

Taming Metals

The Use of Leaded Bronze in Early China

2000–1250 BC



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For Jing

Abstract

It has long been known that leaded bronze, an alloy consisting primarily of copper with the addition of tin and lead, was widely used in early China, starting from around the second millennium BC. The additional lead distinguishes this metal from common bronze, the copper-tin binary alloy, used by most other Early Metal Age civilisations in Eurasia. The reasons behind the use of leaded bronze have not been fully examined in previous literature.

In this thesis, the discussion of metallurgical technologies and the studies on material properties are combined with four case studies of early metal-using communities to reinvestigate the use of leaded bronze in early China. With this approach, the thesis challenges the wide held notion that lead was consciously added by the craftspeople, mainly to facilitate the casting. Instead, I argue that the widespread of leaded bronze objects was mainly due to both the socio-economic concerns in making bronze ritual vessels in Central China and the recycling and reuse of the metals by other communities around Central China. Moreover, the seemingly common use of leaded bronze does not reflect a uniform acceptance of a single set of knowledge and know-how. Rather, people in different communities responded differently to this new material and chose to engage it in different ways.

This study on leaded bronze provides us with a new perspective to recognise the complexity and diversity of technology and material culture in early Chinese communities. Meanwhile, through the active discussion on the theoretical frameworks and research methods for archaeometallurgy and material culture studies, I also suggest approaches which may be useful in future studies of early metallurgy and other craft production.

摘要

宦立旻

长期以来，学界对铅青铜，也即铜、锡、铅三元合金在早期中国的应用已有诸多认识与讨论。中国境内的铅青铜最初出现于公元前二千至一千年间。与欧亚大陆早期文明惯常使用的青铜材料相比，铅的加入是一个特别的现象。对于此现象背后的原因，至今未有全面的分析讨论。

本文试图以冶金技术及金属材料特性的研究为基础，结合四个早期冶金社会的实例来探讨铅青铜在中国的使用。不同于目前的一个主流观点，也即加入铅主要是为了提高青铜的铸造特性，我认为铅青铜的接受与普及主要有两大原因。在中原地区，人们使用铅青铜来制作成本相对不含铅的青铜更低的礼器，这两种材料的区别满足了人们对于青铜礼器等级差异的需求。同时，铅青铜材料和器物也以各种形式流入中原周边地区，并被那里的人们回收利用。这也一定程度上推动了铅青铜在更多地域的使用。不同考古实例的比较也表明不同人群在使用某种看似同样的材料时，可能存在不同的认知和技术选择，并由此产生人与物之间不同的互动和联系。

通过考察铅青铜的使用，本文尝试提供一个新的视角来了解早期中国社会技术与物质文化的复杂性和多元性。本文所涉及的理论讨论也能为今后的早期冶金及手工业研究提供一些新的思路 and 手段。

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The person I feel most grateful to is Professor Dame Jessica Rawson. In 2015, I just quit my banking job and was trying to move my career in a new direction. A former student of Professor Rawson, Dr Deng Fei from Fudan University, recommended me the MSt in Archaeology programme of Oxford (thank Dr Deng for the recommendation letters which sent me here). This

is how I got to study in this wonderful university and met Professor Rawson. In the next few years, she generously supported most of my research, including trips to visit archaeological sites and museums in Turkmenistan (with Professor Pollard, Professor Gosden, and Dr Liu), lead mining sites in Cornwall (with Dr Liu and Professor Chen Jianli, Peking University), and to participate in the experimental archaeology workshop by Professor Chen in Hunan, as well as various other trips, conferences, and workshops. With all these opportunities she offered, I was able to immerse myself in the field of archaeology. Professor Rawson is also a great supervisor, a respectable scholar, a sincere friend, and one of the most engaged readers of my works. Before coming to Oxford, Professor Rawson spent many years in the British Museum working with the artefacts. She also has a deep understanding of the geography of China through her numerous travel experiences over the decades. As I am currently writing this thesis, she is also writing a new book about the early Chinese societies. Through the discussion with her, I learn not only archaeology, but also how to write and, more importantly, how to form an idea by observation and asking questions. I can always find myself filled with new and improved ideas after discussing and arguing with her. I really look forward to her new book.

