

Metallurgical Study on Slim Bronze Dagger Excavated from Wonjangdong, Jeonju

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Abstract

Background/Objectives: This study reports the of microstructure and chemical components analysis of three pieces of slender bronze daggers and one piece of slender bronze dagger fragment excavated at Jeonju Wonjang-dong. **Methods/Statistical Analysis:** This study has conducted microstructure analysis and component analysis for slender bronze daggers from the perspective of metallographic and compares its outcomes with precedent research to examine the similarities and differences in terms of characteristics and manufacturing methods of slender bronze daggers. The structure analysis tests were done via optical microscopes and SEM (Scanning Electron Microscope) after the process of abrasion and collision. While, chemical composition of the samples was measured by EDS (Energy Dispersive Spectrometer) attached to the SEM. **Findings:** As a result of analyzing the microstructure, the study observed arborization structure in all of three pieces of slender bronze daggers and one piece of slender bronze dagger fragment, but not the trace of heat treatment or processing, and so the study judged that all of these had the cast structure. In the meanwhile, the component analysis found that these relics were made of ternary alloys of Cu-Sn-Pb (Cu 74-78%, Sn 18-22%, Pb 3-4%) with small content of As and S. All four pieces of analysis samples had more content of Sn and less of Pb, compared to general alloy composition scope (Sn 6-20%, Pb 5-10%) of bronze daggers so far reported. **Improvements/Applications:** This suggests the probability of the existence of human groups that wielded the unique bronze ware techniques of making such hard weapons as to stand repeated shocks at the time.

Keywords: Component Analysis, Jeonju, Microstructure, Slender Bronze Daggers, Wonjang-Dong

1. Introduction

Slender bronze daggers, which are being discovered at the southern parts of Cheongcheon River, the Korean peninsula belonging to the latter part of the Bronze Age or the former part of the Iron Age, are typical remains of Gojoseon (Ancient Joseon) discovered together with bronze mirrors, bronze spears and bronzes¹. Their origins, inflow routes, development and process of change contain the country's ancient history². While basic concept of a slender bronze dagger is identical with that of a mandolin-shaped bronze dagger, it has been called a slender bronze dagger as the originally-rounded lower half disappeared, shaping a slender form. And the slen-

der bronze dagger with unique form appearing only in the Korean peninsula is also called Korean bronze dagger³. Along the way, slender bronze daggers imported from Korea are also discovered in Maritime Province in Russia and Kyushu, Japan. Generally, a slender bronze dagger has more or less 30cm long dagger body and 2-3 cm long short handle on average and was used by covering a sheath of extraordinary shape. There are polygonal stripes at the center of the dagger. Both sides in front side are slender, allowing space for a belt⁴.

The earliest study of scientific research cases for slender bronze daggers was carried out¹. He sought to examine Korea's slender bronze daggers and bronze bells from the perspective of metallography and also assume producing

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area of raw materials using isotopic composition method⁵. While, In³ sought to identify the characteristics of slender bronze daggers by assuming the casting method and producing area of raw materials through scientific analysis of slender bronze daggers excavated at Muneui-myeon, Cheongwon, Geumgang River area. These days, research on nature and producing area of raw materials of bronze relics including slender bronze daggers continues to be conducted through scientific analysis of bronze relics in the early Iron Age excavated at Jeonbuk area⁶. And this study seeks to identify characteristics of slender bronze daggers from the perspective of metallography through scientific analysis of slender bronze daggers excavated at Wonjangdong Remains, Deokjin-gu, Jeonju City, Jeonbuk.

In 2011, Jeonbuk Cultural Property Research Institute conducted excavation investigation at Jeonju Wonjangdong Remains, and in G Remains identified the existence

of pit features in the Bronze Age, pit burials in the Early Iron Age and pit burials in the Joseon Dynasty, while the investigation excavated such relics as bronze daggers, bronze dagger handles, dagger axes bronze mirrors, clay stripe pottery, black pottery, jades attached to the front part of a crown, ceramic ware and bronze spoons⁷. Of these, the slender bronze daggers were excavated from remains arranged during the surface examination and Pit Burial in the Early Iron Age No. 1, 2, 3, 5. Relics analyzed in this study were four pieces in total; two pieces of slender bronze daggers excavated from Pit Burial No. 1 (Slender Bronze Dagger A, B), one piece of slender bronze dagger excavated from Pit Burial No. 2 (Slender Bronze Dagger C) and one piece of slender bronze dagger (fragment) collected during the surface examination (Slender Bronze Dagger D). The study collected very small amount of samples from them for the analysis shown in Table 1.

