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# 한국 전통 도자기의 화학 조성에 대한 연구 (II): 조선백자

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# A Study of the Chemical Composition of Korean Traditional Ceramics (II): Chosŏn Whiteware

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**초 록** 조선백자에 사용된 재료들에 대한 특성을 연구하기 위하여, 광주관요, 충효동과 다른 4곳의 지방가마에서 출토된 도편들의 태토와 유약의 성분을 분석하고 비교하였다. 조선초기의 백자기술은 고려의 청자기술을 기본적으로 계승하면서, 중국 명대의 백자기술의 영향을 많이 받았다. 광주관요에서 사용한 태토원료는 청자에 사용되었던 도석과 같은데, 다만 철산화물과 티타늄산화물의 함량이 상대적으로 적고, 칼륨산화물의 함량이 높다. 한국과 중국 남부에 풍부하게 존재하는 이러한 원료로 중국의 경질백자와 같은 좋은 질의 백자를 개발할 수 있었다. 반면, 충효동에서는 중국 북부의 요지들에서 사용되었던 고령토를 발견하고 사용함으로써 질이 좋은 경질백자를 개발하였다. 유약에 사용된 용융재는 대체로 석회석이며, 처음에는 태워서 사용하였으나, 점점 빻아서 사용되는 경향이 증가하였다. 유약을 만들 때 용융재와 혼합하는 점토는 글래이즈 스톤이라고 불리는 기본적으로 도석과 같은 광물이다. 태토를 만들 때 사용하는 도석보다, 일반적으로 입자가 더 곱고, 장석함량이 더 높다. 이 논문의 조선백자에 대한 과학기술적인 연구와 비교는 최근에 빠른 속도로 발굴되고 있는 18~19세기의 가마터에도 넓혀져야 할 것이다.

*중심어: 한국전통도자기, 한국자기, 한국도기, 전통도자기의 태토성분, 전통도자기의 유약성분, 청자, 분청, 백자*

**ABSTRACT** The material characteristics of Chosŏn whiteware were investigated by analyzing and comparing the body and glaze compositions of whiteware shards excavated at the Kwangju royal kilns, Ch'unghyodong, and four other local-level kilns. In Korea, the rise of whiteware technology began in the early years of the Chosŏn dynasty, when the indigenous tradition of Koryŏ celadon was strongly influenced by the whiteware aesthetics of the Chinese Ming dynasty. The Kwangju royal kilns eventually made hard-textured whiteware of a quality equivalent to that of the Chinese by using

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a type of porcelain stone that contained slightly less $Fe_2O_3$ and $TiO_2$ and slightly more $K_2O$ than that used for celadon. In contrast, the potters of Ch'unghyodong achieved the same level of quality by finding and using a totally different material: kaolinitic clay. The porcelain stone used at the Kwangju kiln was commonly found in Korea and south China, whereas kaolinitic clay (which has a high aluminum content) was typically found in north China, and was only rarely used in Korea. The flux component of the glaze compositions was mostly limestone, first in burnt form and later in crushed form, and the clay component was often glaze stone, which was a finer-grained porcelain stone with a higher proportion of feldspar. In the future, this comparative analytical study of Korean whiteware components should be extended to the18$^{th}$- and 19$^{th}$-century kilns that are currently being excavated at a rapid pace.

Key Words: Korean traditional ceramics, Korean porcelain, Korean stoneware, Body composition of traditional ceramics, Glaze composition of traditional ceramics, Celadon, *Punch'ŏng*, Whiteware

## 1. Introduction

In the first decades of the Chosŏn dynasty, two main types of ceramic ware became firmly established: *punch'ŏng* and whiteware. *Punch'ŏng*, which was initially an inlaid celadon with simplified decorations, came from the indigenous celadon tradition of the Koryŏ dynasty. In contrast, whiteware was strongly influenced by the ceramics found in China, which had recently gone through the major political upheavals associated with the founding of the Ming dynasty (1368- 1644).

During the initial stage of porcelain production in the Koryŏ dynasty, large-scale production of white teabowls was carried out at kilns such as Sŏri and Bangsandong[1~3]. However, by the end of the 11$^{th}$ century, porcelain production had become centralized, with celadon being produced in the Kangjin and Puan kiln complexes located in the country's southwestern coastal area. Whiteware was largely ignored during this time, except for a handful of wares produced in the Puan complex. When the new Chosŏn dynasty adopted Confucianism as its state philosophy, however, the simple and frugal aesthetics of Chinese whiteware, especially that coming from Jingdezhen, quickly gained favor among governing officials and the literati class. Thus, the technology of making hard-textured whiteware became well established soon after the founding of the dynasty.

The Chosŏn whiteware influenced by the indigenous tradition of Koryŏ celadon and by Ming whiteware were largely produced in two major Korean kiln complexes. The first, located near the capital city in the district of Kwangju, was initially supervised by government officials and became a government complex in 1469. It continued to be a center for royal wares until 1884, when it became private. The other center, Ch'unghyodong, was located in the southwest, close to the Koryŏ celadon centers of Kangjin and Puan. Its first product was inlaid and stamped *punch'ŏng*, which was the direct offspring of inlaid celadon. After numerous trial-and-error developmental efforts, this kiln eventually succeeded in producing some of the highest quality *punch'ŏng* and whiteware. Furthermore, the potters of Ch'unghyodong made an original contribution to Korean porcelain technology by showing that hard-textured whiteware could be made with a type of clay that was much more kaolinitic than the usual porcelain stone.

*Punch'ŏng* evolved into various styles, becoming increasingly more similar to whiteware in appearance, and then disappeared entirely after the Japanese invasion of Korea (1592-1598). In contrast, whiteware production not only revived after the war; it spread widely throughout the country. This paper presents a comparative study of the compositional characteristics of Chosŏn whiteware from the Kwangju (13 groups of shards) and Ch'unghyodong (4 groups) kiln complexes, as well as other local-level kilns (4 groups). The body and glaze characteristics of these groups are compared with those of Chinese whiteware. A similar analysis of *punch'ŏng* will be presented in a separate paper. The analytic methods and organization of the results are similar to those found in a previous study on Koryŏ ceramic wares[4]. The previous report showed that the body material of the ceramics had geological origins in common with the southern Chinese tradition, while the glaze displayed unusual properties that form the basis of the world-famous *pisaek* color. A similar comparison is made here for whiteware.

