Discovery of Collection of Moulds in Luy Lâu (Bắc Ninh): New Achievements in Research of Đông Sơn Bronze Drums in Vietnam

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Abstract: Between 2014 and 2019 the Vietnam National Museum of History carried out many surveys and excavations in collaboration with Japanese researchers of the Luy Lâu ancient citadel area. This was one of the earliest and largest metropolises in North Vietnam during the first ten centuries AD. A noteworthy point is that during the excavations in 2014 and 2015, archaeologists discovered hundreds of fragments of moulds lying in situ in the cultural layer that would have been used to cast Đông Sơn drums. This discovery provides convincing evidence that the drums were cast in the central region of northern Vietnam and this gives an opportunity to thoroughly understand the drum casting process of the ancient Việt people. The significance of this discovery is seen as greater research on the Đông Sơn drum technical manufacturing. In this paper, therefore, the author reviews research on the Đông Sơn drum casting technique, focusing on three main aspects: (1) drum casting methods; (2) alloy composition; and (3) casting experimentation. Based on the research background, comments are made on the significance of the discovery of moulds for casting bronze drums in the archaeological layer of the ancient Luy Lâu citadel, one of the greatest archaeological discoveries in Vietnam in recent years.

Keywords: Drum casting moulds, bronze drum-casting process, Đông Sơn drums, Đông Sơn culture, Luy Lâu citadel.

Subject classification: Archaeology

1. Introduction

The site of Luy Lâu ancient citadel is located in Thanh Khương commune, Thuận Thành district, Bắc Ninh province. It was one of the earliest and the largest urban centres in North Vietnam, providing the most abundant and diversified artefacts in comparison with other archaeological sites dating back to the period of the first ten centuries AD. Luy Lâu

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was not only a political and economic centre but also a cultural and religious one, owing to the adoption and development of Buddhism, Chinese script, and Confucianism. Due to such significance, the site has attracted a lot of attention from Vietnamese and international scholars, especially over the past two decades. From 1998 to 2019, 16 excavations were carried out here. The most remarkable were those done by the Vietnam National Museum of History, Bắc Ninh Provincial Department of Culture, Tourism and Sports, and the University of East Asia (Japan) in 2014 and 2015. In these excavations, hundreds of fragments of moulds for casting Đông Sơn bronze drums were discovered, creating great excitement among scholars. These discoveries went towards proving the origin of Đông Sơn drums and opened a door to thorough research on the ancient Vietnamese drum-casting process. Detailed information on the extremely valuable collection of these fragments was announced in No. 3/2020 of the journal "*Archaeology*" (Trương Đắc Chiến, 2020, pp.42-55).

Map 1: Satellite Image of Luy Lâu Ancient Citadel and Spot Where Moulds for Casting Bronze Drums Were Found

Source: Vietnamese - Japanese Research Team in 2015.

2. How Đông Sơn drums (also called Heger Type I) were cast

This is a topic that has long attracted great attention from both international and Vietnamese researchers. Reviewing the relevant documents available hitherto, the author realises that the main focus is on the following aspects: (1) drum casting methods; (2) alloy composition of the drums; and (3) casting experimentation.

2.1. Drum casting methods

The question of whether the Đông Sơn drums were cast in bronze using the lost-wax method or the piece-mould process has been a highly controversial topic among researchers since the early 20th century. Some opinions relating to the two drum-casting methods are described as follows:

2.1.1. Heger I drums were cast in bronze using lost-wax method

Of those who support this opinion, first up is H. Parmentier (1918) with his work titled "Ancient Bronze Drums" (*Anciens tambours de bronze*) published in No.18 of the Bulletin of the French School of the Far East (*Bulletin de l'École française d'Extrême-Orient - BEFEO*). He considered the study of the Heger Type I drum casting method to be fascinating, which provided further understanding of the civilisation of the owners of the bronze drums. Having studied remaining traces on these drums, he supposed that they were cast in one block (monoblock casting) instead of welding different parts together. He paid special attention to the rectangles found equidistant from each other by 7 to 10cm on the outside surface. In his opinion, this was not accidental, but they were the traces of the spacers used to hold parts of the mould together after the wax melted. He assumed that the handles were welded onto the mantle before the designs were applied, as there were no designs underneath the handles. Although Parmentier did not point out how the drums were cast specifically, he assumed the Heger Type I drums were cast using the lost-wax method as per his description in the publication (Parmentier, H., 1918, pp.15-16).

In a voluminous work titled "*The Kettledrums of Southeast Asia: A Bronze Age World and Its Aftermath",* A. J. Bernet Kempers (1988), a Dutch ethnologist, described in detail the process of casting a bronze drum using the lost-wax method, which consists of the following stages: (1) a core (or inner mould) is produced. It is made of clay and has the same shape as a fully completed drum. It is hollow and has three dimensions, produced on a turning table with support from a tool like a profile-gauge; (2) the clay core is enclosed with wax. The thickness of the wax layer corresponds to that of the bronze drum. The surface of the wax must be soft enough to be inscribed with designs made by a pointed pen or printed by a terracotta mould; (3) spacers and metal dowels are pinned to the wax surface to position the inner mould and fix the thickness of the drum; (4) it is then enclosed

with clay to make the outer mould; (5) the mould is heated to melt the wax; (6) molten bronze is poured into the sprue to fill the space left by the wax; and (7) the moulds (both inner and outer ones) are broken to retrieve the product (Kempers, B., 1988, pp.185-190).