I also want to thank my peers, friends, and classmates in Oxford, particularly, Dr Chen Beichen, Dr Hsu Yiu-Kang, Dr Liu Ruiliang, Dr Rebecca O'Sullivan, Dr Alice Cheng, Dr Tang Xiaojia, Dr Raphael Wong, Dr Wen Wen, Dr Li Peining, Dr Wang Shengyu, Dr Brianne Fung, Du Xuying, Shen Shui, Gao Xuyang, Shi Muyang, Li, Zihan, Ma Qian, Zhang Quan, and Zhang Yun. Doing a DPhil is not a dinner party. There is always time when we are confident and energetic, while there is always time when we feel powerless and helpless. But because of you and your dinner parties, my Oxford days became much brighter.

In the first three years of my DPhil, I was mainly writing in the Sackler Library, the Howard Piper Library of St Hugh, and in the lovely café on the first floor of Blackwell's. A special thank you to the marvellous people working there who offered me the great environment. I was also travelling frequently between Oxford and St. Louis, US to balance work and family life. When

in St. Louis, I had the chance to meet Dr Liu Xinyi and to take part in the lectures and workshops by the Department of Anthropology, Washington University in St. Louis. Especially, when I spent my whole last year in St. Louis due to the covid, the engagement with Dr Liu and his archaeology team is important to me both academically and emotionally to continue my research when I was not able to return to Oxford.

Finally, I want to thank my parents, my wife, and Nana (when you are not chewing my papers), who have often supported me remotely from Shanghai and from St. Louis. Thank you for reminding me that life is more than reading and writing.

Declarations

Chemical Data and Its Visualization

To present the overall pattern of early metalworking, as well as to support the discussion of certain objects, a large number of sites, artefacts, and their chemical compositions are cited in the text. These materials are summarized in two tables as Appendix 1 and 2. The datasets, in the format of Excel spreadsheets, are also included in the supplementary materials, so they can be used by other researchers in future.

Regarding the chemical data of the objects, all the percentage values of the alloying levels used in this thesis are published by previous studies. However, since the datasets are prepared by different researchers in different forms, one problem is that some compositional values are normalized to reflect the relative ratios of alloying elements (e.g. copper + tin + lead = 100 wt%), while others are not. Therefore, to some objects, the sum of the percentages of all alloying elements may be significantly lower than 100%. This is usually caused by two reasons. The first is the presence of other elements which are not considered alloying elements (such as iron, nickel, and zinc) and thus not included in the original datasets. The second is that the objects are highly corroded, so the metals are replaced by elements such as oxygen and sulphide. To deal with these issues, for chemical compositions mentioned directly in-text or in the tables, I use the original, usually un-normalized, values as how they are first published. Meanwhile, to compare the objects chemically, I plot normalized compositions in all the charts. If the sum of all alloying elements in a sample is less than 50% (e.g. un-normalized copper + tin + lead = 40 wt%), I consider the sample too corroded and thus exclude it in my discussion.

For the visualization of the compositional data, I mainly use scatter plot with the relative (normalized) percentages of tin and lead as two axes. An alternative choice, which is also popular

among researchers, is to show the data as ternary plot. An obvious advantage of using ternary plot is that the values of all three elements, copper, tin, and lead, are directly readable. Nevertheless, as our eyes are normally not well trained to interpret a ternary plot, the patterns, such as a cluster, on a ternary plot can sometimes be misleading (easy to visualize, hard to explain).¹ For this concern, I still choose to use two-dimensional scattered plot to present the data.

