Article

Chemical Analysis of Ancient Glass in Vietnam:

A Comparative Study of Glass Beads Found in Vietnam and Japan

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Abstract

Large quantities of glass artifacts have been excavated in Vietnam, but while archaeological evidence for glass production has been found, not enough analytical research on the material has occurred. To identify characteristics of the composition of glass artifacts excavated in Vietnam, we conducted a chemical analysis by portable XRF on artifacts belonging to the Dong Son and Sa Huynh cultures. As a result, most of the glass artifacts analyzed in this research are considered to have been produced in Vietnam. Although a small amount of glass can be inferred to relate to Ban Don Ta Phet in west-central Thailand, there was no clear evidence found for an active relationship with regions further west—such as the Thai-Malay Peninsula, Myanmar, or India. Regarding the relationship with East Asia, glass beads in Vietnam and Yayoi period Japan were similar—consisting mainly of beads made by the drawing method. However, it turned out that glass beads in Vietnam have various combinations of compositional types and colorants different from those in Japan, making it hard to say that Vietnam was a direct source of the Indo-Pacific Beads distributed in Japan.

Key words: Vietnam, Dong Son culture, Sa Huynh calture, Glass, XRF

1. Introduction

Glass has been actively traded on land and sea routes since ancient times and was widely distributed across the Eurasian continent. In East Asia from the 1st century BCE to the 1st century CE, glass beads in the central area of the Han Empire are rarely found, but they were widely distributed in the surrounding Korean peninsula and Japanese archipelago.

Received: August 12, 2020 Accepted: November 16, 2020
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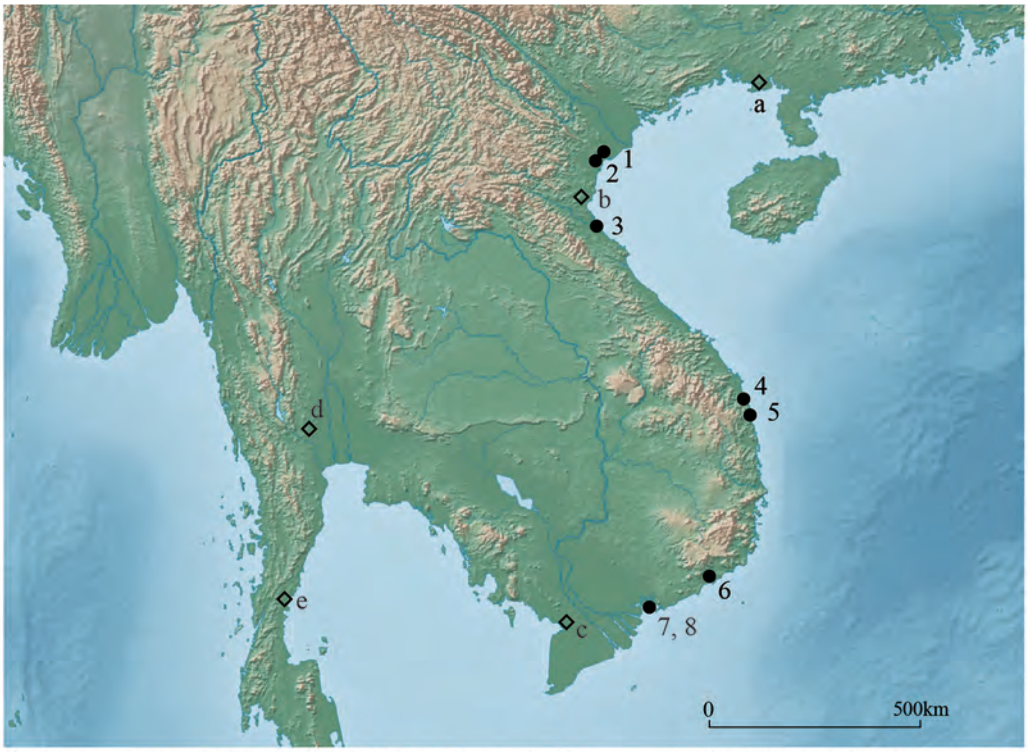

● Analyzed sites in this study: 1. Thieu Duong, 2. Dong Son, 3. Phoi Phoi, 4. Sa Huynh, 5. Dong Cuom, 6. Dong Ba Hoe, 7. Giong Ca Vo, 8. Giong Phet
◇ Related sites: a. Hepu Han tombs, b. Lan Vac, c. Oc Eo, d. Ban Don Ta Phet, e. Khao Sam Kaeo

Fig. 1 Distribution of sites in this study (made with Natural Earth Free vector and raster map data @ naturalearthdata.com.)

Most glass beads are the so-called Indo-Pacific Beads (IPBs), small monochrome beads centered on a diameter of 6 mm or less and manufactured by the drawing technique (Frances 1988–89, 1990). The IPBs were widely distributed across South India, Southeast Asia, and the coastal area of south China, although their predominant colors differ respectively. They are considered to have been first produced at the Arikamedu site in South India (Frances 1988–89). Thereafter, bead-making technology spread throughout Southeast Asia. Even though IPBs share the same bead-making technique, the chemical composition is diverse, depending on the raw material. Therefore, the chemical composition of glass serves as an indicator of its provenance.

The production of glass around the South China Sea was examined by archaeological and scientific research in areas including: from Northern Vietnam to Southern China (Lankton and Dussubieux 2006, Xiong and Li 2011, Oga and Tamura 2013); the Giong Ca Vo site in Southern Vietnam (Francis 1995, Hirano 2001, Lankton and Dussubieux 2006); and, Khao Sam Kaeo in the middle of the Thai-Malay Peninsula (Lankton and Dussubieux 2013, Carter 2016). Of particular interest are the sand-lined pits excavated at the Giong Ca Vo site where archaeological evidence indicates that primary glass materials were probably produced. It is important to increase chemical composition analyses of glass in Vietnam to understand glass production across Southeast Asia. In this study, to clarify the characteristics of the chemical composition of glass artifacts excavated in Vietnam, we conducted chemical analysis by portable XRF on glass artifacts belonging to the Dong Son and Sa Huynh cultures. Both cultures are representative of the Iron Age in Vietnam. It is generally believed that these started around 500 BCE and ended around the 1st century CE. Regarding distribution areas, the Dong Son culture was mainly in northern Vietnam, while the Sa Huynh culture was mainly in central Vietnam.

Also, we will discuss trade routes in ancient Eurasia by comparing the glass artifacts of Vietnam, located on the Maritime route, with the glass beads excavated in Japan, the final destination of long-distance trade.

2. Materials

We examined 72 glass artifacts in the National Museum of Vietnamese History excavated from eight archaeological sites belonging to the Dong Son and Sa Huynh cultures of Vietnam (Fig. 1). The targets of this research included glass beads, earrings, and bracelets. There are few glass products other than these.

2-1. Thieu Duong

This site is in a field belonging to Thieu Duong commune, Dong Son district, Thanh Hoa province. Thieu Duong was discovered in 1960 and excavated in 1961. Through the excavation, archaeologists found both settlement and burial goods with abundant features and artifacts. The chronology of the site has two phases: Dong Son and Dong Son - Han, dating from the 3rd century BCE to the 1st/2nd century CE.

Fig. 2 Glass beads from Thieu Duong

Thirty-eight glass beads were analyzed, which were found from Han period burials. These glasses were stored in several groups including crystal beads. For the correspondence with the analysis numbers in this study: tag LSb44262 is No. 12 to 21; LSb42267 is No. 24 to 30; LSb42263 is No. 32 to 43; and, LSb42258 is No. 48 to 56. Although the four groups may correspond to differences within the burials, from which the series of glass beads were found, details such as burial numbers have not remained with the museum.

Among them, 24 beads are IPBs made by the drawing technique (Fig 2: 12–19, 24–28, 34–35, 48–56). The other 14 beads were as follows: a ribbon shaped bead, colored transparent yellowish brown (Fig 2: 20); a jar shaped bead, colored transparent yellowish brown (Fig 2: 21); a hexagonal column shaped bead, which has transparent bicolor of aquamarine blue and cobalt blue (Fig 2: 32); a shapeless bead, colored translucent green (Fig 2: 36); three ribbon shaped beads (Fig 2: 37, 42, 43); two abacus shaped (bicone shape) beads, colored aquamarine blue—probably made by the folding technique (Fig 2: 38); -one colored cobalt blue, made by an unknown technique (Fig 2: 33); four round beads made by the folding technique (Fig 2: 29, 30, 39, 40); and, a quadrangular column shaped bead (Fig 2: No. 41). Nos. 29 and 30 are transparent blue green in color. Nos. 37, 42, 43, 38, 39, 40 and 40 are transparent aquamarine-blue color.

2-2. Dong Son

The Dong Son site is located on the right bank of the Ma River, in Ham Rong precinct, Thanh Hoa city, and was discovered in 1924. Between 1924 to 1932 it was excavated several times by L. Pajot. From 1935 to 1939 the site was excavated by O. Janse. After 1954, Vietnamese archaeologists excavated the site, with many excavations carried out in the years of 1960–1961, 1969–1970 and 1976. The research results show that this was a residence and burial site, with three different stages: the early stage belonged to the Pre-Dong Son; the next stage belonged to the Dong Son culture; and, the last stage to the Dong Son-Han period. We analyzed one glass bracelet which is a transparent blue green color (Fig. 3); it was found from the cultural layer of the Dong Son period.

Fig. 3 Glass bracelet from Dong Son

2-3. Phoi Phoi

This site belongs to Trung Son/Bac Son village, Xuan Vien commune, Nghi Xuan district, Ha Tinh province. The Phoi Phoi site was discovered and researched in 1974 by professors and students from the Hanoi University. In 1976, the site was excavated and was identified with the Bau Tro culture in the Neolithic, with Sa Huynh cultural elements in the uppermost layer. From 2009 to 2012, the National Museum of Vietnamese History excavated the site area and

Fig. 4 Glass bracelet and earring from Phoi Phoi

discovered a large proto-historic cemetery, with the presence of jar-burials of the Sa Huynh culture and ground-burials of the Dong Son culture as well. This site is the manifestation of the interaction between the Dong Son and Sa Huynh cultures. We analyzed two bracelets (Fig. 4 : 2) and two C-shaped earrings (Fig. 4 : 3) which are colored transparent green; the former ones were found from burials from the Dong Song culture while the latter ones are presumed to belong to the Sa Huynh culture.

2-4. Sa Huynh

This site is located along the An Khe lagoon, in Pho Chau and Pho Thanh communes, Duc Pho district, Quang Ngai province. The site was discovered by M. Vinet in 1909, with the discovery of a huge cemetery of about 200 jar-coffins. After this discovery, the Sa Huynh area was excavated many times by foreign scholars such as Labarre in 1923, Colani in 1934, O. Janse in 1939 and Malleret in 1951. After 1975, this site was investigated by Vietnamese archaeologists in 1976, 1977, 1978. The results of the study showed that there are both residential and burial goods with two different stages extending from the Bronze to Early Iron Ages.

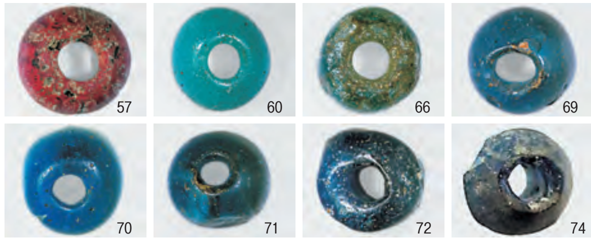

Fig. 5 Glass beads from Sa Huynh

In this research, eight glass beads were analyzed. These glass beads are estimated to have been excavated from a jar coffin, but due to being from an old excavation, the museum did not have any details on which remains they were found from. Seven beads are variously colored IPBs of the drawing technique (Fig. 5: 57, 60, 66, 70, 71, 72). Of those remaining: No. 69 is a transparent dark blue round bead made by the folding technique; and, No. 74 has an abacus-bead shape of transparent cobalt-blue color.