Table 1. Photo showing the locations where samples were taken

No	Artifacts	Findspot	Site analysis	Method analysis
1	Slender bronze daggers(A)	Remains G, Togwangmyo No.1		Microstructure and Component analysis
2	Slender bronze daggers(B)			
3	Slender bronze daggers(C)	Remains G, Togwangmyo No.2		
4	Slender bronze daggers(D)	Earth Surface Investigation		

This study has conducted microstructure analysis and component analysis for slender bronze daggers from the perspective of metallography and by comparing its outcomes with precedent research so as to examine the similarities and differences in terms of characteristics and manufacturing methods of slender bronze daggers⁸. Along the way, the study examines technical systems applied in manufacturing of slender bronze daggers and building on this would like to trace the change process of the relevant techniques. Given the fact that these sorts of slender bronze daggers are limited in the quantity for the analysis and the number of excavated relics is absolutely lacking, this study seeks to record the outcome and so lay foundation for technical aspects of slender bronze daggers as basic data.

2. Artifacts and Analysis Method

2.1 Artifacts

2.1.1 Slender Bronze Daggers (A)

This slender bronze dagger, excavated at the upper part of soil within Pit Burial No. 1, has the handle end lowered downward. The blade part and side groove are missing and at the center of the body a vertebral column is formed, while the vertebral edge is also identified shown in Figure 1. The vertebral edge is formed only up to the middle of the side groove and plain formation of body comes down straight and at the side groove becomes concavely and at the lower part keeps a straight form, though the study was not able to identify the exact form because the relative parts are mainly missing these days. The base is finished by a diagonal line near to a straight line at the edge whereas handle end remains intact as casting trace

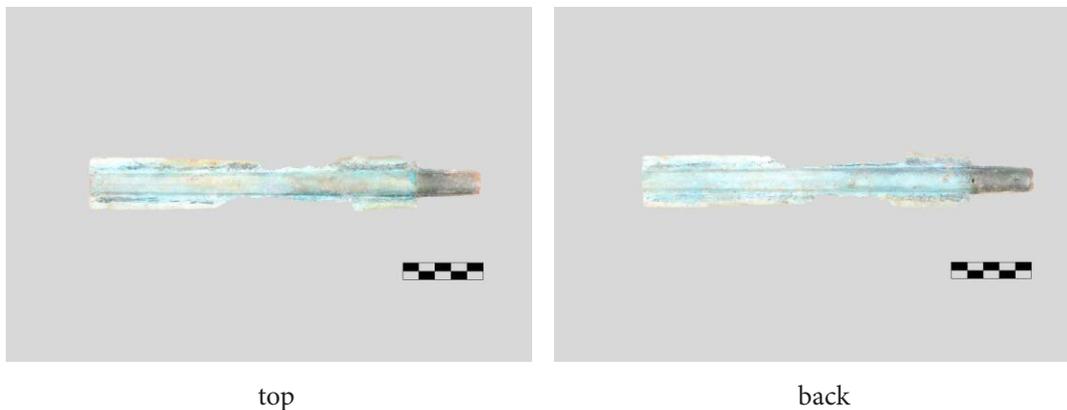


Figure 1. Photos showing the appearance of the Slim bronze dagger (A) excavated from Wonjangdong at Jeonju.

was not ground. Cross section of the vertebral column is octagonal and cross section of the handle end - circular - is 23.7 cm long and 3.2 cm wide based on the remaining part. The vertebral column is 1.3cm wide, the side groove is 5.6 cm long and weighs 204.7 g.

2.1.2 Slender Bronze Daggers (B)

This slender bronze dagger was excavated as a pair with dagger handle. At the time of its excavation, the dagger body was separated and was restored by preservation treatment. Only the edges of blade and blade itself were missing, so sustaining good shapes in general shown in Figure 2. At the center of the body, a vertebral column is formed and the study identified the edges spanning to the border between the side groove and the lower part. Plain formation of the body comes down diagonally and at the side groove becomes concavely and at the lower part narrows again diagonally to reach at the base finally. The blade, now missing by corrosion, is not sharp and the base is finished almost like a straight line, while the vertebral column forms tiny bundles at the side groove. The handle end was ground and cross section of the vertebral column is octagonal and cross section of the handle end is circular. The corrosion of the blade is severe and the remaining relic is 32.9 cm long, 4.0 cm wide. The vertebral column is 1.5 cm wide and the side groove is 3.5 cm long, while the handle end is 2.7 cm long and weighs 341.1 g.