In addition to the description of the casting process, Kempers explained why a ridge ran along the mantle. In his opinion, it is highly probable that they are traces left by the use of the printing mould. There were ridges between the parts of the printing mould used to make designs on wax and consequently they were left on the mantle after casting (Kempers, B., 1988, p.191). He also hypothesized how the handles and the toad statuettes were cast. According to him, there were two possibilities: the first one is that wax models of the handles and the toad statuettes were made separately before being fixed to the wax model of the mantle. Regarding the technique, however, he supposed that this possibility encountered certain difficulties. Because of being made of wax, the handles were fragile and would break easily when the model was enclosed with clay to make the outer mould. For the toad statuettes, it was more feasible, but they probably faced problems during the casting process. As the wax statuettes were stuck on the tympanum, they would have had to bear the weight of the whole drum when the mould was placed upside down for the molten bronze to be poured inside. The second possibility is that the handles and the toad statuettes were cast separately and were then attached to the wax moulds of the drum. Next, the inner mould was enclosed with clay to make the outer mould. The subsequent stages were the same as the above-mentioned process (Kempers, B., 1988, p.192).

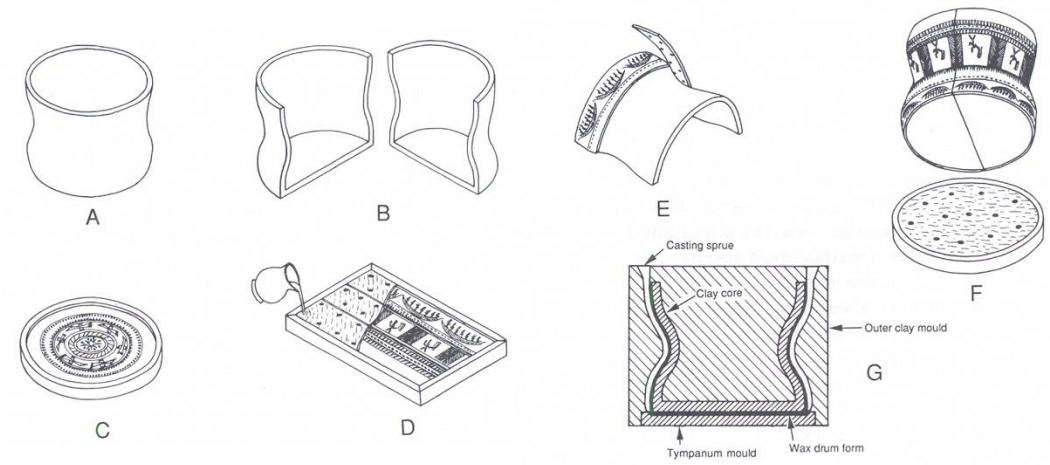
Sharing the same opinion with B. Kempers, C. Higham (1996), in a work titled "*The Bronze Age of Southeast Asia"*, described a similar process of casting bronze drums, but with some differences in the design-making stage.

According to Higham, in order to make the patterns, it was necessary to prepare separate clay pattern moulds - circular for the tympanum and rectangular for sections of the mantle. The surface of the clay was decorated in several ways. It could be impressed with a pattern mould to create panels of motifs or it could be incised with a stylus. This pattern mould would then have been filled with molten wax to replicate the chosen decor. Next, the sheets of cooled wax were transferred to the clay core that had already been prepared. At this stage it was possible to change the decoration. After the bronze spacers were pinned onto the wax mould, it was completely enclosed with a layer of smooth clay, which was further enclosed by another layer of clay and additives, hence an outer mould was formed. In addition, Higham also pointed out that the mould was placed upside down so that molten bronze could be poured into the sprue from the drum base. He supposed that drum casting required very high technical and aesthetic skills. Thus, it could only be done by full-time specialists (Higham, C. 1996, pp.130-131).

Anna Bennet is one of the scholars who strongly advocates the use of the lost-wax method for casting a bronze drum. In her paper titled "Lost-Wax or Piece-Mould Casting" published in the journal "*Arts & Cultures*" in 2006, she put forward the arguments for lost-wax casting instead of three-mould casting. She assumed that if a bronze drum was cast

using the three-mould casting method, the bumps where the joint was would be straight and uninterrupted along the mantle. When viewed under a microscope, however, the bumps are sometimes interrupted, especially in the undecorated sections. In her opinion, the bumps running along the mantle were made by the joint between wax sheets. As the latter were produced by rectangular pattern moulds, as described by Higham, they had their own planes and consequently the joint was uneven. To avoid a gap along the joint, the wax sheets were placed so that they overlapped each other. Bennett also supposed that a joint was never found in the inner surface of the drum, as there was only a clay core left once the wax had completely melted and ran away (Bennett, A., 2006, pp.268-271).

Figure 1: Process of Casting Bronze Drum by Lost-wax Method



Notes: A, B. A clay core is produced; C, D. Wax is poured onto decorated clay; E. The sheets of wax are lifted and placed on the clay core; F. The two halves of the core are then placed over the similarly produced mould for the tympanum. The assemblage is then invested with an outer clay mould and the wax replaced with molten bronze; G. The metal runs down the casting sprue.

Source: Higham, C., 1996, p.131.

In a concise study on the bronze drums in Southeast Asia titled "*Trails of Bronze Drums across Early Southeast Asia",* Ambra Calo (2014) was inclined to hypothesize that the bronze drums were cast using the lost-wax method. Basically, the casting process described by A. Calo is similar to Higham's description. However, she differs in her opinion about the casting of the handles and the toad statuettes. According to her, the handles cast by wax moulds were attached directly onto the wax mantle, before molten bronze was poured into the moulds. In regard to just the toad statuettes, she assumes that

they were cast separately by wax moulds first and then welded onto the tympanum (Calo, A., 2014, p.50).

