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Production and circulation of bronzes among the regional states in the Western Zhou Dynasty

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ABSTRACT

The production and circulation of bronzes among the regional states of the Western Zhou Dynasty are an important way of understanding the political and ritual systems of the dynasty. This paper studies the production and circulation of bronzes from three points of view: the cultural background, techniques, and raw materials of bronzes. First, the authors classified the bronzes excavated from the Zhouyuan Site, Yejiashan Cemetery, the Cemetery of the Lords of Jin, and Yu State Cemetery based on shapes and techniques. On this basis, a trace element analysis and lead isotope analysis were conducted to investigate the quality of the raw materials. The three aspects used for classification—cultural background, technologies and raw materials—complement each other during the discussion of the issues of interest. The authors conclude that high-quality bronzes from Ji-surnamed regional states represented by those excavated from Yejiashan Cemetery and the Cemetery of the Lords of Jin show consistency with Zhouyuan bronzes in the royal court in terms of raw materials, shapes, and techniques, therefore indicating their origin from unified workshops. However, low-quality bronzes produced in these places, and also bronzes from non-Ji-surnamed regional states, represented by those excavated in Yu State and Peng State, possess unique shape and technique characteristics, and included different copper materials and partly the same lead materials, reflecting the degree of independence that regional states enjoyed in terms of bronze production. The imperial court uniformly made high-quality bronzes, and distributed them to all regional states, while the regional states independently produced some low-quality bronzes; this system probably came into being during the early Western Zhou Dynasty. However, from the middle period of the Western Zhou Dynasty, some regional states increased their independence in the production of bronzes, and the distribution system of the imperial court began to collapse gradually.

1. Introduction

One of the most important characteristics of the Western Zhou Dynasty (1046 BCE–771 BCE) lies in its mature ritual system, where bronzes were the material reflection of core cultural ideas (Zhu, 2009). Therefore, the production and circulation of bronzes provide an important way of understanding the political structure and ritual patterns of the Western Zhou Dynasty. The core question in this research is as follows: Was bronze production and casting controlled centrally by the Western Zhou Dynasty? In other words, where do the bronzes from the regional states in the Western Zhou Dynasty come from? Were these bronzes distributed by the imperial court to the regional states? Or were they produced independently in the regional states? Different answers to these questions would provide very different political and ritual connotations.

Although many scholars have discussed the production and circulation of Chinese bronzes from traditional and scientific perspectives, research on the Western Zhou Dynasty is still inconclusive, and two areas require special attention (Barnard, 1961; Kondo, 2013; Linduff and Mei, 2014; Pollard et al., 2017a, 2017b; Mu et al., 2018; Yu et al.,

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2019). First, the regional states of the Western Zhou Dynasty are different, and some have the Ji surname, and some do not have the Ji surname; their positions in the political system are different as well. Generally speaking, the Zhou royal court, which used the Ji surname shares a closer relationship with Ji-surnamed regional states; if so then, did the different regional states obtain their bronzes from different sources? Second, bronzes excavated from a particular regional state have different sources; from the perspective of inscriptions, we can at least assume that each state had multiple sources, such as those with their own state's inscription, those with a Shang Dynasty inscription, and those with inscriptions from other states. Moreover, the bronzes with different qualities and techniques have also been discovered. It is clear that the bronze objects found in a single regional state usually have complex cultural backgrounds and refer to different origins. The bronzes from each regional state were a mixture of bronzes from different sources. In this light, discussing the metal circulation between regional states without considering the archaeological classification of bronzes could lead to incorrect conclusions. For instance, if the data from State A are from high-quality Shang inscription bronzes that were possibly collected and provided by the Zhou royal court, and the data from State B are from low-quality bronzes that were locally produced when the two sets of data are compared, and assuming that they can represent all of the features of that state, this will undoubtedly lead to incorrect conclusions. The neglect of archaeological classification is a common problem in many archaeometallurgical studies in China and around the world. This paper will demonstrate how scientific analyses based on archaeological classification can be conducted to illustrate the metal circulation of Chinese bronzes. The study reveals that different interpretations can be made depending on whether archaeological classification is considered as a premise.

To study the above issues, we systematically discuss the production and distribution of bronzes from three aspects: the cultural background, technique, and raw materials. The cultural background involves the characteristics of the bronzes, such as their shape, motifs, and inscriptions. The cultural background can help us judge whether a bronze was made in its own state, or in other states and whether it belongs to the central plains style or the regional style. The technique mainly refers to the casting technique and quality and can help us judge whether a bronze is of high-quality or low-quality. A comprehensive and scientific standard for bronze classification can be established based on the cultural background and technique. From this classification system, problems concerning raw materials can be explored through scientific analysis. Thereby, the discussion of the different raw materials used by bronzes with different cultural backgrounds and technical characteristics can further clarify the problems faced while discerning their place of origin (Fig. 1).

Following this train of thought, over the past few years, we conducted systematic archaeological research and scientific analyses of bronzes selected from typical sites. We selected the Zhouyuan Site as representative of the royal court, the Yejiashan and the Lords of Jin Cemeteries as representative of Ji-surnamed regional states, and the Yu State Cemetery as representative of non-Ji-surnamed states. We built a classification system after the careful physical examination of most of the bronzes excavated from these cemeteries. We then sampled different types of bronzes and conducted scientific analyses; at the same time, we referred to past research findings to visualise the modes of systematic production and circulation system of bronzes among the regional states in the Western Zhou Dynasty.

2. Materials and methods

The bronzes analysed in this paper are from the Songjia Cemetery and Yaojia Cemetery in Zhouyuan Site in Shaanxi, Yejiashan Cemetery in Hubei, the Cemetery of the Lords of Jin in Shanxi, and the Yu State Cemetery in Shaanxi (Fig. 2).

The Songjia Cemetery is located in the Zhouyuan Site. According to the investigation and exploration data, this cemetery covers an area of about 60,000 square metres and has about 900 tombs, which date back to the Shang and Zhou dynasties until the late period of Western Zhou Dynasty (Chong et al., 2007).

The Yaojia Cemetery is located in the east of the Zhouyuan Site and was discovered in 2010. A total of 132 tombs and chariot sacrifice pits have been excavated to date, and belong to the Western Zhou period; this cemetery is the only one with assured range and tombs in the Zhouyuan Site (Chong, 2018).

Both the Songjia Cemetery and Yaojia Cemetery are typical of the Zhouyuan Site. The Zhouyuan Site was the political centre of the Zhou Dynasty before the establishment of the Western Zhou Dynasty. After the Western Zhou was established and its capital Fenggao was founded, Zhouyuan continued to play its role as a dynastic centre. A large number of tombs, palaces, and bronzes of the Western Zhou Dynasty were excavated at this site, and it is a typical example of a dynastic centre (Institute of Archaeology, CASS, 2004).

Yejiashan Cemetery is located in Suizhou City, Hubei Province, and is a Zeng State cemetery of the early Western Zhou period. During the excavation from 2011 to 2013, more than 140 tombs were discovered, including the tomb of Lords of Zeng (Fig. 3(a) and b; Hubei Institute of Archaeology, 2011, Hubei Institute of Archaeology, 2013, Hubei

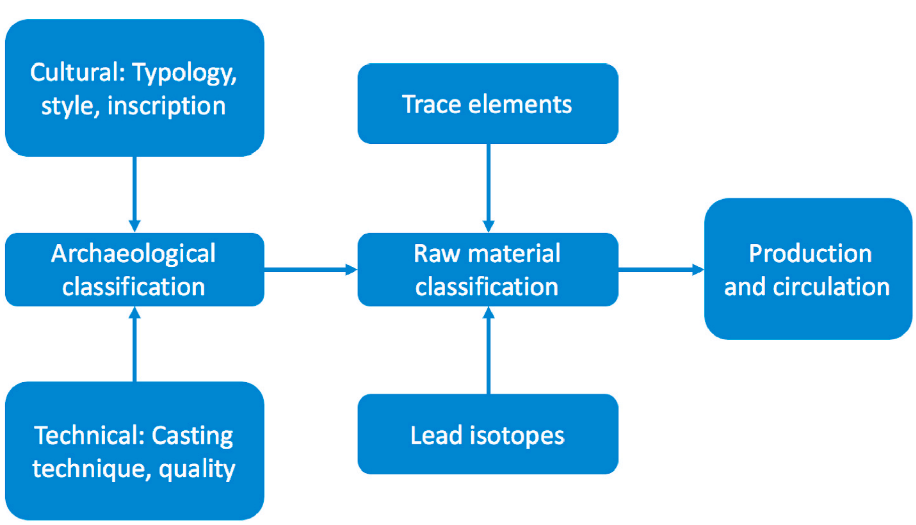

Fig. 1. Workflow diagram for studying the production and circulation of Chinese bronze objects.