Maps

The Maps used in the thesis are created with Esri ArcGIS. The topographic database from the Shuttle Radar Topography Mission (SRTM) is used to produce the digital elevation model (DEM).² To better present the relative size of the East Asian regions, most maps are drawn with the Lambert Conformal Conic projection. Some features, such as shadows and font effects, are created in Adobe Photoshop. The map in the colour plate is created with ArcScene and Photoshop.

Figures and Image Processing Software

Photos and drawings, if not specifically mentioned, are taken or created by the author. Adobe Photoshop and Illustrator are used to create or edit the figures. Charts are created by Microsoft Excel and IBM SPSS.

¹ Statistically speaking, the study on alloying elements is a specific scenario of multivariate analysis. Issues such as the use of ternary plot have been well discussed in this field, see e.g. Aitchison 1986: 5–12.

² The database is downloaded from <http://viewfinderpanoramas.org/>.

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Preface

A Tale of a Metal

You say to brick, “What do you want, brick?” Brick says to you, “I like an arch.” if you say to brick, “arches are expensive and I can use a concrete lintel over an opening. What do you think of that, brick?” Brick says: “I like an arch.”

—Louis Kahn¹

In 2016, I was in the middle of my MSt programme in Oxford and fell in love with the Bodleian Libraries, so I decided to devote the next few years to a doctoral research project. As someone newly moved to archaeology from a physics background, I was fascinated by how people engaged with technology and coped with technological changes in the past. To me, archaeology provides a fresh perspective to understand who we are, and what we may do in future. When discussing the research topic with my future supervisor, Professor Mark Pollard, he, at that time, was leading an ERC research project called “FLAME” (FLoW of Ancient Metals across Eurasia) and was intrigued by the contrast of metallurgical technologies and products across Eurasia. Therefore, Professor Pollard asked me: “Why did the ancient Chinese use leaded bronze?”

The background of his question is a striking contrast found by the FLAME team. Most ancient metal objects, as we already know, were not made of pure copper, but of copper alloyed with small amounts of other metal elements. The word “bronze” as we are all familiar with actually refers to copper alloyed with tin. This material appeared first in South-west Asia at least five

¹ Lesser 2017.

thousand years ago, ushering in a new era known as the “Bronze Age”.² However, when my colleagues in Oxford compared the chemical compositions of early copper-based objects across Eurasia, they found that, for communities in most part of the continent, what people predominately used was the binary alloy of copper and tin. However, in East Asia, people actually preferred a different metal material, the ternary alloy of copper, tin, and lead (see Chapter 1, Figure 1.3).³ The use of this special material, usually called “leaded bronze”, has been known by scholars for decades, but, for the first time, the FLAME team demonstrates that, through the circulation of metal objects and resources, the use of leaded bronze had a profound impact not just on the early Chinese metal-using communities, but also on their neighbours in East Asia and on the Eurasian steppe.⁴ Meanwhile, how this material was initially adopted in East Asia is still not very clear. Previously, most studies focused on metal objects themselves, and tried to link the use of lead to functional reasons. However, recent archaeological excavations and scientific studies have presented us with a tremendous number of new materials, including new sites with metal objects, new dating, and new understanding of the organisation of early metal production. These materials make it possible for us to reconsider how this “great divergence” of the use of leaded bronze between the western and the eastern parts of the continent was initiated.

Therefore, when I was accepted to the doctoral programme, the use of leaded bronze in early China became my research topic for the next four years. To make the title of my research more explanatory, I choose *Taming Metals* as the working title. In a general sense, the word *tame* often refers to the domestication of animals. In this process, wild animals are partially transformed when certain relationships with humans are established. In my initial view, the taming of animals

² Roberts et al. 2009.

³ See more in Chapters 1 and 2.

