Provenance investigation of ancient glass vessels excavated from Silla tombs by nondestructive X-ray fluorescence analysis

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Glass was first developed at West Asia in late 3rd millennium BC and was produced widely at various places in Eurasia during 1st millennium AD. Lot of glass products were traded between Western and Eastern world through the Silk road, and a part of them were exported to ancient Korea and Japan as consuming regions without technique of primary glass production. In the ancient times, glass vessels, a major purpose of glass in the present day, were produced only among limited regions because of the technical difficulty to shape the vessel. Therefore, glass vessels were extremely rare and valued in Eastern Asia including Korea and Japan compared to small glass beads that easily produced and transported. On the other hand, it is interesting that a number of glass vessels were excavated from Silla tombs (late 4th to early 6th centuries AD) located in Gyeongju, south Korea. In this study, therefore, with the aim to reveal where these precious glass vessels come from, we conducted nondestructive X-ray fluorescence analysis of glass vessels excavated from Silla tombs in the collection of Gyeongju National Museum; possible provenance(s) of these glass vessels were estimated by utilizing the chemical composition data as scientific fingerprint.

21 pieces of glass vessel objects excavated from several Silla tombs (Hwangnamdaechong Tomb, Heavenly Horse Tomb, and Gold Crown Tomb, etc.) were investigated in the present study. Note that a part of the objects analyzed are fragments and some of them might originated to same vessel. All of these objects are now stored in Gyeongju National Museum, and one of them, a blue glass cup from Heavenly Horse Tomb, are now designated as National Treasure in Korea. We brought a portable X-ray fluorescence spectrometer 100FA-IIL (Ourstex Corp.) into Gyeongju National Museum and applied it to the chemical composition analysis of Silla glass vessels in the nondestructive manner. The spectrometer mounts a vacuum chamber and a built-in monochromator and can analyze both light elements including Na and trace amount (~ppm) of heavy elements. For further information on the spectrometer, please refer to our previous studies[1,2)].

As the result of our XRF analysis, it was revealed that all of 21 pieces of Silla glass vessels were made by soda-lime silicate glass. Before the 6th century AD, the soda-lime silicate glass was primary produced in three regions: Roman (and early-Byzantine) Empire in the Mediterranean region, Sasanian Empire in West Asia, and Central Asia. The glass products of these three regions can be distinguished by the chemical compositions of the different raw materials used, especially by the difference of soda flux. In the region west of the Euphrates, mainly Roman Empire, natron from lower Egypt, was mainly used as soda flux. By contrast, in the east of the Euphrates, West and Central Asia, a plant ash flux was continuously used since the beginning of glass production. The plant ash contains various elements depending on species and growth environment of plants, and these elements immix into glassware as impurities by using the plant ash. By comparison of chemical composition data between 21 pieces of Silla glass vessels investigated in the present study and literature data of glassware from these three regions, we could identify that 6 pieces including the cup from Heavenly Horse Tomb are Roman natron glass, and the remaining 15 pieces are Central Asian plant ash glass. In addition, detailed production areas and dates are discussed for 6 pieces of Roman natron glass.

Therefore, it is concluded that glass vessels inflowed into the Korean Peninsula during late 4th to early 6th centuries AD could be divided into at least two groups, Roman glass and Central Asian glass, by

nondestructive onsite X-ray analysis. It is interesting that no Sasanian glassware was identified in Silla glass vessels in contrast to some pieces of Sasanian glass vessels transported into ancient Japan.
1) Y. Abe *et al.*: *J. Archaeol. Sci. Rep.*, **17**, 212 (2018).
2) Y. Abe *et al.*: *J. Archaeol. Sci. Rep.*, **20**, 362 (2018).

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