## 2. Experimental

### 2.1. Selection and Archaeological Background of the Sample Shards

The locations of the kilns from which the analyzed shards were excavated are numbered in Figure 1, which also shows the two Koryŏ centers found at the government-run complexes of Kangjin and Puan (empty circles), as well as the most historically important Chinese kilns. The numbers correspond to the group numbers given in Table 1 and those in the graphs of Figures 2 through 6. The table also gives archaeological information about the kilns from which the porcelain shards were excavated (first line), as well as the analyzed chemical compositions of the porcelain body (second line, left) and the glaze (second line, right) of each sample. Because porcelain composition is inherently

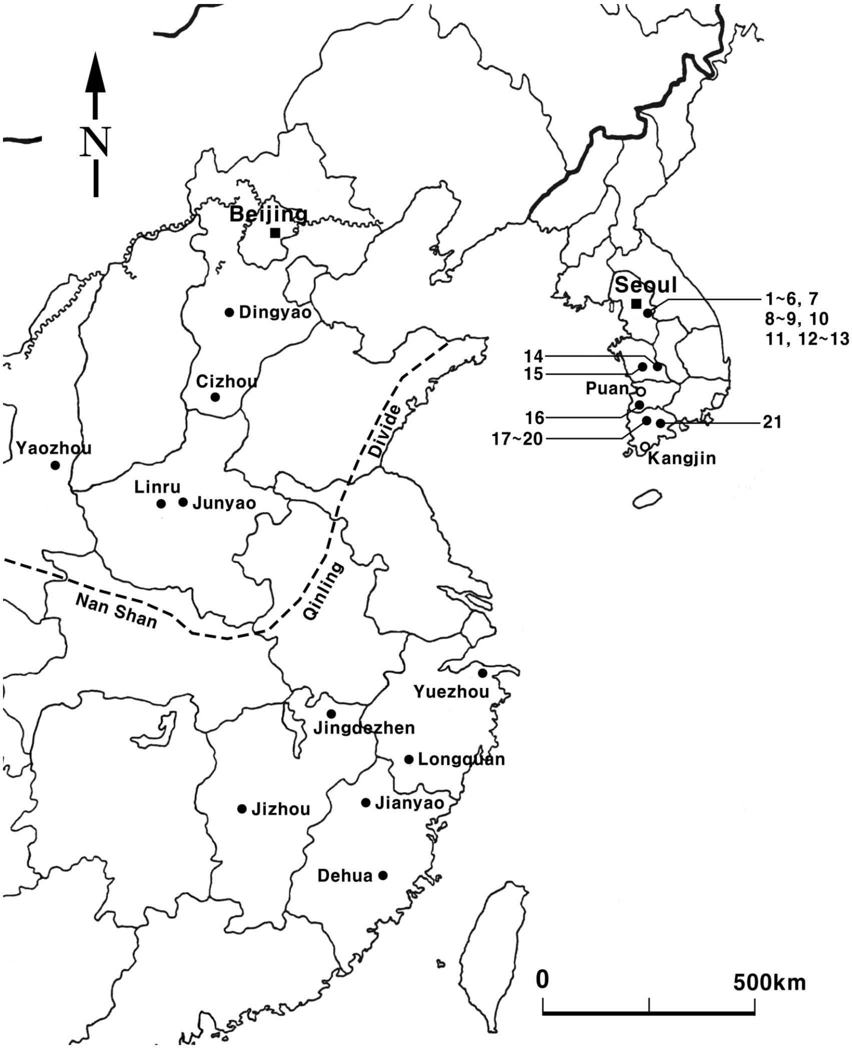


**Figure 1.** Map of the Korean kiln sites from which the analyzed shards were collected. Also shown are the Nan Shan Qinling dividingline and some historically important kiln sites in China. The empty circles indicate the most important Koryŏ celadon centers, Kangjin and Puan.

**Table 1.** Archaeological information on the analyzed shards and their composition of body and glaze (C: century; E: early; M: middle; L: late; No.: Number of shards analyzed for the average value of composition).