2-5. Dong Cuom

This site is in the hamlet of Tang Long, Tam Quan Nam commune, Hoai Nhon district, Binh Dinh province. The Dong Cuom site was discovered and excavated for the first time by M. Colani in 1934. In the years 2001–2002, Binh Dinh Provincial Museum investigated the site and excavated some test pits. In 2003, this site was excavated by the Institute of Archaeology and the National Museum of Vietnamese History. The research results show that this is a burial site of the

Fig. 6 Glass beads from Dong Cuom

Sa Huynh culture, dating from the 2nd century BCE to the 1st century CE.

We analyzed 14 glass beads which were excavated from the Dang Cuom site in 2003. All these beads are IPBs made by the drawing technique. The series of beads in the photo above were excavated from Burial No. 9 (Jar coffin), Excavation Unit 1. Regarding the color: five beads are transparent light blue (Fig. 6: 76–80); another five beads are transparent dark blue (Fig. 6: 87–91); one bead is translucent yellowish green (Fig. 6: 95). The beads in the photo below consist of 140 pieces, but no burial number has been left in the museum. They are transparent purple in color. We analyzed three of them (Fig. 6: 264–266).

2-6. Dong Ba Hoe

The Dong Ba Hoe site belongs to village 5, Ham Duc commune, Ham Thuan Bac district, Binh Thuan province. The site was discovered in the 1920s when the French built National Highway 1. Before 1975, the Dong Ba Hoe site was surveyed by foreign scholars, like O. Janse or H. Fontaine. In early 1975 it was excavated by H. Fontaine, J. Davison and Hoang Thi Than. After 1975, this site was studied by Vietnamese archaeologists in 1979, 1980, 1982, 1984 and especially with the excavation in 2016. The research results show that this is a particularly important settlement and burial site with two different phases. The early stage belongs to the Pre-Sa Huynh phase while the latter belongs to the Sa Huynh culture.

Fig. 7 Glass beads from Dong Ba Hoe

More than 46 orange opaque glass beads (Fig. 7) were found from a large, horizontally-positioned pot. This burial does not show features of the Sa Huynh culture, but is more likely that of the culture in the Central Highlands of Vietnam. From burials at the Noen U-Loke site in the middle Mun Valley, many similar orange glass beads were unearthed (Higham, Kijngam & Talbot eds. 2007). These appeared from phase 3 (1st to 2nd century CE), and continued to be buried until phase 5 (ca. 250–400 CE). These orange glass beads are shaped flat like a disc. The bead-making technique is unclear, but is not typical of the drawing technique. Most of them are significantly weathered on the surface and we analyzed one of them with a fresh fracture surface (Fig. 7: 267).

2-7. Giong Ca Vo

The Giong Ca Vo site is in Hiep Hoa hamlet, Long Hoa commune, Can Gio district, Ho Chi Minh city. The site was discovered and investigated in 1993, and subsequently excavated in 1994 and 1995. These excavation campaigns were conducted by the National Museum of Vietnamese History in Hanoi and Museum of Vietnamese History, Ho Chi Minh City. The excavation results revealed that the site's nature is complex with different archaeological relics—like residential features, burial grounds and a production workshop of ceramics and glass or stone ornaments (Tang and Hien 1997). At first glance, it can be seen that Giong Ca Vo has a very strong influence from the Sa Huynh culture, and therefore often classified as a site of the famous archaeological culture, but the question of its origin is still unanswered. The site is placed in the dating frame of 2700–2000 BP.

We analyzed four, small C-shaped earrings which are colored translucent green (Fig. 8: 7) and one animal-headed earring which is opaque, colored blue (Fig. 8: 8). The animal-headed earring is made by polishing after casting (Hirano 2001: 182). The C-shaped earrings seems to have been made by the winding method.

Fig. 8 Glass earrings from Giong Ca Vo

2-8. Giong Phet

Giong Phet is a cemetery site near the Giong Ca Vo site. Many graves were excavated in the 1990 s and 2000s, and a so-called Ling Ling-O earring was collected in 1993.

This earring is colored translucent green (Fig. 9: 10). Regarding the manufacturing technique, Ling Ling-O earrings from Sa Huynh were indicated to be made by polishing after casting (Hirano 2001: 180). Judging by bubbles and the surface condition, the earring from Giong Phet is assumed to be made by this same technique.

Fig. 9 Glass Ling Ling-O earring from Giong Phet

3. Methods

We conducted microscopic observation and non-destructive material examination to estimate the manufacturing technique and, to identify the compositional type of glass and coloring techniques (colorants). Chemical composition was analyzed by energy dispersive X-ray fluorescence spectrometer (OURSTEC, 100 FA). The target of the X-ray tube is palladium (Pd) and the tube voltage is set to 40 kV, the tube current is automatically adjusted to optimize the detector's dead

Table 1: Known composition of EC 1.1 against normalized XRF results for EC 1.1. (Nakamura *et al*. 2021)

EC1.1	Measured composition Mean (wt%, n=5) ± SD (1σ)	Known composition Reference values (wt%) ± SD (1σ)
Na_2O	13.47 ±0.20	13.41 ± 0.11
MgO	4.03 ±0.11	3.78 ± 0.10
Al_2O_3	0.96 ±0.20	1.08 ± 0.06
SiO_2	72.03 ±0.60	71.97 ± 0.14
K_2O	0.61 ± 0.05	0.59 ± 0.05
CaO	8.47 ± 0.55	8.63 ±0.09
TiO_2	<0.01	0.040 ±0.002
Fe_2O_3	0.13 ± 0.02	0.103 ±0.004

time, and a measuring time (live time) is 100 seconds. The measurements were conducted in a vacuum. The measurement results are normalized by the fundamental parameter (FP) method in a way that the total amount of the oxides of elements detected will be 100%. The FP method was calibrated using Corning Glass A.

We confirmed the accuracy of quantification of the FP method (Nakamura et al. 2021). The results are shown in Table 1. The result shows that the accuracy is enough to determine the compositional type of glass.

It should be noted, however, that we conducted a completely non-destructive method to analyze the weathered surface of the glass artifacts. Therefore, the results of analysis do not directly indicate the chemical composition of the glass in its non-weathered original state, but nevertheless, they are thought to provide certain hints to identify the compositional types and colorants of the glasses.

4. Results

We conducted XRF analysis on 72 glass artifacts from eight archaeological sites containing 61 glass beads, three bracelets and eight earrings. The results are shown in the appendix. The following describes the characteristics of the chemical composition of glass for each archeological site.

4-1. Thieu Duong

Thirty-eight glass beads were analyzed. We identified one lead-barium glass bead (No. 36) and two plant-ash glass beads (No. 20, 21). These are not IPBs. It is considered that lead-barium glass originated in China, and plant-ash glass was made in Western or Central Asia. Regarding the lead-barium glass, while similar to lead-barium glass distributed in Japan by the 2nd century BCE the chemical composition of both PbO and BaO are relatively low, this is a different type of product to that in Japan: most of the lead-barium glass products in Japan are tubular beads (Tamura and Oga 2015). The plant-ash glass beads excavated from this site have a remarkable tendency of $MgO < K_2O$, which indicates that these plant-ash glass beads are of Central Asian origin. Regarding the colorant, the lead-barium glass bead is translucent green colored by copper (Cu), and the plant-ash glass beads are transparent yellowish-brown colored by iron (Fe).

Of the remaining 35 samples, 24 beads contain more than 8% of K_2O and can be judged to be potash glass. However, for the remaining 11 beads (12 measurement points), it is difficult to distinguish between potash glass and soda glass from the concentration of K_2O or Na_2O, which is greatly affected by weathering (Fig. 10).

In our research on ancient glass excavated from Japan, it can be distinguished from potash glass and soda glass by the Rb_2O and SrO concentrations (Fig. 11a). Therefore, we tried to identify the com-

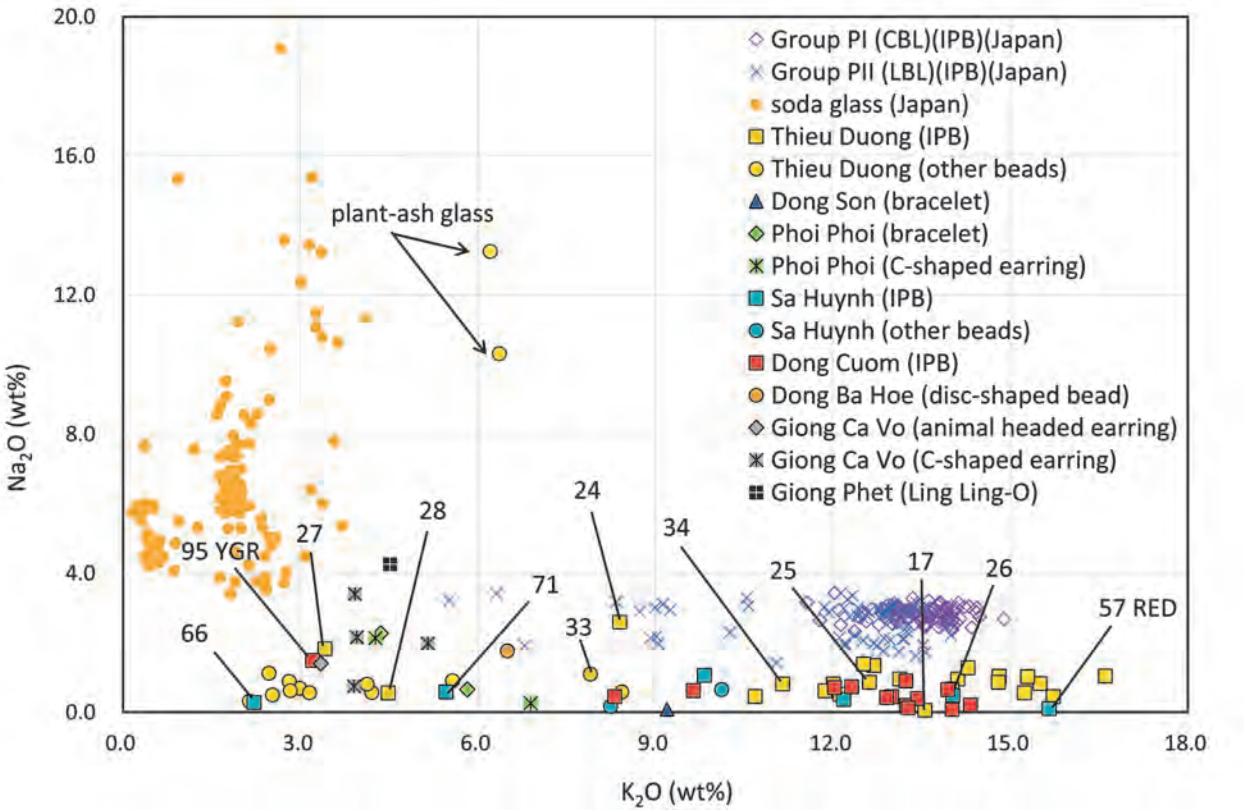

Fig. 10 Characterization of alkali silicate glasses from Vietnam based on the flux (Na_2O vs. K_2O)

positional type of these glass artifacts using Rb_2O and SrO concentrations, which are considered to be relatively less affected by weathering (Yanase *et al*. 2015). Incidentally, most of the potash glass in Japan is classified into either Group PI or PII based on the concentrations of Al_2O_3 and CaO (Oga and Tamura 2013, 2016). Group PI and PII can also be distinguished based on the Rb_2O and SrO concentrations. In the scatter diagram of SrO versus Rb_2O (Fig. 11a), three of the 11 samples with K_2O less than 8% are plotted in the range where standard potash glass in Japan (Group PI and PII) is concentrated, and the rest are between potash glass and soda glass. Still, they contain more Rb_2O than SrO obviously. Furthermore, four samples (No. 24, 25, 26 and 34) containing more than 8% of K_2O are plotted in the intermediate region between potash glass and soda glass. This suggests that there are different compositional types of potash glass in Vietnam that have not been found in Japan. Therefore, we consider for now that the other eight samples, which have low K_2O and the intermediate Rb_2O and SrO concentrations between potash glass and soda glass, are also potash glass, although the possibility of mixed alkali glass (or mixed glass as a result of recycling) cannot be discounted.