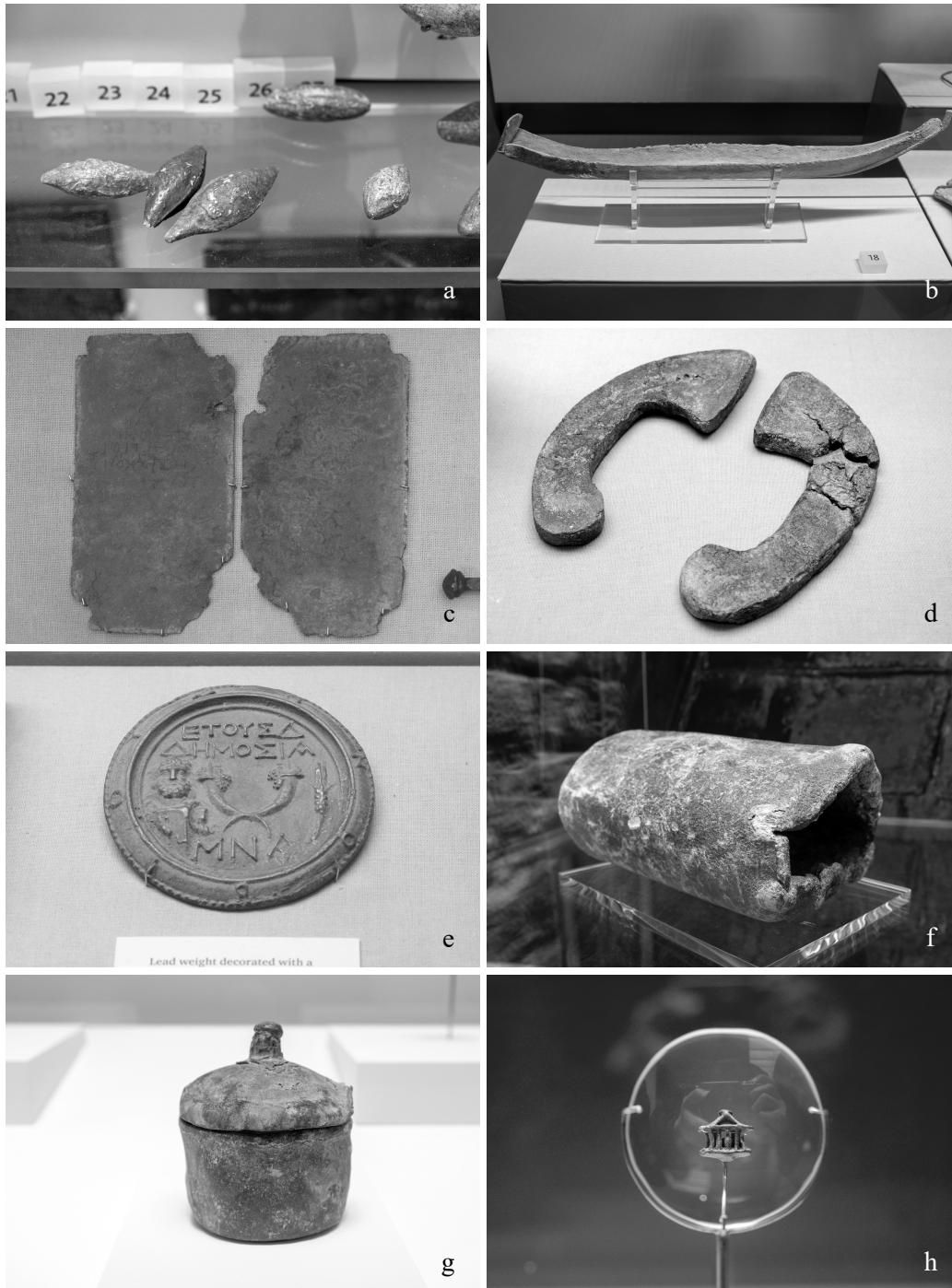
⁴ Hsu, Y. 2016; Hsu, Y. et al. 2016; Liu, R. 2016; Pollard et al. 2017; 2019.