| Group | Kiln address, specific location, shard type | | | | | | | | | | | | | | Operational date (C) | | | | Excavational year | | | | | Shard provider | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (No.) | Body composition (wt.%) | | | | | | | | | | | | | | Glaze composition (wt.%) | | | | | | | | | | | | |
| | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | MgO | CaO | $Na_2O$ | $K_2O$ | $TiO_2$ | MnO | $P_2O_5$ | L.O.I. | Total | $SiO_2$ | $R_xO_y$ | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | MgO | CaO | $Na_2O$ | $K_2O$ | $TiO_2$ | MnO | $P_2O_5$ | Total | $SiO_2$ | $R_xO_y$ |
| 1 | Kyŏnggido Kwangjusi Shilch'onmyŏn Kŏnŏbri | | | | | | | | | | | | | | M15 | | | | 1997~98 | | | | | Haegang Ceramics Museum | | | |
| (7) | 72.68 | 19.28 | 1.66 | 0.57 | 0.21 | 0.44 | 4.67 | 0.14 | 0.01 | 0.04 | 0.24 | 99.95 | 6.40 | 0.46 | 67.70 | 16.15 | 1.48 | 0.77 | 15.21 | 0.63 | 3.71 | 0.06 | 0.06 | 0.01 | 99.77 | 2.93 | 0.45 |
| 2 | Kyŏnggido Kwangjusi Toich'onmyŏn Usanni, 9th kiln | | | | | | | | | | | | | | L15~E16 | | | | 1992 | | | | | Ewha Woman's University Museum | | | |
| (8) | 71.86 | 19.39 | 1.29 | 0.47 | 0.30 | 1.23 | 5.16 | 0.09 | 0.03 | 0.03 | 0.01 | 99.85 | 6.29 | 0.53 | 63.99 | 16.74 | 1.16 | 1.09 | 11.34 | 1.39 | 3.84 | 0.03 | 0.04 | 0.21 | 99.83 | 3.53 | 0.54 |
| 3 | Kyŏnggido Kwangjusi Ch'owŏlmyŏn Mukapni | | | | | | | | | | | | | | 1490 | | | | - | | | | | National Museum of Korea | | | |
| (3) | 74.59 | 18.34 | 1.52 | 0.54 | 0.29 | 0.06 | 4.18 | 0.15 | 0.02 | 0.02 | 0.34 | 100.05 | 6.90 | 0.42 | 60.22 | 15.70 | 1.23 | 0.74 | 18.63 | 0.55 | 3.59 | 0.11 | 0.11 | 0.08 | 100.96 | 2.45 | 0.38 |
| 4 | Kyŏnggido Kwangjusi Jungbumyŏn Bŏnch'ŏnni, 9th kiln, II layer | | | | | | | | | | | | | | L15~E16 | | | | 1998 | | | | | Ewha Woman's University Museum | | | |
| (2) | 72.82 | 19.80 | 0.98 | 0.40 | 0.28 | 1.04 | 4.45 | 0.09 | 0.02 | 0.01 | -0.07 | 99.84 | 6.24 | 0.45 | 63.59 | 17.36 | 1.30 | 0.88 | 11.34 | 1.48 | 3.80 | 0.12 | 0.05 | 0.02 | 99.94 | 3.54 | 0.57 |
| 5 | Kyŏnggido Kwangjusi Jungbumyŏn Bŏnch'ŏnni, 9th kiln, IV layer | | | | | | | | | | | | | | L15~E16 | | | | 1998 | | | | | Ewha Woman's University Museum | | | |
| (4) | 72.45 | 19.78 | 1.13 | 0.35 | 0.30 | 1.04 | 4.71 | 0.08 | 0.02 | 0.01 | 0.07 | 99.95 | 6.22 | 0.46 | 63.16 | 16.85 | 0.93 | 0.88 | 13.96 | 1.15 | 2.94 | 0.12 | 0.03 | 0.01 | 100.02 | 3.20 | 0.50 |
| 6 | Kyŏnggido Kwangjusi Toich'onmyŏn Domari | | | | | | | | | | | | | | 15 | | | | 1964 | | | | | National Museum of Korea | | | |
| (8) | 72.21 | 21.13 | 1.07 | 0.43 | 0.34 | 1.03 | 3.73 | 0.08 | 0.02 | 0.02 | -0.05 | 100.01 | 5.80 | 0.39 | 63.85 | 18.11 | 0.85 | 1.62 | 10.22 | 1.50 | 3.48 | 0.05 | 0.04 | 0.01 | 99.73 | 3.66 | 0.61 |
| 7 | Kyŏnggido Kwangjusi Jungbumyŏn Bŏnch'ŏnni, 5th kiln | | | | | | | | | | | | | | 16 | | | | 1985~'86 | | | | | Ewha Woman's University Museum | | | |
| (4) | 72.94 | 19.08 | 1.49 | 0.41 | 0.28 | 0.97 | 4.50 | 0.13 | 0.03 | 0.03 | -0.04 | 99.83 | 6.49 | 0.48 | 61.31 | 15.57 | 1.13 | 0.56 | 16.22 | 1.48 | 3.54 | 0.04 | 0.12 | 0.06 | 100.04 | 2.73 | 0.41 |
| 8 | Kyŏnggido Kwangjusi Ch'owŏlmyŏn Sŏndongri, 2nd kiln | | | | | | | | | | | | | | 1640~1649 | | | | 1985-'86 | | | | | Ewha Woman's University Museum | | | |
| (3) | 75.25 | 18.49 | 1.34 | 0.45 | 0.22 | 0.00 | 3.67 | 0.12 | 0.02 | 0.03 | 0.41 | 100.00 | 6.91 | 0.36 | 61.03 | 17.39 | 1.30 | 0.64 | 15.86 | 0.31 | 3.63 | 0.07 | 0.07 | 0.01 | 100.30 | 2.88 | 0.48 |
| 9 | Kyŏnggido Kwangjusi Ch'owŏlmyŏn Sŏndongri, 3rd kiln | | | | | | | | | | | | | | 1640~1649 | | | | 1985-'86 | | | | | Ewha Woman's University Museum | | | |
| (3) | 71.34 | 21.74 | 1.74 | 0.55 | 0.27 | 0.01 | 3.70 | 0.18 | 0.03 | 0.04 | 0.46 | 100.06 | 5.57 | 0.34 | 62.23 | 18.33 | 1.39 | 0.90 | 14.33 | 0.14 | 2.97 | 0.09 | 0.08 | 0.02 | 100.48 | 3.21 | 0.56 |
| 10 | Kyŏnggido Kwangjusi Namjongmyŏn Punwŏnni | | | | | | | | | | | | | | M18~L19 | | | | 2001 | | | | | National Museum of Korea | | | |
| (3) | 72.07 | 20.31 | 1.10 | 0.39 | 0.38 | 0.18 | 4.04 | 0.03 | 0.05 | 0.03 | 1.04 | 99.63 | 6.02 | 0.35 | 63.86 | 16.73 | 1.09 | 1.49 | 10.77 | 1.18 | 4.02 | 0.08 | 0.07 | 0.07 | 99.37 | 3.54 | 0.55 |
| 11 | Kyŏnggido Kwangjusi Namjongmyŏn Kŭmsari | | | | | | | | | | | | | | 1721~1751 | | | | - | | | | | National Museum of Korea | | | |
| (3) | 72.63 | 21.28 | 0.95 | 0.75 | 0.38 | 0.34 | 3.24 | 0.04 | 0.04 | 0.02 | 0.19 | 99.87 | 5.79 | 0.35 | 64.50 | 16.05 | 0.89 | 3.95 | 10.71 | 0.91 | 2.52 | 0.07 | 0.06 | 0.00 | 99.67 | 3.18 | 0.47 |