The above are the opinions of some overseas scholars who support the hypothesis about bronze drum casting using the lost-wax method. Regarding Vietnamese scholars, Hà Văn Tấn and Hoàng Văn Khoán (1974) are of the same opinion after researching the traces on the Ngọc Lũ drum. According to these researchers, the model was mainly made of beeswax, which is abundant in Vietnam. The model could be used many times over and be decorated easily. At the same time, broken parts could be repaired without spoiling the whole model. Regarding the decoration, they assumed that both geometric and realistic motifs had been carved on the wax model. However, they noticed that the realistic motifs on the *Viên* (Vienna) bronze drum were made by printing the pattern moulds on the wax model. Regarding the handles, Hà Văn Tấn and Hoàng Văn Khoán supposed that they had been attached to the model before the decoration was applied; they were therefore cast together with the drum body. In respect of how the inner and outer moulds were made, those authors shared the same opinion with Kempers and Higham. Remarkably, they emphasized that the moulds were not heated before the casting, but that they were baked at a temperature of 1,000°C or higher. In respect of how sections of the moulds were joined and how molten bronze was poured into the moulds, Hà Văn Tấn and Hoàng Văn Khoán argued that a number of spacers and chocks had been used to fix the gap between the inner and the outer moulds. While most scholars assumed that the spacers and chocks were made of metal, the two authors surmised they were made of fire clay, which was also used to make the moulds. They thought that the mould was placed upside down allowing molten bronze to pour from the base to the tympanum of the drum (Hà Văn Tấn, Hoàng Văn Khoán, 1974, pp.37-43).

Hoàng Văn Khoán again confirmed the above-mentioned opinion in his research paper 10 years later, titled "Discussing the Techniques for Casting Dong Son Drums" published in the *Bulletin of the National Museum of Vietnamese History* (Hoàng Văn Khoán, 1985, pp.148-153).

Another Vietnamese archaeologist who supported the hypothesis on the lost-wax method is Nguyễn Việt. In his paper titled "Bronze Situlas of Dong Son" published in the journal "*Arts & Cultures"* in 2006, he did not deny the use of the three-mould method for casting bronze drums, but he supposed that the lost-beeswax method was used to cast the handles and statuettes on the tympanum (Nguyen Viet, 2006, pp.234-263).

Sharing the same opinion, ethnologist Tạ Đức (2017) argued that the Đông Sơn bronze drums were cast using the lost-wax method in his monograph titled "Origin and Development of Đông Sơn Bronze Drum". He presented a relatively new approach, compared with the traditional views. He thought Đông Sơn bronze drums in North Vietnam dated back to the 3rd century BC; according to King An Dương's order, the bronze drums were to be given to the local chiefs as a symbol of the Âu Lạc royal power. Tạ Đức believes that the Đông Sơn bronze drums were cast using the lost-wax method by

Cao Lỗ, who was responsible for casting bronze drums for the king. He came from Yelang in the Chu State, where bronze drums were cast early on and where skills were better than other regions (Tạ Đức, 2017, pp.171&182).

The above are opinions of the scholars who support the hypothesis on the use of the lost-wax method for casting bronze drums. Among the assemblage of Đông Sơn drums discovered so far in Vietnam, there are a small number of drums with evidence demonstrating that they were indeed cast using the lost-wax method.

In a paper on the collection of bronze drums found in Bình Định province, published in the journal "*East Asian Cultural Interaction Studies*" in 2008, Nishimura M. and Phạm Minh Huyền singled out a drum called the Gò Rộng drum supposedly cast by the lost-wax method. Through their research, Nishimura and Phạm Minh Huyền realised that the drum did not have a bump along the line where the moulds joined, unlike other drums. Instead, a pseudo-fin was found on the body and traces of decorative patterns printed with the wax mould were over the inner surface (Nishimura, M., Phạm Minh Huyền, 2008, p.214).

Next, in 2014, during the conference on "90 Years of Discovery and Research of Đông Sơn Culture", Ngô Thế Phong and Chu Mạnh Quyền presented a paper on 23 drums, which were collected and preserved at the Vietnam National Museum of History from 2004 to 2014. They assumed that two of those drums, including ST.9196-2008 and ST.10818-2013, were cast by the lost-wax method. A particular observation is that there are strips of circles dotted in the centre running vertically along the joint lines of the moulds. Consequently, the authors assumed they are pseudo-joints of the moulds, and that the two drums were cast by the lost-wax method (Ngô Thế Phong, Chu Mạnh Quyền, 2014, pp.196-197).

Figure 2: Traces of Pseudo-fins on Drum ST.2008 at Vietnam National Museum of History

Source: Taken by Trương Đắc Chiến.

2.1.2. Heger I drums were cast in bronze using the piece-mould method

The first representative of those who support this opinion is Franz Heger, author of the classic work "Old Metal Drums from Southeast Asia" (*Alte Metalltrommenl aus Südost-Asien*, 1902). Talking about the technical manufacturing process, Heger supposed that it was interesting that those bronze drums were cast using two different techniques. According to Heger, all Type I and Type II drums, as well as most of Type IV and intermediate drums, were cast in bronze using the piece-mould method. The drums with two joining lines on the body were cast with three moulds, while the drums with four joining lines were cast with five moulds. Heger assumed that only the Type III drums were cast in bronze using the lost-wax method, since there was no joining line on the mantle and the inside surface of those drums often bore traces of repair (Heger, F., 1902, pp.134-144).

Figure 3: Traces of Joining of Three Mould Casting on Hoàng Hạ Bronze Drum

Source: Taken by Trương Đắc Chiến.