2.1.3 Slender Bronze Daggers (C)

This slender bronze dagger, excavated at the wooden coffin of Pit Burial No. 2, has the vertebral column at the center of the body while the vertebral edge is also identified shown in Figure 3. The vertebral edge spans to the border between the

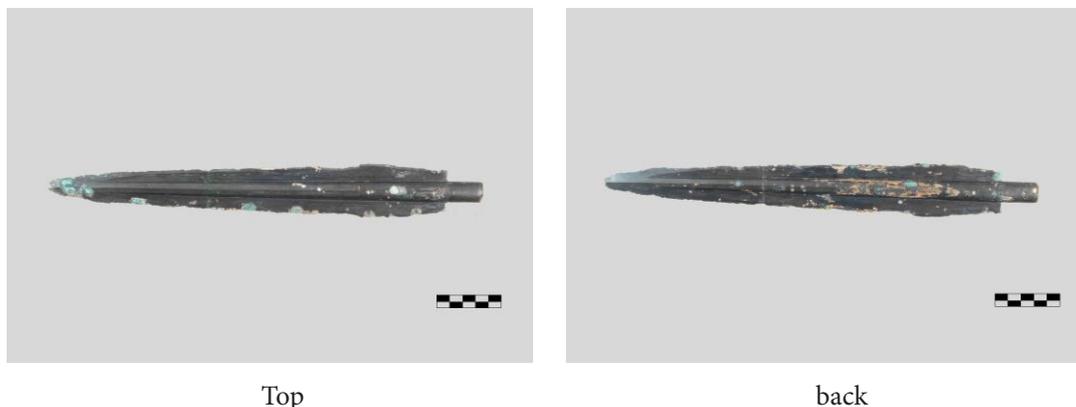


Figure 2. Photos showing the appearance of the Slim bronze dagger (B) excavated from Wonjangdong at Jeonju.

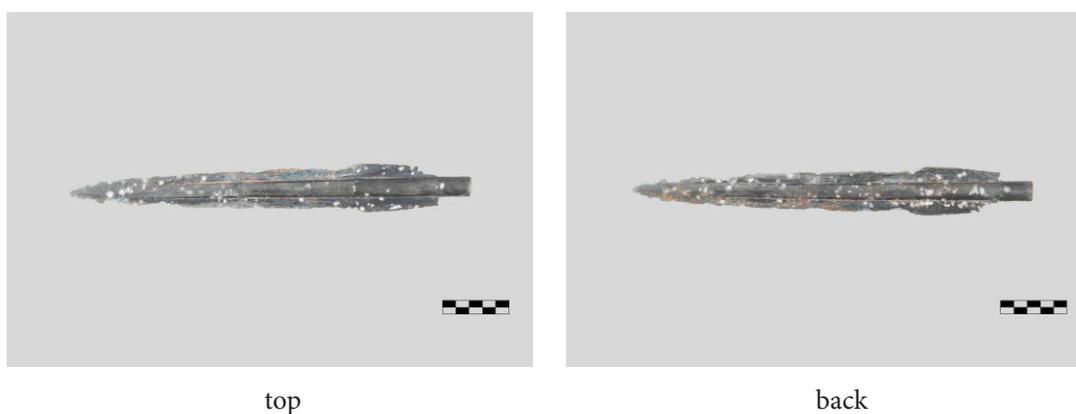


Figure 3. Photos showing the appearance of the Slim bronze dagger (C) excavated from Wonjangdong at Jeonju.

side groove and the lower part. Plain formation of the body comes down gently from the blade and at the side groove becomes concavely and at the lower part narrows again diagonally to reach at the base finally. The blade remains only below the side groove, and the base, with one side missing, and is curved near the edge diagonally almost like a straight line. The blade constitutes tiny bundles at the side groove and the handle end maintains its casting trace intact. Cross section of the vertebral column is octagonal and that of the handle end is circular, whereas the blade is not sharp as most part of this bronze dagger is severely corroded. This remaining relic is 29.5 cm long, 3.5 cm wide, the blade part is 4.5 cm long and vertebral column is 1.2 cm long. The side groove is 3.7 cm long and weighs 224 g.