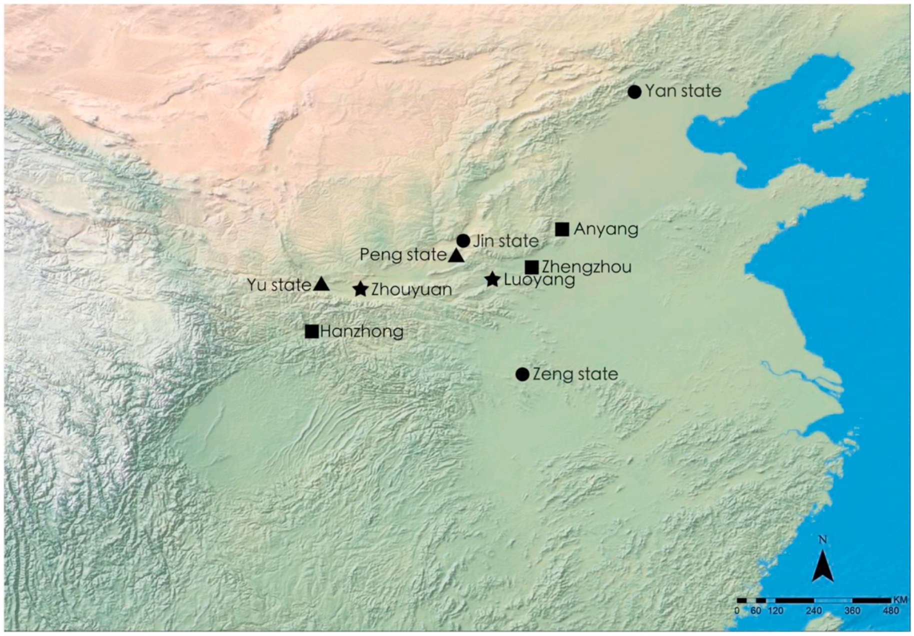

Fig. 2. Map of the sites discussed. Star: The royal court; Circle: Regional states with Ji surname; Triangle: Non-Ji surnamed regional states; Square: Shang sites.

Museum, Hubei Institute of Archaeology, Suizhou Museum, 2013). The inscriptions on the bronzes indicate that Zeng state is a Ji-surnamed regional state. The bronzes, as well as other burial factors, have many similarities with the tombs in the heartland of Zhou, and the archaeological evidence suggests a close relation between Zeng and the royal court of the Western Zhou Dynasty.

The Cemetery of the Lords of Jin is located in Quwo County, Shanxi Province, and represents one of the most important regional states of the Western Zhou Dynasty discovered so far. Up till now, 19 tombs of the Lords of Jin and their wives arranged in nine groups, near 20 subordinate tombs, and dozens of sacrificial pits have been excavated; remains of ten chariot sacrifice pits have also been ascertained (Archaeology

Fig. 3. A. Photograph of Tomb M65 in Yejiashan Cemetery. b. Photograph of unearthed bronze vessels in Tomb M27 of Yejiashan Cemetery. c. Bronze objects found in Yu State Cemetery.

Department of Peking University and Shanxi Institute of Archaeology, 1993, 1994, 1995; Shanxi Institute of Archaeology and Archaeology Department of Peking University, 1994a, 1994b; Xu, 2002). Although several cases of burglary took place at this cemetery, many bronzes were unearthed. The period of these bronzes ranges from the late phase in the early period of the Western Zhou Dynasty, i.e., the reigning period of King Wen of Zhou and King Mu of Zhou, to the early years of the Spring and Autumn period, i.e., the reigning period of King Ping of Zhou.

The Yu State Cemetery in Baoji includes three Western Zhou cemeteries (i.e., Zhifangtou, Zhuyuangou, and Rujiazhuang), all of which belong to the nobility of the Yu State. A total of 27 tombs, two chariot sacrifice pits, and four-horse sacrifice pits have been excavated to date. The tally of unearthed relics has reached 2675 pieces (Lu and Hu, 1988). Many bronzes featuring a diversity of cultural factors have been unearthed from the Yu State Cemetery, and thus, it is an important place to explore the production of bronzes in the Western Zhou Dynasty (Fig. 3 (c)). The bronze inscriptions from the Yu state indicate that it did not have a Ji surname. Some of the bronze objects as well as potteries, have strong regional features and belong to an outsider state.

The materials that were analysed in this paper include 21 bronzes unearthed at Songjia Cemetery, 16 bronzes unearthed at Yaojia Cemetery (Zhouyuan Site), 66 bronzes unearthed at Yejiashan Cemetery, 102 bronzes unearthed at the Cemetery of the Lords of Jin, and 48 bronzes from the Yu State Cemetery (for details, see supplementary Table: S1). The bronzes unearthed at Yejiashan Cemetery and the Cemetery of the Lords of Jin are mainly vessels. Limited by the conditions, the bronzes sampled from Zhouyuan Cemetery and Yu State Cemetery are predominantly chariot objects and weapons. The bronze vessels listed in Fig. 3 (c) were not analysed in this study.

We examined and analysed the majority of the bronzes featured in this study to build the standard for classification. However, as a few bronzes from the Cemetery of the Lords of Jin were not sampled by the authors, their archaeological background cannot be corroborated with certainty. With respect to the scientific analysis, a trace element analysis and lead isotope analysis were the main methods employed in this study; however, due to restrictions in funding, we could not conduct the two types of analysis on all of the bronzes.

We conducted a trace element analysis on 21 bronzes from the Songjia Tomb and 16 bronzes from Yaojia Tomb (at Zhouyuan), 66 bronzes from Yejiashan Cemetery, 81 bronzes from the Cemetery of the Lords of Jin, and 48 bronzes from Yu State Cemetery. We conducted a lead isotope analysis on 22 bronzes from Yejiashan Cemetery, 32 bronzes from the Cemetery of the Lords of Jin, and 48 bronzes from Yu State Cemetery. Except for the published data on Yu State Cemetery (Li et al., 2020), all the new data arising from the above has been published in this paper.

For all of the samples, a small part (more than 100 mg) was cut from each object. The samples were cleaned to remove corrosion and contamination. They were then placed in aqua regia and heated with an electric heating plate (Lab Tech EG37B). After complete dissolution, the solutions were diluted with deionised water to 100 ml. The elemental compositions were measured using a Prodigy inductively coupled plasma-atomic emission spectrometry (ICP-AES) produced by Leeman Labs. The working conditions were as follows: RF power of 1.1 kW, argon gas flow rate of 20 L/min, and nebuliser gas at 20 MPa. A total of 12 elements that might be useful for bronze studies were measured in this experiment, including Sn, Pb, As, Sb, Ag, Ni, Fe, Zn, Se, Te, Au, and Bi.

In recent years, the archaeometallurgy team under the leadership of Professor Mark Pollard of the Research Laboratory for Archaeology and the History of Art at the University of Oxford put forward the Oxford System, namely combining the trace elements, alloy composition, and lead isotope of bronze to determine the circulation of its raw materials (Bray, 2009; Bray and Pollard, 2012; Bray et al., 2015; Pollard et al., 2017a, 2017b). Wherein, in a copper groups method is adopted. This method makes use of the absence or non-absence (with 0.1% as the border to distinguish) of arsenic, antimony, silver, and nickel to build 16 trace element groups and makes use of trace element groups to discuss the circulation of metallic raw materials (Table 1). There are practical reasons for choosing these four elements. First, most published trace elemental data will include these four elements. Second, these elements cover a range of thermodynamic behaviours in molten copper (Pollard et al., 2018, p. 85). Moreover, the possible combinations of presence/absence for four elements provide 16 groups. With one more element included, it will become 32 groups, which is too cumbersome.

This classification method could not include all of the useful information. For instance, other useful elements such as bismuth or cobalt were not included in copper groups. However, this method demonstrates its strength in universality, and specifically, advantages in large scale comparisons. The current case studies demonstrate the four elements grouping is usually sufficient to characterise changes in material records (Pollard et al., 2018, p. 85).

The relation between copper groups and ore sources is complicated. A single ore source might demonstrate multiple copper groups and a single copper group might come from multiple mines. Nevertheless, the method focuses on inter-regional, chronological, or typological patterns rather than mines (Pollard et al., 2018, p. 85).

The quality of the analysis and the method used could also affect the copper groups results. For instance, for the data generated by XRF and SEM, the 0.1% cut-off is unreliable for arsenic because the MDL for arsenic might be as high as 0.18% (Pollard et al., 2018, p. 89). In this study, all the trace element data were measured with ICP-AES from the same laboratory and under the same procedure and standard, which will rule out this problem.

Another problem raised is that some of the four elements do not necessarily come from copper. For instance, silver in the alloy might be associated with lead. However, the copper groups method only aims to detect changes in the composition in the metal flow and the silver is another marker of the metal flow (Pollard et al., 2018, pp. 113–114).

Based on previous papers and our own research experience of the copper groups method, we believe that these copper groups are only specific sets of trace elements and the information provided by a singular 'group' is quite limited. However, bronzes objects from specific locations and period usually have certain combinations of copper groups (Pollard et al., 2017a; Li et al., 2020). With sufficient archaeological analysis and careful scientific examination, the combination patterns of copper groups might be used to discuss the circulation of bronzes objects or their metal material. In addition, we believe that trace element grouping can only be considered meaningful when based on the analysis of the archaeological context. The cultural background of Chinese bronzes is quite complicated; only by building an explicit bronze classification system can we compare the copper groups within different types of bronzes.

Table 1
The definition of Copper Groups (CG: Copper groups).