It was found that there was a clear correlation between the characteristics of the chemical composition and the bead-making technique. That is, the 21 beads with high Rb_2O and low SrO concentration are all IPBs, except No. 33. Only four of the IPBs (No. 24, 25, 26 and 34) are midway between potash glass and soda glass for concentrations of Rb_2O and SrO. On the other hand, all of the non-IPBs, except for the dark blue abacus bead (No. 33), have intermediate concentrations of Rb_2O and SrO between potash glass and soda glass. In addition, these beads tend to have a higher CaO content.

Next, we will discuss the colorants. IPBs from Thieu Duong show various shades of blue. The majority contain 1–2% MnO and a trace amount of CoO. Other than that, Nos. 24, 25, 27, and 28 contain around 1–3% of CuO. Among them: Nos. 24 and 25 contain around 2% of MnO; and Nos. 27 and 28 contain 0.2% of MnO. Nos. 17 and 34 contain more than 1% of MnO and 0.3% of CuO. No. 17 has a higher level of SnO_2 and PbO. In other words, IPBs from Thieu Duong have a wide variety of colorant, and there is no clear relationship between colorant and glass compositional type in potash glass IPBs from Thieu Duong.

The non-IPBs are transparent aquamarine blue or blue-green colored by iron, except for Nos. 32 and 33. The Fe_2O_3 content is significantly higher in blue-green glass than in the aquamarine blue glass. Regarding No. 32, half is an aquamarine blue by iron, but the other half is dark blue, probably colored by cobalt since it is accompanied by 1.34% of MnO, although the amount of CoO is extremely small (0.01%).

4-2. Dong Son

We analyzed one blue green glass bracelet and identified potash glass containing 9.2% of K_2O. For CaO and Al_2O_3 concentration, the Al_2O_3 level is less than standard potash glass in Japan, and does not correspond to existing groups. For SrO and Rb_2O concentration, it is midway between the standard potash glass and the soda glass. As for the colorant, it contains more than 2% Fe_2O_3, which shows that Fe_2O_3 was added intentionally as a colorant.

4-3. Phoi Phoi

Two bracelets and two C-shaped earrings were analyzed. The bracelets are made by the winding method, having a triangular cross section. The C-shaped earrings are probably made by casting and polishing. They are transparent green in color. As a result of analysis, one bracelet and one C-shaped earring seem to be potash glass because of the relatively high content of K_2O (5.8–6.9%), but the other two artifacts have intermediate levels of Na_2O and K_2O between potash glass and soda glass. For the Rb_2O and SrO concentrations, these four artifacts are all intermediate between potash glass and soda glass.

Such compositional characteristics are similar to some potash glass from Thieu Duong. Therefore, we consider that these four glass artifacts are potash glass that do not correspond to the existing compositional groups. However, it should be noted that these artifacts have a significantly high content of, either or both, Al_2O_3 and CaO. It is also noted that they contain 1.5–2% of MgO. Regarding the colorant, they contain 2–3% of Fe_2O_3, and they are colored by iron. It is also noted that they contain elevated levels of SO_3, a characteristic common to the glass earrings of the same color excavated from the Giong Ca Vo site, which will be described later.

4-4. Sa Huynh

We analyzed eight glass beads. They can be judged to be potash glass. Although No. 66 and No. 71 contain low K_2O content due to the weathering, we see both of them as potash glass because of Rb_2O > SrO. In addition, No. 57 and No. 66 have intermediate Rb_2O and SrO concentrations between the standard potash glass and soda glass; that is, they are judged to be a potash glass which does not correspond to the existing compositional groups. No. 57 is also characterized by a large amount of Al_2O_3 and CaO.

As for the bead-making technique and colorant, 6 beads are IPBs (Nos. 57, 60, 66, 70, 71, 72). No. 57 is inferred to be colored by colloidal particles of elemental copper because of its characteristic opaque red color and high amount of CuO. Nos. 60, 66 and 71 are colored by copper. No. 60 is transparent light blue colored by copper without SnO_2 or PbO as impurities in copper materials. No. 66 is transparent dark blue colored by copper with high MnO (1.18%). No. 71 is dark blue transparent colored by copper with high MnO. It is similar to No. 66, but contains around 0.2% of SnO_2 and PbO. Nos. 70 and 72 are cobalt blue transparent. No. 70 is colored by a small amount of CoO with high MnO. No. 72 was judged to be colored by cobalt because it contained 0.98% of MnO, although only traces of CoO were detected.

No. 69 and No. 74 are non-IPBs. No. 69 is a dark blue transparent glass bead manufactured by the folding method. It is colored by copper and contains 0.74% of MnO. It contains around 0.2% of SnO_2 and PbO, and it is similar to No. 71 for colorant. No. 74 has an abacus bead shape. The details of the production technique are unknown. It is transparent cobalt blue in color containing small amount of CoO and high MnO.

Most of the colorants for glass beads from this site are copper-based, but the components contained as impurities of copper material are various and are not related to the bead-making technique or composition type. Many samples contain a large amount of MnO.

4-5. Dong Cuom

We analyzed 14 glass beads. All are IPBs. Nos. 76–80 are light blue transparent; Nos. 87–91 are dark blue transparent; No. 95 is yellow-green translucent;and, Nos. 264–266 are purple transparent in color. As a result of analysis, other than No. 95, they are potash glass containing 9.6–14.3% of K_2O. No. 95 can be judged to be potash glass by the Rb_2O and SrO concentrations, although the K_2O concentration is as low as 3.2%. It has an intermediate Rb_2O and SrO concentration between the standard potash glass and soda glass. In addition, the amount of Na_2O is slightly higher than

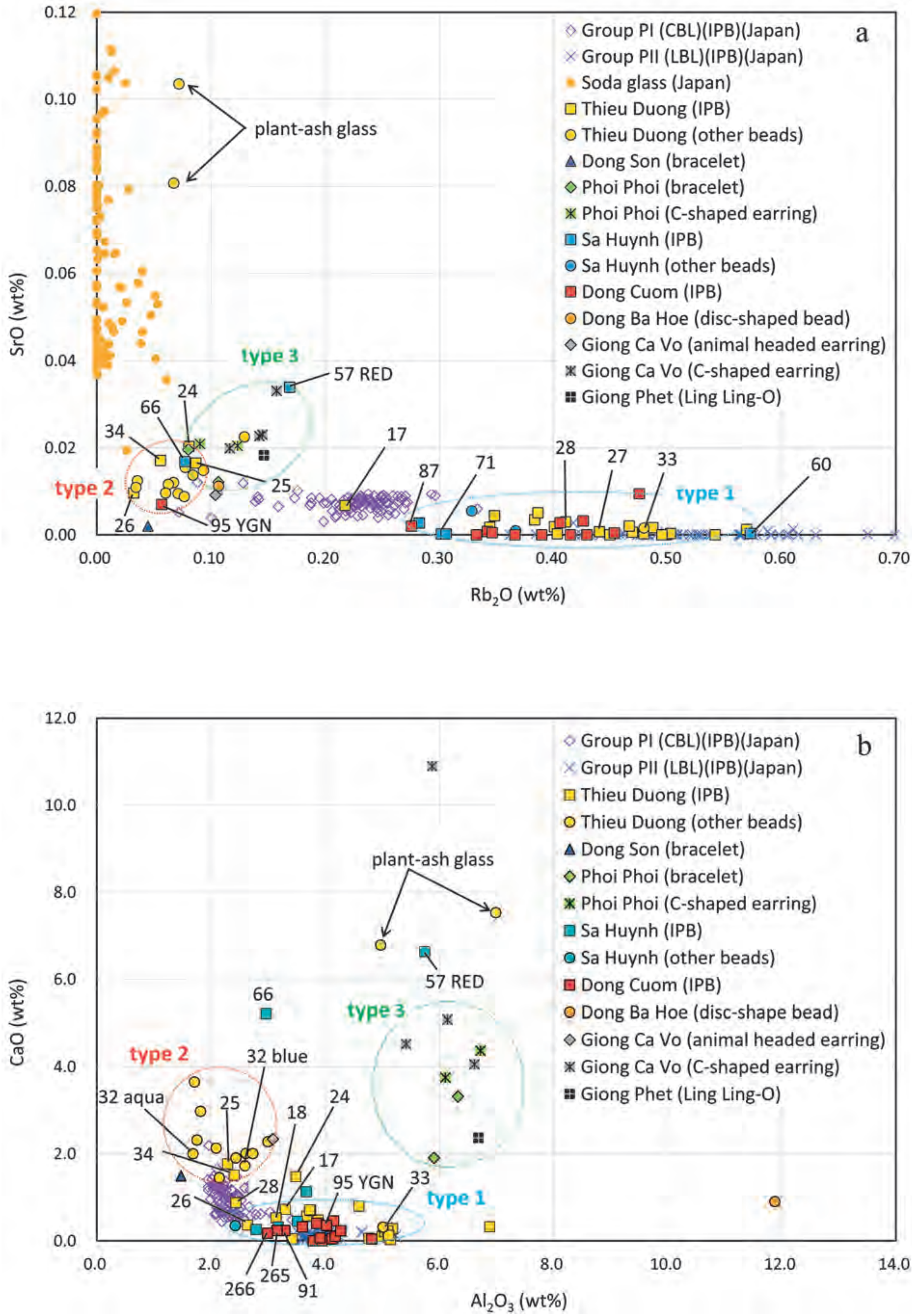

Fig. 11 Characterization of alkali silicate glasses from Vietnam (a: SrO vs. Rb_2O, b: CaO vs. Al_2O_3)

that of other glass beads, and the possibility of mixed alkali glass or mixed glass cannot be denied.

As for color and colorant, Nos. 76–80 are transparent light blue colored by copper (CuO: 1.34–1.73%) with a small amount of SnO_2 (0.16–0.57%) and PbO (0.34–0.80%). Nos. 87–91 are also transparent light blue in color but contain a higher amount of CuO (3.06–3.76%) with SnO_2, but without PbO. No. 95 is translucent yellow green in color and contains CuO (2.49%) with large amounts of SnO_2 (3.9%) and PbO (17.99%). Since yellow opaque particles are observed under the microscope, it can be estimated to be colored with lead stannate. Nos. 264–266 are transparent purple in color. It is colored by manganese because of the elevated level of MnO (3.45–3.90%). Except for the series of purple beads from a different burial, copper-based colorants are dominant, and there are relatively few variations of impurity components of copper material.

