

Microscopic study of Chinese bronze casting moulds from the Eastern Zhou period

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ABSTRACT

Piece mould casting technology, as a hall mark of the central plains of China during the Bronze Age, has attracted scholars' interest globally. Bronze ritual vessels found in this area were produced in large quantities and generally cast with the moulds composed of three or more sections. This enormous industry certainly required workers to have had professional knowledge to ensure the success of every single cast. Mould making technology was one of its most important parts. This research looks into the microstructure of bronze casting moulds of the Eastern Zhou period, which was a rarely studied topic in previous research. Through comparison with local pottery, it is shown that casting moulds in this period were produced with quite specialized sand-rich material, and clay was only a minor component. It is then discussed how this unique material can be beneficial to the bronze casting process and how this technology was integrated as a crucial part of the Chinese bronze casting system. These analyses might be able to portray mould makers in the ancient bronze foundries as a group of specialized people with their own traditions and professional knowledge.

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1. Introduction

The sophisticated piece mould casting technology is taken as a hall mark of the central plains of China during the Bronze Age. Bronze ritual vessels, which were used for serving food and wine for ancestors during worship rituals, and for the legitimization of power, were largely cast with the mould composed of three or more sections. Motifs are divided by mould divisions and usually organized symmetrically. All these patterns were either impressed from a model or carved directly onto the mould. When these sections were dried and fired to an adequate strength, they would be assembled together with an outer casing. A core was set inside the mould, leaving a gap as thick as the bronze object. The molten bronze would then be poured into the mould. When the metal cooled, the mould and core could be broken up and removed. Based on this unique technology, ancient people in China developed a whole set of bronze ritual vessels which have no counterparts in other regions of the world. They usually have symmetrical shapes as well as intricate patterns. Some can be quite big and weigh over

800 kg. The whole process of manufacture, from making the mould, alloying the metal, to finishing the surface of the object was labour intensive and required specialized cross-craft knowledge (Bagley, 1995; Franklin, 1983). The whole foundry therefore needed to be organized accordingly (Li, 2007, 2003).

Bronze casting in the Chinese central plains probably started in the late Neolithic period (2500–2000 BC), but the earliest identified evidence of widespread bronze use appears during the Erlitou culture (around 1900–1500 BC) located in Henan, southern Shanxi and southern Hebei (An, 1993). Size and complexity of bronze vessels gradually increased in the following periods, and it is generally agreed that the bronze casting industry culminated in the central plains of China during the Late Shang to Early Western Zhou period (around 1300–977 BC). Huge ritual vessels in this period were cast with numerous mould sections divided both vertically and horizontally. Motifs often fill the entire body of these vessels and in some cases decorations were made in high relief. The patterns of this period look much more expressive than in earlier periods. After a transition period of around 100 years, the Late Western Zhou (877–771 BC) and Eastern Zhou periods (770–256 BC), witnessed a considerable simplification in the design of the section moulds and wide adoption of welding and casting-on techniques. The production efficiency of the bronze objects was much improved during this period, and the archaeological findings far outnumbered those of earlier periods. The focus of the industry shifted to surface decoration techniques such as tinning, gilding

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and various inlays (for a general review of this topic see Bagley, 1999; Dong, 2007; Von Faulkenhausen, 1999; Hua, 1999; Rawson, 1987; Zhang, 2011). As the central political power collapsed in this period, the bronze casting industry was also decentralized, as evidenced by the emergence of huge foundries serving local states such as at Houma in Shanxi province and Xinzheng in Henan province.

Currently, scholars are still discussing controversially on some technical issues concerning the piece mould casting technology of the Chinese Bronze Age. For example, it is unclear whether the design of the section moulds was made using a model of the complete object or a single repeatable section of it. The pattern and inscription making technologies are also in debate (See Bagley, 1987, 37–45; Chase, 1983; Meyers and Holmes, 1983; Nickel, 2006). Another matter for discussion is the possible use of the lost wax casting technique, which is generally recognized as a western tradition and might act as a supplementary to piece mould casting in China (Chen et al., 2009; Hua, 2010; Tan, 2007). Once all these technical details are sorted out, we will be able to reconstruct a comprehensive picture of the bronze casting system of ancient China. This would also facilitate our ongoing discussion on craftsmen's technical choices, the labour organization within the foundry and knowledge transmission between cultural groups.

