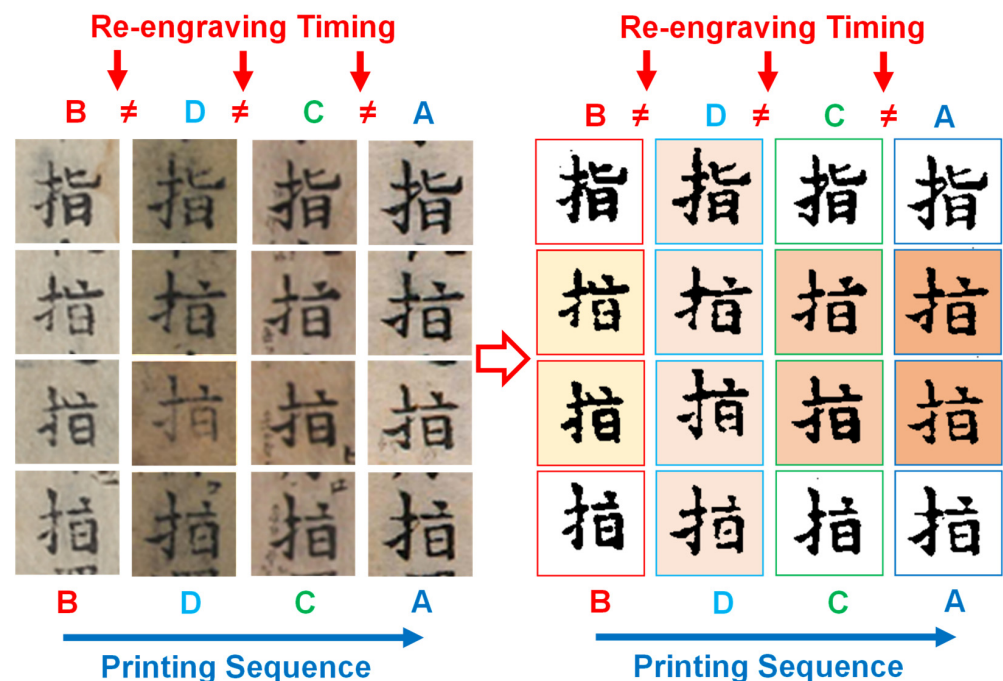
For further verification, all characters on all pages of different versions were compared and many traces of modifications between versions were found. As examples, ten selected characters from various locations on page 10 from all the versions showing modified strokes during re-engraving, missing strokes, chiseling marks and/or wooden texture development by re-engraving and usage. Figure 8 shows the summary of the images. The

contrast of character images from D: the Banyasa Temple version (般若寺本) were adjusted and shown next to the original image for easier comparisons. The re-engraving timing of the woodblock and printing sequence also support the previously determined sequence.



**Figure 8.** Estimated printing sequence and timing of woodblock re-engraving based on comparisons of printed image of the same ten characters at the same location on page 10 and their craftsmanship characteristics of re-engraving. (A: Samseong version (三省本), B: Gongin version (空印本), C: Daegu version (大邱本) and D: Banyasa Temple version (般若寺本)).

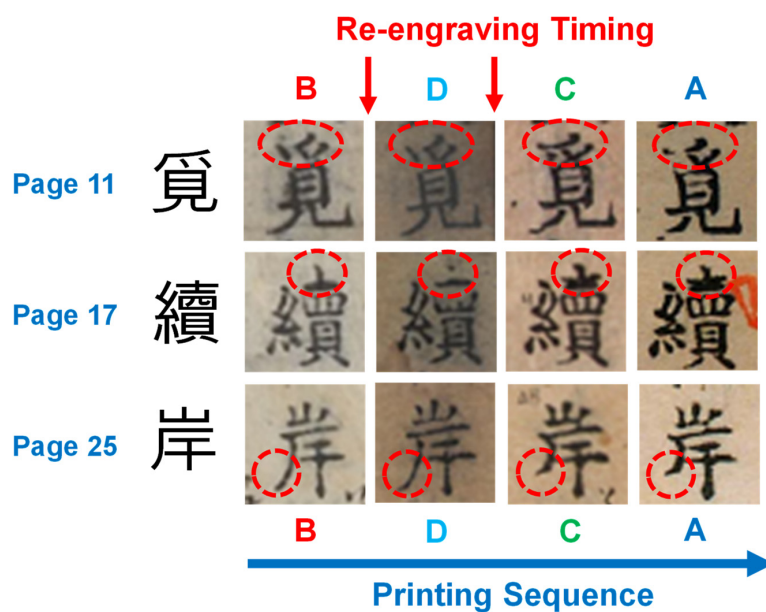
Figure 9 shows four sets of the character “指”, meaning “finger” or “refer to” on page 72 as significant evidence for stroke simplification during re-engraving a new woodblock. The two “指” characters in the second and the third row in the left column for the B: Gongin version (空印本) were simplified during re-engraving the woodblock for D: Banyasa Temple version (般若寺本). For page 72, two out of four 指 characters showed completely different strokes. For the second and third 指 characters from the top, the top portion of the right-side strokes, 乚 became simplified to 一 during the first re-engraving. The simplified characters were copied exactly during subsequent re-engraving between prints. This suggests that the printing blocks for page 72 of all versions were different. It also suggests that the printing blocks for page 72 of all versions were different. The printing sequence remained the previously derived order of B → D → C → A.



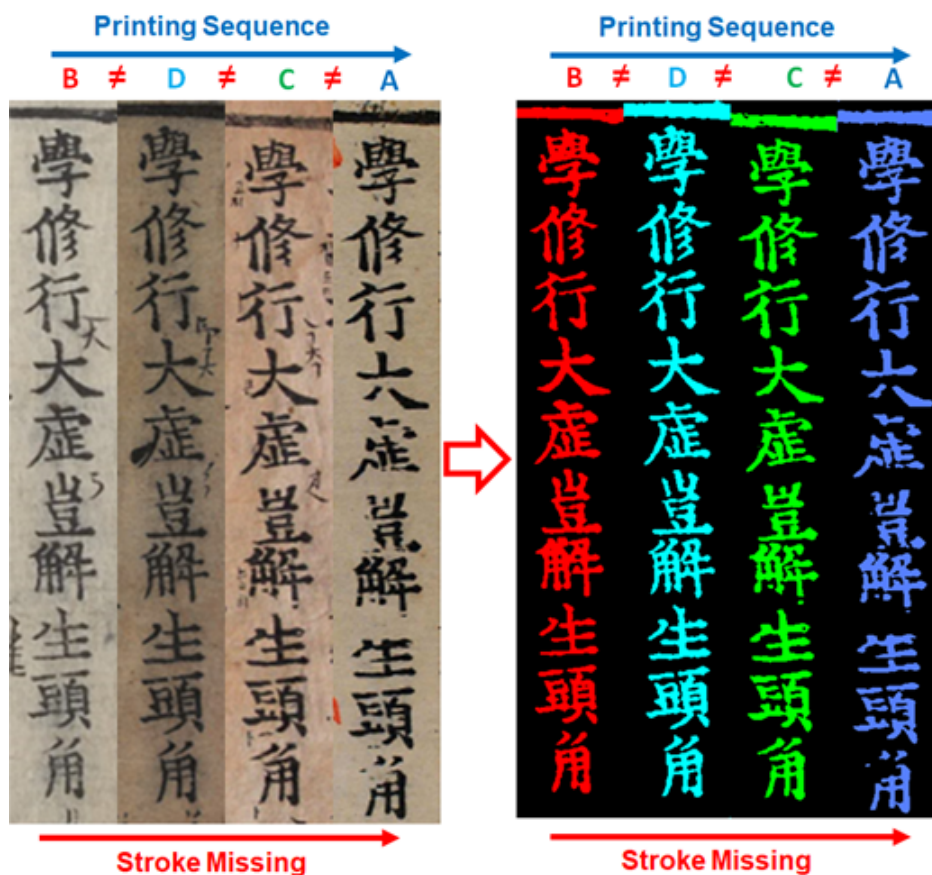
**Figure 9.** Estimated printing sequence and timing of woodblock re-engraving based on comparisons of printed image of the same four characters (指) at the same location on page 72 and their craftsmanship characteristics of re-engraving. (A: Samseong version (三省本), B: Gongin version (空印本), C: Daegu version (大邱本) and D: Banyasa Temple version (般若寺本)).

During re-engraving of Buddhist scriptures, it was a very normal practice to duplicate everything exactly, including errors and defects. The breaks in the borders in the original manuscript were also duplicated during re-engraving. Figure 10 shows a few examples of exact duplication and correction during re-engraving steps. Printing sequence and timing of woodblock re-engraving can be found by observing obvious errors and corrections in different printed versions. Printed images of three characters (覓, 續, 岸) on pages 11, 17 and 25 were traced as examples. Shapes and errors of characters have been changed and/or corrected between versions.