CG	As	Sb	Ag	Ni	Code(As,Sb,Ag,Ni)
1	<0.1%	<0.1%	<0.1%	<0.1%	NNNN
2	>0.1%	<0.1%	<0.1%	<0.1%	YNNN
3	<0.1%	>0.1%	<0.1%	<0.1%	NYNN
4	<0.1%	<0.1%	>0.1%	<0.1%	NNYN
5	<0.1%	<0.1%	<0.1%	>0.1%	NNNY
6	>0.1%	>0.1%	<0.1%	<0.1%	YYNN
7	<0.1%	>0.1%	>0.1%	<0.1%	NYYN
8	<0.1%	<0.1%	>0.1%	>0.1%	NNYY
9	>0.1%	<0.1%	>0.1%	<0.1%	YNYN
10	<0.1%	>0.1%	<0.1%	>0.1%	NYNY
11	>0.1%	<0.1%	<0.1%	>0.1%	YNNY
12	>0.1%	>0.1%	>0.1%	<0.1%	YYYN
13	<0.1%	>0.1%	>0.1%	>0.1%	NYYY
14	>0.1%	>0.1%	<0.1%	>0.1%	YYNY
15	>0.1%	<0.1%	>0.1%	>0.1%	YNYY
16	>0.1%	>0.1%	>0.1%	>0.1%	YYYY

Lead isotope ratios were measured using a VG Elemental multi-collector–inductively coupled plasma mass spectrometer (MC-ICP-MS; VG Elemental Axiom, Thermo Fisher Scientific Inc., USA). Based on the lead composition measured with ICP-AES, the solution was diluted to 1000 ppb and added to the thallium (Tl) standard SRM997. Then, the lead isotopes were measured. The relative errors of the $^{207}Pb/^{206}Pb$, $^{208}Pb/^{206}Pb$, and $^{206}Pb/^{204}Pb$ ratios were <0.01%, <0.01%, and <0.1%, respectively. The SRM981 international lead isotope standard was used as the standard reference to calibrate the spectrometer. The standard was re-measured for every set of 6–8 sample measurements.

3. Results and discussion

3.1. Study on the classification of bronzes

Cultural background and technical characteristics are two parts of the study of bronze classification. By combining our personal examination of the objects of bronzes from Zhouyuan Cemetery, Yejiashan Cemetery, the Cemetery of the Lords of Jin, and the Yu State Cemetery, as well as our extensive examination and investigation of bronzes from other regional states, we classified the bronzes in the regional states of the Western Zhou Dynasty into eight types: bronzes with inscriptions from their state, Shang inscriptions, an unidentified high-quality Central Plains style, inscriptions from other states or regions, local replicas, burial objects, an unidentified low-quality Central Plains style, and the local style (Fig. 4).

From the perspective of technical characteristics, the first four types of bronzes are high-quality and are collectively designated as high-quality bronzes. The latter four bronzes are generally low-quality, were created using diverse casting techniques, and are generally called low-quality bronzes. From the perspective of the cultural background, the former three types of bronzes follow the Central Plains style; the fourth type as 'other states or region', reflects both the Central Plains style and regional style; all the 'local replica', 'burial objects' and 'low-quality Central Plains style' also belong to the Central Plain style; and the 'local style' belongs to regional style (Fig. 4).

Two points need to be made. First, this classification system is built on objective and unified standards. The classification between high-quality and low-quality bronzes is mainly based on the clarity of the degree of ornamentation, the regularity of the vessel shape, disposal of casting defects, and smoothness of the vessel surface. The classification of the bronze style is based on both its shape and motifs and has already been widely accepted in China. Second, the eight types of bronzes cover most bronzes that emerged in the regional states, but there are still a small number of bronzes that are inconsistent with this classification system, for example, some 'local style' bronzes might be of high-quality. Some bronzes cannot be classified as their shapes are too simple. Even so, this classification system is sufficient for representing the general situation of Western Zhou bronzes.

Usually, not all of the eight types of bronzes were excavated from one cemetery of a regional state. Taking Yejiashan Cemetery as an example, we briefly introduce six types of bronzes therein (see Fig. 5 for more details). The 'inscription from own state' category, in this case, the Zeng State, is characterised by a universal high-quality, typical Central Plains style, and usually emerges in a set; the core of the bronze ritual vessel set is usually the 'inscription of own state'. The 'Shang inscription' bronzes were often seen in all the regional states in the early period of the Western Zhou Dynasty, and most came from the redistribution by the imperial court of the Western Zhou Dynasty. The 'other states or region' bronzes are ascertained by their inscriptions, and some bronzes also take

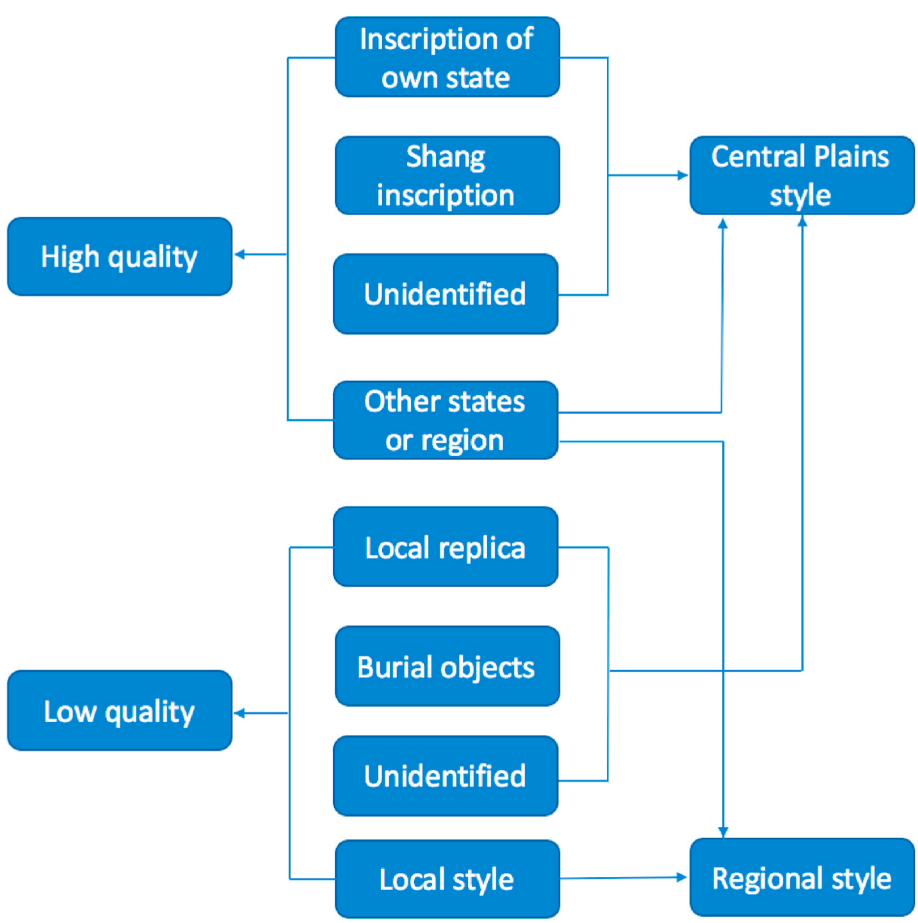

Fig. 4. Diagram of the classification of regional states' bronze objects.

Fig. 5. Classification of bronze objects in Yejiashan Cemetery.

on a regional style. For example, in the 'other states or region' in Fig. 5, the bell takes on the southern style, while the Ding (an ancient cooking vessel) takes on the Central Plains style. The 'unidentified high-quality Central Plains style' has the largest quantity, and its regionality cannot be identified because there is no inscription. The 'unidentified low-quality Central Plains style' refers to bronzes with specific regional characteristics and low-quality, which occur in a small amount. The 'local replica' refers to bronzes made in purposeful imitation of the Central Plains style in terms of shape and ornamentation, but of poor technique, and identifiable as replicas.

Although the above classification reflects different cultural and production characteristics of bronzes, it still cannot be used to ascertain their place of origin. Hence, a systematic scientific analysis of bronzes was conducted to determine the different raw materials used by different types of bronzes.

3.2. Trace element study

Trace element data results are given in supplementary Table: S1. In addition to the trace element data analysed in this paper, Yu used ICP-AES to conduct a trace element analysis on 90 pieces of bronzes from Yejiashan, and we include some data therein (Yu, 2015; Yu et al., 2019); moreover, we combined the data of 66 bronzes from Yejiashan analysed in this paper for the trace element grouping study, to gain the grouping results for 100 bronzes (supplementary Table: S1 and Table 2).

Based on the analysis results, we first carried out a backward verification of this method using bronzes whose production backgrounds are relatively explicit, to observe the sensitivity and accuracy of this method in indicating the raw materials of bronzes. It is generally considered that bronzes with consistent styles and similar inscriptions that appear in sets were produced in the same batch; and bronzes made in the same batch might use raw materials of the same origin; thus, they should have the same trace element grouping.

Table 2
Percentage results of 'Copper Groups' analysis of bronze objects from Yejiashan Cemetery (CG: Copper groups; HQ: High quality; LQ: Low quality; CP: Central Plains style).

