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title: Case Study 3

subtitle: Determining the Casting Process of a 3,000-Year-Old Bronze Elephant from China

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abstract: The question of when lost-wax casting was first used in central China has been of long-standing debate. When a rare sculptural ritual vessel, or *huo*, was first studied in the 1960s, it was thought to have been cast by such a method. But more recent excavations of foundry remains contemporaneous to this vessel at Anyang, and the refinement of examination and analytical tools used for the technological study of bronzes, provide new insights into the casting methods of such vessels in central China during the eleventh century BCE in the Yangtze River Valley. More recent technical study of the elephant-shaped vessel revealed clear evidence of quite a different method of production, namely the piece-mold casting technique, the most prevalent method used to create such bronze vessels at that time.

short\_title: Case Study 3

## Slide 1: Introduction

The question of when %%lost-wax casting%% was first used in central China has been of long-standing debate. When this rare sculptural ritual vessel, or *huo*, was first studied in the 1960s, it was thought to have been %%cast%% by such a method. But more recent excavations of foundry remains contemporaneous to this vessel at Anyang, and the refinement of examination and analytical tools used for the technological study of %%bronzes%%, provide new insights into the casting methods of such vessels in central China during the eleventh century BCE in the Yangtze River Valley. More recent technical study of the elephant-shaped vessel revealed clear evidence of quite a different method of production, namely the %%piece-mold%% casting technique, the most prevalent method used to create such bronze vessels at that time.

**Fig. 500**

## Slide 2: Context

The Freer Gallery of Art in Washington, DC, acquired this vessel of unknown archaeological provenance in 1936. To date, its function is unknown. Stylistic evaluation and dating of a sample of the remaining clay %%core%% material suggest it was fabricated in China’s Middle Yangtze Valley in the first half of the eleventh century BCE. The sculptural elephant form is very rare for Chinese bronze vessels of its time.

**Fig. 500**

## Slide 3: The main questions

• What characteristics point to piece-mold rather than lost-wax casting?

• Can one tell whether the decorations were created on the%% model%%, the %%mold%% sections, or both?

• What accounts for the object’s condition?

**Fig. 500**

## Slide 4: Piece-mold casting

In general, the design of an object cast using the piece-mold method is constrained by the fact that its model is made in loess, a fine-grained refractory soil found throughout northern China that gives very sharp detail when carved. The mold was made in pieces or sections (hence the terms “piece-mold” or “section-mold” casting) designed like a 3D puzzle to deal with undercuts and allow removal without damage to either the model or the mold pieces. The vessel and lid would have been cast separately using the piece-mold casting process consisting of the following main steps (note that the diagram in **fig. 26** uses a simpler model):

1. A model representing the final form is created, most probably including some of the decorative details.
2. Multiple mold sections or pieces are built up around the model.
3. The mold pieces are removed from the model and the decorative inner mold surfaces further enhanced by carving.
4. The model is cut back (pared down) to create the core that was sectioned to separate the feet from the container core. Small rectangular metal spacers (%%chaplets%%), or loess core extensions placed at intervals, serve to stabilize the core in relation to the outer mold.
5. The mold sections are reassembled around the core. Vents and a pouring cup are cut into the piece mold.
6. Molten bronze is %%poured%% into the reassembled mold, filling the gap created by the paring down of the model.
7. The cast bronze is broken free of the mold and imperfections addressed.

**Fig. 26**

## Slide 5: Evidence for piece molding on the vessel (1 of 3)

Metal %%seam lines%% invariably developed along mold joins on the exterior surface of the cast object. Some were ingeniously incorporated into the design as raised, decorative flanges. Others were removed during the finishing process, but often traces can still be detected on the surface. One such seam line can be recognized running along the top of the elephant’s trunk and continuing as a raised linear feature between the elephant’s forehead and the rim of the vessel opening. Visual and microscopic examination allowed us to identify the traces of mold joints across the surfaces of both vessel and lid, and thereby reverse engineer the design of the piece mold segments, which add up to at least a dozen for the main body of the vessel alone.

**Fig. 501**

## Slide 6: Evidence for piece molding on the vessel (2 of 3)

It was determined that the hollow of the vessel’s body was defined by a core inside the belly that reached up to the oval rim of the opening and into the trunk, but did not extend into the legs (A). On the outside, two main mold sections bisected the elephant vertically, running up the tail, along the middle of the back to the back of the ears, and perpendicularly across the top of the head and out over the ears (C).

**Figs. 110, 111, 116**

## Slide 7: Evidence for piece molding on the vessel (3 of 3)

A large mold section ran along the belly, including the insides of the legs and the lower lip (D). Two vertical face molds ran down the front of the ears and across the top of the trunk and include the exterior of the tusks (E). A third head mold section included the rest of the mouth and tusks (F). A further mold piece formed the front of the trunk (G).

**Figs. 112, 113, 116**

## Slide 8: Evidence for piece-molding on the lid

For the lid, two main mold sections (H) were used for either side of the body, including the ear, trunk, tail, and ridge down the tail (H). A core filled the space inside the legs and under the tail and trunk (K). Another core (I) filled the underside of the lid using core extensions to secure its attachment to the bottom mold section (J). The holes in the %%cast%% rim locate the extensions’ positions.