Figure 11 shows characters on the same vertical line on page 12 of all versions. It clearly shows that the shapes of printed characters are all different. The woodblock for the D: Banyasa Temple version (般若寺本), C: Daegu version (大邱本) and A: Samseong version (三省本) seemed to be the same. However, the frequency of missing strokes increases in the order of D → C → A due to the partial breaking off of engraved characters on the woodblock.



**Figure 10.** Estimated printing sequence and timing of woodblock re-engraving based on comparisons of printed images of the three characters (覓, 續, 岸) on pages 11, 17 and 25. (A: Sam-seong version (三省本), B: Gongin version (空印本), C: Daegu version (大邱本) and D: Banyasa Temple version (般若寺本)).



**Figure 11.** Estimated printing sequence based on image comparisons for missing strokes due to the woodblock damage of characters on the same vertical line on page 12. (A: Samseong version (三省本), B: Gongin version (空印本), C: Daegu version (大邱本) and D: Banyasa Temple version (般若寺本)).

The B: Gongin version (空印本) was different from other versions. This was confirmed by page-by-page image comparisons as shown in Figures 2–4. At least five woodblocks for the three versions (A: Samseong version (三省本), C: Daegu version (大邱本) and D: Banyasa Temple version (般若寺本)) may have been re-engraved between versions, as we saw from Figures 6–10. In the case of page 12, the same woodblock was used for printing three versions other than the B: Gongin version (空印本), as seen in Figure 11. This means that the woodblocks are often re-engraved to maintain the printing quality. Some woodblocks may have survived for a long period. The re-engraving of woodblock for page 12 was about to occur after printing the A: Samseong version (三省本), judging from the quality of printed characters.

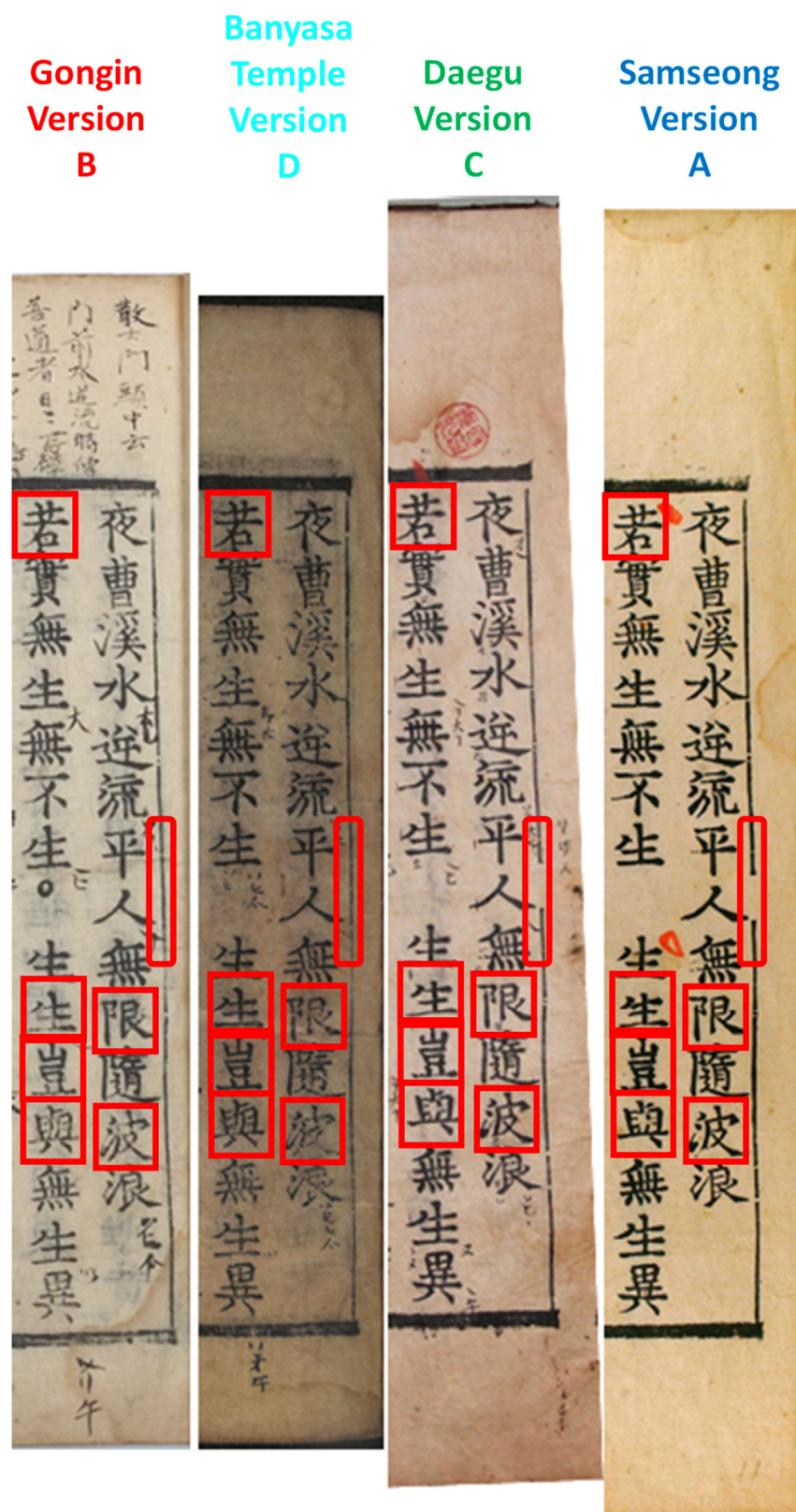
### 3.3. Image Comparisons of Border Lines and Page Width

To look for other evidence, shapes of printed border lines and page widths of all pages were compared. Figure 12 shows the images of the right-side border line on page 11. The B: Gongin version (空印本) and the D: Banyasa Temple version (般若寺本) show the solid lines while the C: Daegu version (大邱本) and the A: Samseong version (三省本) show the broken lines near the center of the vertical border line. The C: Daegu version (大邱本) and the A: Samseong version (三省本) shows missing strokes of characters, 若 and 與 while the other two versions show no missing strokes. The noticeable differences between versions were highlighted using red rectangles.

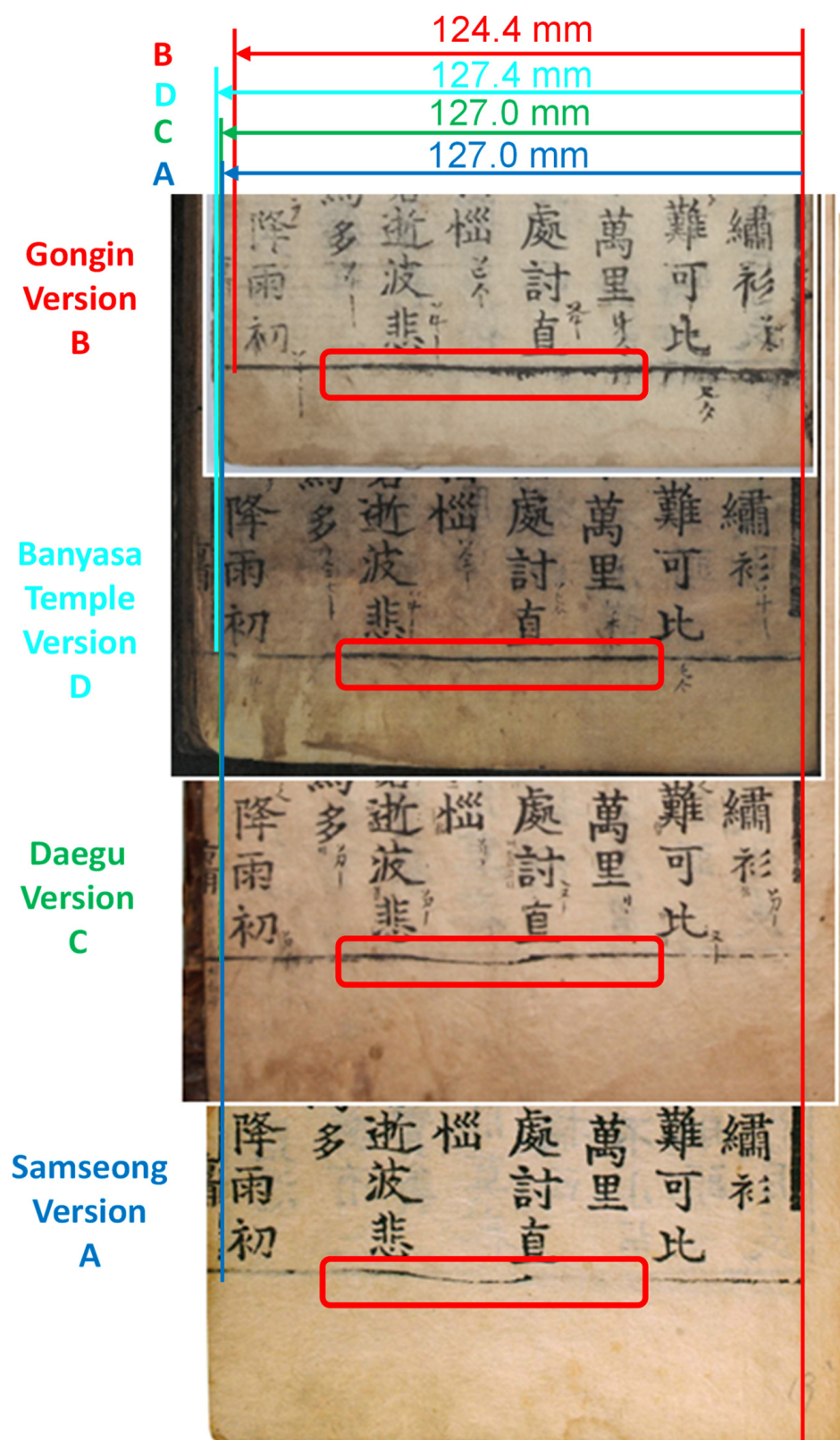
Figure 13 shows the images of the bottom border lines and page width of page 19. The shape difference in the bottom horizontal border line is highlighted using red rectangles. The B: Gongin version (空印本) shows the straight bottom border line and narrowest page width. The D: Banyasa Temple version (般若寺本) also show the straight bottom border line, but wider page width. The C: Daegu version (大邱本) and the A: Samseong version (三省本) show partially curved border lines and wider page width. The page widths of three versions other than the B: Gongin version (空印本) were almost identical. Few other pages also show similar evidence. The width between vertical border lines, for all four versions, were measured. The maximum difference was 3.0 mm between the B: Gongin version (空印本) and the D: Banyasa Temple version (般若寺本). The B: Gongin version (空印本) has the narrowest width.