Types		Copper Groups						
		CG1	CG2	CG3	CG4	CG6	CG12	Total No.
HQ	Zeng inscription	**28%**		**16%**		**28%**	**28%**	17
	Shang inscription	**10%**	11%	**16%**	5%	**32%**	**16%**	19
	Unidentified HQ CP	**24%**	2%	**12%**	10%	**19%**	**26%**	41
	All HQ	**21%**	4%	**14%**	6%	**24%**	**24%**	77
LQ	All LQ				**22%**		**61%**	23
	Local style				**26%**		**58%**	19
	Local replica						**75%**	4

The results demonstrate that of the five bronzes made by the Lord Jian of Zeng for his wife Kui, the You (a kind of wine vessel), the Zun (a kind of wine vessel), and the Gui are entirely consistent in inscription content and font, and classified into CG3, while the other two Hu (a kind of wine vessel) and Yan (a kind of food steaming utensil) are different in content or font, and are classified into other different copper groups (Fig. 6). Similarly, Lord Jian's inscribed bronzes with the same inscription font belong to the same copper group; The two pieces of Gui of Lord Kang of Zeng share the same inscription font and shape and are consistent in the grouping (Fig. 6). Other similar examples verify the consistency of the trace element grouping with bronze production batches and demonstrate that this method can be used to reflect the raw material sources of bronzes accurately.

Moreover, another assumption is that if the bronzes were determined to come from a specific outside region, then their metal material usually have the same characteristic as those bronzes found in the specific outside region. Following this assumption, the data from Hanzhong bronzes and Yinxu bronzes were used to verify the copper groups method. Hanzhong is out of the Shang territory and found with many local style bronzes as well as Shang style bronzes. The Shang style bronzes in Hanzhong belong to two different periods: the Early and Middle Shang, and the Late Shang period. Despite the differences in date, most of these Shang style bronzes have the same shape, motif, and casting technique and were confirmed to come from the Shang territory, most likely the centre of the Shang Dynasty. Chen et al. and Mei et al. carried out systematic scientific analyses on Hanzhong bronzes, which provided trace element data (Chen et al., 2009; Mei et al., 2009). Based on their data, the Shang style bronzes from the Early and Middle Shang period were distributed in CP1, CP2, and CP4. The Late Shang period Shang style bronzes belong to CP1 and CP9 (Fig. 7). Pollard et al. have summarised the major copper groups in the Shang and Zhou Dynasties (Pollard et al., 2017a) and the Zhengzhou (the centre in the Early and Middle Shang period) bronzes are CP1, CP2, CP4, and CP9; and the Anyang (the centre in the Late Shang period) bronzes are CP1, CP2, and CP9. Compared to the Hanzhong bronzes with the Shang centres bronzes, it demonstrates that the copper groups of Hanzhong Shang style bronzes fell into the category of Shang centres bronzes. The copper groups' result accords with our assumption. Our verification suggests that the copper groups correspond well to the archaeological context and could refer to the feature of metal resources.

According to the results of the trace element grouping of bronzes from Yejiashan, Zeng State inscription bronzes, Shang inscription bronzes, and unidentified high-quality bronzes, they not only take on the typical Central Plains style, but also generally have relatively high casting quality, and their raw materials are all dominated by CG1, CG3, CG6, and CG12 (Table 2). The combination of CG1, CG3, CG6, and CG12 repeatedly appears in the three types of high-quality bronzes, which illustrates a high possibility that the above bronzes came from the same production source.

Comparatively speaking, the low-quality bronzes include the 'local

Fig. 6. Relation of 'Copper Groups' and bronze vessels with inscription. (CG: Copper Groups).

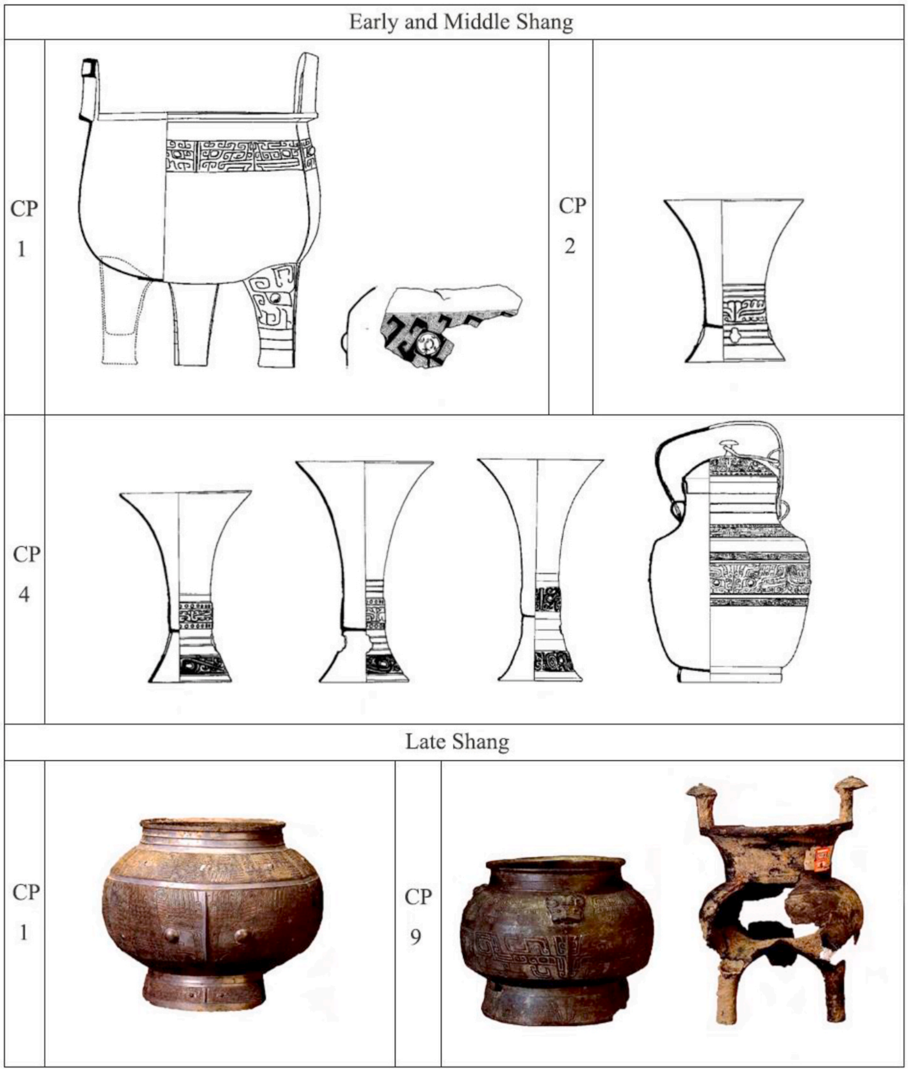

Fig. 7. Copper Groups results of Hanzhong Shang style bronzes.

style' and 'local replica', and are different from high-quality bronzes in style, and also manifest poorer casting techniques; their raw materials are concentrated in CG4 and CG12 (Table 2), and they are different from high-quality bronzes in shape, technique, and raw material, and therefore, it can be speculated that these low-quality bronzes have a different production source from the high-quality bronzes.

The trace element data of 81 bronzes from the Cemetery of the Lords of Jin include the data of 62 high-quality bronzes and the data of 19 low-quality bronzes. Jin inscription bronzes are distributed in four groups; namely, CG1, CG2, CG3 and CG6; other region bronzes have only four pieces, distributed among CG1, CG3 and CG10; The two types of bronzes have a relatively small amount of data and limited reference information. There are 48 'unidentified high-quality Central Plains style' bronzes, mainly distributed among CG1, CG6 and CG12. A comprehensive view of all high-quality bronzes from the Cemetery of the Lords of Jin reveals that CG1, CG3, CG6, and CG12 are the principal groups (Table 3).

Low-quality bronzes include 'local style', 'unidentified low-quality

Table 3
Percentage results of 'copper groups' analysis of bronze objects from Jin State Cemetery (CG: Copper groups; HQ: High quality; LQ: Low quality; CP: Central Plains style).

Types		Copper Groups										
		CG1	CG2	CG3	CG5	CG6	CG7	CG10	CG12	CG13	CG14	Total No.
HQ	Jin inscription	**20%**	**10%**	**30%**		**40%**						10
	Other states or region	**50%**		**25%**				**25%**				4
	Unidentified CP	**19%**	2%	**9%**	2%	**29%**	4%		**31%**	2%	2%	48
	All HQ	**21%**	3%	**13%**	1%	**29%**	3%	2%	**24%**	2%	2%	62
LQ	All LQ					**37%**	5%		**48%**	5%	5%	19
	Patching material					**67%**			**33%**			3
	Local style					**67%**			**16%**		**17%**	6
	Unidentified CP						**20%**		**80%**			5
	Burial objects					**20%**			**60%**	**20%**		5

Central Plains style', and 'burial objects'; the 'patching material' is also classified into this type. In general, these types of bronzes are concentrated in CG6 and CG12, and no case was found in CG1 or CG3. This demonstrates that low-quality bronzes and high-quality bronzes are different in terms of raw material sources.

Based on the above analysis, it can be determined from the trace element grouping results of the Zeng State bronzes and Jin State bronzes that high-quality bronzes from both states have the same trace element groups, namely, CG1, CG3, CG6, and CG12. At the same time, all their low-quality bronzes use different raw materials.