**Figs. 114, 115, 117**

## Slide 9: Evidence of core material

Currently, there is soil in the interior of the elephant vessel’s belly and in the trunk, but it was originally emptied of its loess core to allow it to function as a vessel. The legs retain their core material, as is often the case with elements like handles and feet in vessels that do not need to be emptied out for functional reasons. A core sample was drilled from the elephant’s rear right leg to date the vessel using thermoluminescence analysis(see [II.8§1](#II.8§1)). It placed it in the first half of the eleventh century BCE.

**Fig. 111, 112**

## Slide 10: Radiographic evidence

X-radiography shows that the walls of the vessel are relatively thin and even. The more X-ray-opaque or whiter features, like the decorative elements, indicate areas of thicker metal. Compared to the belly and head, the slightly greater density of the legs and trunk is caused by the extant core material. Radiography also confirmed that the tops of the legs are closed off by the metal wall of the vessel’s body.

Surprisingly, neither radiography nor visual examination revealed any evidence of metal spacers in the vessel, suggesting that it was loess core extensions that anchored the core in position in relation to the mold. One such extension would have connected the core and mold through the opening on the back of the elephant. Another may have been through the trunk. The cores of the legs would have extended out the openings at the bottom to attach to outer mold sections.

**Fig. 502**

## Slide 11: Decorative elements

The elaborate sunken and relief decorations across the surface of the *huo* were executed avoiding undercuts to facilitate piece molding. The fine loess soil used in China to make the models and molds was able to capture very sharp, clearly detailed decorative designs. Further refinements would often be added by carving directly into the mold’s surface, as has been found on excavated mold remains from Anyang. In the absence of surviving mold sections from this vessel, it remains unclear whether the *huo*’s finer thunder pattern (*leiwen*) in low relief or the dragons and hooks in high relief were created in the model, the mold, or both. No refinements were made to the design after casting. The *leiwen* patterns, at least, show no signs of %%chasing%% in the metal.

**Fig. 503**

## Slide 12: Condition

Originally, the vessel’s surface would have been a golden bronze color, perhaps with a pigmented %%inlay%% material in the recesses, as has been found on other pieces excavated in better condition. Its current appearance in the larger raised areas—mottled, pale gray, green, reddish brown, and very dark and shiny gray—is mostly the result of thousands of years of chemical action during burial in the ground. Despite this %%corrosion%%, all the details of the *huo*’s original design are maintained with little or no disturbance of the surface. What accounts for this, given that corrosion often distorts, expands, and/or destroys the surface, giving it a rough, bulging, craggy appearance?

X-ray fluorescence analysis (XRF, see [II.5§2.1](#II.5§2.1)) identified the corrosion as having a high tin content, presumably a reflection of the alloy composition and burial environment. Tin oxide gives it a smooth appearance and is a much smaller molecule than the green copper carbonates. High-tin bronzes have relatively good resistance to corrosion in burial conditions, but at the same time are very brittle. That may explain the multiple chips on the higher ridges across the surface. Closer examination showed that the vessel had also been restored post-excavation: many edge losses had been filled and in-painted to make the surface more aesthetically appealing.

**Figs. 500, 503**

## Slide 13: Summary of findings

Close examination of this elephant-shaped vessel provides irrefutable evidence that it was cast by the piece-mold method rather than by the lost-wax process, and allowed for a precise reconstruction of the mold sections. The casting of this rare form shows great technical skill. The preservation of core material made it possible to date the sculptural vessel more accurately. The good preservation of the surface detail in spite of the *huo*’s lengthy burial is no doubt thanks to the nature of the alloy. There is not much evidence to suggest that the vessel was heavily reworked during restoration.

**Fig. 116**

## Slide 14: Synopsis

All of the studies referenced were undertaken by and with conservators using equipment at the Department of Conservation and Scientific Research of the Freer Gallery of Art and Arthur M. Sackler Gallery of Art in the Smithsonian Institution in Washington, DC.

An individual object examination is part of the day-to-day work of the department and no additional costs were incurred. The durations for each step were approximately as follows: photography and X-radiography, five hours; spectrographic analysis: eight hours; sampling for thermoluminescence testing: three hours; microscopic examination: three hours; interpretation of results: four hours.

## Slide 15: Further questions

• How much was the surface reworked after casting?

• Could industrial computed tomography (CT) scanning provide clearer images of the intersections of the tops of the elephant’s legs with the bottom of its body cavity and help clarify how these were constructed?

• If there were residues of ritual offerings on the interior of the belly, could analyses determine what the vessel contained?

• Can technical comparisons to other ancient bronze elephants recently excavated in China from provenanced sites provide further information about the Freer elephant?

## Slide 16: Further resources

{Pope and Gettens 1969}

{Pope et al. 1969}, 228–31

{Bagley 1987}, 15–140

{Yue and Yinxu Xiaomintun Archaeological Team 2008}

{Stoltman et al. 2018}