2.1.4 Slender Bronze Daggers (D)

Slender bronze dagger fragment (D) has merely the blade part as the relic was collected at the time of surface examination shown in Figure 4. The blade part has its edges of vertebral column - at the center of the dagger - connected to the end, whereas the blade part and blade itself, with

its edges now missing, are not sharp. Cross section of the vertebral column is octagonal and the blade part is diamond-shaped. This remaining relic is 6.05 cm long; 2.3 cm wide, the vertebral column is 1.0 cm long and weighs 26 g.

2.2 Analysis Method

Table 1 shows the places from which very small amount of analysis samples were collected during maintenance process. Analysis samples were used for structure analysis tests via optical microscopes and SEM (Scanning Electron Microscope) after the process of abrasion and collision. While, chemical composition of the analyzed samples was measured by EDS (Energy Dispersive Spectrometer) attached to the SEM⁹.

3. Result and Consideration

3.1 Slender Bronze Daggers (A)

Figure 5, the microstructure of Slender Bronze Dagger (A), constitutes corroded layers at the right lower part

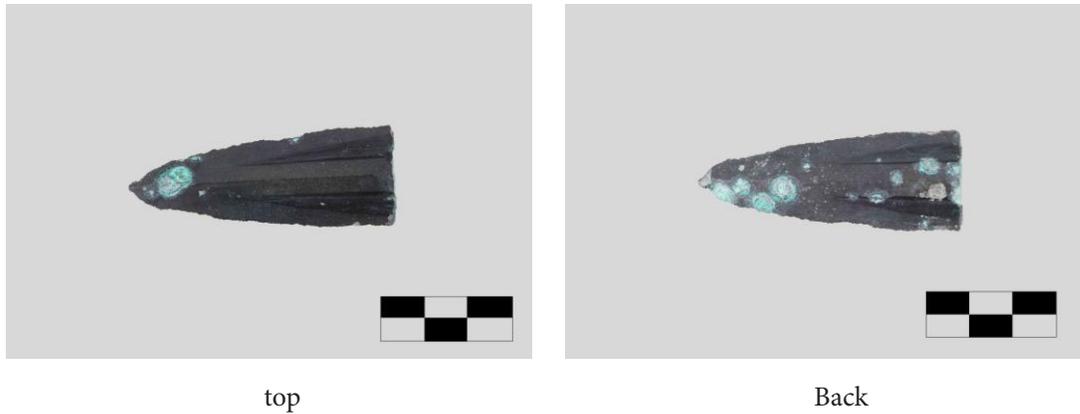


Figure 4. Photos showing the appearance of the Slim bronze dagger (D) excavated from Wonjangdong at Jeonju.

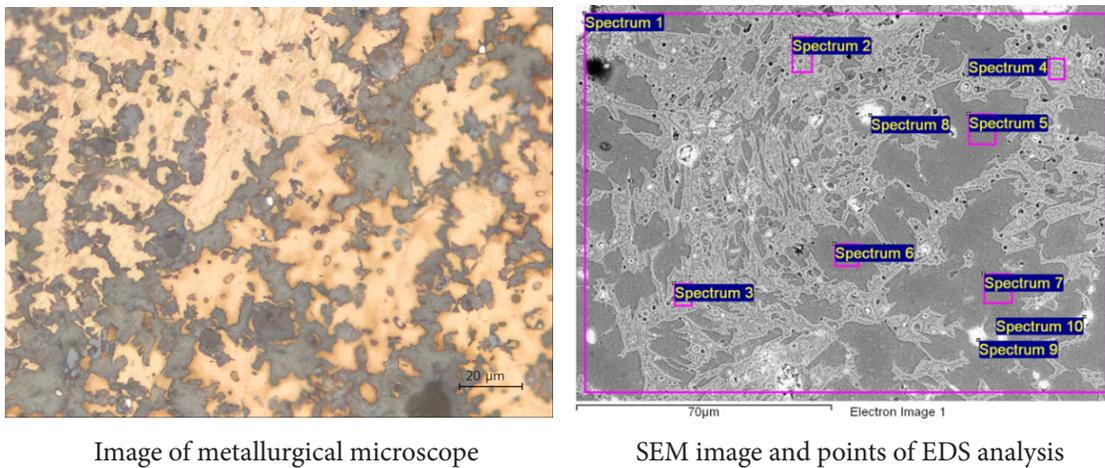


Figure 5. Microstructure of Slim bronze dagger (A).