With the Zhouyuan Site as the representative of the royal court of the Western Zhou Dynasty, the trace element grouping of 37 bronzes unearthed their concentrations in CG1, CG2, CG3, and CG6 groups, most of which fall in the range of raw materials adopted by the Zeng State and Jin State. The similarity in data demonstrates that bronzes unearthed in the core area of the Western Zhou Dynasty to important Ji-surnamed regional states were all made from the same raw materials. Although these bronzes were unearthed in some regions fairly distant from each other, such as Shaanxi, Shanxi, and Hubei, they have substantially high consistency in terms of the casting technique and shape. We further infer that these 'high-quality Central Plains style' bronzes are likely to have come from the same place of production. This production source is most likely located in the core area of the Western Zhou Dynasty, where most bronze workshops were discovered. To clarify, we believe that the high-quality bronze vessels in the Zeng State and Jin State were centrally made and distributed. Other important Ji-surnamed regional states probably demonstrate the same phenomenon.

The origin data of bronze vessels suggests that the Western Zhou Dynasty and Ji-surnamed regional states enjoyed a close relationship with the dynasty. With respect to non-Ji-surnamed regional states, we analysed the bronzes from the Yu State Cemetery (Li et al., 2020), and also cite the bronze data on Peng State Cemetery in Hengshui previously obtained by scholars (Shanxi Institute of Archaeology, 2012). The two cemeteries are located in Baoji of Shaanxi and Jiang County of Shanxi and belong to non-Ji-surnamed regional states having distinctive regional characteristics (Fig. 2). We analysed 12 'low-quality local style' bronzes and 36 'low-quality Central Plains style' bronzes from the early and middle period of the Western Zhou Dynasty from the Yu State Cemetery. The data on the Peng State Cemetery in Hengshui is cited from the analysis conducted by Song Jianzhong and Nan Puheng on 14 bronzes from the middle period of the Western Zhou Dynasty using the ICP-OES method; however, the types of these bronzes are not clear. Trace element grouping indicates that the data on the Yu State Cemetery is concentrated in CG4, CG9, CG12, and CG16, while that of Peng State Cemetery is concentrated in CG1, CG2, and CG9. This indicates that they are entirely different from those unearthed in Jin State, Zeng State, and Zhouyuan Site in terms of the groups' pattern (Table 4). As mentioned above, most data from the Yu State are from chariot fittings and small accessories, the copper groups result indicate that they were probably locally made.

Moreover, there are many local style vessels in Yu tombs, where we could not take samples, we assume they were also locally produced (Fig. 3(c)). It is worth noting that low-quality bronzes from Yejiashan and low-quality bronzes from Yu State Cemetery are the same in terms of the trace element grouping, which implies that raw material circulation probably occurred between the two places (Table 4). Archaeological evidence for communication between the two places can be found (Li et al., 2020). Although high-quality Central Plains-style bronzes from Yu State and Peng State cemeteries were not analysed, the widely different data patterns, arising from the examination and cultural analysis of high-quality bronzes between these two places and Ji-surnamed regional states suggest that independent production of bronzes probably existed in the two states. However, some high-quality vessels in Yu State have inscriptions made by educated scribes, and these vessels probably came from the Zhou royal court.

In addition to the copper groups analysis, we also compared the different sets of data from the scatter diagrams. The study demonstrates that the ratios of silver and nickel are related to the ore used. Arsenic and antimony could provide information about the ore type (Krause, 1988). Therefore, the diagrams of arsenic vs antimony and silver vs nickel were employed to study the relations among the different sets of data. In Fig. 8, the high-quality bronzes from Zeng state and Jin state, and the bronzes from Zhouyuan site and Peng state were compared. Fig. 8(a) illustrates that the former three sets of data clustered together while the data from Peng state were distributed in a separate area, which is also evident in the copper groups pattern. Fig. 8(b) suggests that the Zhouyuan data were only distributed in the areas where silver is less than 0.1%. The copper groups result correspondingly reveals that CG12 (As + Sb + Ag) is absent from the Zhouyuan data, while it makes up 24% of Zeng state and Jin state data sets. The minor difference between the Zhouyuan data and the Zeng and Jin states' data is still unclear. However, most Zhouyuan data came from chariots and other accessories, while the Zeng and Jin states' data mostly came from vessels. This might be a reason for the difference.

Fig. 9 presents the comparison of low-quality bronzes from Zeng state, Jin state, and Yu state. Both Fig. 9(a) and (b) illustrate that Zeng state and Yu state data clustered well while Jin state data has a different distribution. This also corresponds to the copper groups pattern.

Fig. 10 presents the comparison of high-quality bronze and low-quality bronze from Zeng state. In Fig. 10(a), some of the data of the low-quality bronze clustered with the high-quality bronzes. Fig. 10(b) indicates that most data from low-quality bronzes were distributed in the areas where silver is more than 0.1%. In the copper groups study, most low-quality bronze belongs to CG4 (Ag) and CG12(As + Sb + Ag), both of which contain more than 0.1% silver. Therefore, all the scatter diagrams correspond well with the copper groups results. Nevertheless, the copper groups present a much more precise and distinct pattern to illustrate the overlaps and differences.

3.3. Lead isotope study

The results of the lead isotope analysis are given in supplementary Table: S2. No consistent opinions on the raw material types reflected by lead isotope data have been found. Some scholars believe that lead content in bronze from 50 ppm to 4% indicates the presence of copper, while other scholars have put forward different standards (Gale and

Table 4
Comparison of 'copper groups' between different states. (CG: Copper groups; HQ: High quality; LQ: Low quality; CP: Central Plains style).

Types		Copper Groups								
		CG1	CG2	CG3	CG4	CG6	CG9	CG12	CG16	Total No.
HQ	Zeng State	**21%**		**14%**	6%	**24%**		**24%**		77
	Jin State	**21%**	3%	**13%**		**29%**		**24%**		62
	Zhouyuan site	**16%**	**11%**	**11%**		**54%**				37
LQ	Jin State					**37%**		**48%**		19
	Zeng State				**22%**		8%	**61%**	9%	23
	Yu State LQ local style				**17%**		**17%**	**41%**	**25%**	12
	Yu State LQ CP				**11%**	3%	**11%**	**64%**	8%	36
Unclear	Hengshui site	**14%**	**72%**				**14%**			14

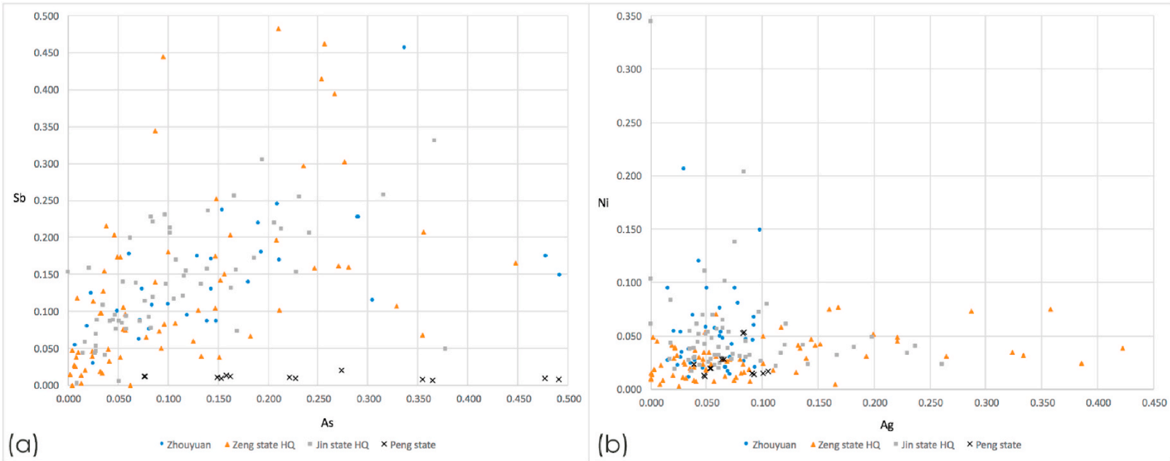

Fig. 8. Scatter diagram for comparison between Zhouyuan, Zeng state, Jin state, and Peng state. (a) Arsenic vs antimony. (b) Silver vs nickel.

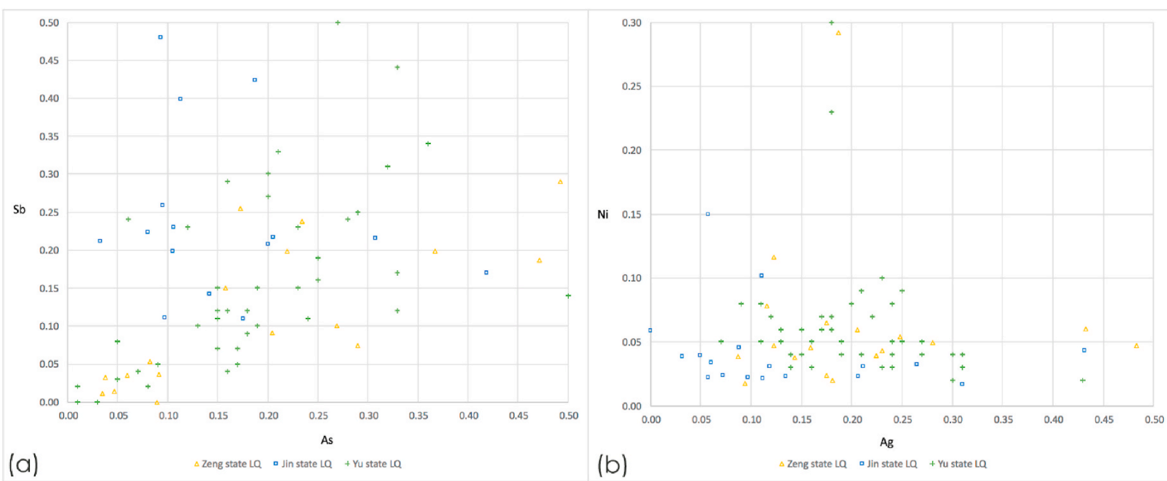

Fig. 9. Scatter diagram for comparison between data of low-quality bronzes from Zeng state, Jin state, and Yu state. (a) Arsenic vs antimony. (b) Silver vs nickel.