4-6. Dong Ba Hoe

We analyzed one of the orange glass beads found from this site (No. 267). It contains 6.5% of K_2O. We see it as probably potash glass because of Rb_2O > SrO. It has an intermediate Rb_2O and SrO concentrations between potash glass and soda glass. In addition, it is peculiar in terms of the extremely large amount of Al_2O_3 (11.9%), although the influence of weathering cannot be ruled out. Regarding colorant, it is considered to be colored by colloidal particles of cuprite because of its characteristic orange color and high content of CuO (11.96%).

4-7. Giong Ca Vo

Four green translucent small C-shaped earrings and one blue opaque animal-headed earring were analyzed. The tendency of Na_2O < K_2O is recognized, although the K_2O content is low at 3.9–5.2%. Regarding the amount of Rb_2O and SrO, they are intermediate between standard potash glass and soda glass, and the trend of Rb_2O > SrO is obvious.

Green C-shaped earrings are characterized by higher amounts of Al_2O_3 and CaO. It is noteworthy that a small amount of MgO and SO_3 are contained. They are colored mainly by iron containing about 3–4% Fe_2O_3.

As mentioned before, similar C-shaped earrings have been excavated from the Phoi Phoi site. These C-shaped earrings from both sites have the same trend of Rb_2O-SrO and Al_2O_3-CaO concentrations. They contain a small amount of MgO and SO_3 in common. Therefore, it is considered that these earrings (and also bracelets from Phoi Phoi) are made from the same kind of glass material. Since one of the earrings from Phoi Phoi contains 6.9% of K_2O, which is likely to be potash glass, C-shaped earrings from Giong Ca Vo with similar compositional characteristics are also considered to be potash glass, although the possibility of mixed alkali glass or mixed glass cannot be denied.

Animal-headed earrings also have a small amount of K_2O (3.3%), but the trend of Rb_2O and SrO concentrations belongs to an intermediate group between standard potash glass and soda glass. The amount of Al_2O_3 and CaO is smaller than that of small C-shaped earrings, but larger than that of standard potash glass. These compositional characteristics are similar to the aquamarine blue ribbon -shaped glass beads found in Thieu Duong, and we consider it is potash glass. It is colored by copper without tin or lead, which are impurities in the copper raw material.

4-8. Giong Phet

One Ling Ling-O was analyzed, and its chemical compositional characteristics are almost the same as the C-shaped earrings at Giong Ca Vo. It is considered to be potash glass, although the possibility of mixed alkali glass or mixed glass cannot be denied.

5. Discussions

The results of our research include glass beads, earrings and bracelets. Here, we discuss the characteristics of glass artifacts during the Dong Son and Sa Huynh cultures in Vietnam, mainly from the compositional point of view. Furthermore, we would like to discuss the glass trade routes by comparing glass artifacts excavated in other Southeast Asian countries and East Asia, especially in Japan.

5-1. Compositional characteristics of glass in Vietnam

Among the 72 glass artifacts analyzed in this study, 69 were judged to be potash glass (including the samples that may be mixed alkali glass). Other than potash glass, there were only two plant–ash type soda glass and one lead-barium glass.

The 69 glass artifacts judged as potash glass are roughly divided into three compositional types. First, they are divided into the high Rb type and the low Rb type. Furthermore, the high Rb type has a low SrO concentration, but the low Rb type has a low to medium level of SrO (Fig. 11a). However, the tendency of Rb_2O > SrO of the low Rb type is still obvious compared with soda glass.

The high Rb type (Type 1) probably corresponds to Group PII introduced by the authors for potash glass excavated in Japan. Furthermore, Group PII corresponds to the mKA-lowC (Lankton and Dussubieux 2006) or m-K-Al (Lankton and Dussubieux 2013) with high probability. This result is consistent with previous studies that mKA-lowC or m-K-Al glass is densely distributed in the coastal areas between central Vietnam and southern China (Lankton and Dussubieux 2006).

The low Rb type has compositional characteristics that are not common to potash glass from Japan and does not correspond to existing compositional groups. Furthermore, the low Rb types are divided into Type 2 with slightly more CaO than in Group PI and into Type 3 with both CaO and

Al_2O_3 being significantly more than in standard potash glass from Japan (Fig. 11b). Type 2 and Type 3 can be distinguished to some extent from the Rb_2O and SrO concentrations (Fig. 11a).

It is also noted that the potash glass subgroups (Type 1–3) based on the chemical composition as described above has a correlation with both the artifact type and bead-making technique. Among the 69 artifacts judged to be potash glass, 44 were IPBs, and most of them are Type 1, which almost correspond to Group PII. Only seven IPBs were low Rb type. Regarding IPBs, we will discuss later focusing on the relationship with the IPBs excavated from Japan.

Earrings, bracelets, and most of the non-IPBs correspond to Type 2 or Type 3. Only three artifacts correspond to Type 1: a cobalt blue abacus bead from Thieu Duong; a small round bead made by the folding method; and, a cobalt blue abacus bead from Sa Huynh. It is interesting that both cobalt blue abacus beads belong to Type 1.

Type 2 is composed mainly of blue-green or aquamarine blue transparent glass beads found from Thieu Duong. The Hexagonal bead has a bicolor of aquamarine blue and dark blue, and both parts belong to Type 2. Also, the animal-headed earring from Giong Ca Vo and the bracelet from Dong Son are similar to Type 2. However, the bracelets excavated from Dong Son may differ from any of Types 1 to 3 due to the smaller amount of Al_2O_3 and the extremely small amount of Rb_2O and SrO (Fig. 11).

Type 2 tends to have a larger amount of CaO than Group PI, which correspond to mKCA (Lankton and Dussubieux 2006) or m-K-Ca-Al (Lankton and Dussubieux 2013). Furthermore, due to its characteristic aquamarine-blue color, Type 2 might correspond to mKC-lowA (Lankton and Dussubieux 2006) or mK-Ca (Lankton and Dussubieux 2013) glasses found from the Ban Don Ta Phet in Thailand. However, Type 2 does not have a significantly smaller amount of Al_2O_3 than Group PI. The bracelet from Dong Son, which has slightly different compositional characteristics from those of Type 2, may be more likely to be Ban Don Ta Phet type of glass. However, there is still an inconsistency that the bracelet from Dong Son contains less CaO than the Ban Don Ta Phet type glass.

For Type 3, there is a strong correlation between the C-shaped earrings and bracelets with green color. However, as mentioned above, only the bracelet from Dong Son is an exception. Unlike other C-shaped earrings and bracelets, the Dong Son bracelet is slightly bluish in color. In addition, the Dong Son bracelet differs from other bracelets in the feature of its low level of SO_3.

Green bracelets and earrings other than Dong Son have significantly larger amounts of CaO and Al_2O_3 than other types (Fig. 11b). Considering they contain higher Na_2O than other potash glass, these glasses might correspond to the high-Na_2O potash glass (mKCA-N), which was found in South India and Sri Lanka, and also in Ban Don Ta Phet in the previous study (Lankton and Dussubieux 2006). It has been pointed out that mKCA-N glass is a mixture of potash glass (mKCA) excavated in Arikamedu, and Arikamedu-type soda glass, and is characterized by higher MgO. The green glasses such as Phoi Phoi, Giong Ca Vo and Giong Phet also have a slightly higher MgO than other glasses. Although they may be soda glass from Khao Sam Kaeo (m-Na-Al KSK) (Lankton *et al*. 2006) due to the commonality of the artifact type and their green color, it is unlikely that these are soda glasses due to the trend of Rb_2O > SrO. In addition, a green potash glass bracelet was unearthed at Khao Sam Kaeo (Dussubieux and Bellona 2017), but this is still different from the green glasses of the Sa Huynh culture analyzed in this paper.

Only seven IPBs were low Rb type. There are: four dark blue IPBs colored by copper with high MnO (Nos. 24, 25, 34 from Thieu Duong, and No. 66 from Sa Huynh); one cobalt blue IPB with high MnO (No. 26 from Thieu Duong); one red opaque IPB by colloidal copper (No. 57 from Sa Huynh); and, one yellow-green translucent IPB (No. 95 from Dong Cuom). Except for the red opaque of No. 57, the concentrations of Rb_2O and SrO are like Type 2, although most of them cannot be clearly identified from the contents of Al_2O_3 and CaO (Fig. 11).

The red opaque No. 57 is similar to Type 3 for Rb_2O and SrO concentration, but unlike bracelets and earrings, it is a typical potash glass containing 15.7% of K_2O and extremely low Na_2O. It might be mKCA, which is the parent glass of mKCA-N. Although mKCA probably corresponds to Group PI from Japan (Oga and Tamura 2013), No. 57 does not correspond to Group PI for Rb_2O and SrO concentrations. In South and Southeast Asia, the mKCA glass consists mainly of cobalt blue and red opaque glass (Lankton and Dussubieux 2006). Group PI however, in Japan, consists of mostly cobalt blue glass, while red opaque glass has not been found so far. The cobalt blue mKCA and the red opaque mKCA is possibly distinctive by the Rb_2O and SrO concentrations. It has also been pointed out that the early type of mKCA disappeared after the last few centuries BCE and was replaced by a different type of mKCA (Lankton and Dussubieux 2013). Group PI, which rapidly increased after the 1st century CE in Japan, might be different from the early type of mKCA. It is also noteworthy that three of the seven low Rb type of IPBs: Nos. 25, 26 and 34 from Thieu Duong correspond to Group PI for the concentrations of Al_2O_3 and CaO. Furthermore, No. 26 has the same colorant characteristics as Group PI from Japan. In any case, we analyzed only a few samples in this research, and further investigation is necessary.

Finally, regarding the disc-shaped orange opaque beads from Dong Ba Hoe, it was judged to be potash glass since it contains more Rb_2O than SrO. In the previous study, however, similar disc-shaped orange opaque beads found in India or Sri Lanka were made of mixed alkali high-alumina glass (Lankton and Dussubieux 2006). It is possible that the orange beads from Dong Ba Hoe are also mixed alkali glass, but it is difficult to discuss further, based on the results of non-destructive analysis.

5-2. Glass making in Vietnam

Glass production in Southeast Asia is an important research topic. In a recent study (Carter 2016), samples were collected to examine where sites of primary production (glass making) and secondary production (glass working) were conducted. There may have been several production sites from North Vietnam to South China, and some researchers suggest that Lang Vac of the Dong Son culture was one of the production sites of glass (Hirano 2001: 179). In this study, a cluster of the chemical composition Type 2 was seen among the glass of Thieu Duong in the Dong Son - Han period of the same cultural area. However, the glass artifacts at this site displayed a variety in the morphology and chemical composition, and it was highly possible that these were assembled from traded items from around the South China Sea. The reason is as follows: the beads in Type 2– such as a hexagonal column-shaped beads, ribbon-shaped beads, and colorless glass beads–are closely related to the western Mekong Delta region, including Oc Eo (Hirano 2001: 183–186). Plant-ash glass and lead-barium glass, which was definitely imported from outside of Vietnam, were also found at Thieu Duong. It is for further study to assess whether such a unique combination of glass artifacts is related to the characteristics of the Thieu Duong site, belonging to the Han period.

Although not entirely consistent, regarding the chemical composition of the C-shaped earrings unearthed in Lang Vac (Hokura and Nakai 2004), one was similar to Type 3 and the other was similar to the bracelet of the Dong Son culture. Combined with the results of this paper, it can be suggested that glass artifacts including IPBs in the Dong Son culture were obtained through various forms of distribution.