and has distributions of silver-white $\alpha+\delta$ phase based on yellow α phase. As a result of semi-quantitative analysis using the EDS (Energy Dispersive Spectrometer), the study detected CU 74.91%, Sn 20.71%, Pb 4.16%, As 0.5% shown in Table 2. Compared to general alloy composition scope of slender bronze daggers (Sn 6-20%, Pb 5-10%), it has lower content of Pb but the study believes that it was produced using more Sn content and less Pb content so that it could penetrate into the objects easily taking advantage of the traits of bronze weapons. Moreover, component 'As' often found in the Bronze Age was generally what remained in copper from the ore through smelting process rather than intentional addition and so As detected from Slender Bronze Dagger (A) can be assumed to have been contained by the same route (Han Woo Rim; Cultural Asset No. 48, 2). It has also general cast structure that shows no sign of heat treatment or processing, given its structural characteristic.

Table 2. EDS results of Slim bronze dagger (A)(not detected)

Analysis Position	Composition (wt.%)				
	Cu	Sn	Pb	As	S
1	72.9	21.5	5.6	.	.
2	69.8	25.7	4.6	.	.
3	69.5	25.1	5.4	.	.
4	69.8	25.8	3.8	0.6	.
5	81.0	15.8	3.2	.	.
6	80.9	15.2	3.4	0.4	.
7	80.5	15.9	3.1	0.5	.
Average	74.91	20.71	4.16	0.50	.

3.2 Slender Bronze Daggers (B)

Figure 6, the microstructure of Slender Bronze Dagger (B) has a structure that well developed dendrite - a typical cast structure of bronze - and comprises heterogeneous α phase and eutectoid $\alpha+\delta$ phase. As a result of component

analysis using the EDS, the study detected Cu 74.3%, Sn 21.6%, Pb 3.84%, as 0.26%, S 0.5% shown in Table 3. While most of slender bronze daggers contains 6-20% of Sn and 5-10% of Pb, this study believes that Slender Bronze Dagger (C) required higher level of hardness fitting the characteristic of weapons that could stand repeated shocks and penetrate into hard objects, by containing more Sn and less Pb. Moreover, component 'As' often found in the Bronze Age was generally what remained in copper from the ore through smelting process rather than intentional addition and so as detected from Slender Bronze Dagger (C) can be assumed to have been contained by the same route. In the meanwhile, detection of very small amount of S component tells us that this belongs to inclusion in the sulfide group. Given its structural characteristic, this relic must have a typical cast structure that shows no sign of heat treatment or processing.

3.3 Slender Bronze Daggers(C)

Figure 7, the microstructure of Slender Bronze Dagger (D), has distributions of silver-white $\alpha+\delta$ phase based on yellow α phase. As a result of the analysis using the EDS, the study detected Cu 78.14%, Sn 18.07%, Pb 3.76% (Table 4). Though this result is not within general alloy composition scope of slender bronze daggers (Sn 6-20%, Pb 5-10%), the study believes that it was made harder by addition of Sn content and lowering of Pb like general alloy composition scope of bronze arrowheads (Sn 12-20, Pb lower than 5%). Given its structural characteristic, this relic is believed to have been coagulated relatively slowly while being cast and then have cooled down slowly without further processing.