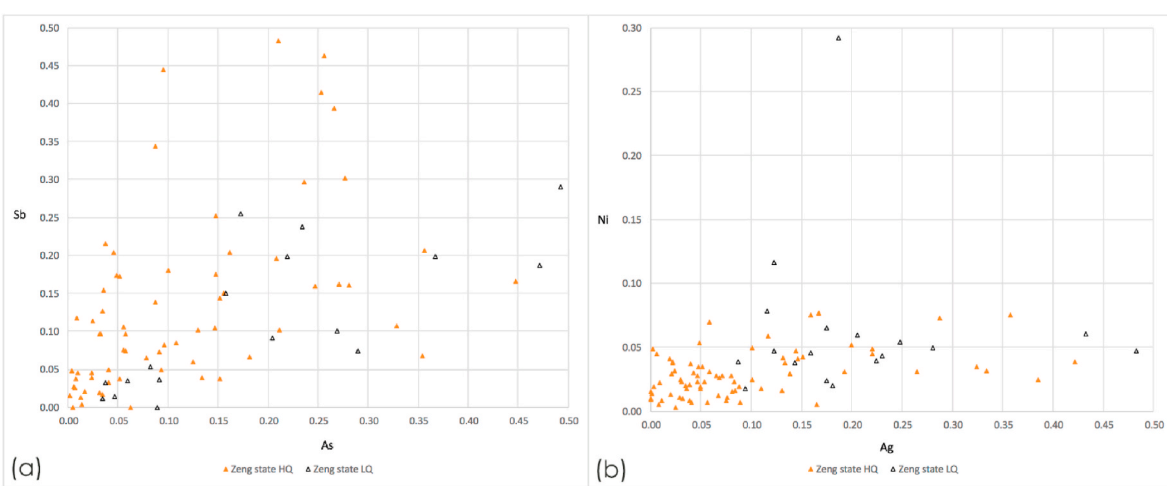

Fig. 10. Scatter diagram for comparison between data of high-quality bronze and low-quality bronzes from Zeng state. (a) Arsenic vs antimony. (b) Silver vs nickel.

Stos-Gale, 2000; Ling et al., 2013; Baron et al., 2014; Cui and Wu, 2008). With respect to the lead isotope in Yejiashan Cemetery, Yu and other scholars adopt the commonly used 2% as the standard to judge the alloy type and believe that the lead isotope of the Zeng State inscription Cu–Sn–Pb bronzes and that of its Cu–Sn bronzes originate from different areas. In this paper, we also adopted 2% as the alloy standard to discuss problems concerning lead isotope. For the sake of prudence, we prefer to use lead isotope data to discuss the lead source of Cu–Sn–Pb bronzes only.

Firstly, we studied the relationship of lead isotope data of different types of bronzes from the same cemetery. As bronzes tested from Yejiashan Cemetery and Yu State Cemetery have corresponding explicit archaeological data, we thus took Yejiashan Cemetery and Yu State Cemetery as examples for discussing lead isotope data. We considered alloy types and bronze types comprehensively to prepare the respective diagrams. It can be seen from Fig. 11 that, the Cu–Sn–Pb and Cu–Sn bronzes with the 'Zeng inscription', 'Shang inscription', those of 'unidentified high-quality Central Plains style', and 'low quality', are generally distributed in two ranges. The value of $^{206}Pb/^{204}Pb$ in Cu–Sn–Pb bronzes generally falls between 17.10 and 17.60, while that of Cu–Sn bronzes falls between 17.7 and 18.5 (Fig. 11).

Second, there is a significant overlap in the data of different types of bronzes. The data overlapping of Cu–Sn–Pb bronzes indicates that most of the Pb materials used by high-quality bronzes such as the 'Zeng inscription', 'Shang inscription', and 'unidentified high-quality Central Plains style' are generally the same. A surprising result is that compared to low-quality bronzes, most high-quality and low-quality bronzes also gather in the same range, which implies that the lead materials probably came from the same source. On the other hand, in the Cu–Sn–Pb area, some low-quality bronzes were out of the overlapping area, which also suggests the possibility of different lead sources. Some unidentified high-quality Central Plains style bronzes and one Shang inscription bronze also have differences. This is understandable, considering the complex background of these two types of bronzes (Fig. 11). In the Cu–Sn region, most data also clustered together, and each type of bronze was seen with data out of the clustered areas.

In addition to the bronzes from Yejiashan, the archaeological background and alloy composition of bronzes from Yu State are clear; and the archaeological background of bronzes from Peng State Cemetery in Hengshui is unclear; however, their alloy composition is precise. We developed a diagram of the lead isotope data of bronzes from Yu State and Peng State based on the known information. Fig. 12 illustrates that Cu–Sn–Pb bronzes and Cu–Sn bronzes generally fall into two different areas. The value of $^{206}Pb/^{204}Pb$ for Cu–Sn–Pb bronzes generally falling between 17.30 and 17.90, and Cu–Sn bronzes generally fall between 17.90 and 18.20. In the Cu–Sn–Pb area, it can be determined from the comparison between the local style low-quality bronzes and Central Plains style bronzes from Yu State that there is much overlap between them; therefore at least, part of the lead material originated from the same source. The Peng State data were distributed in a different area from the Yu State data and therefore suggested different lead sources. Moreover, outside the clustered area, each type of bronze has variables, in a small number.

We also analysed the lead isotope data of 32 bronzes from Jin State; among the 32 bronzes, only some of them have a clear archaeological background, and there is no alloy composition data. This paper also cites the lead isotope data of 25 bronzes from the Cemetery of the Lords of Jin that were analysed by Yang (2005). In addition, the lead isotope data of bronzes from Yan State Cemetery in Liulihe have been published, but there is also a lack of archaeological information and composition data on these bronzes (Zhang et al., 2005). All lead isotope data are compared based on states and qualities. As illustrated in Fig. 13, the lead isotope has a complex distribution. First, regardless of whether the bronzes were high-quality or low-quality, there are many overlaps between bronzes from Zeng State, Jin State, Yu State, or Yan State. This demonstrates that a large number of bronzes in these states were probably made by similar lead resources.

This phenomenon has been noticed earlier by other scholars. For example, Yu and other scholars undertook a systematic comparison of the lead isotope data of the bronzes from all the states in the Western Zhou Dynasty, and analysed the data of bronzes from the core areas of the Western Zhou Dynasty, such as from Beiyao Site and Zhouyuan Site; their results demonstrate that the lead isotope data from the core areas of the Western Zhou Dynasty and all regional states generally fall in the same range (Yu et al., 2016). The consistency of lead isotope data demonstrates that centralised control and distribution patterns of lead materials might have existed in the Western Zhou period. However, out of the clustered area, the scattered data, even in a small amount, cannot be neglected, and each state was seen with such variables. Moreover, the Jin State data are more scattered than others, which might suggest a more complex lead source.

3.4. The distributive system of the Western Zhou Dynasty and the independent bronze production of regional states

By comprehensively analysing the trace element group results and lead isotope data of bronzes from all regional states, we believe that the Central Plains style bronzes unearthed from Yejiashan Cemetery and the Cemetery of the Lords of Jin are suitable representatives of Ji-surnamed regional states, in that they have the same trace element grouping results, and are consistent with the bronzes unearthed from Zhouyuan Site—the core area of the dynasty. The lead isotope data also demonstrate the same characteristics. These high-quality bronzes have a high degree of consistency with respect to shape and style, production techniques, quality characteristics, and raw materials, which indicates that these bronzes might have come from the same production workshop and then underwent distribution.

