Application of Accelerator Mass Spectrometry in Establishing the Chronological Framework of Ancient Iron Technology in Korea

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Synopsis: Iron technology plays an important role in many of the mechanisms postulated crucial in the formation and development of early Korean states. Despite its importance in Korean history and the abundance of material evidence recovered in the peninsula, the study on the ancient iron production based strictly on scientific evidences is still in its infant stage. Two major problems confronting the archaeological study on the appearance and the later diffusion of iron throughout the Korean peninsula include the uncertainties in chronology arising from reliance on relative dating based on typology and the lack of metallurgical studies on its production techniques. It is imperative, therefore, to remove such uncertainties if the iron industry and its integration into society can be compared and contrasted in different areas and thereby the history of iron production is to be better understood in terms of state formation. The present study will briefly review recent metallurgical works on ancient iron artifacts and then test the possibility of introducing the accelerator mass spectrometry (AMS) in establishing the chronological framework of ancient iron technology in Korea.

1. Microstructure Examination

Figures 1a and 1b present 2 iron axes made during the Korean Three Kingdoms Period.[1)] The axes in Figure 1a and 1b were recovered from the former Silla and Paekche territory, respectively.[2,3)] Specimens were taken from their blade and body part noted in both figures by arrows 1 and 2, respectively.

Figure 1c is an optical micrograph of the microstructure observed at the blade of Figure 1a. Here, the gray region near the left edge is filled with a corrosion product, indicating that it corresponds to the cutting edge that was exposed. The region next to the corroded layer is seen to consist of dark pearlite that is replaced by white ferrite as

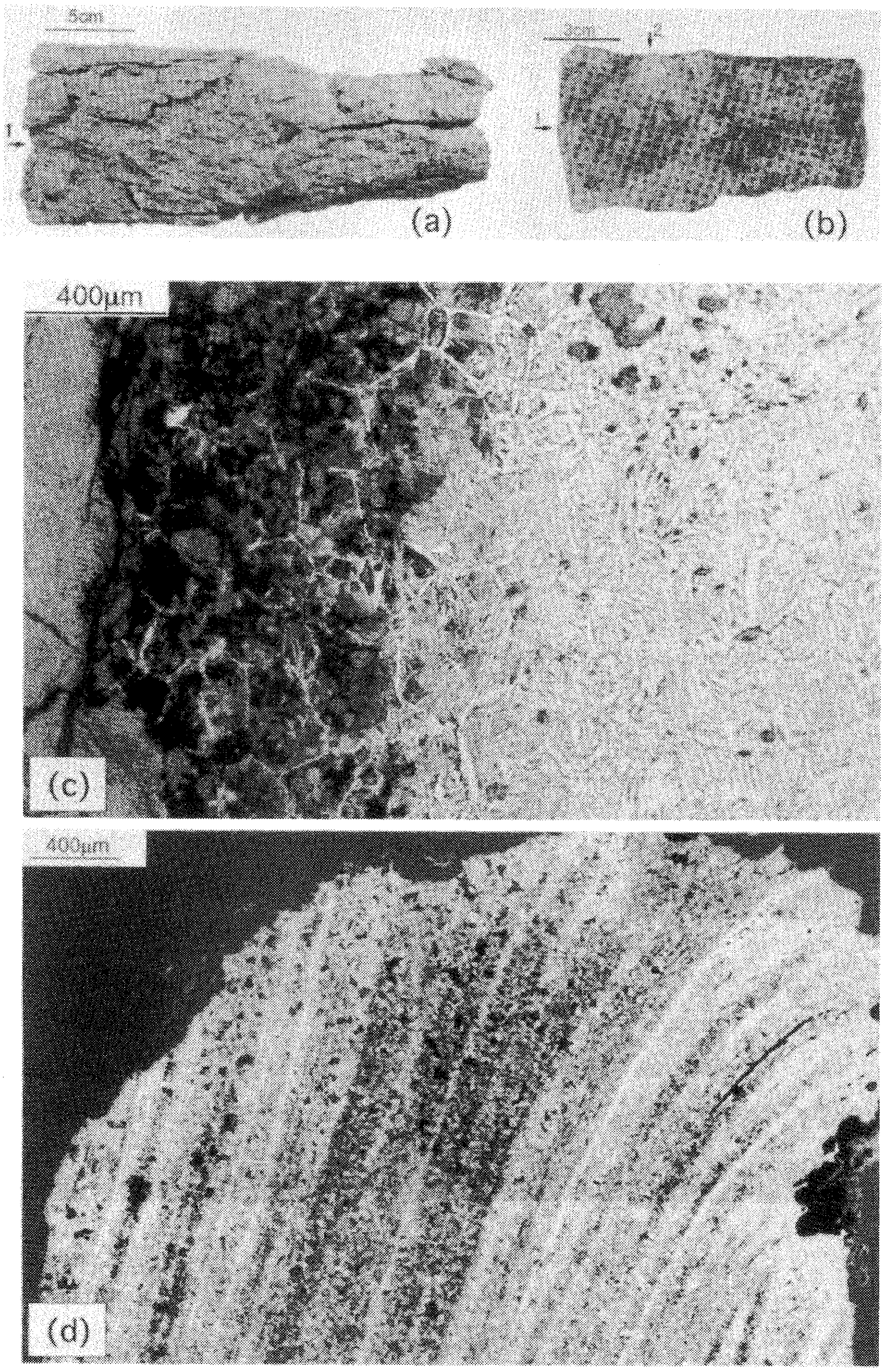

Figure 1. Ancient iron axes and their microstructure.
(a)Silla ax, (b) Paekche ax,
(c) & (d) microstructure of (a) and (b), respectively.