**Table 1.** (continued).

| Group | Kiln address, specific location, shard type | | | | | | | | | | | | | | Operational date (C) | | | | Excavational year | | | | | Shard provider | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (No.) | Body composition (wt.%) | | | | | | | | | | | | | | Glaze composition (wt.%) | | | | | | | | | | | | |
| | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | MgO | CaO | $Na_2O$ | $K_2O$ | $TiO_2$ | MnO | $P_2O_5$ | L.O.I. | Total | $SiO_2$ | $R_xO_y$ | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | MgO | CaO | $Na_2O$ | $K_2O$ | $TiO_2$ | MnO | $P_2O_5$ | Total | $SiO_2$ | $R_xO_y$ |
| 12 | Kyŏnggido Kwangjusi Shilch'onmyŏn Kŏnŏbri (Chŏson celadon) | | | | | | | | | | | | | | M15 | | | | 1997~98 | | | | | Haegang Ceramics Museum | | | |
| (2) | 72.69 | 19.36 | 1.74 | 0.52 | 0.17 | 0.52 | 4.61 | 0.14 | 0.01 | 0.03 | 0.16 | 99.96 | 6.37 | 0.45 | 60.38 | 15.67 | 0.93 | 1.25 | 16.05 | 0.94 | 3.71 | 0.09 | 0.22 | 0.61 | 99.85 | 2.60 | 0.40 |
| 13 | Kyŏnggido Kwangjusi Toich'onmyŏn Usanni, 9th kiln (Chŏson celadon) | | | | | | | | | | | | | | L15~E16 | | | | 1992 | | | | | Ewha Womans University Museum | | | |
| (4) | 72.66 | 19.21 | 1.54 | 0.39 | 0.22 | 0.98 | 5.19 | 0.09 | 0.03 | 0.04 | 0.01 | 100.33 | 6.42 | 0.51 | 60.33 | 16.82 | 1.95 | 1.93 | 13.60 | 0.83 | 3.37 | 0.12 | 0.22 | 0.90 | 100.05 | 2.77 | 0.46 |
| 14 | Taejŏnsi Chunggu Jŏngsaengdong | | | | | | | | | | | | | | L16~E17 | | | | 1997 | | | | | Haegang Ceramics Museum | | | |
| (6) | 69.72 | 22.07 | 1.84 | 0.51 | 0.52 | 0.30 | 4.69 | 0.10 | 0.04 | 0.03 | 0.10 | 99.91 | 5.36 | 0.42 | 64.15 | 16.24 | 1.53 | 0.34 | 12.31 | 0.48 | 4.79 | 0.06 | 0.08 | 0.01 | 99.98 | 3.58 | 0.53 |
| 15 | Ch'ungch'ŏngnamdo Puyeogun Jangtaesan Kakzomgol | | | | | | | | | | | | | | L16~E17 | | | | 2000 | | | | | Chungchong Cultural Properties Research Institute | | | |
| (6) | 70.79 | 20.99 | 1.98 | 0.49 | 0.30 | 0.50 | 3.90 | 0.42 | 0.07 | 0.02 | 0.43 | 99.89 | 5.72 | 0.42 | 61.03 | 17.40 | 1.52 | 0.43 | 15.67 | 0.61 | 2.96 | 0.09 | 0.20 | 0.00 | 99.91 | 2.95 | 0.50 |
| 16 | Chŏllapukdo Koch'anggun Asanmyŏn Yonggyeri | | | | | | | | | | | | | | L15~E16 | | | | - | | | | | Chungpuk University Museum | | | |
| (2) | 61.40 | 29.60 | 1.00 | 0.64 | 0.70 | 0.41 | 3.83 | 0.15 | 0.04 | 0.06 | 1.65 | 99.45 | 3.52 | 0.29 | 63.92 | 19.91 | 0.95 | 4.42 | 5.59 | 0.36 | 4.28 | 0.10 | 0.07 | 0.01 | 99.50 | 3.96 | 0.73 |
| 17 | Kwangjusi Ch'unghydong Kŭmgok, CHW2-8 | | | | | | | | | | | | | | around1457 | | | | 1963, '91 | | | | | National Kwangju Museum | | | |
| (2) | 60.60 | 29.57 | 0.98 | 0.40 | 0.07 | 0.19 | 5.99 | 0.16 | 0.03 | 0.04 | 1.76 | 99.76 | 3.48 | 0.30 | 60.02 | 15.42 | 1.08 | 1.75 | 13.25 | 0.58 | 5.96 | 0.03 | 0.32 | 0.83 | 99.24 | 2.70 | 0.41 |
| 18 | Kwangjusi Ch'unghydong Kŭmgok, CHW2-3 | | | | | | | | | | | | | | 1477~1483 | | | | 1963, '91 | | | | | National Kwangju Museum | | | |
| (3) | 60.53 | 29.07 | 1.20 | 0.49 | 0.35 | 2.17 | 4.98 | 0.11 | 0.05 | 0.04 | 0.62 | 99.62 | 3.53 | 0.41 | 64.81 | 14.63 | 1.14 | 1.45 | 9.82 | 2.83 | 3.87 | 0.00 | 0.15 | 0.38 | 99.08 | 3.48 | 0.46 |
| 19 | Kwangjusi Ch'unghydong Kŭmgok, CHW2-2 | | | | | | | | | | | | | | 1490~1510 | | | | 1963, '91 | | | | | National Kwangju Museum | | | |
| (4) | 60.20 | 29.34 | 0.89 | 0.37 | 0.32 | 2.65 | 4.63 | 0.04 | 0.04 | 0.04 | 1.22 | 99.72 | 3.48 | 0.39 | 66.46 | 15.26 | 1.14 | 1.57 | 7.01 | 2.78 | 5.64 | 0.03 | 0.06 | 0.12 | 100.08 | 3.98 | 0.54 |
| 20 | Kwangjusi Ch'unghydong Kŭmgok, CHW3-H | | | | | | | | | | | | | | after 1457 | | | | 1963, '91 | | | | | National Kwangju Museum | | | |
| (4) | 59.12 | 30.90 | 1.10 | 0.41 | 0.30 | 2.07 | 4.62 | 0.06 | 0.05 | 0.04 | 1.09 | 99.74 | 3.25 | 0.35 | 63.17 | 16.52 | 1.33 | 1.35 | 11.42 | 1.73 | 3.64 | 0.04 | 0.07 | 0.37 | 99.62 | 3.33 | 0.51 |
| 21 | Chŏllanamdo Sunch'ŏnsi Songkwangmyŏn Hugokri 17 | | | | | | | | | | | | | | L17 | | | | 1986~'87 | | | | | Ewha Womans University Museum | | | |
| (3) | 65.98 | 24.70 | 2.34 | 0.99 | 0.13 | 0.02 | 5.38 | 0.21 | 0.03 | 0.02 | 0.19 | 99.99 | 4.53 | 0.42 | 63.90 | 18.47 | 1.70 | 2.76 | 6.76 | 0.53 | 5.55 | 0.10 | 0.06 | 0.01 | 99.84 | 3.95 | 0.67 |

heterogeneous, two to eight shards were analyzed for each group; the average values are reported in the table, along with the number of shards analyzed in each case (given in parentheses).

Beginning early in the 20th century and continuing into the present day, the Kwangju complex has received a great deal of attention from archaeologists and other ceramic scholars. To date, at least 300 kilns have been identified within the complex. The pressure of highway construction in the 1980s expedited the excavation[5], and several systematic excavations were carried out in the 1990s[5~11]. A thorough, large-scale surface investigation was carried out in 1997, and another one during four years period between 2004 and 2008. Gyeonggi Provincial Museum selected a set of 360 shards from 57 sites from these investigations for a comprehensive scientific study on the kiln complex[12].

The important Ch'unghyodong site was first excavated by Korean researchers in 1963. A much more thorough excavation in 1991 revealed nine layers of shards showing that the kiln had produced only *punch'ŏng* at the beginning of its 100-year history, but soon began to experiment with whiteware, and produced only whiteware by the end of its operations[13]. A small percentage of soft-textured whiteware shards (4.7%) were found among the *punch'ŏng* shards in the second oldest layer, which was estimated to represent operation around 1457. Hard-textured whiteware with a quality similar to those from Kwangju and China emerged in the third layer from the top. This hard-textured whiteware increased in quantity to 37% of the whole in the second layer from the top, and the *punch'ŏng* found at the same level had been made to look white by the brushed-on application of a white slip. The top layer was composed almost entirely of whiteware.