However, the low-quality bronzes from Yejiashan Cemetery and the

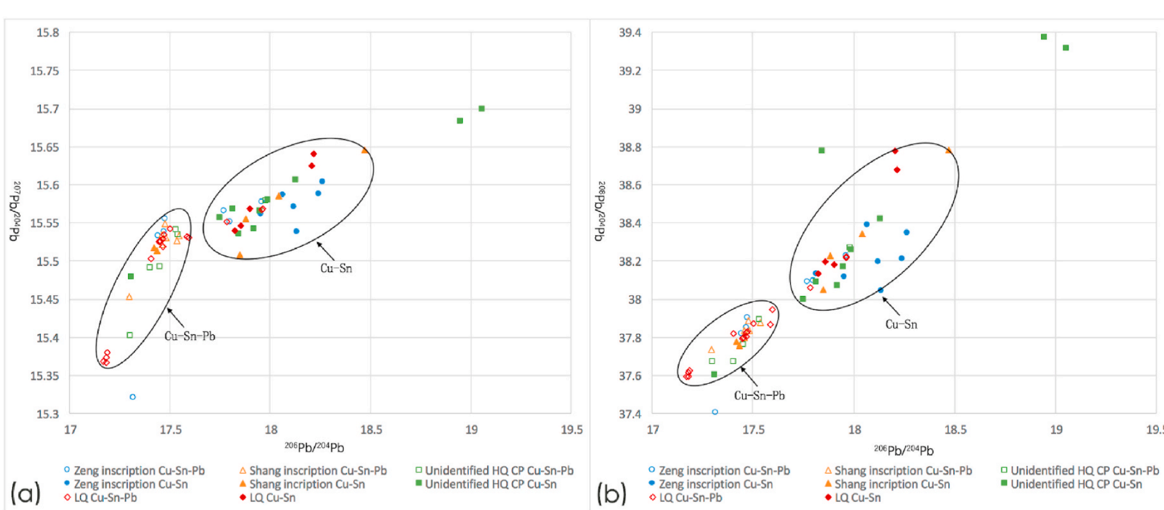

Fig. 11. Diagram of lead isotope data of bronze objects from Yejiashan Cemetery. (HQ: High quality; LQ: Low quality; CP: Central Plains style).

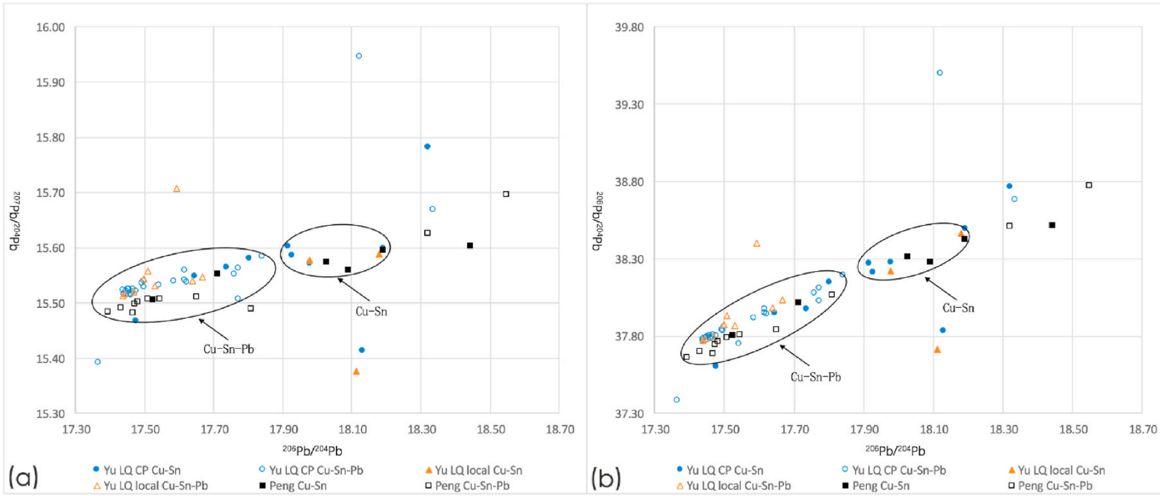

Fig. 12. Diagram of lead isotope data of bronze objects from Yu State Cemetery and Peng State Cemetery. (HQ: High quality; LQ: Low quality; CP: Central Plains style).

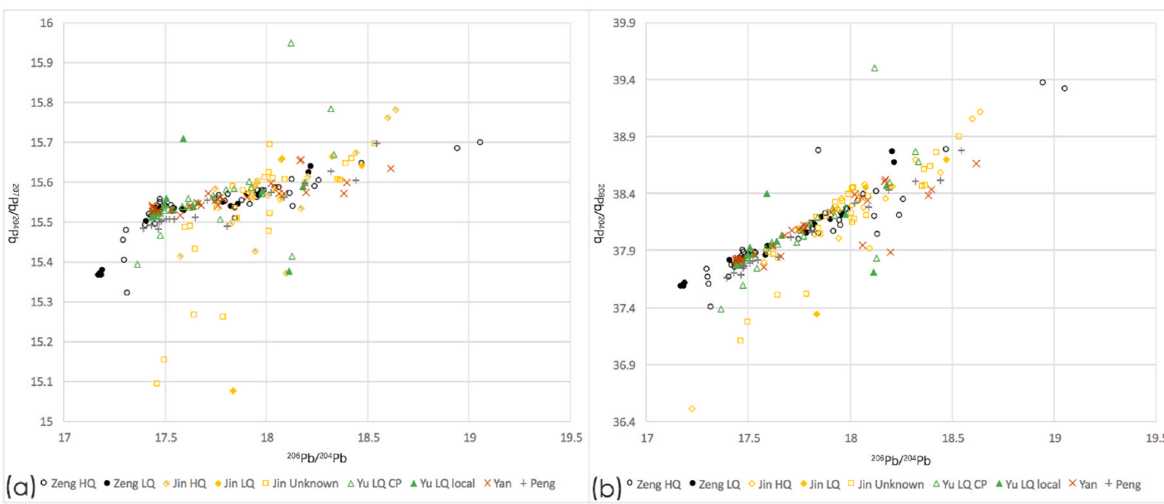

Fig. 13. Comparison of lead isotope data of bronze objects from Zeng State (Yejiashan), Jin State, Yu State, Yan State, and Peng State. (HQ: High quality; LQ: Low quality; CP: Central Plains style).

Cemetery of the Lords of Jin have trace element grouping characteristics different from those of high-quality bronzes. As the style, technique, and raw material are all different, it is quite likely that these bronzes were produced locally. This also implies that the regional states possessed the capability of independent production, albeit only at a small scale and with low-quality technique level. Moreover, it is interesting that the lead materials used in the local production of bronzes are the same as those of high-quality bronzes, which might indicate that the lead material might come from a unified distribution.

Compared with the Ji-surnamed regional states, non-Ji-surnamed regional states have a more independent bronze-casting trend. Specific distinctions exist between the trace element grouping results of bronzes from Yu State and Peng State, and the data of high-quality bronzes from Ji-surnamed regional states, which demonstrates that their copper materials might come from different sources. However, the lead isotope data illustrate that their lead material might come from a unified distribution from the royal court. Therefore, the independence of this casting activity does not mean a complete disjunction with the central dynasty. In addition, the high-quality Central Plains style bronzes from Yu State and Peng State are not analysed in this paper; we infer that it is still possible for these bronzes to come from central workshops.

Based on the above analysis, we can see the origins of bronzes from the same regional state are not the same; there are at least two types, i.e., distribution by the royal court and local production. Differences also exist between Ji-surnamed states and non-Ji-surnamed states, and current archaeological materials also support this explanation.

The bronze-casting workshops discovered in the core areas of the Western Zhou Dynasty are mainly distributed at the Zhouyuan Site (Zhouyuan Archaeology Team, 2002, 2004; 2011; Shaanxi Institute of Archaeology, 2007; Wei and Li, 2007) and Beiyao Site in Luoyang (Luoyang Museum, 1981; Luoyang Archaeology Team, 1983). Bronze-casting workshops or related relics have been found in multiple places at Zhouyuan Site, including Lijia, Qijia, Qizhen, Zhougongmiao, Kongtougou, and Yuntang-Qizhen Sites. In addition, ceramic moulds were also discovered at Chang'an Zhangjiapo (Institute of Archaeology, CASS, 1962) and Mawangcun Site (Fengxi Team of the Institute of Archaeology, CASS, 1962). It can be seen that the bronze-casting workshops were widely distributed in the core areas of the Western Zhou Dynasty and were relatively common. Bronzes consistent with the ceramic moulds discovered in these bronze-casting workshops can be found in most regional states. For example, some bronzes from Yan State, Yu State, and Zeng State are consistent with multiple types of ceramic moulds unearthed in the bronze-casting workshops at Beiyao Site in Luoyang. Based on existing materials, it can be inferred that the bronze-casting workshops discovered in the core areas of the dynasty were likely to function as the workshops of the royal court that supplied bronzes to all regional states.

This also complies with the investiture of the Western Zhou Dynasty. While the Western Zhou Dynasty granted land and people to the regional rulers, it is quite possible for the dynasty to distribute high-quality bronzes, especially bronzes in sets, as political and ritual symbols, to all the regional states. The standard distribution involved not only bronzes but also another representative motif—proto-porcelain. Proto-porcelain were quite rare and valuable in the Western Zhou Dynasty. We find that proto-porcelain items unearthed from elite tombs in different regional states are quite similar in shape and generally the same in set (Fig. 14). We hold the opinion that the places of production of such resources lie in the southeast area centring on the basin of the Qiantang River. After these resources were delivered to the royal court, they may have been distributed by the royal court to different regional states, which may be the general distribution pattern adopted by the royal court of the Western Zhou Dynasty in distributing rare and precious resources (Li, 2018).