Figure 14 shows the images of the bottom border lines and page widths of page 79. The A: Samseong version (三省本) only showed the straight border line. All other versions showed partially curved, border lines near the right broad line. The shape difference in the bottom border line is highlighted using red rectangles. It is very clear that the A: Samseong version (三省本) is a replicated or repaired woodblock. The width between vertical border lines for all four versions was measured and the maximum difference between the B: Gongin version (空印本) and the D: Banyasa Temple version (般若寺本) was measured to be 4.0 mm. The B: Gongin version (空印本) has the narrowest width of all. This also indicates the D: Banyasa Temple version (般若寺本) and the C: Daegu version (大邱本) were different from the B: Gongin version (空印本).

The publication in early Korea (Goryeo and early Joseon dynasty) are conducted by the government and private organizations, including Buddhist temples. The quantity of government publications was much greater than that from private organizations. Since books were published for public purposes and not for sales, the circulation of books was not as dynamic as in China or Japan. The main purpose of publication was to spread the country's ruling philosophy and Buddhist teachings. A limited number of published books were distributed only to a few top officials, nobles, local government officials and Buddhist monks. As a result, production and circulation were very limited.



**Figure 12.** Image comparisons for right-side vertical border lines and selected characters showing shape difference and missing strokes on page 11. ((A): Samseong version (三省本), (B): Gongin version (空印本), (C): Daegu version (大邱本) and (D): Banyasa Temple version (般若寺本)).



**Figure 13.** Image comparisons for bottom horizontal border lines and printed page widths on page 19. ((A): Samseong version (三省本), (B): Gongjin version (空印本), (C): Daegu version (大邱本) and (D): Banyasa Temple version (般若寺本)).



**Figure 14.** Image comparisons for bottom horizontal border lines and printed page widths on page 73. ((A): Samseong version (三省本), (B): Gongjin version (空印本), (C): Daegu version (大邱本) and (D): Banyasa Temple version (般若寺本)).

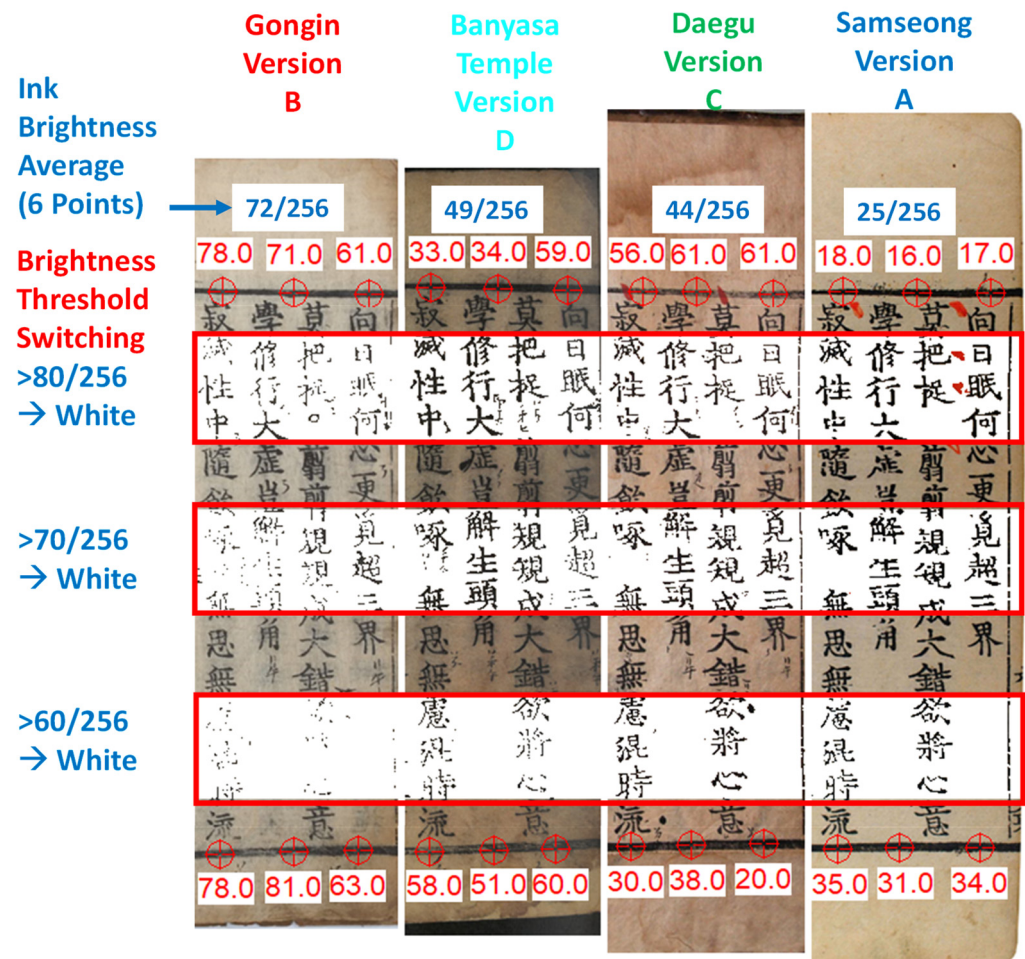
The two major publishing sources of early Korean prints are the government and private organizations. The quantity of government publications greatly outnumbers that of private ones. During the Joseon Dynasty, in particular, publications were initiated predominantly by the government. Books had different uses back then. They were not for sale; rather, they were the means of spreading the country's ruling philosophy. Published books, including archived editions, were distributed to only a few top officials and nobles, and as a result, production and circulation were bound to be limited. The government of Joseon, founded on Confucian ideology, regarded publishing books as an effective educational tool and utilized it vigorously. At the local government level, provincial officers at Yeong Yeong (嶺營, Gyeongsang Provincial Office), Wan Yeong (完營, Jeolla Provincial Office) and Gi Yeong (箕營, Pyeongan Provincial Office) took the leading role in publishing. Private entities such as Buddhist temples and schools, as well as families and individuals also published books. They often made woodblocks by engraving an upside-down copy of an original movable type print or woodblock print. In Korea, there is a large quantity of antique books printed by duplicated woodblocks due to the convenience of the method. This type of printed books is referred as beongakbon (飜刻本). Since previously existing books were used for re-engraving woodblocks by gluing the printed copies upside-down on individual woodblocks, new manuscripts were not necessary. During the re-engraving process, craftsmen tend to duplicate everything exactly, including defects in characters and border lines.