The Ch'unghyodong complex began operating in the first decades of the Chosŏn dynasty and closed at the beginning of the 16th century. The Yonggyeri kiln (represented by Group 16) is a later kiln that produced both *punch'ŏng* and whiteware near the time that Ch'unghyodong closed. The other three local-level kilns covered in this study, Jŏngsaengdong (Group 14), Kakzomgol (Group 15), and Hugokri (Group 21) produced only whiteware, and were in operation slightly after Yonggyeri (late 16th through the 17th centuries).

In contrast to the local-level kilns, which opened and closed at various times, the state-sponsored Kwangju kiln complex operated throughout the entire Chosŏn dynasty. The present study examined shards from kilns within the complex, representing a range of time periods. The first five kilns (Groups 1-6, 12 and 13) were contemporary with Ch'unghyodong, while the Bŏnch' ŏnni kiln designated as the 5th (Group 7) was in operation in the 16th century, Sŏndongri (Group 8 and 9) in the 17th, Kŭmsari (Group 10) in the 18th, and Punwŏnni (Group 11) in the 18th and 19th. Within the complex, the kilns were moved to new locations about every 10 years, to facilitate firewood collection. In 1752, however, the Punwŏn site near the Han River was made permanent; thereafter, waterways were used to bring firewood to the site and transport ceramic products to the palace and other government offices.

## 2.2. Experimental Procedures

Except for the Usanni shards of Groups 2 and 13, the body compositions were measured at the Korea Basic Science Institute using a PW1480 X-ray Fluorescence Sequential Spectrometer (Philips Inc.). In brief, the glaze was ground off and the body was powdered and made into cylindrical beads for application to the spectrometer. The samples were analyzed at 40 kV and 30 mA; the other details are as previously reported in a paper on the Sŏri results[14].

For groups other than Usanni, the compositions of intact glaze samples were analyzed from the shards embedded in epoxy resin using an Electron Probe Microanalyzer (Jeol Superprobe JXA-8600SX) equipped with SEM and EDS (Oxford Pentafet$_{ATW}$ Detector). The analyses were conducted at 15 kV and 2.5 nA. An average of four to six measurements were taken from different areas of either $48 \times 36\ \mu m^2$ or $34 \times 25\ \mu m^2$.

For analysis of the Usanni samples (both the glaze and the body), the shards were embedded in epoxy resin and polished for cross-sectional measurement. They were analyzed at the Hoffman Geological Laboratory (Harvard University) using a Cameca MBX electron microprobe equipped with a Tracor Northern TN-5502 Energy Dispersive Spectrometer (EDS) and a stage-automation system[15]. A square raster beam was used to scan an area of 100 × 100 μm$^2$ for analysis of the bulk chemical composition of each body, and a clear 60 × 60 μm$^2$ area for analysis of the glaze composition. The beam energy was 15 kV and the beam current was 14 nA. Ten measurements were taken for each composition, and the results are presented as average values.

## 3. Results and Discussion

### 3.1. Comparison of Body Compositions

The analytic results (given as Seger graphs) for the body and glaze compositions are shown in Figures 2 and 3, respectively. The gray areas denote the compositional ranges of the three most prominent Chinese whiteware kilns: Jingdezhen and Dehua in the south and Dingyao in the north[16]. When the Seger values were calculated, all oxides other than $Al_2O_3$ and $SiO_2$ were included in the term, $R_xO_y$.

In Figure 2, which shows the results for body composition, the Kwangju groups distributed to the gray areas representing Jingdezhen and Dehua (southern China). Surprisingly, however, the Ch'unghyodong and Yonggyeri groups distributed to the gray area representing Dingyao (northern China). Whiteware from Ch'unghyodong and Yonggyeri are unique among the 80 groups of Korean ceramic shards included in this three-part series of composition studies in that their body compositions are unusually high in aluminum (around 30 wt .%) and relatively low in flux.

As shown in Figure 1, the northern and southern clay zones of China are separated by a dividing line called Nan Shan Qinling. Above this line, the clay is rich in kaolinite; below it, the comparable material is porcelain stone composed of quartz and hydromica, with minor amounts of primary clay and feldspar. South Korea is located south of this line, which is heavily biased southwest to northeast[17]. As pointed out in the previous study on Koryŏ celadon and whiteware[4], the weathered rock that is abundant in Korea and southern China possesses all the properties necessary for the production of high-temperature-fired ceramics. Hydromica provides plasticity and together with remnant feldspar also the fluxing property, while quartz provides the refractory property necessary for high-temperature sintering. Thus, it is not

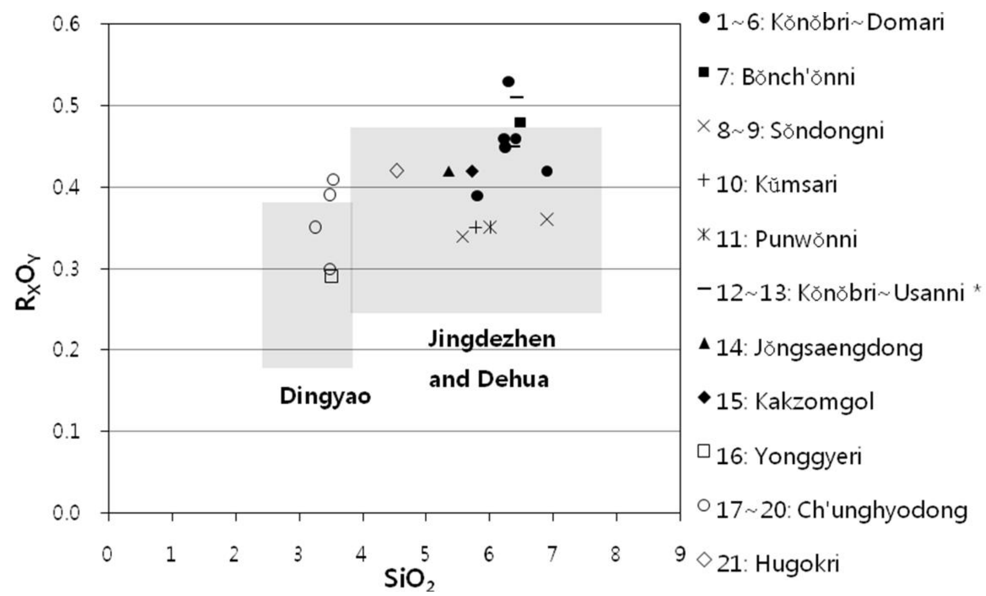


**Figure 2.** Seger graph of body compositions ($SiO_2$ as a function of $R_xO_y$). The* indicates a special type of ceramics, called Chosŏn celadon, that has a whiteware body and celadon glaze.

surprising that the overwhelming majority of Korean ceramics, from *togi* to whiteware, are made of this porcelain stone. It was truly innovative for Ch'unghyodong potters to use kaolinitic clay in a manner similar to that seen in northern China at the whiteware kiln of Dingyao and the celadon kilns of Yaozhou and Ru[18, 19].

