Estimation of the Thermal History, Usage and Age of a Korean Cast Iron Artifact

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Iron is considered to have played a crucial role in the rise and subsequent development of the first Korean states. Archaeological study on the history of iron production in Korea, however, is plagued with uncertainties due primarily to lack of metallurgical work and reliable chronological framework. The present study has examined a cast iron artifact in terms of its microstructure and its date of manufacture. The artifact was excavated from a burial site of the former Kaya kingdom located at the modern city of Kimhae. The artifact is found to hold unique microstructural characteristics indicating employment of a long thermal treatment applied on white cast iron. It also includes a considerable amount of arsenic, suggesting the establishment of trade routes between two ancient kingdoms, Kaya and Silla. The 14C age determined through accelerator mass spectrometry on carbon material extracted from the artifact, as well as the thermoluminescence age of a shard sample, were in fairly good agreement with the relative ages of their excavation sites estimated on typological grounds, i.e., the 4th century AD. These results demonstrate the potential importance of metallurgical examination, if combined with reliable chronology, in the characterization of specific iron technologies practiced in ancient societies. The results also support the use of radiocarbon dating on C from iron artifacts as a potential method of establishing a reliable chronology in Korea.

Keywords: ancient Korea, cast iron artifact, thermal treatment, radiocarbon dating, thermoluminescence dating

1. INTRODUCTION

Iron plays an important role in various mechanisms considered to have been crucial in the rise and subsequent development of the first Korean states. Despite the importance of iron on state formation and the abundance of material evidence recovered on the Korean peninsula, the quest for evidence of ancient iron production based strictly on scientific methods is still in its infant stage. As a result, archaeological study on the appearance and the later diffusion of iron throughout the Korean peninsula is plagued with uncertainties arising from reliance on relative dating based primarily on typological grounds and lack of metallurgical studies on production techniques. It is believed by some that the period ascribed to most iron-bearing sites prior to the 5th century AD in Korea is at best an estimate [1]. It is imperative, therefore, to remove such uncertainties if the regional and temporal characteristics introduced in the establishment of local iron industry are to be compared and contrasted, thereby allowing the history of iron production to be better understood in terms of state formation.

As an initial step toward achieving such a goal, this study has tested the use of cast iron artifacts in the scientific assessment of their thermal history, usage and age, as well as the origin of ores supplied in smelting. A cast iron artifact excavated from a tomb in a historical site known as the Daeseongdong Tomb Complex has been chosen for the test. Located in the modern city of Kimhae near the southern coastal area, as shown in Fig. 1, the site is estimated to have been under construction from as early as the 1st century AD through the early 5th century AD within the territorial boundary of the ancient kingdom, Kaya. Each of the tombs in the site was given an approximate date of construction by reference to the characteristic typology of burial pits and goods [2]. Kimhae, the capital of the former Kaya state, is known for the account of this city given in the Chinese history book, Weizhi, written in the 3rd century AD and quoted by Barnes [3]. It is reported that iron articles produced there were exported to Chinese commanderies occupying the northern region at the time and to other polities in the peninsula as

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well as to Japan. This period was a critical moment in Korea, which saw the rise from among the many preexisting polities of the first ancient states that would eventually develop into Koguryo in the north and Paekche, Silla, and Kaya in the south, as shown in Fig. 1 [4]. This era is currently referred to as the Three Kingdoms Period, likely because the first three states survived longer than Kaya before they were merged into Silla. In 668 AD, the Unified Silla was established, becoming the first unified kingdom in the Korean Peninsula. The reference in Weizhi, however, was made concerning the Kaya iron industry, indicating its crucial role in the production and supply of iron. Throughout the entire period of their existence, the four kingdoms were in constant rivalry, and as such production by the iron industry of various weapons, tools, and utensils as well as semi-finished iron products would have been a necessary requirement for their very survival.

2. COMMENTS ON ARTIFACT AND EXPERIMENTAL METHODS

Fig. 2 shows the general appearance of the cast iron article examined in this study. As seen in Fig. 2(a) it was broken when recovered from Tomb#18, dating on typological grounds to the early 4th century AD [2]. Fig. 2(b) is a sketch of the assembled form of the specimen. Artifacts in this shape are among those most frequently and abundantly excavated throughout the entire Korean peninsula from both residential and burial sites. They began to appear in very early iron sites dating as early as to the 3rd century BC. They are referred to in Korea as well as in Japan as ‘cast iron axes’, due probably to the material they are made from and their peculiar shape resembling axes. But the brittle nature of cast iron, especially when it is in the form of white cast iron as found in most cast iron artifacts, raises doubts regarding whether they had in fact been used as real axes. Sometimes they are found in bundles, each holding several tens, with occasional occurrence of a clay core still remaining in the socket. This may indicate potential usage as a means of trade and transportation. If this is the case, additional treatments, either thermal or mechanical, may have been necessary before they were made into final products.

The present study first examined the metallurgical microstructure of a broken piece from the artifact to determine if there is any evidence of deliberate thermal or mechanical treatments. The sample was prepared following standard metallographic procedures and then etched with 2 % nital for the microstructure examination using an optical microscope and a scanning electron microscope (SEM). An energy dispersive spectrometer (EDS) equipped in the SEM was used for micro-composition analysis.

The second experiment employed a Tandetron accelerator mass spectrometer (AMS) installed in the Dating and Materials Research Center at Nagoya University to assess whether the AMS technique could give a valid age estimation of the present artifact. The AMS technique, with the required amount of C reduced to the level of a few mg, opens the door for iron and steel artifacts to be candidate archaeological materials for age determination. Among the aims of the present experiment is assessing the possibility of using the numerous C-bearing iron artifacts excavated in Korea in establishing an absolute archaeological chronology. Unlike C in organic materials such as wood, grain, plants, and fabric, C alloyed in metallic material, if it lies deep inside the material, away

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**Fig. 1.** Approximate locations of Koguryo, Paekche, Silla and Kaya, and the city of Kimhae within the territorial boundary of the former Kaya kingdom.

**Fig. 2.** General appearance of a cast iron article from Tomb#18 of Daejeongdong Tomb Complex located in the modern city of Kimhae: (a) photograph and (b) sketch.