When a replicated woodblock is engraved from printed papers, the printed paper is flipped and pasted onto a woodblock. Then the outline is carved with a small knife. After the surrounding wood is removed with a chisel, the woodblock is finished. During the printed paper pasting process, glue is applied to the woodblock and the printed paper is placed on the woodblock. The printed paper is rubbed to remove any air pockets between the paper and wood. During this rubbing process, the paper tends to slightly expand in the rubbing directions. Since the woodblock dimension is larger in the horizontal direction (wider than the width of two printed pages), replicated woodblock can be wider if the printed paper was glued upside down on the woodblock and rubbed against the woodblock repeatedly, in the horizontal direction, to remove any air bubbles between the glued paper and the woodblock. This can make the glued paper stretch in the horizontal direction and result in width widening, as observed in this study. All woods shrink as the moisture content decreases below 25%. The tangential shrinkage along the age ring is the greatest (6~8% shrinkage). The radial shrinkage is about 3~4% and the lengthwise shrinkage along the growth direction is 0.3~0.4% [29,30]. The long side of the woodblock is typically aligned to the growth direction. Page width widening or shrinkage cannot be explained by the wood shrinkage due to the moisture content loss. Thus, the B: Gongin version (空印本) with the narrowest width is likely the original version. The differences in page width between the four versions strongly suggests that the D: Banyasa Temple version (般若寺本), the C: Daegu version (大邱本) and the A: Samseong version (三省本) are all printed using replicated woodblocks. Many other pages also show similar results. Thus, the B: Gongin version (空印本) can be distinguished as the unique and earliest version.

### 3.4. Darkness and Uniformity of Ink

To compare the darkness of ink on borderlines six points we measured on page 12 of all four versions (Figure 15). The RGB average value for brightness (inverse of darkness) were displayed in 8-bit ( $2^8 = 256$  levels) at each measuring points on the border lines in the figure. The average brightness of six measurement points was calculated and displayed as fractions in the figure. The denominator was fixed as 256 ( $=2^8$ ). The smaller the numerator, the darker the ink. The lightest ink was used in the B: Gongin version (空印本) and the darkest ink was used in the A: Samseong version (三省本). The RGB average brightness values of 80/256, 70/256 and 60/256 are set as threshold switching brightness levels. All pixels of three selected areas for all four versions highlighted by red rectangles were switched to white at 80/256, 70/256 and 60/256 to visualize the difference in darkness

and uniformity of ink, used for all versions. The B: Gongin version (空印本) showed the lightest and most non-uniform ink color. The darker parts of printed characters leave spotty ink marks at lower threshold values, while the other three versions still show printed characters in fairly uniform ink tones. It is clearly visualized that the ink used for the B: Gongin version (空印本) was the lightest and most non-uniform.



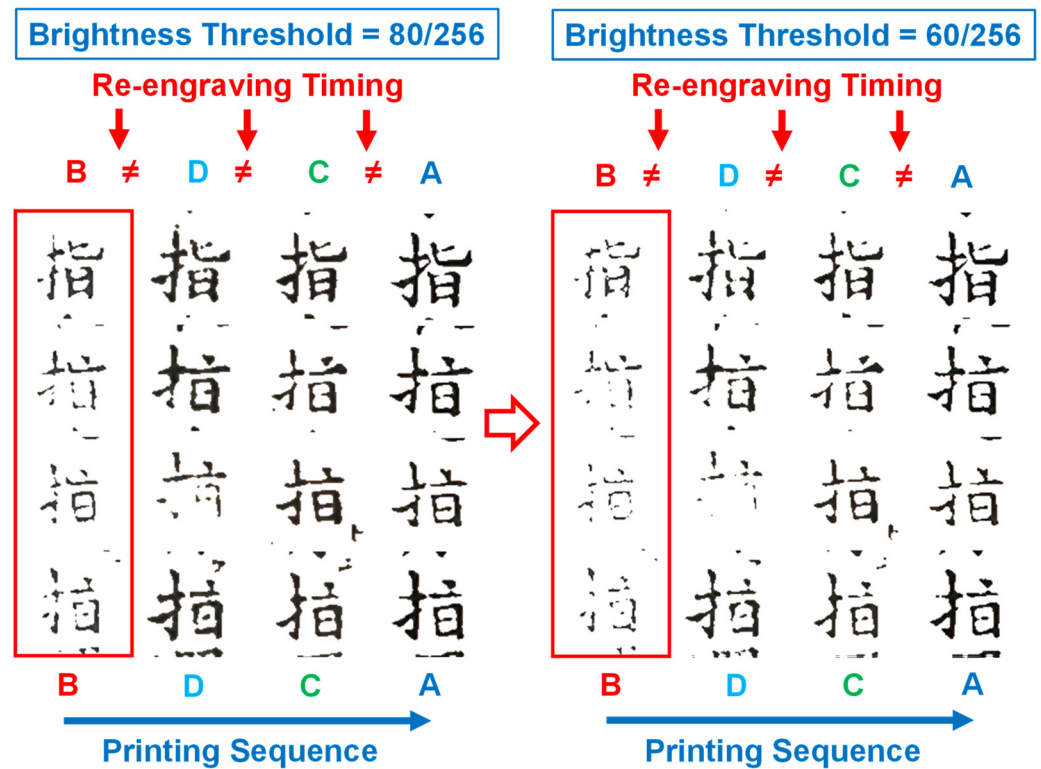
**Figure 15.** Darkness and non-uniformity comparisons of ink of the characters on the three left vertical lines on page 12, after brightness threshold switching at 80/256, 70/256 and 60/256. ((A): Samseong version (三省本), (B): Gongin version (空印本), (C): Daegu version (大邱本) and (D): Banyasa Temple version (般若寺本)).

The four 指characters on page 72 (Figure 9 left side) of all four versions were highlighted by saturating brightness higher than 80/256 and 60/256 (Figure 16). The darkness of ink color for the four 指characters of the B: Gongin version (空印本) was brighter and exhibited greater non-uniformity than all other versions. This strongly suggests that the usage of the rough surface of movable metal type and the special ink made of plant oil charcoal (Yuyeonmuk (油煙墨)) formulated for movable metal type exhibited poor wetting properties. The ink made of plant oil charcoal is less dark than the pine charcoal ink (Songyeonmuk (松煙墨)) used for woodblock printing.

### 3.5. Names Engraved in Woodblocks

It is time to give some thought to the third question, regarding the role of people whose names were engraved with the woodblocks, regardless of type of material, either metal or wood. Eleven names (得 (or 得仁), 東伯, 叔駘 (or 叔敦), 玠才, 唐甫, 公大, 吳準, 一明, 二世 (or 公世), 元暉, 思集 (or 思儒)) appeared in 44 folding leaves (88 pages). The

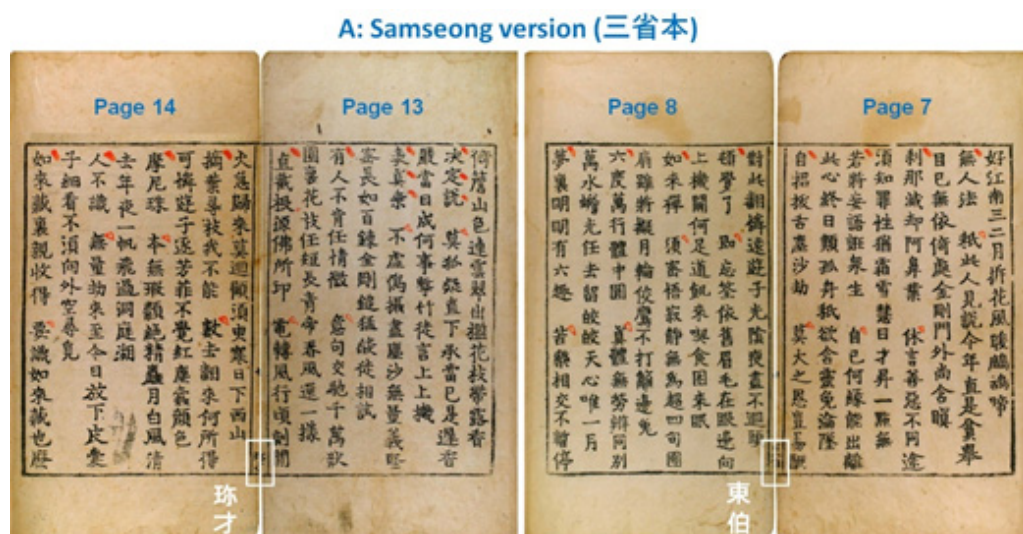
names were engraved at the bottom of the center where the sheets of papers were folded. Figure 17 shows examples of two names (琮才 and 東伯) of craftsmen from pages 8–9 and pages 13–14 of the A: Samseong version (三省本). Historians strongly believe that these names belong to the craftsmen who engraved the woodblock. This is one of the reasons why historians believe that all four versions were printed from the same woodblocks.



**Figure 16.** Darkness and non-uniformity comparisons of ink of the same four characters (指) at the same location on page 72 after brightness threshold switching at 80/256 and 60/256. (A: Sam-seong version (三省本), B: Gongin version (空印本), C: Daegu version (大邱本) and D: Banyasa Temple version (般若寺本)).