In the Sa Huynh culture, Giong Ca Vo has attracted attention as a glass production site. The chemical composition of the products made by the winding and casting form the cluster of Type 3: they were very likely to have been produced there. However, there are some problems in making techniques. A C-shaped earring from Phoi Phoi is similar to those of Lang Vac, mentioned above. They are presumed to have been cast in an open mold, based on the observation of bubbles on the surfaces (The Vietnam-Japan Joint Archaeological Research Team 2004). In contrast, those from Giong Ca Vo were made by the winding method because of the bubble's extending parallel to the central hole. However, according to the analysis in this study, the C-shaped earrings from both sites have the same chemical composition. Considering the fact that a bracelet from Phoi Phoi was made by the winding method, it is estimated that earrings and bracelets were produced in different secondary production sites while using the same glass material in the Sa Huynh culture.

Glass Ling Ling-O has a type which has a longer projection than that of stone and were distributed from North to South Vietnam (Miyama 2012). Since the example of Giong Phet corresponds to Type 3, this is also likely to have been produced in the Sa Huynh culture. In order to pursue the production of glass in Vietnam, it is necessary to keep increasing the number of analyses and to reveal the relationship between production techniques and chemical composition. It will also be necessary to compare with the whole of Southeast Asia.

5-3. Indo-Pacific Beads

While bracelets and earrings are artifacts that suggest relatively local production and distribution in Southeast Asia, IPBs are artifacts that have a broader distribution from South Asia to East Asia. Thus, we will compare IPBs excavated in Vietnam with those excavated in Japan to understand the actual situation of long-distance trade of IPBs.

As described above, most of the potash glass in Japan is classified into either Group PI or PII from the concentrations of Al_2O_3 and CaO. They can be also distinguished based on the Rb_2O and SrO concentrations. Group PII is highly likely to correspond to the Type 1 glass in Vietnam, but from the level of the Al_2O_3 and CaO concentrations, some Type 1 glass does not match Group PII.

In the 24 IPBs from Thieu Duong, 19 beads are Type 1. Among them, Nos. 18 and 28 appear to match Group PII for the Rb_2O and SrO levels, but No. 18 is intermediate between Group PI and PII for the Al_2O_3 and CaO concentrations, and No. 28 has the same level as Group PI (Fig. 11). In the four IPBs of Sa Huynh, six beads are Type 1, but except for No. 60, Rb_2O level is slightly lower than Group PII in Japan. In addition, all the Type 1 IPBs are intermediate between Group PI and PII for the levels of Al_2O_3 and CaO. The IPBs from Dong Cuom are also Type 1 except for No. 95: yellow-green IPB. Most of them are consistent with Group PII both for CaO and Al_2O_3 concentrations and the Rb_2O and SrO concentrations. However, Nos. 91, 265 and 266 are intermediate between Group PI and PII for the Al_2O_3 and CaO levels. Furthermore, compared to Group PII in Japan, Rb_2O levels of Type 1 from Dong Cuom tend to be slightly lower overall, and especially No. 87 has lower level of Rb_2O.

In addition, potash glass IPBs in Japan has a clear relationship between colorants and compositional types. Most of them are cobalt blue or copper blue in color, while the other colors are extremely rare. Cobalt blue potash glass corresponds to Group PI and copper-blue potash glass corresponds to Group PII, respectively. Cobalt blue potash glass almost always contains 1–2% MnO. Copper–blue potash glass contains small amounts of SnO_2 and PbO without exception.

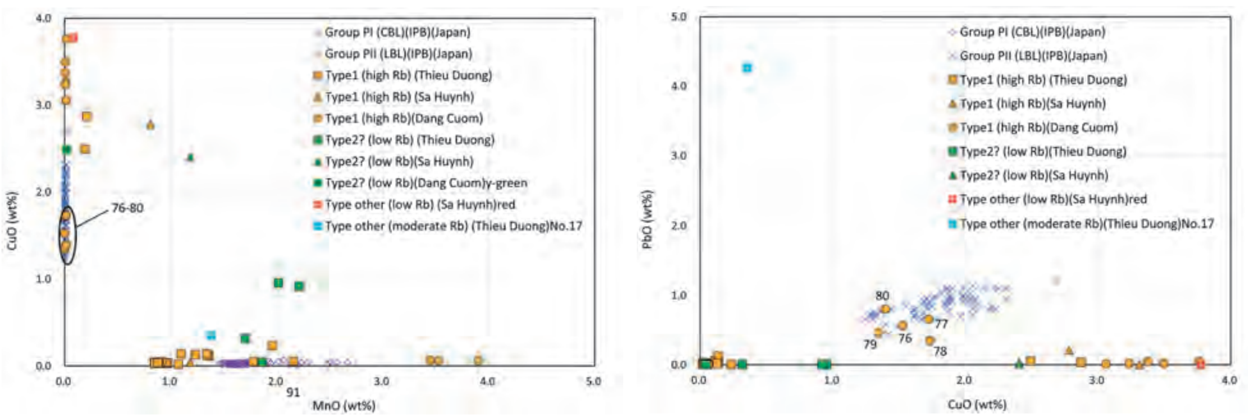

Fig. 12 Characterization of colorant of potash glass IPBs (left: CuO vs. MnO, right: PbO vs. CuO)

On the other hand, IPBs in Vietnam have no clear relationship between colorants and compositional types. Furthermore, the impurity components associated with colorants are not as simple as those from Japan (Fig. 12). Among the potash glass IPBs from Thieu Duong, most of the Type 1 are colored by cobalt with 1–2% MnO. Although Type 1 is highly likely to correspond to Group PII, the characteristics of colorant are common to Group PI, not Group PII. It is a feature of IPBs from Thieu Duong that many of them are colored by cobalt with high MnO, and it is noteworthy as a characteristic different from IPBs from other sites. On the other hand, there were no IPBs from Thieu Duong to which the same colorant as Group PII distributed in Japan was applied. Among the IPBs analyzed in this research, only five specimens of the Type 1 IPBs excavated from Dong Cuom (Nos. 76–80) are consistent with Group PII in Japan, including the characteristics of colorants (Fig. 12).

Another important feature of IPBs in Vietnam, which was revealed by comparison with those of Japan, is that none of the IPBs were classified as Group PI. Only No. 17 from Thieu Duong matches Group PI for Rb_2O and SrO concentrations, but the level of Al_2O_3 and CaO is intermediate between PI and PII. The colorant is also unique: it contains more than 1% of MnO and0. 35% of CuO with a higher level of SnO_2 and PbO.

To summarize the IPBs in Vietnam, 36 out of 44 specimens are Type 1, which corresponds to Group PII. It suggests that most of the IPBs analyzed in this research were produced in Vietnam or its surrounding areas. On the other hand, Type 1 has a larger compositional variation than Group PII in Japan. In other words, the compositional uniformity of the potash glass IPBs distributed in Japan is noteworthy.

5-4. Glass route from Southeast Asia to East Asia

After examining the findings, the characteristics of glass artifacts for the Dong Son and Sa Huynh cultures have been clarified to some extent, although the samples analyzed in this research are only part of the whole glass artifact assemblage. Here we discuss the glass trade from Southeast Asia to East Asia by comparing glass artifacts from Vietnam and Japan.

Glass beads distributed throughout the Dong Son and Sa Huynh cultures in Vietnam, and glass beads in Japan during the Yayoi period, are similar in that they have many IPBs. The IPBs in Vietnam however, have many different combinations of compositional types and colorants to those in Japan.

Interestingly enough, there was no glass that definitely corresponded to Group PI. In Japan, a large number of Group PI glasses were distributed in the 1st century CE (Oga and Gupta 2002, Oga and Tamura 2013, 2016). The earliest IPBs that flowed into Japan were also Group PI (3rd century BCE), and until the 2nd century BCE, the number of IPBs excavated in Japan was very small, but most were Group PI. During these periods, the major IPBs distributed to both areas are distinctly different.

These results are important findings in considering trade routes of potash glass beads between Southeast Asia and East Asia. We believe Group PI were probably from India (Oga and Tamura 2013), since a large number of cobalt blue mKCA glasses corresponding to Group PI were found at Arikamedu in South India (Lankton and Dussubieux 2006). It is necessary to consider a route not through the coast of Southeast Asia but through the inner part of Southeast Asia or inland China, such as Yunnan (雲南) Province, as a trade route of Group PI from India to East Asia.

Most IPBs from Vietnam belong to Type 1. Type 1 highly corresponds to Group PII, which was distributed in Japan as widely as Group PI. Type 1 glasses in Vietnam, however, are different in colorant from the Group PII in Japan. Only five beads from Dong Cuom Burial No. 9 were judged to correspond as typical of Group PII, including the characteristics of colorant. It is noted, however, that the potash glass IPBs with a different colorant were excavated together with those typical of Group PII. Therefore, it is difficult to say for now that Vietnam was a direct source of the Group PII glasses distributed in Japan because it is unlikely that only those typical of Group PII were selected from glass beads with a similar blue appearance.

Although there are many colorant variations, Vietnam's IPBs are characterized by shades of blue. On the other hand, IPBs with colors other than blue, such as yellow-green or yellow opaque, red opaque, are extremely rare. It is noted that elsewhere in the Southeast Asian region, a number of yellow-green and yellow IPBs (Group PII) colored with lead stannate have been found in southern Myanmar (Tamura 2019).

As mentioned above, there are many differences between the IPBs distributed in Vietnam and Japan from the 3rd century BCE to the 1st century CE, but there were some examples related to IPBs found in Japan. One example are purple beads from Dong Cuom. These belong to Type 1 in the classification of this paper. For CaO and Al_2O_3 concentrations, they are between Group PI and Group PII found in Japan. The minute, purple beads colored by manganese, with such compositional characteristics, have been excavated from jar burial No. 15 and wood coffin burial No. 15 in the Iwara-Yarimizo (井原鑓溝) site of Fukuoka Prefecture in Japan and date to the 1st century CE. Also, yellow–green beads like No. 95 from Dong Cuom, even though they are few, have been found in pit burial No. 13 in the Tsujita (辻田) section of the Monden (門田) site, Fukuoka prefecture (Oga and Tamura 2016). Since these purple and yellow-green IPBs are extremely rare in Japan and Vietnam, it does not prove that direct glass trade was actively carried out between Vietnam and Japan, although this is still important for considering the trade route of these beads.

Another feature is that glass artifacts other than beads, such as bracelets and earrings, are common in Vietnam. There are no examples of glass earrings found in Japan, and only one bracelet has been found at the Oburo-minami (大風呂南) No. 1 burial in Kyoto prefecture, apart from those made of lead glass. The glass bracelet from Oburo-minami is made of potash glass and is aquamarine blue in color. Although the concentrations of trace elements such as Rb_2O and SrO are not known, from the previous research (Koezuka 1999), the concentrations of Al_2O_3 and CaO is close to that of Group PI. The glass bracelets from Phoi Phoi and Don Son in Vietnam are made of different compositional types of potash glass, which have not been found in Japan, and the color is also different. From previous research, aquamarine blue glass bracelets were found from Ban Don Ta Pet in Thailand, but they are low-alumina type potash glass (mKC-lowA) (Lankton and Dussubieux 2006), which is also different from the Oburo-minami example. The Oburo-minami example is dated to the 2nd century CE, later than Ban Don Ta Pet. Considering the possibility that the Group PI distributed in Japan correspond to the 'new type'of mKCA, it may suggest that the chemical composition of the glass bracelets had also changed with time.