one goes to the right. The specimen from the body, arrow 2 in Figure 1a, was found to consist mostly of ferrite. The most apparent feature here is that the high C concentration at the near-surface region of the blade gradually decreases to the interior until it becomes negligible. This is a strong indication that the ax was given a carburization treatment at the surface. The original pattern of C distribution still maintained indicates that carburization was applied at the last stage, most probably upon the completion of shape forging. If the C content is raised at the last stage, it implies that the raw material supplied does not have enough C to meet the strength requirement. The present ax was, therefore, evidently made of low C iron, which was first forged for shaping and then carburized for the sake of hardening.

Figure 1d is an optical micrograph showing the microstructure at the body of the ax in Figure 1b. The structure consists of many layers running vertically. They are apparent because of the different microstructures caused by the uneven C content. The specimen taken from the blade was found to have the similar layered structure. The different gray level, originating from the varying C content between layers, indicates that the raw material supplied for making the ax was not uniform in its local C content. The numerous fine layers must then have resulted from the unique mechanical treatment given in the ax making. Such a layered pattern can emerge when the forging and folding operation is applied repeatedly in cycles on a piece of steel with uneven C distribution.

The above 2 axes are clearly distinguished in the amount and distribution of C in a raw material, which come to determine the kind of thermo-mechanical treatments required. The C adjustment, named steel making, is an indispensable step to be incorporated for hardening somewhere in the process of every ax making. It is found that the 2 axes were manufactured following 2 different engineering sequences depending on the time this steel making is performed relative to shape forging. The one in Figure 1a may be characterized by the sequence of 'shape forging prior to steel making' as opposed to that of 'steel making prior to shape forging' that is identified in the other ax.

2. Accelerator mass spectrometric (AMS) dating

A broken cast iron cauldron was excavated from the Hwangnam Great Tomb, together with the ax in Figure 1a. The tomb is located in Kyongju, a former capital of Silla. A fragment from the cauldron was subjected to the AMS dating. Table 1 presents the result based on a 5568-yr half-life and corrected for carbon-isotopic fractionation. The age is estimated to be 1619±24 in yr BP with the most probable calibrated age positioned in 425 AD. It is noted that the probabilities of the calibrated age falling in the ranges of 404-441, 450-466 and 518-529 AD are of 62.9, 16.3 and 11.2%, respectively.

The construction of the Hwananm Great Tomb is closely associated with the period Silla started on her way to becoming a powerful ancient state, which would finally unify the Korean Peninsula for the first time in history in 668 AD.[1] The burial goods recovered from it hold special importance in studying the material culture of not only Silla but also the two kingdoms in rivalry at the time, Paekche and Koguryo, since little written account is available. They are also important in the study of Japanese Kofun period during which there had been a constant cultural influence between the Korean Peninsula and the Japanese Archipelago. Unfortunately, however, the exact date of its construction, and thereby the incubation period for the powerful Silla, is in disagreement among scholars. The present AMS result is found to fall within the age range predicted by some archaeologists on typological grounds.[4] Additional cast iron samples from the tomb are awaiting measurements to test further the use of the AMS technique in establishing a reliable chronology.

Table 1. Result of the accelerator mass spectrometric (AMS) dating performed at the Nagoya University, Japan.

Lab Code	$\delta^{13}C$ [‰]	^{14}C Age [yr BP]	Calibrated Age [cal. AD]	Calibrated Age range [cal. AD]
NUTA2-4233	-29.3±0.1	1619±24	425	404-441 (62.9%) 450-466 (16.3%) 518-529 (11.2%)

3. Summary

The microstructural data suggest that there were at least 2 distinct iron infrastructures established in ancient Korea. They may be characterized by the unique sequence of manufacturing processes, 'shape forging prior to steel making' and 'steel making prior to shape forging'. The distinction is seen to arise from the selection of a particular starting material and the pertinent mechanical treatment. The combination was apparently based on such important technical aspects of iron industry as iron smelting and steel making. There is no doubt that such a technological framework of a certain society is established in close association with the socio-political and geographical conditions it is in. The proper recognition of iron industry in terms of its general and particular features could therefore lead to the better understanding of ancient societies, especially with regard to the flow and development of technical ideas among them. This can only be attained when there is a wide spectrum of reliable data available over space and time through extensive researches in metallurgy as well as in scientific chronology. The overall picture of the history of iron production in ancient Korea cannot be drawn until a reliable chronological framework has been established in association with technical and socio-political aspects. It is, therefore, too early to draw any conclusion of the regional or temporal variations incorporated due perhaps to the different routes taken in adopting iron technology. The present study, however, highlights the potential diversities in iron production that might exist in such a dynamic period of Korean history throughout the rise and development of the first states. More importantly, this article has tested, on scientific grounds, the possibility of detecting such diversities in association with the scientific dating based on AMS to the better understanding of ancient societies. The results are indeed encouraging.

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