Following Heger, many scholars believed that most bronze drums, especially the Type I ones, were cast by the piece-mould method. Pieter Meyers, a technical researcher, offered the opinion that Đông Sơn drums must have been produced by the three-mould casting

method. In a research paper on the Đông Sơn bronze casting technique published in the journal "*Arts & Cultures*" in 2006, he argued that joining traces must be found on the body, as the drums were produced using the three-mould casting method. Furthermore, if the drums were cast in wax moulds, the moulds certainly would have been refined to avoid joining traces, as it was a very simple process like casting monoblock statuettes. If the drums were cast in bronze using the lost-wax moulds, it would be very abnormal for joining lines to be found only on the outer surface and not the inner one. He also noticed that the drums were produced using the three-mould casting technique so the handles could not be in the middle but were placed lopsidedly. This would not be the case with a drum cast using the lost-wax method (Meyers, P., 2006, pp.264-267).

In a research work on the bronze artefacts in Yunnan province (China), Robert E. Murowchick (2001) supposed that most of the bronze artefacts of the Dian culture, including ritual and musical instruments as well as other items, were cast in bronze using the piece-mould method. In his opinion, the early bronze drums such as the Pre-Heger Type I drums, also called the Wanjiaba drums, were all cast by the piece-mould method (Murowchick, R. E., 2001, p.148).

Researching the bronze artefacts in Yunnan province, Chiou-Peng shared the same opinion as Murowchick. In his paper titled "*The Technical History of Early Asian Kettledrums"*, he divided the history of metallurgy in Yunnan into three phases relating closely to the technical manufacture of drum casting: (1) *the Initial Phase*, which dates back to the period from the 13th to the 8th centuries BC. Drum casting, which used open moulds or two-piece moulds, was dominant during this phase. The products were mainly small-sized simple tools; (2) *the Formative Phase*, which dates back to the period from the 7th to the 4th centuries BC. Owing to improved metallurgy techniques, piece-mould casting was initially implemented. Larger-sized tools, typically the Wanjiaba bronze drums, were produced. During the period, most bronze goods in general and bronze drums in particular were produced using the piece-mould casting method. Chiou-Peng highlighted that metal spacers were used to fix the gap between the outer and inner moulds; (3) *the Florescent Phase*, which dates back to the period from 350 BC to 50 AD. At that time, the use of terracotta moulds remained popular, but new pattern-making skills were applied, especially the lost-wax method. Large artefacts such as bronze drums were produced by three-mould casting, while the lost-wax casting method was used to make small artefacts and pierced reliefs. In conclusion, TzeHuey Chiou-Peng assumed that the lost-wax method was used in Yunnan no earlier than the 4th century BC and that was only applied in casting small artefacts or parts of some items. Bronze goods in Yunnan, including bronze drums, were basically produced by terracotta three-mould casting (Chiou-Peng TzeHuey, 2011, pp.17-26).

Most Chinese scholars support the opinion that the drums were cast in bronze using the piece-mould method. Recently, Wu Chongji, Luo Kunxin, and Cai Rong (2018) expressed

the same opinion in their publication titled "*Decoration Art of Ancient Bronze Drums*". They argue that ancient people used terracotta piece-moulds to cast bronze drums in the initial phase in a similar way that bells are cast. Only Ximeng drums, i.e., the Heger Type III drums in Myanmar, were cast in bronze by the lost-wax method (Wu Chongji, Luo Kunxin, Cai Rong, 2018, p.12).

Regarding Vietnamese scholars, in the book "*The Đông Sơn Bronze Drums Discovered in Vietnam"* published in 1975, Nguyễn Văn Huyên and Hoàng Vinh suggested that Đông Sơn drums were produced by piece-mould casting; the traces of spacers found on the edge of the drums were the actual air vents of the moulds (Nguyễn Văn Huyên, Hoàng Vinh, 1975, p.130).

Later, Trịnh Sinh also argued that the bronze drums were cast by the piece-mould method. In his opinion, terracotta moulds were completely appropriate for the casting of large-sized artefacts with complicated decorations such as bronze drums. To produce a drum, three-mould casting was used with a set of spacers that helped fix the positions of the inner and outer moulds when molten bronze was poured into them. The spacers were made of metal, most probably copper (Trịnh Sinh, 1996, p.50), and placed equidistantly along the tympanum, the mantle, the barrel, and the base. Decorative patterns were carved directly on the clay moulds before being baked. In respect of the sprues, through which molten bronze was introduced into the moulds, after examining some Heger Type II drums, Trịnh Sinh suggested that molten bronze was poured into a point on the edge of the tympanum or the mantle (Trịnh Sinh, 2012, pp.161-162).

Recently, Kiều Quang Chẩn, a researcher and collector with a strong passion for the Đông Sơn culture, published a book titled "Echo from the Đông Sơn Drums" (*Vang vọng từ trống Đông Sơn*) (2018). In this book, an entire chapter (chapter III) is devoted to discussing the technical manufacturing of the Đông Sơn drums. After reviewing some relevant research, he visited private foundries in Thanh Hóa and Nam Định provinces to study the present-day technique of casting bronze drums. In those foundries, he observed workers casting drums using both methods: three-mould casting and lost-wax casting. Based on the empirical study, plus the knowledge he had amassed over many years of the Đông Sơn drums, Kiều Quang Chẩn supposed that it was easier to produce a bronze drum using the three-mould casting method and the drum looked similar to the ancient one, although it was a longer process than lost-wax casting. Consequently, he concluded that the Đông Sơn bronze drums were produced using terracotta piece-mould casting, similar to the drums discovered in South China (Kiều Quang Chẩn, 2018, pp.27-35).