The potters of Ch'unghyodong used kaolinitic clay relatively early in their attempts to develop whiteware, beginning in roughly the middle of 15th century. It took approximately two decades for them to figure out how to vitrify the high-aluminum-content clay into true porcelain of a quality equivalent to the whiteware of Kwangju or China. The earliest whiteware shards, found in the second-to-lowest layer (Group 17), were underfired and soft-textured. The firing technology available at the time in Korea was appropriate for porcelain stone, which could be vitrified at a lower firing temperature than that required to vitrify kaolinitic materials. It wasn't until the Ch'unghyodong potters found a kaolinitic material with a high enough content of flux (in the form of albite) that they could produce truly hard-textured whiteware, such as that represented by shards in the third layer from the top (Group 18). The scarcity of albite-rich kaolinitic material and the difficulty of raising the firing temperature may be among the factors that caused the complex to close down in the first decade of the 16th century.

This small cluster of kaolinitic whiteware seems to represent a small anomaly among the traditional ceramic wares. The only other group that had a substantially higher aluminum content (24.70 wt .%) than ordinary porcelain stone represented the 17th century output of the Hugokri kiln (Group 21). Two local-level kilns that operated about half a century earlier than Hugokri, Jŏngsaengdong (Group 14) and Kakzomgol (Group 15), used the traditional body material of hydromica quartz stone. The local-level kilns of the 18th and 19th centuries have not been analyzed yet, because they are only now being excavated. In the future, systematic studies should be carried out on samples from these excavations, in order to determine whether the Ch'unghyodong type of high-aluminum-content material was used at later points in the production of Korean ceramics.

### 3.2. Comparison of Glaze Compositions

In the Seger graph of Figure 3, the Chosŏn whiteware glazes are found very near the leftmost edge of the glaze ranges of Jingdezhen and Dehua. Even though the body compositions of Ch'unghyodong and Yonggyeri groups

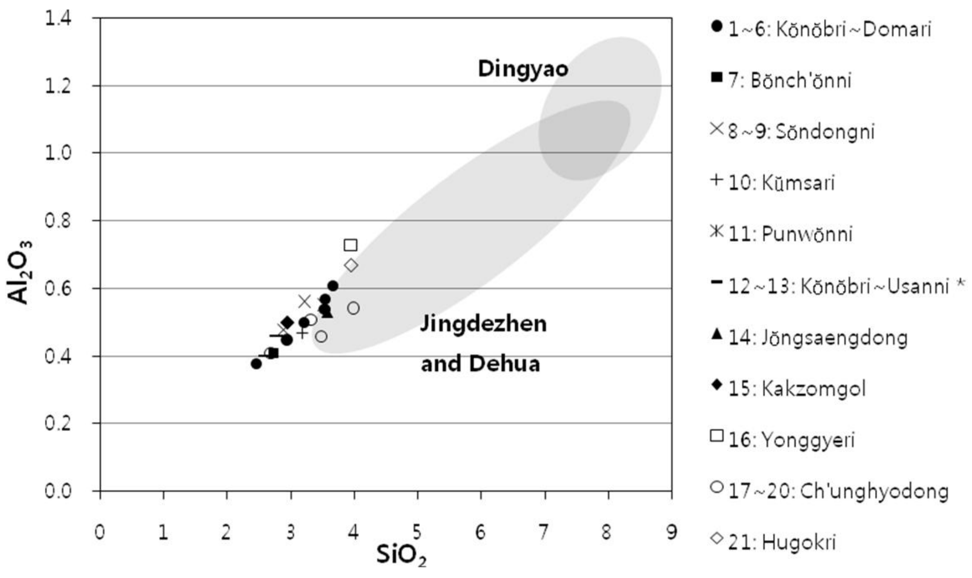


**Figure 3.** Seger graph of glaze compositions ($SiO_2$ as a function of $Al_2O_3$). The * indicates Chosŏn celadon.

distributed with the Dingyao range, their glazes landed within the other Chosŏn whiteware range, which is far from the Dingyao data points. Overall, the Chosŏn glazes, including those of Ch'unghyodong and Yonggyeri, contained more flux than the Chinese glazes. This indicates that the firing temperatures used for Korean whiteware were slightly lower than those used at Jingdezhen and Dehua, and much lower than those used at Dingyao. A relatively high firing temperature (even > 1300°C) was required to vitrify the high content of aluminum in the kaolinitic clay used at Dingyao; thus, the glazes did not require nearly as much flux ingredients as the glazes used at other kilns.

Figures 4 through 6 show the direct comparisons of the individual Chinese data points from Jingdezhen[20], Dehua[21] and Dingyao[19]. The graph of calcium and alkali oxides in Figure 4 shows that, similar to the Koryŏ wares[4] and most of the high-temperature-fired Chinese glazes[22], the chief fluxing ingredient in most Chosŏn whiteware glazes was calcium oxide.

The Chinese glazes have been categorized into four different types according to their calcium oxide contents: high-lime, lime, lime-alkali, and acid rock[23]. Based on the typical values of each type (shown as circles), most of the Chosŏn glazes can be categorized as lime, with a few corresponding to lime-alkali. The lime-alkali glaze type was probably adopted from China, where it was first developed in the 10th century at Jingdezhen. Although largely forgotten during the period of *yingqing* production, this glaze type regained popularity in China as part of the cobalt-blue underglaze developed in the first part of the 14th century. The lime-alkali glazes had a higher viscosity, and therefore did not run or diffuse pigment as much as the lime-type glazes, which were highly transparent and could, therefore, show off the finely incised decorations of *yingqing* wares[24].

Only three groups from local-level kilns, the latest Ch'unghyodong and Yonggyeri groups (late 15th through early 16th centuries), and the Hugokri shards of the late 17th century, were found to have the low calcium contents that characterized the acid-rock glazes. In these glazes, the lower calcium content was compensated for by the presence of magnesium (in Yonggyeri and to a lesser extent in Hugokni) or potassium oxide (in Ch'unghyodong). The "snow-white" glaze from Kwangju Kŭmsari (early 18th century), which was considered the most beautiful among the Korean white glazes, had a magnesium content similar to that of Yonggyeri (around 4 wt .%).