As we saw in the evidence all along, the woodblocks are not the same. The B: Gongin version (空印本) significantly differ from the other three versions in size and aspect ratio (Figures 2–4). The other three versions matched quite well considering deviations during manual printing using old Korean paper (*Hanji*) (Figure 4). The first book was printed in September 1239. All evidence indicates the A: Samseong version (三省本) was printed last, many years after the printing date of the C: Daegu version (大邱本) in June 1472. There is a minimum of a 233-year difference between the printing dates of the first version and the last version. Based on the life expectancy of a human, it is impossible that the same craftsman re-engraved woodblocks over that time period. Thus, all names appearing on the print were exact copies of original printing blocks by some other craftsmen in the later generations. This means that the names of the craftsmen appearing in the D: Banyasa Temple version (般若寺本), C: Daegu version (大邱本) and A: Samseong version (三省本) have no relationship with woodblock making. The same names from the original printed version (probably, the B: Gongin version (空印本)) have been copied when the woodblocks were engraved by some craftsmen in the later generations.

Based on these observations, the names of craftsmen in all versions are the ones who were involved in making the original printing block, whether they are made of metal or wood.



**Figure 17.** Examples of names (陈才 and 東伯) printed from the woodblock for A: Samseong version (三省本). The total of eleven names appears at the bottom of the folded area of all 44 leaves for 88 pages.

#### 4. Discussion

Woodblock printing is a technique for printing text, images or patterns. This printing technique has been widely used throughout East Asia including China, Korea, Japan, Viet Nam and so on [1–4,7,10–12,25,26,31–36]. To have woodblocks used for printing, people often have to use wood to carve. Traces of wood carving for printing purpose were found in China as early as 220 [32]. The woodblock printing method existed in China from the 7th century and has continued for a long time. In Korea, the woodblock printing was popular until the beginning of the 20th century before modern paper making and printing techniques were adapted.

Mongol invaders burned the original Tripitaka Koreana (初雕大藏經), carved in 1087, to ash in 1232. The Goryeo dynasty re-engraved the Tripitaka Koreana as prayers to the power of Buddha for the protection of the nation from the invading Mongols. The Tripitaka Koreana (Goryeo Tripitaka, 高麗大藏經 or The 2nd Goryeo Tripitaka 再雕大藏經) or Palman Daejanggyeong (Eighty-Thousand Tripitaka, 八萬大藏經) is a Korean collection of the Tripitaka (Buddhist scriptures), engraved onto 81,258 wooden blocks by carving, in the 13th century (by 1251). It is the world's most comprehensive and oldest intact version of Buddhist canon in Hanja (漢字, Chinese character) script, with no known errors or errata in the 52,330,152 characters [34]. They are organized in over 1496 titles and 6568 volumes.

In 1234, the Goryeo dynasty also commissioned a civil minister, Choe Yun-ui (崔允儀, 1102–1162), to print another Buddhist text, The Prescribed Ritual Text of the Past and Present (Sangjeong Gogyeum Yemun, 詳定古今禮文). That book was 50 volumes long and would have required a large number of woodblocks. So, he came up with an alternative method of metal casting of movable type blocks by adapting the bronze coin making casting technique. This movable metal type could be arranged in a frame, coated with ink, and used to press many sheets of paper, one at a time, similar to the woodblock process. The project was completed by 1250. It was the first book ever printed in movable metal type. This was the event, about 200 years prior to Gutenberg's Bible being printed using movable metal type in 1448. Unfortunately, no copies of the earliest printing work, including Choe Yun-ui's project, have survived. Thus, the oldest existing book printed with movable metal type is "The Anthology of Great Buddhist Priests' Zen Teachings" (Baegun Hwasang Chorok Buljo Jikji Simche Yojeol, often simply called *Jikji*), dating to 1377, which was printed over 100 years after Choe Yun-ui's Ritual Text. It is still nearly a century earlier than the Gutenberg Bible [8].

Newman nicely put the timetable for the history of movable type in her article entitled “The Buddhist History of Moveable Type” [8]. She covered from the end of 11th century to the beginning of the 16th century (from the Goryeo (高麗) dynasty’s effort produce the first Tripitaka in 1087 to Martin Luther’s publication of 95 Theses in 1517). The author has added a few more details and timing of significant events in red font to understand the sequence of events and dating of the four printed versions of “the Song of Enlightenment” based on the image comparisons and printing sequence analysis in Table 2.

**Table 2.** Timetable for History of Early Printing in Korea.

1087	The Goryeo (高麗) dynasty—a monarchy ruling the area of the modern Korean peninsula—is prompted by attempted foreign invasion to produce woodblock carvings of the Buddhist canon, the Tripitaka (初雕大藏經).
1227	Genghis Khan, Mongol leader of the largest consolidated empire in human history, dies.
1231	Genghis Khan’s successor, Ögedei Khan, orders the invasion of the Korean peninsula.
1232	Mongol invaders burn the Tripitaka to ash; in response, the Goryeo dynasty commissions a second printing project, “as prayers to the power of Buddhas for the protection of the nation from the invading Mongols.”
1251	Workers linked to Korea’s Buddhist monasteries had carved all 81,258 woodblocks (Tripitaka Koreana, 八萬大藏經) necessary for the full text.
1234	The Goryeo dynasty commissions Choe Yun-ui (崔允儀, 1102–1162), a civil minister, to produce a 50-volume Buddhist text, “The Prescribed Ritual Text of the Past and Present” (Sangjeong Gogyeum Yemun, 詳定古今禮文). These were the first books ever printed in movable metal type. No printed copies exist.
1239	The Song of Enlightenment, Gongin version (空印本) printed using movable metal type
Between 1239–1472	The Song of Enlightenment, Banyasa Temple version (般若寺本) printed using woodblocks
1250	Choe prints Sangjeong Gogyeum Yemun, in its entirety, using individual characters cast in metal and sheets of paper instead of woodblocks for carving: the first use of movable type technology (two centuries before Gutenberg).
1259	Korea becomes a vassal state under the Yuan (元) dynasty, one of the four divisions of the Mongol empire, and remains so until roughly 1339.
1377	Decades after Korea’s 80 years under Mongol rule, the Goryeo dynasty produces “The Anthology of Great Buddhist Priests’ Zen Teachings” (Baegun Hwasang Chorok Buljo Jikji Simche Yojeol, 白雲和抄錄佛祖直指心體要節), the oldest extant book printed in movable metal type.
1392	Joseon (朝鮮) dynasty started
1400	Johannes Gutenberg is born; Mongol elements of technological innovation infiltrate beyond Eastern Europe into Germany and France.
1403	Movable Metal Type—Gyemija (癸未字) fonts manufactured by casting
1420	Movable Metal Type—Gyeongjaja (庚子字) fonts manufactured by casting
1434	Movable Metal Type—Gabinja (甲寅字) fonts manufactured by casting
1440s	Gutenberg establishes a workshop and attempts to print a book.
1446	Korean Characters (Hangeul) invented and promulgated in September
1450	Gutenberg creates several copies of short texts.
1454	Gutenberg achieves world-altering technological success by producing a complete copy of the Bible, 1275 pages of 42 lines each.
1472	The Song of Enlightenment, Daegu version (大邱本) printed using woodblocks
After 1472 (perhaps in 16th century)	The Song of Enlightenment, Samseong version (三省本) printed using woodblocks
c. 1500	Printing presses are established in 250 European cities.
1517	Martin Luther publishes his 95 Theses.

Three types of movable metal type block casting, 1403 for Gyemija (癸未字) fonts, 1420 for Gyeongja (庚子字) and 1434 for Gabinja (甲寅字) in Joseon (朝鮮) dynasty were also added. The year 1446 for invention and promulgation of Korean characters (*Hangeul*) were added to help understanding the usage of Gugyeol (口訣) symbols in B: Gongin version (空印本) and D: Banyasa Temple version (般若寺本) to transcribe grammatical morphemes of Chinese sentences before and some period after Koran character invention. The C: Daegu version (大邱本) has both handwritten Gugyeol symbols and Korean characters next to the main text.

Table 3 summarizes the estimated printing method and printing date of four different versions of “the Song of Enlightenment” in the order of printing. The absolute printing date of the C: Daegu version (大邱本) is verified to be June 1472 from a prayer or epilogue attached to the main text. Intentional removal of this attachment was discovered during the examination process of Cultural Property Designation Application. The prayer or epilogue was written by Kim Su-on and printed using small movable metal type blocks of Gabinja (甲寅字) fonts, cast in 1434. Many hand written Gugyeol symbols and old Korean characters started using 1446 were also found in the book.

**Table 3.** Estimated printing method and printing date of four different versions of the Song of Enlightenment in the order of printing.