However, this pattern may have changed over time. We observe an interesting phenomenon that in the early period of the Western Zhou Dynasty, this distribution system was followed in the strictest manner. In the early period of the Western Zhou Dynasty, all bronzes inscribed with 'Duke' and 'Lord' from regional states belong to typical high-quality Central Plains style bronzes, and no such bronze was produced at local places of bronze production. However, at the start of the middle period of the Western Zhou Dynasty, some regional states such as Yu State and Ying State began to produce low-quality bronzes with such inscriptions. At the start of the middle period of the Western Zhou Dynasty, the proportion of local style bronzes in Yu State and other regional states also significantly increased. This indicates that the distribution system managed by the royal court gradually deteriorated. The same trend has also been found in inscriptions.

We referred to the *Collections of the inscriptions and pictures of the Shang and Zhou bronzes* (Wu, 2012), and the *Index to Collection of Inscriptions on Bronze Objects of the Shang and Zhou Dynasty* (Zhang, 2001) as the primary reference sources in the systematic retrieval and summarising of inscriptions on bronze objects related to the Western Zhou Dynasty and Eastern Zhou Dynasty (770BCE–256BCE). We hold the opinion that in the inscriptions on the bronze objects, recordings related to the circulation of bronzes and copper materials mainly include three types (awarded copper material, captured copper material, and contributed cooper material); wherein the inscriptions on awarded bronze objects accounted for the largest proportion. In the early period of the Western Zhou Dynasty, the inscriptions on awarded bronze objects were the most common; the main group who were awarded copper were senior nobles, including kings, dukes, lords, and princes, with the king and dukes of the royal family accounting for the overwhelming proportion. In the middle period of the Western Zhou Dynasty, the number of inscriptions on awarded bronze objects gradually decreased; the frequency of the kings awarding these bronzes reduced, while it became more common for local dukes and lords to award copper. From the late period of the Western Zhou Dynasty to the Eastern Zhou Dynasty, the type of inscriptions, especially those recording the copper awarding activities of the king, almost completely disappeared. It can be seen that from the early period of the Western Zhou Dynasty to the Eastern Zhou Dynasty, the copper material distribution managed by the royal court gradually disappeared, while the regional states became the agencies of distribution.

In addition, the inscription on the bronze objects that can most directly reflect the production of bronzes is the word 'made'; here we mainly talk about the difference between the two expressions found on the objects, i.e., 'Yongzuo' (made the bronze with copper materials) and 'Zizuo' (made the bronze by oneself). Through the analysis, we found that in the early and middle periods of the Western Zhou Dynasty, the inscription most commonly seen was 'made the bronze with copper materials'. In the late period of the Western Zhou Dynasty, the occurrence of the inscription 'made the bronze by oneself' began to increase significantly, and by the time of the Spring and Autumn period, it had become extremely common. Although the specific difference between 'made the bronze with copper materials' and 'made the bronze by oneself' cannot be confirmed from the perspective of palaeography, by analysing the overall changes in the trends of copper production in the Western Zhou Dynasty and Eastern Zhou Dynasty, we can infer that the two expressions might indicate different production backgrounds. It is assumed that 'made the bronze with copper materials' means non-local production and 'made the bronze by oneself' represents local production; then, the popularity of the former inscriptions in the early period of

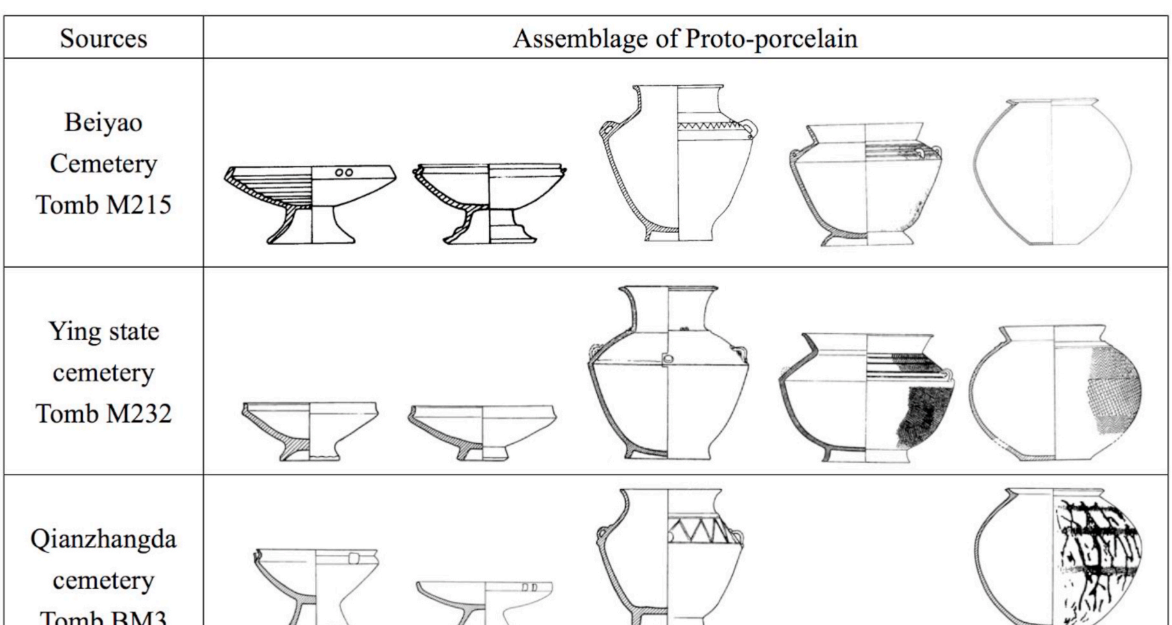

Fig. 14. Comparison of proto-porcelain found in different locations of the Western Zhou Dynasty.

the Western Zhou Dynasty indicate that most inscribed bronzes at that time were indeed produced and then redistributed by the royal court. In the later period of the Western Zhou Dynasty and the Spring and Autumn period, as the 'made the bronze by oneself' inscription became popular, local places possessed more and more independent capabilities of bronze production. Certainly, this is only an assumption, and more materials are required for verification.

Therefore, the distribution system of the royal court and the independent production of regional states are two phenomena coexisting in the early period of the Western Zhou Dynasty, and these continuously changed over time. Through careful observation of the bronzes from the regional states of the Western Zhou Dynasty, we can see that low-quality bronzes are not rare. However, these bronzes that were poor in quality did not play a core role in the ritual vessel set, and thus, were often not valued. For example, the local replicas from Yejiashan were only used to supplement the lack of high-quality bronzes and to complete bronze sets.

Viewed from the perspective of bronze-casting remains, although the discovered bronze-casting workshops of the Western Zhou Dynasty are concentrated in the core area of the dynasty, there are some sporadic bronze-casting traces in some regional states. For example, ceramic moulds have been discovered in Liulihe Site (Archaeology Department of Peking University and Beijing Institute of Archaeology, 1996); copper slag, ceramic moulds and blast pipes have been discovered at Lijiayao Site near the Guo State Cemetery; a bronze-casting workshop has been found in the northeast corner of Shangyang City (Ning, 1991, Archaeology Team of Lijiayao site, 2001); and two ceramic moulds have been unearthed in Hengshui Tomb JHM2167 in Jiang County (Shanxi Institute of Archaeology, 2012). The bronze-casting remains discovered in local, regional states are far less comprehensive and poorer compared with those discovered in central sites; however, these archaeological discoveries provide strong evidence for the production of bronzes by local, regional states.

4. Conclusions

In this paper, we selected Yejiashan Cemetery and the Cemetery of the Lords of Jin as representatives of Ji-surnamed regional states, Yu State Cemetery as the representative of non-Ji-surnamed regional states, and Songjia Cemetery and Yaojia Cemetery at Zhouyuan Site as the representative of core areas of the dynasty. A systematic classification study was conducted on the bronzes from the places mentioned above, and sampling was also conducted on this basis for trace element and lead isotope analyses.

Based on the analysis results, we believe that high-quality bronzes from Yejiashan, the Cemetery of the Lords of Jin, and Zhouyuan Site have the same characteristics in the trace element grouping and many overlap on lead isotope data; these bronzes have consistency at three levels, i.e., from shape to technique to raw material, and most probably have come from the unified production workshop of the royal court. However, local style bronzes from these cemeteries and bronzes from Yu State, Peng State, and other non-Ji-surnamed regional states have different characteristics in their trace element grouping. The lead isotope is more complex. First, there are many overlaps between the low-quality bronzes and high-quality bronzes in Zeng State, Yu State, and Jin State, which suggests that many low-quality bronzes were made by the same lead sources. Nevertheless, there are also some low-quality bronzes from these states that were made of different lead sources. It is also worth mentioning that the data from Peng state do not overlap with the other states. The Jin State data are more scattered than the others, and the overlaps and variables are both important phenomena of the lead sources.

For the first time, this study reveals that the distribution by the central dynasty and the independent production by regional states were two aspects of the bronze production and distribution system of the Western Zhou Dynasty. From the start of the middle period of the Western Zhou Dynasty, as the strength and autonomy of regional states increased, the bronze-casting industry of some regional states increasingly developed, and finally, a mutually independent situation came into being in the Eastern Zhou period. This study depicts a complex picture of bronze production and circulation based on the detailed archaeological classification. Future studies of metal circulation are encouraged, based on the precondition of bronze classification, as this is a logical way to approach historical truths and avoid false assumptions.

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Declaration of competing interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jas.2020.105191.

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