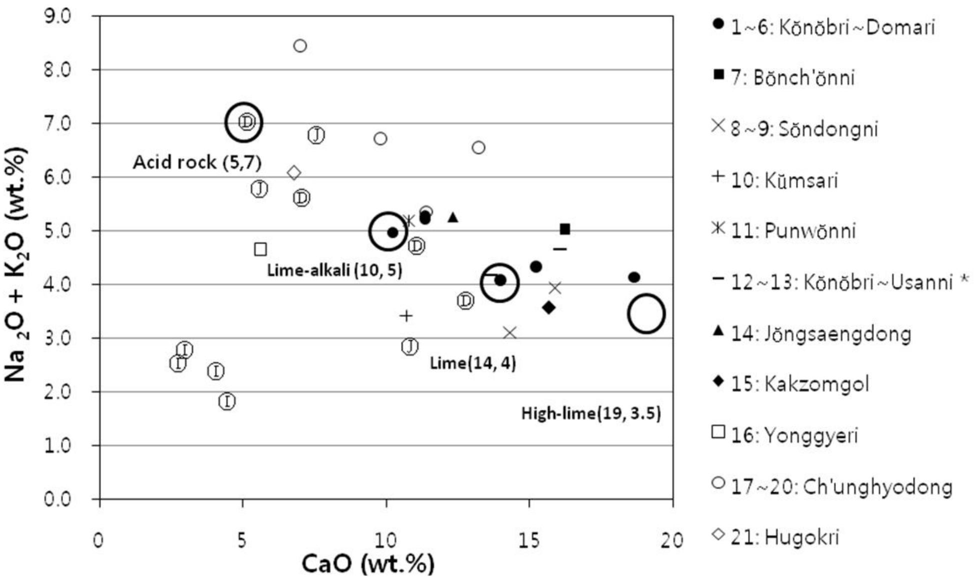


**Figure 4.** Graph showing CaO content vs. that of $Na_2O + K_2O$ in the glaze. Data from the Chinese kilns are shown as lettered points: Ⓙfor Jingdezhen, Ⓓfor Dehua, and Ⓘfor Dingyao. The* indicates Chosŏn celadon.

In Figure 4, the individual data points from Jingdezhen and Dehua are intermixed with those representing the Chosŏn glazes, but those from Dingyao cluster separately at the lower left. The Chosŏn and southern Chinese glazes were usually made by mixing flux material (wood ash and/or limestone) with some type of clay material (the body material and/or glaze stone). Glaze stone was similar to the weathered porcelain rock used for forming the bodies, but it was usually finer-grained and had a higher feldspar content. It was regularly employed for glazing *yingqing* at the Jingdezhen kilns in the 13th and 14th centuries[25].

Figure 5 shows that crushed limestone was chiefly used as the flux material in Kwangju. Wood ash contains higher levels of $P_2O_5$, MnO, and MgO compared to limestone. Glazes that contain higher levels of these oxides are likely to have been made from a greater proportion of wood ash versus burnt limestone (glaze ash), whereas glazes composed solely of crushed limestone typically lack $P_2O$ and MnO. With the exception of the samples from Usanni, all of the tested Kwangju whiteware had little (< 0.1 wt.%) or no $P_2O_5$. This indicates that their glazes were composed of crushed limestone alone, or crushed limestone with only a very small amount of burnt limestone. Two of the earliest Kwangju kilns, Kŏnŏbri and Usanni, made a special type of ceramics called Chosŏn celadon, which had a whiteware body but wore a celadon glaze. For these types, the $P_2O_5$ content was noticeably higher, as would be expected of celadon glazes. The individual Chinese data points show that most of the Chinese glazes were made with crushed limestone, but the presence of $P_2O_5$ in some glazes indicate that either wood ash or glaze ash were also used occasionally.

There was a notable $P_2O_5$ content in the earliest of Ch'unghyodong whiteware (0.83 wt.%), but the level decreased over the years until shards from the most recent strata contained only a nominal amount of this oxide, at a level similar to that found in samples from the Kwangju kilns (0.12 wt.%). Wood ash was certainly employed as the main flux ingredient at the beginning of the complex's operations, but toward the end of the hundred-year production period, the chief glaze ingredient was limestone. Notably, the Ch'unghyodong glazes had an unusually high content of alkali components, especially potassium oxide. Compared to Kwangju glazes having similar lime contents, all of the Ch'unghyodong groups contained substantially higher amounts of alkali (Figure 4). In fact, the latest whiteware studied herein (Group 19), which were produced in the last decade

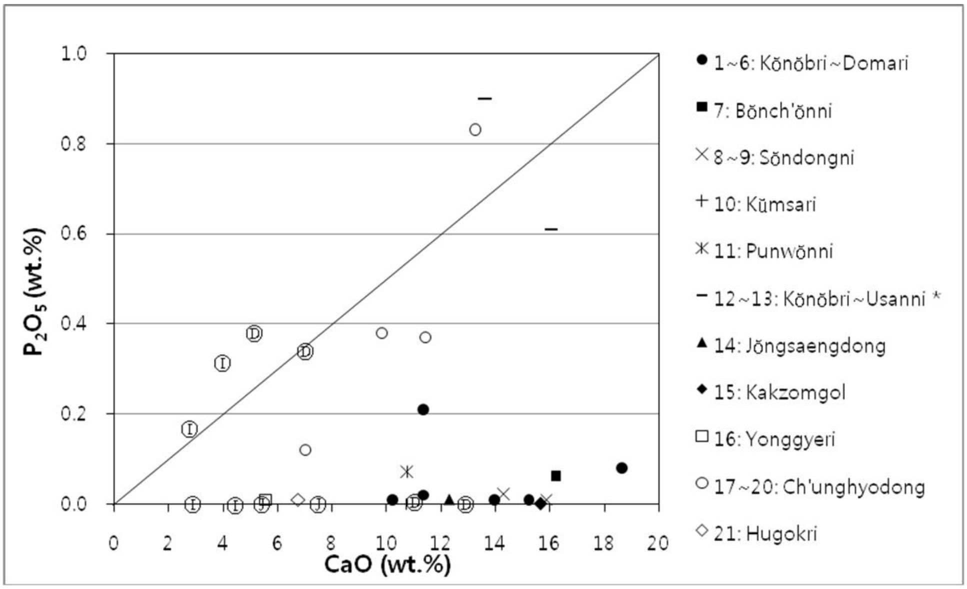


**Figure 5.** Graph showing CaO content vs. that of $P_2O_5$ in the glaze. Abbreviations and symbols: Ⓙ Jingdezhen Ⓓ Dehua Ⓘ Dingyao *, Chosŏn celadon.

of the 15th and the earliest decade of the 16th centuries, had a higher content of alkali (8.42 wt.%) than calcium (7.01 wt.%). Moreover, in two of the four groups, the $K_2O$ content in the glaze was either very similar to or higher than that in the body. This unusually high potassium content suggests that Ch'unghyodong may have employed potassium feldspar as the chief flux in their glazes. Such a practice would represent a real departure from the normal Korean glaze tradition.