3.4 Slender Bronze Daggers (D)

Figure 8, the microstructure of Slender Bronze Dagger (E), has distributions of silver-white $\alpha+\delta$ phase based on

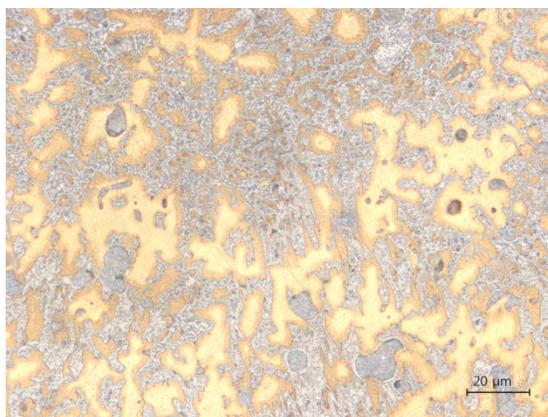
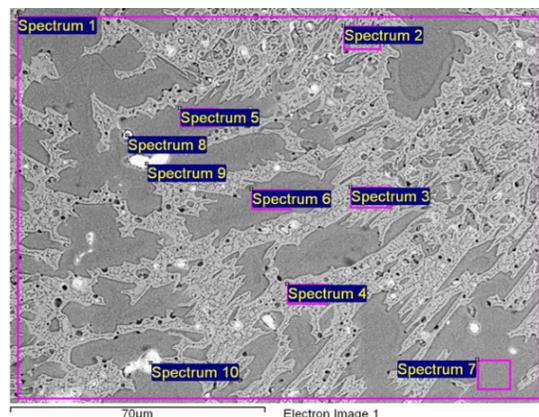


Image of metallurgical microscope

Figure 6. Microstructure of Slim bronze dagger (B).



SEM image and points of EDS analysis

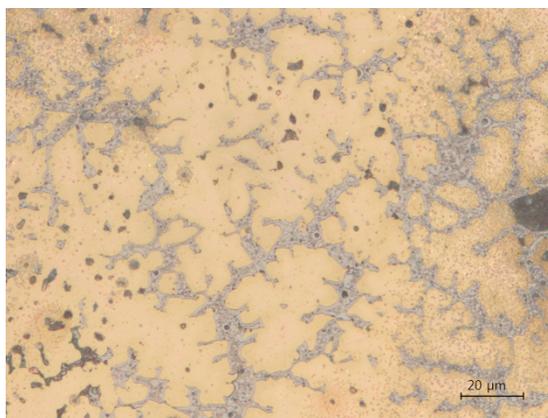
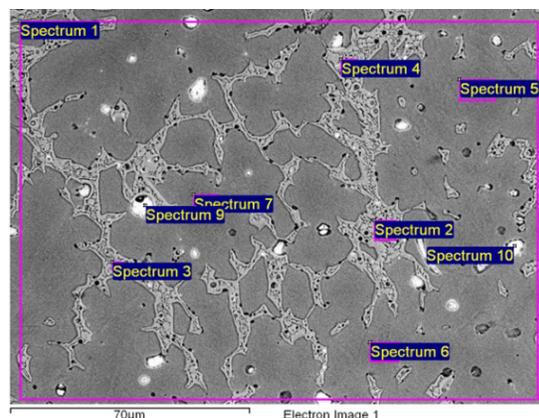


Image of metallurgical microscope

Figure 7. Microstructure of Slim bronze dagger(C).



SEM image and points of EDS analysis

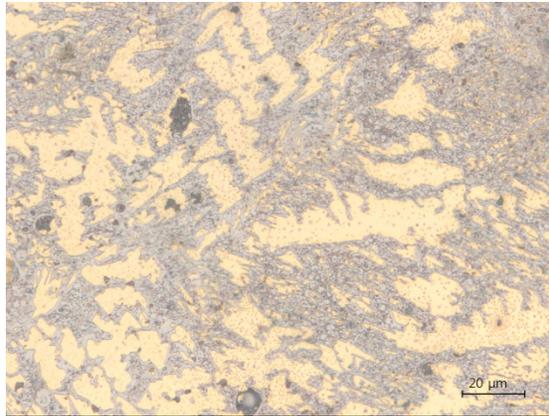
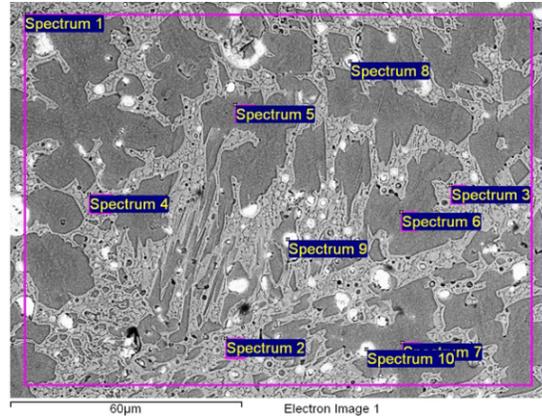


Image of metallurgical microscope



SEM image and points of EDS analysis

Figure 8. Microstructure of Slim bronze dagger (D).