Version Symbol	Formal Name	Korean Treasure Status	Estimated Printing Method	Estimated Printing Date	Remarks
B	Gongin Version (空印本)	Designated on 29 June 2012	Movable metal type	September 1239 Goryeo Dynasty	As the postscript of Choi Yi dated September 1239, this is the original version of movable metal type printing. No wood texture and chiseling marks were observed. Many handwritten old Gugyeol symbols also support this fact. Ink color was different and the lightest among all four versions. This is the world oldest extant movable metal type printed document.
D	Banyasa Temple Version (般若寺本)	Application in progress	Woodblock	Between September 1239 and June 1472	All characters are very similar to the Gongin version and many old Gugyeol symbols were hand written in the main text. Very few wood texture and chiseling marks were found.
C	Daegu Version (大邱本)	Application denied in 2017 due to intentional removal of pages	Woodblock	June 1472 Joseon Dynasty	The prayer or epilogue written by Kim Su-on, dated as June 1472, can be used as the factual printing date. Many Gugyeol symbols and old <i>Hangeul</i> characters also indicate the age of book. Simplified and modified characters from the Gongin version and Banyasa Temple versions were found.
A	Samseong Version (三省本)	Designated on 30 May 1984	Woodblock	Much later than 1472 (tens to hundreds of years later)	All evidence such as shapes of characters and missing strokes in printed books indicate the timing of printing is much later than that of the Daegu version (1472). Simplified and modified characters from the Gongin version and Banyasa Temple versions matched with Daegu version.

The D: Banyasa Temple version (般若寺本) was definitely printed prior to the C: Daegu version (大邱本). The A: Samseong version (三省本) was definitely printed much after the C: Daegu version (大邱本) based on careful examination of patterns of missing strokes of Chinese characters due to the wear and tear of woodblocks. The B: Gongin version (空印本), with a unique aspect ratio and narrow width compared to the other three versions, is the oldest version of all. It had hand written Gugyeol symbols, such as the D: Banyasa Temple version (般若寺本), and no typical textures in printed characters from woodblock printing.

Tens of movable metal type from the Goryeo dynasty have been excavated in 2011 [4,37]. Some of them are considered to be the actual movable metal type used for printing the Song of Enlightenment. The radiocarbon dating of the charcoal ink remaining in the movable metal type revealed that they were used between 531–695 ( $613 \pm 82$ ) and 1039–1223 ( $1131 \pm 92$ ) in the Goryeo dynasty (918–1392) [37]. Radiocarbon dating is a method that provides objective age estimates for carbon-based materials that originated from living organisms [38]. An age can be estimated by measuring the amount of carbon-14 present in the sample and comparing this against an internationally used reference standard [39]. The printing date of September 1239 is very close to the radiocarbon dating results of ink on the excavated movable metal type. The metal surface was very rough compared to that of typical woodblocks. This also supports the usage of the lighter ink (Yuyeonmuk (油煙墨) formulated for movable metal type) and resulting in non-uniformities of printed characters in the B: Gongin version (空印本) as demonstrated in Figures 15 and 16.

With the very clear supporting evidence, the B: Gongin version (空印本) should be recognized as the original printing from movable metal type in the beginning of September 1239, as dated in the postscript by Choi Yi. It was printed using movable metal type 138 years prior to the *Jikji*, UNESCO Memory of the World. This book is the oldest extant document printed using movable metal type blocks.

In the book titled “Early Printings in Korea”, the author discussed the difficulties in identifying printing methods and deducing publication dates [4,33]. The following paragraph is the exact statement.

“Extensive experiences and careful observations are required when making these distinctions. In many cases, antique books tend to suffer damage from various factors over time, whether it be their covers or contents; when there is considerable wear and tear or corrections, it is especially difficult to differentiate the prints. Even so, some typical differentiating factors can be identified. Movable metal type blocks are cast using molds and thus tend to be thinner, more uniform and regular. Wooden type blocks, on the other hand, have no identical-looking letters, even when using the same characters, so their strokes tend to be irregular. When the type blocks are worn down, metal type strokes become even thinner, and deformed in some cases, but the strokes are usually still intact. For wooden ones, the wear tends to blot out the letters, so the print appears coarse. There are no engraving marks in metal type prints whereas clear chisel marks are apparent in wooden type, at times, and sometimes knife marks appear in the crossing point of vertical and horizontal strokes. The movable metal type blocks are finished with a file after casting, so the end of each stroke usually appears round; no tattered parts are shown in wooden type prints. Because the metal type prints typically use Yuyeonmuk (油煙墨, plant oil charcoal ink), spots can be observed, if seen under a microscope. Songyeonmuk (松煙墨, pine charcoal ink) is used for wooden type blocks, and the ink color tends to be more intense as a result. When seen under the microscope, ink is smeared around the letters.”

Extensive experience and careful observation were emphasized. All factors influencing determination of printing techniques and dates are very subjective to individual examiners. Visual inspection and examiner’s personal opinion could flip the examination results.

Printing dates for the A: Samseong version (三省本) and the B: Gongin version (空印本) were once determined in 13th century Goryeo dynasty and restated to be later than 1472 in the Joseon dynasty. However, this was only after learning of the removal of the prayer

or epilogue (跋文) from the back of the C: Daegu version (大邱本), written by Kim Su-on (金守溫) dating back to June 1472. The publication date has been restated to 233 years later from the originally estimated date. This incident clearly demonstrates that new objective judgment criteria must be introduced.

As demonstrated in this study, image comparison and image analysis using advanced image processing and analysis software (PicMan) together with logical and scientific investigation can greatly improve objectivity of the conclusion deducing process. A data-driven conclusion deducing process makes it much easier to acquire unanimous agreement. It is time to introduce advanced technology and scientific investigation methods to mine hidden cultural heritages waiting to be found.

Based on the careful observations of characteristics of the B: Gongin version (空印本) and proper interpretation of Choi Yi's postscript, it can be concluded that the book is the World's oldest book printed by movable metal type, which was determined to be in 1239. There is little evidence proving the B: Gongin version (空印本) of the Song of Enlightenment (南明泉和頌證道歌) was printed using movable metal type.

First, Choi Yi's post script clearly mentioned about making metal type. Second, the B: Gongin version (空印本) contains many characters were printed using cast metal types with defects such as missing stroke (聞, 相, 殿, 續, 淥 etc.), excessive metal pieces (折, 微, 殊, 盛, 莫 etc.), agglomeration (茶, , 爾, 亂 etc.). Third, is the use of incorrect characters (折, 低, 淥 etc.). Fourth, use of different sizes of characters in the main text (some characters (折, 衫, 人 etc.) are 30–40 % smaller area than others. Fifth, eight of the same two letter word (煩惱; afflictions, defilement or worry) in different pages were misaligned and/or spacing between two characters were adjusted during typesetting. Sixth, the ink appears very speckled, or uneven in most characters due to the uneven metal type surface and/or typesetting errors. Seventh, no wood grain or chisel marks were seen in the printed characters when viewed under a microscope.

Figure 18 shows selected images of defective characters of the B: Gongin version (空印本) indicating strong evidence for movable metal type printing. They have either missing stroke(s) or extra metal piece(s) on metal type. Figure 19 shows characters with poor printing and reduced size (highlighted characters in the center). Figure 20 shows eight of the two letter words (煩惱) appeared in eight different pages for easy comparison of alignment and spacing between two characters. All these images of characters point towards the printing method of the B: Gongin version (空印本) to be movable metal type printing. All characters were fairly similar. Since this is very early stage of metal type development, no identical metal type was used. All metal type was used once in this book. This book was printed 783 years ago in 1239. We should consider it is 216 years prior to Gutenberg's bible printed in 1455. We should consider the fact that the metal casting technique was not mature at the time of printing the Gongin version (空印本).

The number of Roman characters is far less than 100, even with upper case alphabets, lower case alphabets, symbols and numbers. All characters are also simply arranged horizontally. In the case of Chinese characters, a large number of characters are required for printing documents or books. The number can easily exceed a few thousand. In fact, the total number of characters used in the Song of Enlightenment was 9402 and 1653 different kinds of characters were used in the main text. This was one of the reasons why the metal type printing technology, developed in 13th century in Korea, was not really practical at that time. To print documents and books using Chinese characters, a few thousand to several tens of thousands of variations of metal movable types were required. Some Chinese characters were very similar and it was extremely difficult to pick the right characters of mirror image during typesetting.