Finally, it is also noteworthy that Chinese lead-barium glasses, which have been excavated in large quantities in Japan from the middle and late Yayoi period (Oga 2010, Tamura and Oga 2015), were rare in Vietnam. Only one shapeless piece of lead barium glass from Thieu Duong was identified in this research. Although there is a possibility that lead-based glass did not survive because of weathering, it cannot be considered that all of it was lost by weathering, since the lead barium glass identified in this research is in relatively good condition. It seems that the glass of Chinese origin was not distributed much to this area. The same situation can be seen in other surrounding areas of China, other than Japan, such as Mongolia and the Korean Peninsula. In Korea, although some lead -barium glass (Group LIA), which are considered to have originated in Northeast China, were distributed in small numbers before the 1st century BCE, other types of lead-barium glass (Group LIB or LIC) have not been found. On the other hand, in Japan, a large number of lead-barium glass of Group LIB and LIC were distributed from the 1st century BCE to the 2nd century CE. It attracts attention as a peculiarity of Japan.

6. Conclusion

The glass artifacts analyzed in this research were classified into three compositional types (Type 1 to 3). There was a clear correspondence between artifact types and chemical composition. Type 1 is likely to correspond to m-K-Al or Group PII, and most IPBs belonged to this type. On the other hand, Type 2 is composed of non-IPBs of aquamarine blue and are possibly related to mK-Ca from Ban Don Ta Phet in Thailand. Finally, the green bracelets and earrings are Type 3, which may be Na-rich potash glass (mKCA-N). They were also found in Ban Don Ta Phet. In this research, potash glass corresponding to Group PI and soda glass corresponding to Group SII or SV were not identified. In contrast, these glasses are the main type from Arikamedu in South India and Khao Sam Kaeo in the Thai-Malay Peninsula.

Regarding distribution, there are many glasses that are thought to have been produced in Vietnam, and although there is a small amount of glass that can be inferred to be related to Ban Don Ta Phet in central Thailand, no evidence can be found that indicates an active relationship with regions further west , such as the Thai-Malay Peninsula, Myanmar, and India. In addition, the glasses distributed in Vietnam were also different from those in Japan. Distribution of IPBs increased rapidly in Far East Asia from the 1st century CE. The divergence in glass artifacts distributed in Vietnam and Japan might be related to the changing situation in the glass production and distribution systems caused by the decline of the Dong Son and Sa Huynh cultures of Vietnam in the 1st and 2nd centuries CE. A detailed study is a topic for future research, but it is noteworthy that there exists a possible relationship with the establishment of the production of potash glass vessels (and possibly beads) found at Hepu (合浦) Han tomb, etc. in the Guangxi (広西) Province of China.

When the chronological changes of chemical compositions and distribution pattern of ancient glass in Southeast Asia are clarified in more detail, it is expected that the trade routes connecting India, Southeast Asia and Far East Asia will be revealed.

Acknowledgments

We would like to thank Nguyen Van Doan, Le Van Chien, Dinh le Huyen for their great cooperation in the analysis at the Vietnam National Museum of History. This research was partially supported by JSPS KAKENHI grant number 15K02972 and 18H00736.

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Appendix: Description and chemical compositions of glass artifacts in Vietnam analyzed using XRF

Sample No.	Site	Province	Museum No.	Artifact type	Bead-making technique/ shape	color/ transparency	size (mm)		Compositional classification	
							diameter	thickness	Flux type	Type
12	Thieu Duong	Thanh Hóa	LSb42262	Bead (IPB)	drwaing	light blue/ transparent	7.68	6.23	Potash	Type 1
13	Thieu Duong	Thanh Hóa	LSb42262	Bead (IPB)	drwaing	cobalt blue/ transparent	7.70	7.07	Potash	Type 1
14	Thieu Duong	Thanh Hóa	LSb42262	Bead (IPB)	drwaing	cobalt blue/ transparent	7.35	6.01	Potash	Type 1
15	Thieu Duong	Thanh Hóa	LSb42262	Bead (IPB)	drwaing	cobalt blue/ transparent	7.18	5.42	Potash	Type 1
16	Thieu Duong	Thanh Hóa	LSb42262	Bead (IPB)	drwaing	cobalt blue/ transparent	7.63	7.00	Potash	Type 1
17	Thieu Duong	Thanh Hóa	LSb42262	Bead (IPB)	drwaing	cobalt blue/ transparent	8.11	7.53	Potash	
18	Thieu Duong	Thanh Hóa	LSb42262	Bead (IPB)	drwaing	cobalt blue/ transparent	7.61	6.58	Potash	Type 1
19	Thieu Duong	Thanh Hóa	LSb42262	Bead (IPB)	drwaing	cobalt blue/ transparent	8.76	6.70	Potash	Type 1
20	Thieu Duong	Thanh Hóa	LSb42262	Bead	unknown/ ribon shape	yellowish brown/ transparent	10.54	4.73	Soda (Plant-ash)	-
21	Thieu Duong	Thanh Hóa	LSb42262	Bead	unknown/ jar shape	yellowish brown/ transparent	8.97	4.48	Soda (Plant-ash)	-
24	Thieu Duong	Thanh Hóa	LSb42267	Bead (IPB)	drwaing	dark blue/ transparent	4.28	4.15	Potash/mixed?	Type 2?
25	Thieu Duong	Thanh Hóa	LSb42267	Bead (IPB)	drwaing	dark blue/ transparent	4.69	4.30	Potash	Type 2?
26	Thieu Duong	Thanh Hóa	LSb42267	Bead (IPB)	drwaing	cobalt blue/ transparent	4.33	4.04	Potash	Type 2?
27	Thieu Duong	Thanh Hóa	LSb42267	Bead (IPB)	drwaing	dark blue/ transparent	6.28	5.11	Potash	Type 1
28	Thieu Duong	Thanh Hóa	LSb42267	Bead (IPB)	drwaing	dark blue/ transparent	5.85	5.70	Potash	Type 1?
29	Thieu Duong	Thanh Hóa	LSb42267	Bead	folding/ round shape	blue green/ transparent	8.60	6.90	Potash/mixed?	Type 2
30	Thieu Duong	Thanh Hóa	LSb42267	Bead	folding/ round shape	blue green/ transparent	8.54	7.54	Potash/mixed?	Type 2
32	Thieu Duong	Thanh Hóa	LSb42263	Bead	polishing and drilling/ hexaglonal column shape	aquamarine blue/ transparent	8.63	15.57	Potash/mixed?	Type 2
						cobalt blue/ transparent			Potash/mixed?	Type 2
33	Thieu Duong	Thanh Hóa	LSb42263	Bead	unknown/ abacus bead shape	cobalt blue/ translucent	7.61	7.42	Potash	Type 1
34	Thieu Duong	Thanh Hóa	LSb42263	Bead (IPB)	drwaing	cobalt blue/ transparent	5.38	4.43	Potash	Type 2?
35	Thieu Duong	Thanh Hóa	LSb42263	Bead (IPB)	drwaing	cobalt blue/ transparent	8.14	8.22	Potash	Type 1
36	Thieu Duong	Thanh Hóa	LSb42263	Bead	shapless piece	green/ translucent	14.92	6.37	Lead-barium	-
37	Thieu Duong	Thanh Hóa	LSb42263	Bead	unknown/ ribon-shape	aquamarine blue/ transparent	4.69	10.15	Potash/mixed?	Type 2
38	Thieu Duong	Thanh Hóa	LSb42263	Bead	folding?/abacus bead shape	aquamarine blue/ transparent	9.16	7.77	Potash/mixed?	Type 2
39	Thieu Duong	Thanh Hóa	LSb42263	Bead	folding/ round shape	aquamarine blue/ transparent	7.53	7.42	Potash/mixed?	Type 2
40	Thieu Duong	Thanh Hóa	LSb42263	Bead	folding/ round shape	aquamarine blue/ transparent	8.10	8.04	Potash/mixed?	Type 2
41	Thieu Duong	Thanh Hóa	LSb42263	Bead	unknown/ quadrangular column shape	aquamarine blue/ transparent	3.99	6.34	Potash/mixed?	Type 2
42	Thieu Duong	Thanh Hóa	LSb42263	Bead	drwaing and segmenting/ ribon shape	aquamarine blue/ transparent	3.88	7.37	Potash/mixed?	Type 2
43	Thieu Duong	Thanh Hóa	LSb42263	Bead	drwaing and segmenting/ ribon shape	aquamarine blue/ transparent	4.09	4.77	Potash/mixed?	Type 2
48	Thieu Duong	Thanh Hóa	LSb42258	Bead (IPB)	drwaing	cobalt blue/ transparent	7.64	6.99	Potash	Type 1
49	Thieu Duong	Thanh Hóa	LSb42258	Bead (IPB)	drwaing	cobalt blue/ transparent	6.25	7.60	Potash	Type 1
50	Thieu Duong	Thanh Hóa	LSb42258	Bead (IPB)	drwaing	cobalt blue/ transparent	5.86	6.45	Potash	Type 1
51	Thieu Duong	Thanh Hóa	LSb42258	Bead (IPB)	drwaing	cobalt blue/ transparent	6.66	4.87	Potash	Type 1
52	Thieu Duong	Thanh Hóa	LSb42258	Bead (IPB)	drwaing	cobalt blue/ transparent	7.41	5.82	Potash	Type 1
53	Thieu Duong	Thanh Hóa	LSb42258	Bead (IPB)	drwaing	cobalt blue/ transparent	7.76	5.85	Potash	Type 1
54	Thieu Duong	Thanh Hóa	LSb42258	Bead (IPB)	drwaing	cobalt blue/ transparent	6.29	5.29	Potash	Type 1
55	Thieu Duong	Thanh Hóa	LSb42258	Bead (IPB)	drwaing	cobalt blue/ transparent	6.24	6.95	Potash	Type 1
56	Thieu Duong	Thanh Hóa	LSb42258	Bead (IPB)	drwaing	cobalt blue/ transparent	6.55	7.48	Potash	Type 1
5	Dong Son	Thanh Hóa	LSb19492	Bracelet	winding/ triangular cross cection	blue green/ transparent	90.05	11.78	Potash	Type 2?
1	Phoi Phoi	Ha Tinh	LSb21320	Bracelet	winding/ triangular cross cection	green/ transparent	73.20	13.15	Potash/mixed?	Type 3
2	Phoi Phoi	Ha Tinh	LSb21322	Bracelet	winding/ triangular cross cection	green/ transparent	72.50	13.20	Potash/mixed?	Type 3
3	Phoi Phoi	Ha Tinh	LSb21326	Earring	casting and polishing/ C-shape	green/ transparent	53.22	5.00	Potash/mixed?	Type 3
4	Phoi Phoi	Ha Tinh	LSb21325	Earring	casting and polishing/ C-shape	green/ transparent	52.39	4.83	Potash/mixed?	Type 3
57	Sa Huynh	Quang Ngai	LSb19625	Bead (IPB)	drwaing	red/ opaque	4.19	2.18	Potash	
60	Sa Huynh	Quang Ngai	LSb19625	Bead (IPB)	drwaing	light blue/ transparent	3.75	2.73	Potash	Type 1
66	Sa Huynh	Quang Ngai	LSb19625	Bead (IPB)	drwaing	dark blue/ transparent	4.13	3.16	Potash/mixed?	Type 2?
69	Sa Huynh	Quang Ngai	LSb19625	Bead	folding/ round shape	dark blue/ transparent	6.53	5.82	Potash	Type 1
70	Sa Huynh	Quang Ngai	LSb19625	Bead (IPB)	drwaing	cobalt blue/ transparent	4.87	4.82	Potash	Type 1
71	Sa Huynh	Quang Ngai	LSb19625	Bead (IPB)	drwaing	dark blue/ transparent	6.78	6.56	Potash	Type 1
72	Sa Huynh	Quang Ngai	LSb19625	Bead (IPB)	drwaing	cobalt blue/ transparent	6.95	5.16	Potash	Type 1
74	Sa Huynh	Quang Ngai	LSb19625	Bead	unknown/ abacus bead shape	cobalt blue/ transparent	7.52	6.18	Potash	Type 1
76	Dang Cuom	Bình Định	LSb42180	Bead (IPB)	drwaing	light blue/ transparent	5.59	4.25	Potash	Type 1
77	Dang Cuom	Bình Định	LSb42180	Bead (IPB)	drwaing	light blue/ transparent	5.22	5.63	Potash	Type 1
78	Dang Cuom	Bình Định	LSb42180	Bead (IPB)	drwaing	light blue/ transparent	4.52	3.95	Potash	Type 1
79	Dang Cuom	Bình Định	LSb42180	Bead (IPB)	drwaing	light blue/ transparent	3.56	3.81	Potash	Type 1
80	Dang Cuom	Bình Định	LSb42180	Bead (IPB)	drwaing	light blue/ transparent	4.56	3.17	Potash	Type 1
87	Dang Cuom	Bình Định	LSb42180	Bead (IPB)	drwaing	dark blue/ transparent	4.14	3.33	Potash	Type 1
88	Dang Cuom	Bình Định	LSb42180	Bead (IPB)	drwaing	dark blue/ transparent	3.65	3.78	Potash	Type 1
89	Dang Cuom	Bình Định	LSb42180	Bead (IPB)	drwaing	dark blue/ transparent	4.27	3.50	Potash	Type 1
90	Dang Cuom	Bình Định	LSb42180	Bead (IPB)	drwaing	dark blue/ transparent	4.07	3.04	Potash	Type 1
91	Dang Cuom	Bình Định	LSb42180	Bead (IPB)	drwaing	dark blue/ transparent	3.26	3.72	Potash	Type 1
95	Dang Cuom	Bình Định	LSb42180	Bead (IPB)	drwaing	yellowish green/ translucent	4.25	3.70	Potash/mixed?	Type 2?
264	Dang Cuom	Bình Định	LSb42178	Bead (IPB)	drwaing	purple/ transparent	4.00	2.75	Potash	Type 1
265	Dang Cuom	Bình Định	LSb42178	Bead (IPB)	drwaing	purple/ transparent	3.60	3.00	Potash	Type 1
266	Dang Cuom	Bình Định	LSb42178	Bead (IPB)	drwaing	purple/ transparent	3.10	2.97	Potash	Type 1
267	Dong Ba Hoe	Bình Thuận		Bead (fragment)	unknown	orange/ opaque	5.99	2.40	Potash?	
6	Giong Ca Vo	Hồ Chí Minh	LSb24943	Earring	winding/ C-shape	green/ translucent	19.73	4.97	Potash/mixed?	Type 3
7	Giong Ca Vo	Hồ Chí Minh	LSb24942	Earring	winding/ C-shape	green/ translucent	19.41	4.90	Potash/mixed?	Type 3
8	Giong Ca Vo	Hồ Chí Minh	LSb24941	Earring	casting and polishing/ Animal-headed shape	blue/ opaque	45.00	12.73	Potash/mixed?	Type 2?
9	Giong Ca Vo	Hồ Chí Minh	LSb24945	Earring	winding/ C-shape	green/ transparent	18.32	3.21	Potash/mixed?	Type 3
11	Giong Ca Vo	Hồ Chí Minh	LSb24944	Earring	winding/ C-shape	green/ transparent	18.84	4.01	Potash/mixed?	Type 3
10	Giong Phet	Hồ Chí Minh	LSb24910	Earring	casting and polishing/ Ling Ling-O	green/ transparent	21.89	13.38	Potash/mixed?	Type 3