Table 3. EDS results of Slim bronze dagger(B)(not detected)

Analysis Position	Composition(wt.%)				
	Cu	Sn	Pb	As	S
1	72.3	22.6	4.7	0.4	.
2	70.6	25.1	4.1	0.3	.
3	70.0	26.0	3.5	.	0.5
4	69.5	26.4	4.0	0.1	.
5	79.3	17.1	3.6	.	.
6	79.1	17.1	3.5	0.3	.
7	79.3	16.9	3.5	0.2	.
Average	74.30	21.60	3.84	0.26	0.50

Table 4. EDS results of Slim bronze dagger(C)(- : not detected)

Analysis Position	Composition(wt.%)				
	Cu	Sn	Pb	As	S
1	78.4	17.1	4.4	.	.
2	73.3	23.3	3.4	.	.
3	72.4	24.1	3.5	.	.
4	71.0	24.4	4.6	.	.
5	84.1	12.5	3.3	.	.
6	84.0	12.2	3.8	.	.
7	83.8	12.9	3.3	.	.
Average	78.14	18.07	3.76	.	.

yellow α phase. As a result of the analysis using the EDS, the study detected Cu 76.07%, Sn 22.01%, Pb 3.05% shown in Table 5. While this result shows lower content of Pb compared to general alloy composition scope of slender bronze daggers (Sn 6-20%, Pb 5-10%), the study believes that it was made harder and shockproof by addition of

Table 5. EDS results of Slim bronze dagger(D)(- : not detected)

Analysis Position	Composition(wt.%)				
	Cu	Sn	Pb	As	S
1	73.3	22.3	4.4	.	.
2	70.9	26.7	2.4	.	.
3	73.1	26.9	.	.	.
4	71.2	26.0	2.8	.	.
5	80.1	17.3	2.6	.	.
6	81.6	17.9	.	.	0.5
7	82.3	17.0	.	.	0.7
Average	76.07	22.01	3.05	.	0.60

Sn content and lowering of Pb like general alloy composition scope of bronze arrowheads (Sn 12-20, Pb lower than 5%). Given its structural characteristic, this relic is believed to have been coagulated relatively slowly while being cast and then have cooled down slowly without further processing. And detection of very small amount of S component tells us that it may belong to inclusion in the sulfide group.

4. Conclusion

Based on the above findings, the following is the assumption of characteristics and manufacturing techniques of three slender bronze daggers and one slender bronze dagger fragment excavated at Wonjang-dong, Jeonju.

As a result of analyzing the microstructure, the study observed arborization structure in all of three pieces of slender bronze daggers and one piece of slender bronze

dagger fragment, but not the trace of heat treatment or processing, and so the study judged that all of these had the cast structure. The component analysis found that these samples were made of ternary alloys of Cu-Sn-Pb (Cu 74-78%, Sn 18-22%, Pb 3-4%). And the study found small amount of As and S contained therein - belonging originally to the ore - and accordingly not created intentionally. All four pieces of analysis samples had more content of Sn and less of Pb, compared to general alloy composition scope (Sn 6-20%, Pb 5-10%) of bronze daggers so far reported.

In¹ Ju's treatise, which summarized the analysis result of total 24 bronze daggers including two pieces of mandolin-shaped bronze daggers and 22 of slender bronze daggers, reported that all bronze daggers except one contained 2% or more Pb with their average Sn content and Pb content being 12.1% and 6.7% respectively. Precedent studies on bronze daggers, with the main objective measuring the chemical components of alloys, lacked the data for microstructure, which means that the research has not been able to figure out the production methods. Given that if Pb were to be added, striking process would be difficult to carry out, the study concluded reasonably that all of these samples might have been manufactured by the casting process.

The slender bronze daggers in this study, with extremely high content of Sn up to 22% and eutectoid structure observed, were judged to be in conditions unavailable for striking process and so have been manufactured by casting. The study could find that the slender bronze daggers were manufactured for actual battles by reinforcing the traits as a weapon by lowering Pb content and so standing hard and repeated shocks. And the study could presume there might have been human groups that wielded the unique bronze ware techniques in Jeonju area at the time.

5. References

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