The above are opinions of the researchers who advocate the hypothesis that the bronze drums were made by piece-mould casting. In reality, except a few drums made by the lost-wax casting method mentioned earlier, most of the Đông Sơn drums discovered so far were made by three-mould casting. This will be discussed in more detail in the following part that refers to the significance of the collection of the Luy Lâu drums.

2.2. Alloy composition

Another important factor for casting bronze drums is the alloy composition. In general, all research conducted on the alloy composition of the Đông Sơn drums demonstrates that it consists of copper, lead, and tin.

In 1902, F. Heger stated that the composition of Type I drums contained copper, lead, and tin. In this the proportion of copper ranged from 60.82% to 71.71%; the proportion of lead ranged from 14.25% to 26.69%; and the proportion of tin ranged from 4.9% to 10.88% (Heger, F., 1902, p.143).

In 1954, L. Malleret also released information on the composition of some Đông Sơn drums, according to which Quảng Xương II, Đắc Glao, and Đồng Văn I drums contained mainly copper, lead, and tin (cited from Trịnh Sinh, 1996, p.47).

In 1981, Diệp Đình Hoa analysed the chemical composition of six Đông Sơn drums and realised that the composition mainly contained copper and lead; or copper, lead, and tin. Tin made up a very small proportion (0.4% to 8.77%), while lead accounted for a higher proportion (1.35% to 25.6%). From a technical perspective, he noticed that the mixture would be outstanding, especially for making musical instruments, if it also contained zinc (Diệp Đình Hoa, 1981, pp.166-168).

Bernet Kempers also published the chemical composition of 33 Heger Type I drums found in Southeast Asia. These mainly contained copper (42.20% to 84.04%), tin (4.40% to 26.09%), and lead (1.22% to 27.80%) (Kempers, B., 1988, pp.200-201).

In a monograph on the technique for casting bronze drums published in the journal "*Archaeology*" in 1996, Trịnh Sinh also presented analytical findings of the chemical composition of six Đông Sơn drums. Based on these, he assumed that the composition of most of the drums contained the four elements of copper, lead, tin, and arsenic. The lead content ranged from 10% to 30%, tin was less than 10%, and the level of arsenic varied from 0.1% to 3.1%. The presence of lead helps to lower the melting point of the alloy making it easier for the molten mixture to fill all the space of the moulds. The presence of tin also contributed to lowering the melting point. Remarkably, arsenic is present in the alloy. In Trịnh Sinh's opinion, this was not accidental, but was an extremely important matter. Arsenic lowers the melting point of the alloy and makes cast products look shinier and more beautiful. In addition, arsenic helps the alloy to flow well. A little content of arsenic in bronze can make the molten bronze spread faster and fill up the moulds (Trịnh Sinh, 1996, pp.47-48).

2.3. Experimental castings

One of important issues in the research on the techniques for casting bronze drums is experimental casting. From 1964 to 1975, the Vietnam National Museum of History collaborated with the Museum of Fine Arts in carrying out the process of casting the Ngọc Lũ

drum five times. The process, results, and the experience learned from each casting were summarised by Trần Khoa Trinh (1977, 1985) and Trịnh Sinh (1996). The main points are described below:

- *The first casting*. The mould was placed upside down. The sprue was set in the drum base. When molten bronze was poured into the mould, the mould broke. The reason for this is that the mould had been baked too long, thereby it cracked. At the same time, the mould was not tied carefully (Trần Khoa Trinh, 1977, p.74). Trịnh Sinh argued that it was largely due to the clay used and the position of the mould. It is very important to ensure the mould can bear the pressure of molten bronze (Trịnh Sinh, 1996, p.43).

- *The second casting*. The mould was again placed upside down. This time the mould did not break after molten bronze was poured in. However, the latter did not completely fill the mould. As air vents were not set around the edge of the mould, the molten bronze did not fill the tympanum and consequently there was a large gap in the centre (Trần Khoa Trinh, 1977, p.74). According to Trịnh Sinh, the molten bronze probably was not liquid enough to flow fast; as a result, it solidified too soon. Thus, it was necessary to consider the composition of the bronze (Trịnh Sinh, 1996, p.43).

- *The third casting*. The mould was placed at a tilt. The sprue was set below the tympanum and the handles. The mould did not break after molten bronze was poured in. However, the product was not acceptable. The tympanum had a large gap and the drum lacked two handles. The inner mould had moved from its correct position, so the thickness of the drum was uneven. The decorative patterns were not clear (Trần Khoa Trinh, 1977, p.74). Obviously, the reason for this failure lay in certain factors: the pressure of molten bronze, the composition of the alloy, and the position of the sprue (Trịnh Sinh, 1996, p.43).

- *The fourth casting*. Two moulds were used for this casting. The tympanum and the mantle were cast separately. After being cast, they were welded together to make a drum. As the mould had been over baked, it became too loose to bear the pressure of molten bronze. As a result, the thickness of this drum was two or three times higher than that of the original drum, the decorative patterns were not clear, and there were cracks (Trần Khoa Trinh, 1977, p.43).