### B: Gongjin Version (空印本)

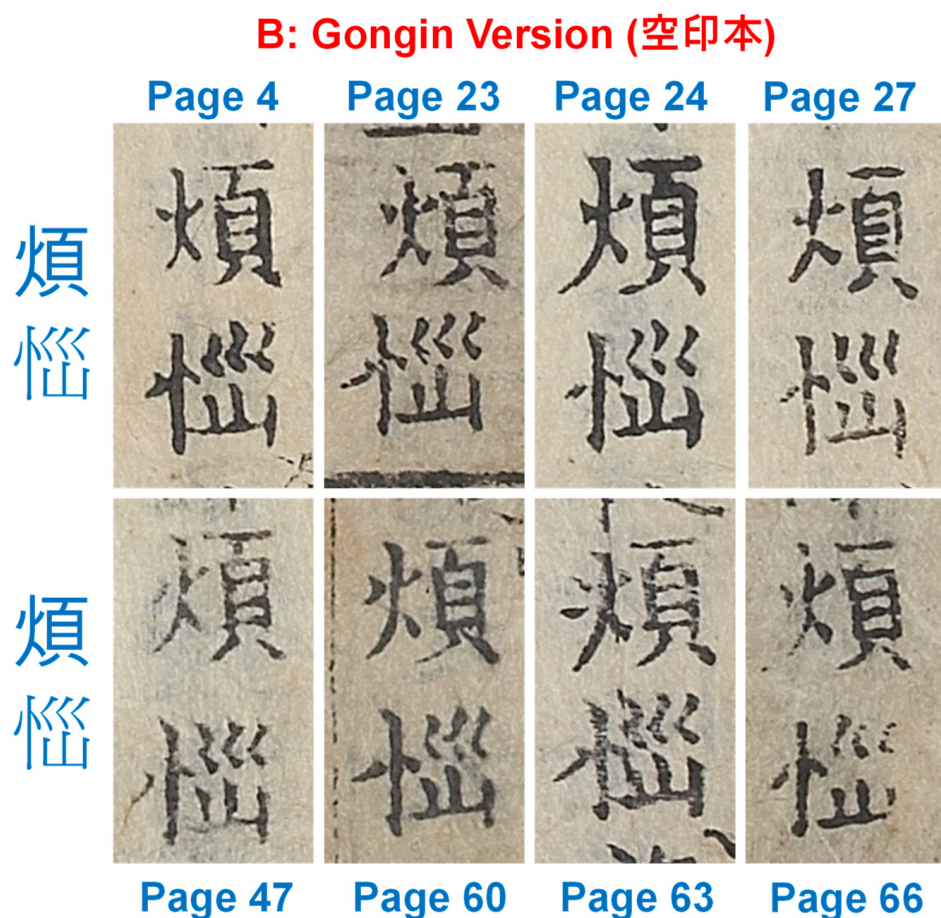


**Figure 18.** Selected images of defective characters of the B: Gongjin version (空印本) indicating strong evidence for movable metal type printing. (Upper row: missing or deformed strokes, Lower row: extra strokes possibly from metal pieces).

### B: Gongjin Version (空印本)



**Figure 19.** Selected images of characters with poor printing and smaller in size (highlighted characters in the center).



**Figure 20.** Eight of the two letter word (煩惱) for easy comparison of alignment and spacing between two characters are printed in different pages.

Spennemann performed a biblio-forensic examination of the origins and longevity of an illustration of a *Crocodylus niloticus* in Jan Jonston's *Historiae naturalis de quadrupetibus* to investigate the origin of Matthäus Merian's crocodile in Japan [40]. In his supplemental data to his paper, a pictorial documentation of all images and image variants were provided for easy comparisons. The biblio-forensic technique has been pioneered by Eggert [41] and adopted by Spennemann in his study. Coincidentally, similar documentations have been performed for comparing the four versions of the Song of Enlightenment by the author. However, the content of this study is printed in Chinese characters instead of drawings. The main focus of this study is to find out (1) whether the four versions were printed using identical woodblocks, (2) what other printing technique might be used, (3) what is the most likely printing sequence and (4) how do we determine the printing date. A thorough biblio-forensic investigation is strongly recommended to find out the true witness of printing history of mankind.

Decisions made more than 50-years ago by several well-respected historians, regarding visual inspection and their impact could deprive us of important insights. We almost missed very precious ancient books which could be the proof of one of the great inventions in human history. The recent excavation of movable metal type blocks from the Goryeo dynasty and radiocarbon dating results of the ink remaining on them, strongly support the B: Gongjin version (空印本) being the oldest existing book printed using movable metal type blocks, executed in September 1239. The author would prefer to urge researchers around the world to look closely at the ancient book, "*Nammyeong Cheon hwasangsong jeungdoga* (南明泉和頌證道歌, Song of Enlightenment with Commentaries by Buddhist Monk Nammyeong Cheon)" "The Song of Enlightenment" designated as Korean Treasure No. 758-2 (referred as B: Gongjin version (空印本) in this paper). This can be a great

candidate for UNESCO Memory of the World to add to our insight into a truly impactful contribution of long ago; the use of movable type to facilitate our understanding and preservation of history.

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## References

1. Sohn, P.-K. Early Korean Printing. *J. Am. Orient. Soc.* **1959**, *79*, 96–103. [CrossRef]
2. Shon, P.-K. *Early Korean typography*; Korean Library Studies Association: Seoul, Korea, 1971.
3. Hye-bong, C. 200 years before Gutenberg: The master printers of Koryo. Available online: <https://en.unesco.org/courier/december-1978/200-years-gutenberg-master-printers-koryo> (accessed on 14 January 2022).
4. Ok, Y.J. *Early Printings in Korea*; The Academy of Korean Studies Press: Seoul, Korea, 2013.
5. UNESCO. Memory of the World. Available online: <https://en.unesco.org/programme/mow> (accessed on 14 January 2022).
6. UNESCO. MOW JIKJI Prize. Available online: <https://en.unesco.org/prizes/jikji-mow-prize> (accessed on 14 January 2022).
7. Cultural Heritage Administration (Korea). Memory of the World. Available online: [http://english.cha.go.kr/cop/bbs/selectBoardList.do?bbsId=BBSMSTR\\_1205&uniq=0&mn=EN\\_03\\_03&ctgryLrcls=CTGRY211](http://english.cha.go.kr/cop/bbs/selectBoardList.do?bbsId=BBSMSTR_1205&uniq=0&mn=EN_03_03&ctgryLrcls=CTGRY211) (accessed on 14 January 2022).
8. Newman, M.S. The Buddhist History of Moveable Type—Forget Johannes Gutenberg. The First Person to Ever Make a Book Printed with Moveable Metal Type was Named Choe Yun-ui. 2016. Available online: <https://tricycle.org/magazine/buddhist-history-moveable-type/> (accessed on 14 January 2022).
9. Wikipedia. Movable Type. Available online: [https://en.m.wikipedia.org/wiki/Movable\\_type#Europe](https://en.m.wikipedia.org/wiki/Movable_type#Europe) (accessed on 14 January 2022).
10. Park, D.S. *Goryeo Metal-Type Printing, 'Nammyeongcheon Hwasangsong Jeungdoga' Hyangto Andong*; Society for the Study of Local History of Andong: Andong, Korea, 1988; Volume 1, pp. 15–192.
11. Park, S.K. *Nammyeong Jeungdoga, the World's First Metal Type Print*; Gymmyoung Publishers: Seoul, Korea, 2020.
12. Park, S.K. *Nammyeongcheon Hwasangsong Jeungdoga, Birth of the World's First Metal Type Print*; Gymmyoung Publishers: Seoul, Korea, 2020.
13. The Dong-A Ilbo. Jeungdoga of Goryeo Dynasty, Designated as a Korean Treasure, Revealed in a Joseon Dynasty Version. 2016. Available online: <https://www.donga.com/news/Culture/article/all/20160129/76197418/1> (accessed on 10 February 2022).
14. Yoo, W.S.; Kim, J.G. Comparative Study on Very Similar Jeungdoga Scripts through Image Analysis—Fundamental Difference between Treasure No. 758-1 and Treasure No. 758-2-. *J. Korean Conserv. Sci. Cult. Prop.* **2021**, *37*, 791–800. [CrossRef]
15. BTN News. First Confirmation that Nammyeongjeungdoga of Samseong-Version and Gongin-Version Are Different. A Korean-American Scholar Published a Research Paper in the Latest Issue of the Journal of Conservation Science. . . . Overturning the Judgment of the Cultural Heritage Committee. Available online: <https://www.btnnews.tv/news/articleView.html?idxno=69828> (accessed on 14 January 2022).
16. Cultural Heritage Administration (Korea). *Nammyeong Cheon Hwasangsong Jeungdoga (Song of Enlightenment with Commentaries by Buddhist Monk Nammyeong)*. Available online: [http://english.cha.go.kr/chaen/search/selectGeneralSearchDetail.do;jsessionid=nd0ZlgBeYj8i1YxOg6ZT3BxdR4n08DOaL55DdA3sdKKSNUYO40xYpjae9FwifxbL.cha-was02\\_servlet\\_engine4?mn=EN\\_02\\_02&sCcebKdcd=12&ccebAsno=07580100&sCcebCtcd=11&pageIndex=113&region=&canAsset=&ccebPcd1=&searchWrd=&startNum=&endNum=&stCcebAsdt=&enCcebAsdt=&canceled=&ccebKdcd=&ccebCtcd=](http://english.cha.go.kr/chaen/search/selectGeneralSearchDetail.do;jsessionid=nd0ZlgBeYj8i1YxOg6ZT3BxdR4n08DOaL55DdA3sdKKSNUYO40xYpjae9FwifxbL.cha-was02_servlet_engine4?mn=EN_02_02&sCcebKdcd=12&ccebAsno=07580100&sCcebCtcd=11&pageIndex=113&region=&canAsset=&ccebPcd1=&searchWrd=&startNum=&endNum=&stCcebAsdt=&enCcebAsdt=&canceled=&ccebKdcd=&ccebCtcd=) (accessed on 14 January 2022).