Sample	XRF results (wt.%)																						
No.	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	Cr_2O_3	MnO	Fe_2O_3	CoO	NiO	CuO	ZnO	Rb_2O	SrO	ZrO_2	SnO_2	Sb_2O_5	BaO	PbO
12	0.7	0.8	3.5	77.1	1.9	0.1	12.1	0.3	0.23	0.00	1.23	1.32	0.04	0.00	0.13	0.01	0.33	0.00	0.12	0.00	0.00	0.03	0.02
13	0.6	0.9	3.9	76.7	1.8	0.1	11.9	0.5	0.26	0.01	1.10	1.40	0.05	0.00	0.14	0.02	0.34	0.00	0.13	0.00	0.00	0.19	0.03
14	1.3	0.8	3.7	74.6	1.6	0.0	12.7	0.7	0.27	0.00	1.78	1.59	0.06	0.00	0.05	0.05	0.39	0.01	0.09	0.00	0.00	0.29	0.00
15	0.9	0.8	4.6	71.7	1.8	0.1	14.1	0.8	0.31	0.00	1.96	2.03	0.07	0.00	0.23	0.02	0.40	0.00	0.07	0.02	0.00	0.00	0.00
16	0.8	0.8	3.9	76.7	1.4	0.1	12.0	0.4	0.26	0.00	1.36	1.41	0.05	0.00	0.12	0.01	0.38	0.00	0.10	0.00	0.00	0.15	0.06
17	0.1	0.0	3.3	69.6	0.0	2.4	13.6	0.7	0.24	0.00	1.38	1.74	0.00	0.00	0.35	0.01	0.22	0.01	0.12	1.99	0.00	0.06	4.27
18	0.5	0.7	3.1	77.3	1.4	0.1	12.1	0.5	0.23	0.00	1.34	1.94	0.06	0.00	0.12	0.00	0.35	0.00	0.13	0.01	0.00	0.00	0.04
19	0.6	0.5	3.4	74.4	1.6	0.1	15.2	0.0	0.31	0.00	2.16	0.92	0.04	0.00	0.05	0.01	0.50	0.00	0.12	0.00	0.00	0.00	0.00
20	10.3	2.8	7.0	57.7	0.5	0.5	6.4	7.5	0.35	0.02	0.09	5.76	0.01	0.00	0.03	0.23	0.07	0.10	0.34	0.00	0.00	0.28	0.00
21	13.2	3.2	5.0	58.4	0.3	0.3	6.2	6.8	0.33	0.02	0.10	5.65	0.02	0.00	0.02	0.13	0.07	0.08	0.20	0.00	0.00	0.02	0.00
24	2.6	1.0	3.5	74.4	3.5	0.0	8.4	1.5	0.30	0.00	2.02	1.12	0.00	0.00	0.95	0.07	0.08	0.02	0.09	0.00	0.00	0.46	0.00
25	0.9	0.7	2.3	74.8	2.3	0.1	12.6	1.8	0.34	0.00	2.21	0.90	0.00	0.00	0.92	0.00	0.09	0.02	0.12	0.00	0.00	0.04	0.00
26	0.7	0.6	2.6	75.2	2.2	0.2	14.0	0.4	0.38	0.00	1.86	1.55	0.00	0.00	0.04	0.00	0.03	0.01	0.19	0.00	0.00	0.00	0.00
27	1.8	0.7	3.7	82.1	2.5	0.2	3.4	0.7	0.12	0.00	0.21	0.73	0.00	0.00	2.87	0.11	0.44	0.00	0.04	0.01	0.03	0.23	0.03
28	0.6	0.5	2.4	85.1	2.0	0.3	4.5	0.9	0.09	0.00	0.19	0.50	0.00	0.00	2.49	0.00	0.41	0.00	0.04	0.02	0.00	0.03	0.06
29	0.6	0.6	1.7	83.0	3.3	0.0	4.2	3.6	0.06	0.03	0.01	2.61	0.00	0.00	0.05	0.00	0.07	0.01	0.00	0.00	0.00	0.06	0.00
30	0.3	0.6	1.8	86.7	2.3	0.1	2.1	3.0	0.05	0.02	0.04	2.78	0.01	0.00	0.05	0.00	0.04	0.01	0.01	0.00	0.00	0.03	0.00
32	1.1	0.5	1.7	87.1	2.1	0.1	2.5	2.0	0.07	0.13	0.12	1.46	0.00	0.00	0.02	0.03	0.13	0.02	0.31	0.00	0.01	0.61	0.03
	0.6	0.7	2.6	80.6	2.0	0.1	8.4	1.7	0.31	0.01	1.42	1.40	0.01	0.00	0.03	0.00	0.08	0.01	0.08	0.00	0.00	0.03	0.00
33	1.1	0.7	5.0	77.5	2.6	0.2	7.9	0.3	0.30	0.00	1.16	1.81	0.02	0.00	0.65	0.01	0.48	0.00	0.19	0.01	0.00	0.12	0.00
34	0.8	0.8	2.4	76.5	2.4	0.1	11.2	1.5	0.37	0.01	1.70	1.66	0.01	0.00	0.32	0.04	0.06	0.02	0.10	0.01	0.00	0.00	0.00
35	0.5	0.7	3.7	77.9	1.5	0.1	10.7	0.6	0.25	0.01	1.34	1.50	0.01	0.00	0.14	0.01	0.40	0.00	0.12	0.00	0.00	0.41	0.13
36	0.9	0.0	1.7	63.4	1.9	0.0	0.1	0.3	0.58	0.00	0.01	0.34	0.00	0.00	0.83	0.01	0.00	0.14	0.02	0.55	0.05	4.21	24.98
37	0.8	0.8	2.6	84.3	3.4	0.0	4.1	2.0	0.22	0.01	0.22	1.06	0.00	0.00	0.03	0.01	0.09	0.01	0.05	0.00	0.00	0.19	0.00
38	0.7	0.7	2.4	87.2	2.9	0.1	3.0	1.9	0.14	0.02	0.01	0.61	0.00	0.00	0.01	0.01	0.03	0.01	0.09	0.00	0.00	0.09	0.00
39	0.5	0.8	2.1	88.7	2.9	0.0	2.5	1.4	0.12	0.02	0.07	0.62	0.00	0.00	0.02	0.00	0.07	0.01	0.05	0.00	0.00	0.00	0.00
40	0.9	0.9	2.1	87.9	2.3	0.0	2.8	2.1	0.13	0.00	0.10	0.65	0.00	0.00	0.02	0.01	0.06	0.01	0.07	0.00	0.00	0.00	0.00
41	0.6	0.8	1.8	87.9	2.4	0.0	3.2	2.3	0.12	0.02	0.08	0.61	0.00	0.00	0.02	0.01	0.06	0.01	0.04	0.03	0.00	0.11	0.00
42	0.6	0.7	2.7	86.1	3.2	0.0	2.8	2.0	0.21	0.01	0.26	1.08	0.01	0.00	0.02	0.01	0.08	0.02	0.05	0.00	0.00	0.00	0.00
43	0.9	0.9	3.0	82.9	2.6	0.0	5.6	2.3	0.22	0.00	0.22	1.11	0.00	0.00	0.03	0.04	0.08	0.01	0.06	0.00	0.00	0.11	0.00
48	1.4	0.4	6.9	70.9	1.8	0.5	12.5	0.3	0.37	0.00	1.07	2.44	0.02	0.00	0.02	0.10	0.57	0.00	0.19	0.01	0.01	0.42	0.02
49	1.3	0.0	5.0	74.3	1.2	0.4	14.3	0.1	0.33	0.01	0.91	1.38	0.03	0.00	0.05	0.01	0.49	0.00	0.23	0.00	0.00	0.00	0.02
50	1.0	0.1	5.1	72.6	0.6	0.4	16.6	0.1	0.32	0.01	0.90	1.38	0.02	0.00	0.03	0.01	0.50	0.00	0.23	0.00	0.00	0.01	0.02
51	1.0	0.6	5.1	72.8	1.3	0.3	14.8	0.0	0.35	0.01	0.97	1.46	0.02	0.00	0.03	0.02	0.54	0.00	0.19	0.00	0.00	0.42	0.03
52	0.4	0.0	5.0	74.1	0.7	0.5	15.7	0.2	0.33	0.01	0.85	1.33	0.02	0.00	0.04	0.01	0.45	0.00	0.26	0.00	0.00	0.00	0.01
53	0.8	0.1	5.2	73.2	0.7	0.5	15.5	0.3	0.35	0.00	0.97	1.44	0.00	0.00	0.04	0.04	0.50	0.00	0.21	0.00	0.00	0.19	0.01
54	0.9	0.3	5.1	74.1	0.8	0.4	14.8	0.2	0.35	0.01	0.88	1.42	0.03	0.00	0.03	0.02	0.48	0.00	0.11	0.00	0.00	0.15	0.01
55	1.0	0.2	5.1	75.7	1.0	0.4	13.1	0.1	0.31	0.01	0.85	1.35	0.00	0.00	0.03	0.00	0.47	0.00	0.26	0.00	0.00	0.06	0.01
56	1.0	0.4	4.8	73.7	1.2	0.3	15.3	0.1	0.31	0.01	0.88	1.26	0.03	0.00	0.03	0.01	0.47	0.00	0.19	0.00	0.00	0.16	0.01
5	0.1	0.7	1.5	82.1	1.5	0.5	9.2	1.5	0.20	0.02	0.00	2.73	0.02	0.00	0.02	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00
1	0.7	1.4	5.9	78.2	0.7	1.3	5.8	1.9	0.45	0.01	0.12	2.71	0.01	0.00	0.06	0.02	0.11	0.01	0.31	0.00	0.01	0.29	0.00
2	2.3	1.4	6.3	76.9	0.0	1.3	4.4	3.3	0.46	0.02	0.14	2.90	0.00	0.00	0.01	0.02	0.08	0.02	0.25	0.06	0.00	0.11	0.00
3	2.1	0.1	6.1	76.7	0.0	3.0	4.3	3.8	0.45	0.03	0.14	2.89	0.00	0.00	0.01	0.02	0.09	0.02	0.28	0.00	0.00	0.00	0.00
4	0.3	1.2	6.7	71.5	0.0	4.5	6.9	4.4	0.46	0.03	0.11	3.16	0.00	0.00	0.12	0.02	0.12	0.02	0.21	0.02	0.00	0.29	0.00
57	0.1	0.4	5.7	60.7	0.0	2.5	15.7	6.6	0.72	0.03	0.08	3.24	0.01	0.00	3.78	0.03	0.17	0.03	0.23	0.00	0.00	0.00	0.00
60	1.1	0.3	3.7	78.0	0.6	0.6	9.8	1.1	0.16	0.02	0.01	0.64	0.00	0.00	3.31	0.02	0.57	0.00	0.06	0.01	0.00	0.00	0.00
66	0.3	0.0	3.0	81.5	0.0	2.6	2.2	5.2	0.07	0.01	1.18	0.98	0.00	0.00	2.41	0.01	0.08	0.02	0.00	0.03	0.01	0.45	0.02
69	0.6	0.4	2.4	78.5	1.6	0.3	10.1	0.3	0.18	0.00	0.74	1.20	0.00	0.00	2.66	0.00	0.33	0.00	0.05	0.29	0.00	0.00	0.23
70	0.5	0.6	3.5	75.1	1.7	0.2	14.0	0.4	0.28	0.00	0.98	1.82	0.02	0.00	0.04	0.00	0.28	0.00	0.10	0.00	0.00	0.42	0.00
71	0.6	0.0	2.8	83.0	0.0	2.0	5.5	0.3	0.16	0.00	0.81	1.33	0.01	0.00	2.78	0.01	0.30	0.00	0.04	0.26	0.00	0.00	0.21
72	0.4	0.2	3.2	78.2	1.4	0.4	12.2	0.3	0.37	0.01	1.18	1.67	0.00	0.00	0.04	0.01	0.31	0.00	0.11	0.00	0.00	0.00	0.01
74	0.2	0.0	4.0	80.8	0.0	1.9	8.2	0.3	0.30	0.00	1.24	2.12	0.04	0.00	0.19	0.01	0.37	0.01	0.13	0.00	0.01	0.14	0.02
76	0.2	0.4	4.1	74.6	1.5	0.3	14.3	0.0	0.26	0.02	0.00	0.96	0.00	0.00	1.53	0.00	0.39	0.00	0.16	0.57	0.00	0.09	0.56
77	0.2	0.0	4.2	76.6	0.6	0.6	13.2	0.1	0.25	0.01	0.00	0.99	0.00	0.00	1.72	0.00	0.37	0.00	0.10	0.40	0.00	0.00	0.65
78	0.4	0.0	4.8	75.9	0.8	0.4	13.4	0.0	0.30	0.02	0.01	1.22	0.00	0.00	1.73	0.00	0.34	0.00	0.08	0.16	0.00	0.00	0.34
79	0.1	0.2	3.8	76.4	1.3	0.4	14.0	0.0	0.25	0.02	0.00	0.91	0.00	0.00	1.34	0.00	0.33	0.00	0.12	0.38	0.00	0.00	0.46
80	0.1	0.5	3.9	76.6	0.8	0.4	13.3	0.0	0.25	0.02	0.01	0.93	0.00	0.00	1.40	0.00	0.35	0.00	0.12	0.45	0.00	0.09	0.80
87	0.7	0.8	3.9	74.2	2.1	0.5	12.3	0.4	0.11	0.03	0.01	0.94	0.00	0.00	3.06	0.01	0.28	0.00	0.02	0.21	0.00	0.42	0.01
88	0.4	0.7	4.1	80.2	0.1	0.7	8.3	0.5	0.10	0.02	0.01	0.78	0.00	0.00	3.24	0.01	0.45	0.00	0.01	0.15	0.00	0.12	0.02
89	0.9	0.9	4.3	72.6	1.6	0.3	13.2	0.2	0.15	0.05	0.02	0.86	0.00	0.00	3.76	0.02	0.41	0.00	0.13	0.06	0.00	0.38	0.05
90	0.6	0.5	3.9	79.0	0.6	0.5	9.6	0.1	0.12	0.02	0.00	0.79	0.00	0.00	3.37	0.00	0.39	0.00	0.06	0.18	0.00	0.13	0.05
91	0.7	0.6	3.3	75.8	1.7	0.3	12.0	0.2	0.14	0.03	0.01	0.75	0.00	0.00	3.50	0.00	0.43	0.00	0.10	0.15	0.00	0.24	0.02
95	1.5	0.6	4.0	63.5	0.5	0.0	3.2	0.4	0.03	0.02	0.02	1.55	0.00	0.00	2.49	0.00	0.06	0.01	0.04	3.90	0.00	0.28	17.99
264	0.4	0.5	3.6	74.4	1.5	0.4	13.0	0.3	0.30	0.00	3.45	1.19	0.00	0.00	0.07	0.00	0.43	0.00	0.16	0.00	0.00	0.26	0.00
265	0.6	1.1	3.2	72.4	2.1	0.2	13.9	0.2	0.28	0.01	3.90	1.23	0.00	0.00	0.06	0.01	0.48	0.01	0.16	0.01	0.00	0.07	0.01
266	0.4	0.7	3.0	75.4	1.5	0.2	12.9	0.2	0.26	0.00	3.53	1.10	0.00	0.00	0.06	0.00	0.41	0.00	0.13	0.00	0.00	0.19	0.00
267	1.8	1.4	11.9	56.8	1.7	0.2	6.5	0.9	0.42	0.02	0.47	4.35	0.03	0.00	11.96	0.16	0.11	0.01	0.07	0.37	0.00	0.78	0.21
6	3.4	1.6	5.4	75.6	0.0	1.4	3.9	4.5	0.42	0.02	0.11	2.88	0.00	0.00	0.01	0.02	0.15	0.02	0.21	0.00	0.02	0.20	0.00
7	2.2	1.9	5.9	68.3	0.1	1.2	4.0	10.9	0.53	0.05	0.13	4.53	0.00	0.00	0.00	0.02	0.16	0.03	0.30	0.00	0.00	0.00	0.00
8	1.4	0.9	3.1	84.6	2.0	0.0	3.3	2.3	0.11	0.01	0.01	0.44	0.00	0.00	1.38	0.00	0.10	0.01	0.07	0.00	0.00	0.18	0.00
9	2.0	1.5	6.6	74.8	0.0	1.4	5.2	4.1	0.48	0.01	0.14	3.42	0.02	0.00	0.01	0.01	0.12	0.02	0.33	0.00	0.00	0.00	0.00
11	0.7	2.0	6.1	76.5	0.8	1.0	3.9	5.1	0.47	0.03	0.11	2.84	0.00	0.00	0.02	0.02	0.14	0.02	0.23	0.00	0.00	0.00	0.00
10	4.3	1.8	6.7	74.8	0.7	0.8	4.5	2.4	0.53	0.00	0.09	3.07	0.00	0.00	0.01	0.01	0.15	0.02	0.26	0.00	0.00	0.00	0.00