- *The fifth casting*. Based on the experience learnt from the previous castings, the fifth one (in 1975) produced a better product. The mould was placed in a hole at a depth of 60cm. The mould was tilted at an angle of 15°. The sprue was set on the tympanum. The mould did not break after molten bronze was poured in, completely filling it up. According to experts' assessment, however, it only met about 80% of the requirements of the original drum. The thickness was higher than that of the original drum, the decorative patterns on the mantle were fine but those on the tympanum were not sharp and sometimes blurred. Regarding the mould, five iron belts had been used to reinforce the mould to ensure it could withstand the pressure of molten bronze, which the ancient people are unlikely to have done (Trần Khoa Trinh, 1985, p.158; Trịnh Sinh, 1996, p.45). Recently, Nguyễn Thơ Đình (Institute of Archaeology) studied the casting of the Đông Sơn

drums from an ethnological empirical perspective. His research was carried out in Chè Đông village (Thiệu Trung commune, Thiệu Hóa district, Thanh Hóa province). Below are some of his main findings (Nguyễn Thơ Đình, 2017, pp.47-48):

- A complete set of terracotta moulds were made, consisting of two fragments for the mantle mould, one fragment for the tympanum mould, and one for the inner mould. The inner surfaces of the fragments for the tympanum and the mantle moulds were carved manually with decorative patterns, which were then carefully refined. After casting, the decorations were very sharp and clear. However, those on the drum cast by the lost-wax method were unclear. Thus, it was better to decorate by carving patterns on the terracotta moulds.

- The mould was baked until steam completely evaporated, before molten bronze was poured in (the mould was baked twice - first at around 900°C and then at 1,000°C or 1,100°C.

- The sprue was set in the centre of the tympanum or the mantle. For large products such as drums, it was better to be in the centre.

- To position the moulds, spacers were used made of copper alloy taken from the failed castings. Spacers were not placed on the tympanum.

- The alloy contained copper, tin, and lead.

The drum looked quite beautiful and shiny, with clear sharp decorations. Although it was an experimental casting of a new bronze drum and what Nguyễn Thơ Đình recorded as merely a description of the drum-casting process carried out in a traditional handicraft village, the process contributed partly to the awareness of the technical manufacturing proess of bronze drums in the past.

In conclusion, the experimental castings of the Đông Sơn drums are really important in proving the authors' hypotheses. Yet, how the ancient people cast those drums still remains a secret. As Trần Khoa Trinh states: "in scientific terms, we have not been able to affirm that we have more or less answered the question how people in the period of the Hùng Kings cast such large and beautiful bronze drums like the Ngọc Lũ drums" (cited from Trịnh Sinh, 1996, p.45).

3. Significance of discovery of Luy Lâu moulds

As described above, how the Đông Sơn drums were cast is still questioned by Vietnamese and international scholars.

Whether the piece-mould method or the lost-wax method was used to cast bronze drums has been debated inconclusively for a hundred years. Arguments raised by both schools of thought seem to be reasonable but are not scientifically persuasive enough to make scholars of the other school change their mind. Those arguments have mainly relied on ethnological observations and traces left on the drums. The lack of materials directly relating to the actual casting process is the main cause of these ongoing debates.

The chemical composition analysis shows which alloys the ancient people used but gives no clues about the casting method. Experimental castings to discover casting processes of the past take a lot of effort. These were carried out by trained technicians and engineers in collaboration with experienced drum casting artisans. However, the experimental castings were never successes, although they were just replication-castings instead of creating a brand new sample.

The experimental castings were unsuccessful because researchers carried out the previous castings mostly on the basis of ethnological documents and predictions from traces left on the drums. Although fundamental steps in the casting of a bronze drum could be imagined, they are still too far from being able to cast successfully such a perfect drum like the Đông Sơn drums. Experience and learnings were gained after each experimental casting. The main reasons for failure lay in factors such as the clay that was used to make moulds, the baking and position of the moulds, and the alloy composition.

We can see that three quarters of the reasons of failures are related to the moulds. While the chemical composition can be realised through analyses of the Đông Sơn drums, there is hardly any information on the fragments of the moulds. In archaeological excavations, researchers found many features and artefacts such as the kilns, ore cinders, and the moulds for casting axes, spears, and daggers. However, no fragments of the moulds for casting bronze drums have yet been found. Obviously, this lack of information poses a big challenge to the research on bronze drum casting in ancient times. Without directly related materials, research has to rely on ethnological observations and experiences of present-day craftsmen. That's why these experimental castings were not as successful as wished to be.

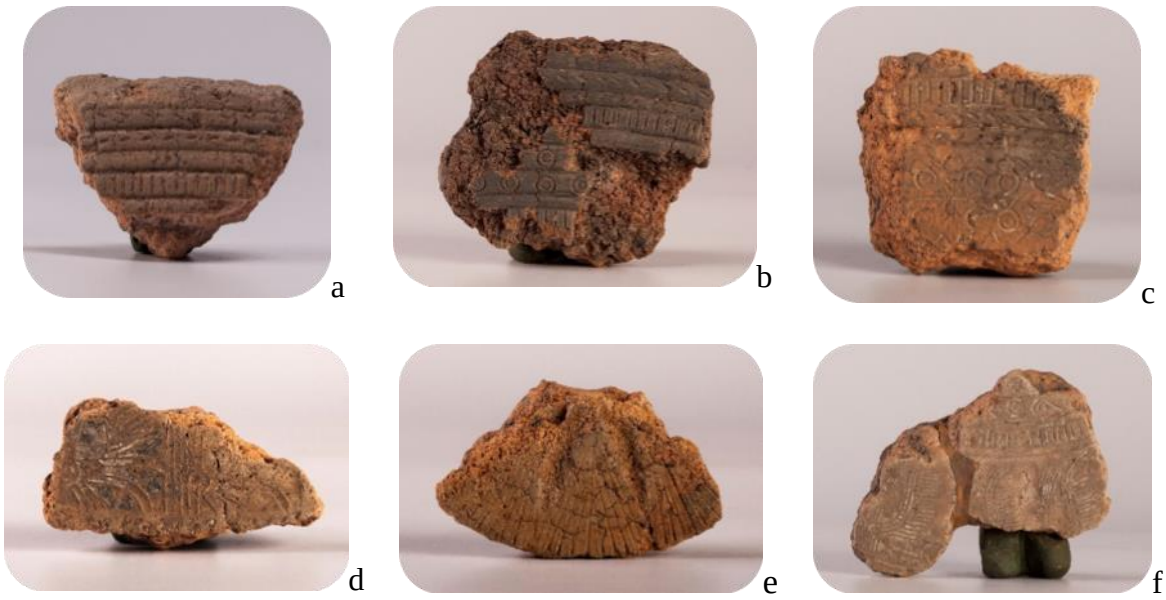
Table 1: Classification of Fragments of Moulds for Casting of Luy Lâu Drums