17. Cultural Heritage Administration (Korea). Nammyeong Cheon Hwasangsong Jeungdoga (Song of Enlightenment with Commentaries by Buddhist Monk Nammyeong). Available online: [http://english.cha.go.kr/chaen/search/selectGeneralSearchDetail.do?sessionId=nd0ZlgBeYj8i1YxOg6ZT3BxdR4n08DOaL55DdA3sdKKSNUYO40xYpjae9FwifxbL.cha-was02\\_servlet\\_engine4?mn=EN\\_02\\_02&sCcebKdcd=12&ccebAsno=07580200&sCcebCtd=38&pageIndex=113&region=&canAsset=&ccebPcd1=&searchWrd=&startNum=&endNum=&stCcebAsdt=&enCcebAsdt=&canceled=&ccebKdcd=&ccebCtd=](http://english.cha.go.kr/chaen/search/selectGeneralSearchDetail.do?sessionId=nd0ZlgBeYj8i1YxOg6ZT3BxdR4n08DOaL55DdA3sdKKSNUYO40xYpjae9FwifxbL.cha-was02_servlet_engine4?mn=EN_02_02&sCcebKdcd=12&ccebAsno=07580200&sCcebCtd=38&pageIndex=113&region=&canAsset=&ccebPcd1=&searchWrd=&startNum=&endNum=&stCcebAsdt=&enCcebAsdt=&canceled=&ccebKdcd=&ccebCtd=) (accessed on 14 January 2022).
18. Wikipedia. Song of Enlightenment. Available online: [https://en.m.wikipedia.org/wiki/Song\\_of\\_Enlightenment](https://en.m.wikipedia.org/wiki/Song_of_Enlightenment) (accessed on 14 January 2022).
19. The Matheson Trust. The Song of Enlightenment. Available online: <https://www.themathesontrust.org/library/cheng-dao-ke> (accessed on 14 January 2022).
20. amitof3 TV, Yǒngjiā dàshī zhèng dào gē(永嘉大師證道歌: Master Yongjia's Song of Enlightenment). Available online: <http://www.amitof3.net/books/b083.html> (accessed on 14 January 2022).
21. Fotozhengfa. Cheng-Tao-Ko. Available online: <https://fotuzhengfa.com/archives/35352> (accessed on 14 January 2022).
22. Pacific Zen Institute. Song of Enlightenment—Yongjia Xuanjue. Available online: <https://www.pacificzen.org/library/ceremonies-long-readings-for-afternoon-song-of-enlightenment-yongjia-xuanjue/> (accessed on 14 January 2022).
23. The Matheson Trust. The Song That Attests to the Way. Available online: <https://www.themathesontrust.org/papers/buddhism/shasta-song.pdf> (accessed on 14 January 2022).
24. Yoo, Y.; Yoo, W.S. Digital Image Comparisons for Investigating Aging Effects and Artificial Modifications Using Image Analysis Software. *J. Korean Conserv. Sci. Cult. Prop.* **2021**, *37*, 1–12. [CrossRef]
25. Yoo, W.S.; Kim, J.G.; Ahn, E.J. An Experimental Study on the Printing Characteristics of Traditional Korean Paper (Hanji) Using a Replicated Woodblock of Wanpanbon Edition Shimcheongjeon. *J. Korean Conserv. Sci. Cult. Prop.* **2021**, *37*, 289–301. [CrossRef]
26. Yoo, W.S.; Kim, J.G.; Ahn, E.J. An Experimental Reproduction Study on Characteristics of Woodblock Printing on Traditional Korean Paper (Hanji). *J. Korean Conserv. Sci. Cult. Prop.* **2021**, *37*, 579–689. [CrossRef]
27. Yoo, W.S. Comparison of Outlines by Image Analysis for Derivation of Objective Validation Results: “Ito Hirobumi’s Characters on the Foundation Stone” of the Main Building of Bank of Korea. *J. Korean Conserv. Sci. Cult. Prop.* **2020**, *36*, 511–518. [CrossRef]
28. Kim, G.; Kim, J.G.; Kang, K.; Yoo, W.S. Image-Based Quantitative Analysis of Foxing Stains on Old Printed Paper Documents. *Heritage* **2019**, *2*, 2665–2677. [CrossRef]
29. Woodcraft. How to Air-Dry Lumber: Turn Freshly Cut Stock into a Cash Crop of Woodworking Woods. Available online: [https://www.woodcraft.com/blog\\_entries/how-to-air-dry-lumber-turn-freshly-cut-stock-into-a-cash-crop-of-woodworking-woods](https://www.woodcraft.com/blog_entries/how-to-air-dry-lumber-turn-freshly-cut-stock-into-a-cash-crop-of-woodworking-woods) (accessed on 8 March 2022).
30. WoodWorks. Accommodating Shrinkage in Multi-Story Wood-Frame Structures. Available online: [https://www.woodworks.org/wp-content/uploads/wood\\_solution\\_paper-Accommodating-Shrinkage.pdf](https://www.woodworks.org/wp-content/uploads/wood_solution_paper-Accommodating-Shrinkage.pdf) (accessed on 8 March 2022).
31. British Library. Printed Copy of the Diamond Sutra. Available online: <https://www.bl.uk/collection-items/the-diamond-sutra> (accessed on 14 January 2022).
32. Hang, L.T.; Van, V.H. Method of Printing Carved on Wood under the Nguyen Dynasty of Vietnam: Study of Woodblocks Recognized by UNESCO as a World Documentary Heritage. *Int. J. Psychosoc. Rehabil.* **2020**, *24*, 2701–2708. [CrossRef]
33. CefiaWiki. Early Printing in Korea—1. Korea’s Memory of the World and Early Printing. Available online: [http://cefia.aks.ac.kr:84/index.php?title=Early\\_Printing\\_in\\_Korea\\_-\\_1.\\_Korea%E2%80%80%99s\\_Memory\\_of\\_the\\_World\\_and\\_Early\\_Printing\\_\(%E5%8F%A4%E5%8D%B0%E5%88%B7\)](http://cefia.aks.ac.kr:84/index.php?title=Early_Printing_in_Korea_-_1._Korea%E2%80%80%99s_Memory_of_the_World_and_Early_Printing_(%E5%8F%A4%E5%8D%B0%E5%88%B7)) (accessed on 14 January 2022).
34. Wikipedia. Tripitaka Koreana. Available online: [https://en.wikipedia.org/wiki/Tripitaka\\_Koreana](https://en.wikipedia.org/wiki/Tripitaka_Koreana) (accessed on 14 January 2022).
35. Kornicki, P.F. Material Texts: Manuscripts, Xylography, and Typography. In *Languages, Scripts, and Chinese Texts in East Asia*; Oxford University Press: Oxford, UK, 2018; pp. 103–129. [CrossRef]
36. McMurtrie, D.C.; Hunter, D. Papermaking: The History and Technique of An Ancient Craft. *Am. Hist. Rev.* **1943**, *49*, 82. [CrossRef]
37. Nam, K.H. The Results of a Study on Academic Bases of Zeungdogaja. *J. Inst. Bibliogr.* **2015**, *64*, 5–47.
38. American Chemical Society National Historic Chemical Landmarks. Discovery of Radiocarbon Dating. Radiocarbon Dating—American Chemical Society (acs.org). Available online: <https://www.acs.org/content/acs/en/education/whatischemistry/landmarks/radiocarbon-dating.html> (accessed on 10 February 2022).
39. Beta Analytic Testing laboratory. Radiocarbon Dating. Available online: <https://www.radiocarbon.com/about-carbon-dating.htm> (accessed on 10 February 2022).
40. Spennemann, D.H.R. Matthäus Merian’s crocodile in Japan. *Scr. Print* **2019**, *43*, 201–239. Available online: <https://www.biodiversitylibrary.org/bibliography/64232> (accessed on 8 March 2022).
41. Eggert, P. Editing a nation’s literature: The Academy Editions of Australian Literature project [Paper presented at the History of the Book in New Zealand. Conference (1995: Auckland)]. *Bibliogr. Soc. Aust. New Zealand Bull.* **1996**, *20*, 146–153.