ベトナム古代ガラスの化学分析
―ベトナムと日本で出土したガラス小玉の比較研究―

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ベトナムでは多くのガラス製遺物が出土しており、ガラスの製造を示唆する遺物も発見されている。一方で、これらのガラス製遺物の分析研究は少なく、化学組成の特徴については十分に明らかになっていない。本研究では、ドンソン文化およびサーフイン文化のガラス製遺物72点について、可搬型の蛍光Ｘ線分析装置による非破壊分析を行った。

本研究で分析したガラス製遺物は、３点を除いてカリガラスと判断され、さらに化学組成から３種類（Type１～３）に大別された。また、製作技法と化学組成との間には明確な対応関係が認められた。分析対象の主体を占める引き伸ばし法によるガラス小玉のほとんどがType１に属した。Type１は先行研究でベトナム北部から中国南部の沿岸部で生産されたと推定されるAl_2O_3の多いカリガラス（m-K-Al または Group PII）に対応する可能性が高い。一方、Type２は主にアクアマリンブルーを呈する引き伸ばし法以外のガラス玉に対応し、タイ中部のバンドンタペットで出土するAl_2O_3が少ないカリガラス（mK-Ca）との関係が想定されるが、相違点もある。Type３は緑色の腕輪や耳飾りに対応し、Na_2Oの多いカリガラス（mKCA-N）の可能性が示された。一方、インドやタイ南部のカオサムケオで中心的な位置を占めるソーダガラスやAl_2O_3が中程度のカリガラス（m-K-Ca-Al または Group PI）は確認されなかった。

今回分析を行ったガラス製遺物は、その多くがベトナムまたはその周辺地域で生産された可能性の高いガラスと判断された。タイ中部との関係を示唆するガラスはあるものの、マレー半島、ミャンマー、インドなど、より西方の地域との活発な関係は見出しにくい。東アジアとの関係については、ベトナムで出土するガラス製品と日本の弥生時代に流通したガラス製品は、引き伸ばし法によるガラス小玉を主体とする点で類似するが、基礎ガラスの種類や着色剤との組み合わせ関係が異なっており、ベトナムが弥生時代に流通したガラス小玉の直接的な流入源であるとは考えにくいことがわかった。東アジアへのガラス小玉の流入経路を考える上で重要な知見であると言えよう。

キーワード：ベトナム、ドンソン文化、サーフィン文化、ガラス、蛍光Ｘ線分析