Type	Outer mould				Inner mould				Unidentified	Total
Position	Tympanum	Mantle	Barrel	Base	Tympanum	Mantle	Barrel	Base		
Quantity	37	17	27	2	47	75	56	52	610	923
Total	83				230				610	

Therefore, in this context, the discovery of hundreds of fragments of moulds for casting bronze drums found in the cultural layer of Luy Lâu ancient citadel in 2014 and 2015 became extremely important. These fragments were lying in situ in the archaeological layer. They were found together with the architectural and ceramic artefacts dating back

to the period from the Eastern Han Dynasty to the [period of] Six Dynasties. The find consisted of fragments of the outer and inner moulds for the tympanum, the mantle, and the base (Table 1). There were also artefacts relating to drum casting such as fragments of the crucibles and funnels used for melting and pouring bronze, the funnel used to pour the bronze, axes of the rotating tables, fragments of the foundry grates, and ore cinders. Based on these materials, archaeologists from the Vietnam National Museum of History found initial answers to the question about the casting technique of the Đông Sơn drums (Trương Đắc Chiến, 2020, pp.49-52).

Figure 4: Fragments of Outer Moulds: Tympanum



Source: Taken by Trương Đắc Chiến.

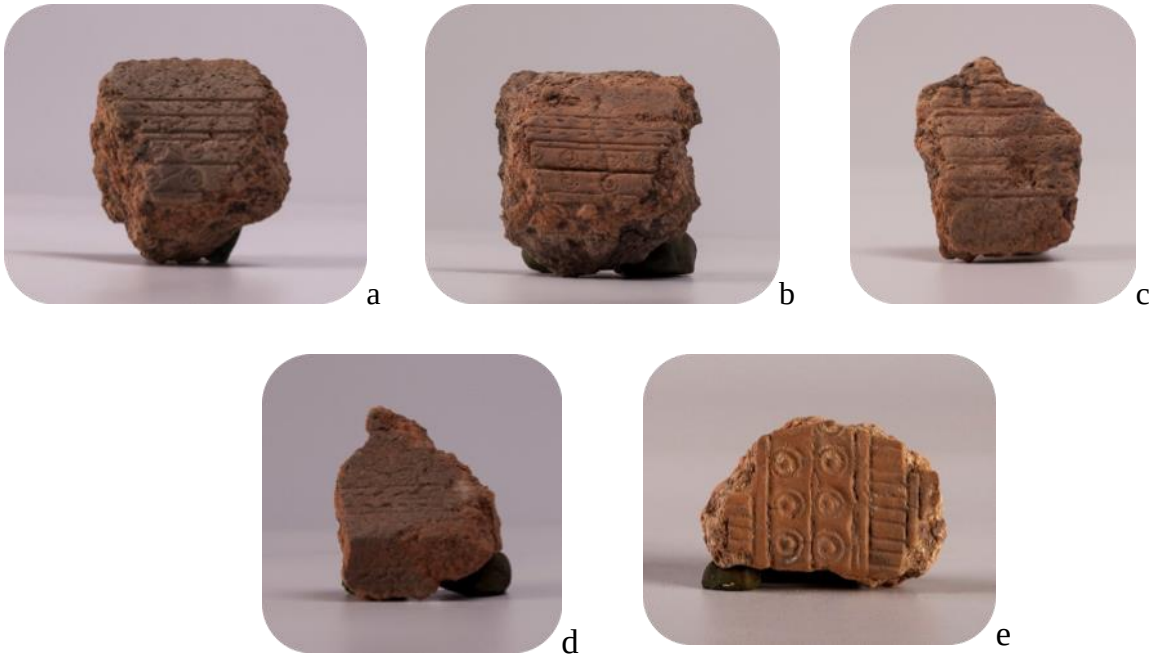
- *Regarding the question whether the Đông Sơn drums were cast by the piece-mould or the lost-wax method*: the discovery of the moulds in Luy Lâu convincingly show that the terracotta piece-mould casting method was used to produce the Đông Sơn drums.

- *Regarding the materials and the baking temperature*: although the analyses of petrography and the differential scanning calorimetry have not been made, one can see with the naked eye that the Luy Lâu mould consists of two layers. The inner one was made of fine clay, while the outer layer was made of a mixture of clay, dried rice husks or plant residues; the surface was covered by a smooth coat; the mould was probably dried or baked at a maximum temperature of 500°C.

- *Regarding decoration*: in the previous empirical research works, the decoration was assumed to have been applied on the drum sample (made of clay or beeswax); then the sample was enclosed by a layer of clay to make outer moulds. Based on fragments of the latter found in Luy Lâu, we can realise that the decoration was carved or printed directly onto the outer moulds. They include geometric patterns such as a tangential circle, parallel lines, the letter "N" carved upside down, and ears of rice. Meanwhile, the pattern of feathered men was printed on the moulds. This helps to explain why the decoration consists of a harmonious combination of both sunken and embossed designs.