Figure 6 clearly shows that Korean whiteware contained more $Fe_2O_3$ than Chinese whiteware, in terms of both the body and the glaze. At present, it is unclear whether Chosŏn potters preferred materials with such high amounts of iron oxide, or if this was simply what was available to them. Numerous records in Chosŏn literature refer to the difficulty of mining good white clay[26~28], suggesting that Korea did not have an enormous natural mine of pure whiteware material, such as that in China's Jingdezhen. The lack of such material may also be a reason why Chosŏn did not produce colorfully decorated whiteware for export, as China and Japan did so successfully up until the 18th century, when Europe began making its own porcelain.

## 4. Conclusion

This compositional study on Chosŏn whiteware showed that Chosŏn potters adopted the basic techniques and materials used by their predecessors in the Koryŏ dynasty, but they made important changes in order to develop hard-textured whiteware with a quality equivalent to that of Chinese porcelain. In the beginning, the centralized royal kiln complex of Kwangju and the far distant, local-level operations in the countryside of Ch'unghyodong continued the Koryŏ tradition of making *punch'ŏng* with inlaid decorations. However, both soon turned their efforts to developing and producing whiteware. The potters at Kwangju did so by rediscovering the material that Sŏri and Bangsandong potters had used for making their whiteware nearly five centuries earlier. For the glaze, they replaced wood ash with limestone as the chief flux agent, first in burnt form and then increasingly in crushed form. They also started using glaze stone as the clay component. The overall amount of calcium oxide was decreased, so the resulting glazes fell within the lime or lime-alkali types rather than the high- lime or lime types used by the Koryŏ potters.

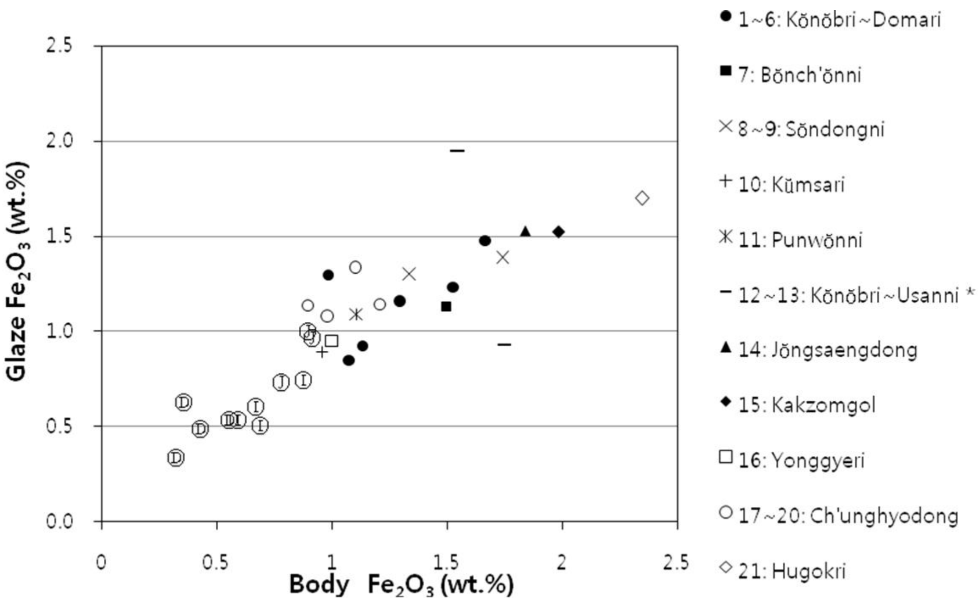


**Figure 6.** Graph showing $Fe_2O_3$ content in the body vs. that in the glaze. Abbreviations and symbols: Ⓙ Jingdezhen Ⓓ Dehua Ⓘ Dingyao *, Chosŏn celadon.

Ch'unghyodong's developmental efforts were more innovative and involved than those of the Kwangju complex. After a long search, the Ch'unghyodong potters succeeded in finding a totally different type of material for the ceramic body: kaolinite with a high content of albite. In the beginning, they used wood ash as the chief flux material for their glazes, but they eventually replaced the wood ash with limestone, and toward the end of the complex's hundred-year operation, they began using potassium feldspar to make a new type of glaze whose composition was similar to acid-rock composition type.

The local-level kilns at Yonggyeri and Hugokni show some similarities with Ch'unghyodong, but it is unclear how extensively, if at all, the high-aluminum-content kaolinite body material and acid-rock glazes were employed at local-level kilns operating at later dates. The whiteware-producing local-level kilns of the $18^{th}$ and $19^{th}$ century, especially those in the provinces of Kyongsangpukdo and Kyongsangnamdo, are only now being excavated. Systematic compositional studies on samples from these kilns should provide new insights on whether this departure from the traditional porcelain stone of Korea and southern China became an integral part of Korean ceramics, or if it was more of an anomaly.

Four groups of whiteware shards from the early Kwangju kilns of Kŏnŏbri and Usanni, two representing regular whiteware (Group 1 of Kŏnŏbri and Group 2 of Usanni) and two representing Chosŏn celadon (Group 12 of Kŏnŏbri and Group 13 of Usanni), highlight the importance of correlating the visible and artistic characteristics with the analytical results. In these cases, the difference in appearance between the regular whiteware and Chosŏn celadon was so slight that the samples were considered the same, and their compositional measurements were averaged in the initial analysis. The resulting values for the two kilns were puzzling, as the $P_2O_5$ contents were significantly higher than those of the other Kwangju kilns. However, once the shards were separated as whiteware and Chosŏn celadon, the averaged values showed that wood ash was the chief flux material in the Chosŏn celadon glaze, while burnt limestone is likely to have been used in the whiteware glaze.

The current study on 21 groups representing only eight centralized kilns in Kwangju and five local-level kilns in and around Ch'unghyodong is fairly limited in its scope, meaning that the conclusions drawn on the material characteristics of Chosŏn whiteware and their changes over time should be considered tentative. Even the kilns covered in this work have been inadequately investigated in most cases, as enormous piles of shards, saggers, and other kiln wastes accumulated over the tens and hundreds of years the kilns were operational. The adequate analysis and representation of general kiln characteristics is a daunting challenge that can, at best, be only be partially resolved. However, given close cooperation between ceramics art historians and archaeologists, careful selection of shard samples, and correlation of the data with visible and artistic characteristics, such representations should be possible. In the future, systematic compilation of new data within the present framework should lead to a deeper understanding of the individual kilns and their comparison to other kilns whose combined histories, from *togi* to whiteware, span over a thousand years. With information drawn together from such continued work, the story of ceramics in Korea can then be related more meaningfully to those of China, Japan, and the rest of the world.

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