In parallel, some scholars have been studying mould-making technology, which has been recognized as a crucial part of Chinese bronze industry. To ensure the success of every cast, the mould material should bear some special properties such as low shrinkage during drying, high resistance to thermal shock, low thermal conductivity and good ventilation during the casting (Tan, 1999). Many chemical analyses have been conducted on mould fragments found in Anyang in Henan province, Zhouyuan in Shaanxi province, Houma in Shanxi province and some other Bronze Age sites (Lian, 1996; Liu et al., 2007; Liu and Yue, 2005; Tan, 1999; Wang, 2002; Zhou et al., 2009). These analyses have confirmed that casting moulds were manufactured with silica-based materials and usually have silica contents higher than normal ceramics. Chinese scholars have suggested that they were made by fine clay tempered with silt, sand and plant ash (Tan et al., 1993). Research has also been conducted to identify the firing

temperature of bronze casting moulds. Some scholars have suggested that this temperature should be higher than the decomposition temperature of calcite (898 °C), while other studies on thermal expansion tests have revealed that casting moulds may not have been fired over 700 °C (See Liu et al., 2008; Tan, 1999).

However, the microstructure of this material never seems to have received much attention in these studies. Indeed, published microscopic observations made by Stoltman et al. (2009) and Freestone et al. (1989) form the entire body of literature on this topic. However, these two papers have actually demonstrated the significance of microscopic study, which provides essential information about the specific physical characteristics of this material and whether specialized technology and knowledge were needed for bronze workers to make the mould. Explored in detail this will contribute to the reconstruction of the whole bronze manufacturing system in the Bronze Age of China and explain in part why those bronze vessels could be made with such high quality. It will also help in the discussion surrounding the specialization of bronze craftsmen. Moreover, microscopic observations, when quantified by point-counting (Stoltman et al., 2009), can be compared with data from other sites of different periods to shed light on the initiation and development of the bronze casting system of ancient China.

2. Materials

All the materials in this project were excavated from bronze foundries in a site located at Xinzheng, Henan province (Fig. 1) and dated to the Eastern Zhou period which can be subdivided into the Spring and Autumn (770–476 BC) and the Warring States periods (475–221 BC). The site is named *Zheng Han gu cheng* and was the capital city of the ancient *Zheng* and *Han* states.

This site was firstly occupied by the State *Zheng* during the early Spring and Autumn period. State *Han* brought down *Zheng* in 375 BC and set its capital at Xinzheng until it was conquered by the First Empire Qin in 230 BC. The bronze casting activities in this site nearly covered the entirety of the Eastern Zhou period. The ritual vessels of *Zheng* and *Han* states are characterized by their massive size, intricate patterns and novel designs, and may represent the highest level of casting skills during the Eastern Zhou period. The

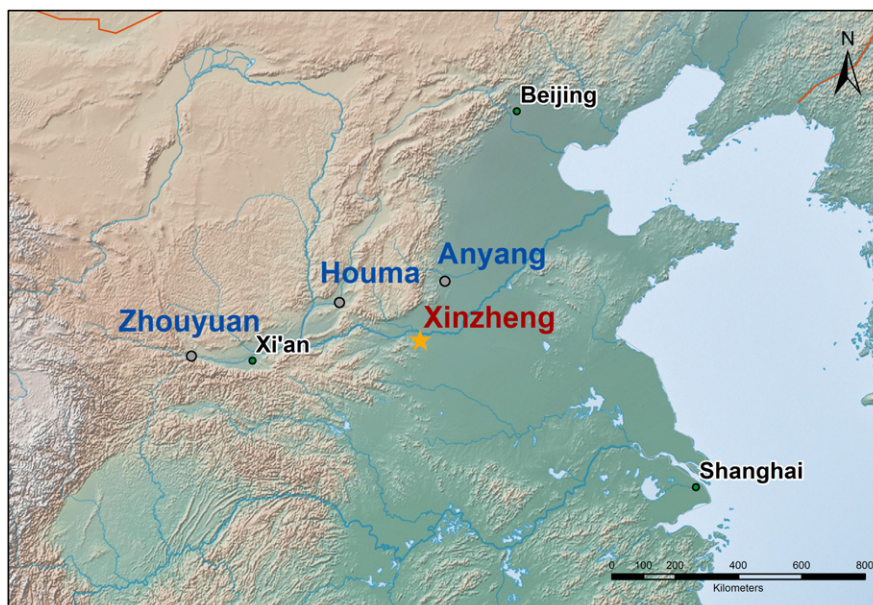


Fig. 1. Map shows the location of Xinzheng, in the central plains of China. Several other Shang and Zhou bronze casting foundries are also labelled in the map.

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