- *Regarding the use of spacers*: most researchers assume that spacers used for casting were made of metal, probably copper as the melting point of copper is higher than that of bronze (Trịnh Sinh, 1996, pp.50-51). The discovery of ceramic spacers lodged in a fragment of the mould, however, has verified the opinion of Hoàng Văn Khoán and Hà Văn Tấn, who assumed that ancient Vietnamese people used fired clay to make spacers as well as moulds (Hoàng Văn Khoán, Hà Văn Tấn, 1974, p.41).

Figure 5: Fragments of Outer Mould for Barrel



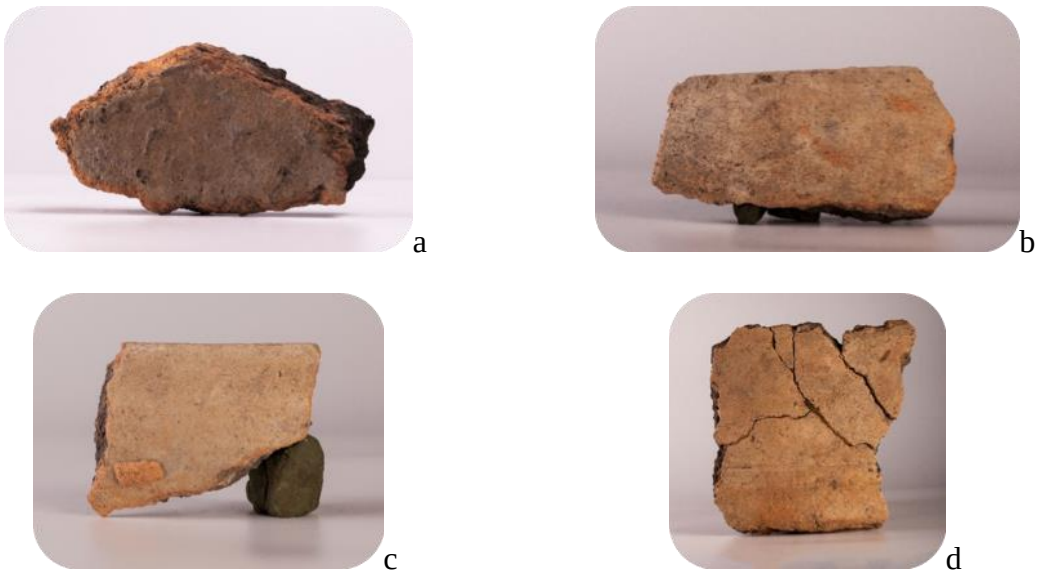
Source: Taken by Trương Đắc Chiến.

- *Regarding the position of the sprue*: at present, researchers mostly think that the moulds were placed upside down and the sprue was set at the drum base, when molten

bronze was introduced into the moulds. After studying the fragments of the moulds found in Luy Lâu citadel, the authors believe the sprue was set in the middle of the star in the centre of the tympanum. When examining some bronze drums preserved in the National Museum of History, the authors also noticed traces of the sprue in the centre of the tympanum, especially the Đắc Glao drum (Kon Tum province) and the Phú Duy drum (Mỹ Đức district, Hanoi).

- *Regarding the date of the artefacts*: according to the two samples of the moulds sent to Germany for the carbon-14 dating, one sample dates back to 357-167 BC, while the other dates back to 1401-1268 BC. The dates of the two samples are very different. The first dates back to the period of the Đông Sơn culture, while the second one dates back to the period of the Phùng Nguyên - Đồng Đậu culture, when no Đông Sơn drums were produced. To determine the date of the collection of the above-mentioned mould fragments, the authors analysed the accompanying artefacts found in layer 3b, particularly the architectural and ceramic artefacts, of which the dating could be calculated. The fragments of bricks, tiles, and ceramics in this layer mainly date back to the period from the late Eastern Han Dynasty to the Six Dynasties, i.e., from the 3rd-6th centuries. The date of layer 3b also matches that of the cultural layer found in other excavated holes and the general cultural layer in Luy Lâu citadel. It is consequently possible to affirm that the moulds date back to the period from the 3rd-6th centuries.

Figure 6: Fragments of Inner Mould



Notes: a. Tympanum; b. Mantle; c. Mantle Stuck with Terracotta Spacer; d. Base

Source: Taken by Trương Đắc Chiến.

- *Regarding the types of drums and their relationship*: the drums cast in the Luy Lâu moulds are Heger Type I drums belonging to Group C. They have a straight barrel and are decorated with patterns of the teeth of a comb and twin circles, like the drums found in Đắc Glao (Kon Tum province), Thôn Mống (Ninh Bình province), Thôn Bùi (Thanh Hóa province), and Phú Phương I (Hanoi). According to the classification in Vietnam, the drums in Group C date back to the period from the 3rd century BC to the 1st century AD. Based on the Luy Lâu moulds found in the cultural layer of the Six Dynasties, however, we have to consider reclassifying the date of the Đông Sơn drums that have been found, as the period to which the drums in Group C date back lasted until the 3rd and even the 6th century AD.

4. Conclusion

Based on the above descriptions, one can see that the Luy Lâu moulds provide fundamental answers to the questions raised about the techniques and methods used to cast the Đông Sơn drums. In the light of this newly discovered material, we can now answer the thorny questions that have seemed unsolvable. In addition to great scientific and technical significance, the fragments of the moulds for casting bronze drums found in the Luy Lâu ancient citadel, from historical and cultural perspectives, are evidence that the Đông Sơn drums were native in North Vietnam, and demonstrate the vitality of the Đông Sơn culture in history. Due to such significance, the hope is that these artefacts, which are part of the heritage of the Đông Sơn culture and the pinnacle of the ancient Vietnamese civilisation, will soon be included on the list of national treasures.

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