and the making of metal alloys and metal objects are two technologies (the discussion of technology, see Chapter 3) with some similar characteristics, since metallurgy also represents a transformation of things which were originally natural. As the studies on animal domestication aim to show how our transformation of the animals also transformed us, for leaded bronze, I also want to discuss the impact of this technological choice on the culture and the everyday lives of people in the early metal-using communities. Moreover, there is also a particular analogy between the taming of animals and the use of leaded bronze. Animals after taming are often gentler and easier to control. For leaded bronze, lead also makes the material softer, less strong, and easier to cast (Chapter 4).⁵

As I was exploring the topic, the immediate transformation happened on myself was that I started to think much harder about our relationship with metals, and especially with lead. This was also the time when I realised how the role played by this metal in our history is often undervalued. One of the books I benefited a lot from is Jerome Nriagu's *Lead and Lead Poisoning in Antiquity*.⁶ As an environmental chemist, he provided a wonderful overview of the use of lead in the past, which reveals that the applications of lead were much wider than we usually expect (and also much wider than what we archaeologists usually focus on). After reading his book, when I went to museums again, I always tried to find lead objects—usually quite small—which I previously failed to notice (see some examples on the last page). These objects also led me to

⁵ Of course, after some research, I realised that I am certainly not the first person who noticed this similarity between animal domestication and metallurgy. In her book *The Domestication of Metals: The Rise of Complex Metal Industries in Anatolia*, Aslihan Yener has already analogized the adoption of metals to the domestication of plants and animals as these two practices both shaped the early settled farming communities in Anatolia: Yener 2000.

⁶ Nriagu 1983.



Some lead objects I encountered in museums. a: sling-shot bullets, Perugia, Italy, 1st century AD (Ashmolean Museum); b: boat model, said to be from a tomb at “Drakatis” on Naxos, Greece, c. 2800–2300 BC (Ashmolean Museum); c: tablets with a curse inscription, said to be from Kaklik in Phrygia, Roman, 1st–3rd century AD (British Museum); d: pair of jumping weights (*halteres*), Etruscan, found at Vulci, c. 5th century BC (British Museum); e: decorated weight, Roman, 1st century BC; f: pipe, The Roman Baths, Bath, 1st century AD (The Roman Baths); g: votive box, Thonis-Heracleion, Egypt c. 664–120 BC (2018 “Sunken Cities” exhibition, Saint Louis Art Museum); h: amulet in the form of a Greek-style temple of Isis or Serapis, Canopus, Egypt, c. 332–30 BC (2018 “Sunken Cities”).

imagine how people in the past knew and felt about lead. To empathize with them, I bought a small galena mineral and put it on my bookshelf. Sometimes I just stared at it and wondered, why were people attracted by this mineral? My interests in leaded bronze also introduced me to the field of metallurgy in general. Two experiences are particularly important to me in these years, both sponsored by Professor Jessica Rawson. The first is a trip to visit the tin mining sites in Cornwall. In this trip, I gained first-hand experience in the operation of modern metal production, especially issues which I was not fully aware of from reading books, such as occupational safety and health. The other experience is the experimental archaeology workshop in Hunan, China, organised by Professor Chen Jianli from Peking University. For a week, I played with charcoals, ores, and messy mud (as the refractory material for furnace-building). Since the location of our temporary workshop was close to a local hotel, we got some curious spectators but also lots of complains. Our tricky relationship with the residents also led me to think the social impact of metalworking.

During my research, I was also intrigued by studies which focus on the history, especially the global history of a certain type of thing. Such things can be food (e.g. fish, spice, salt, coffee, tobacco), minerals (e.g. copper, iron, also salt), or anything which people desire (e.g. wood, coral, mirror, or even English breakfast).⁷ These studies are all about the concept which we may call “the global lives of things”, first proposed by Anne Gerritsen and Giorgio Riello and used as the title of their edited book.⁸ By reading these books and articles, I realised that there is a possibility of combining archaeology, history, and culture studies to understand material culture. One book I am particularly interested in is a study on Sony Walkman by Paul du Gay and colleagues.⁹ By dividing a cultural phenomenon into five processes—representation, identity, production,

⁷ E.g. Ennos 2020; Kurlansky 1999; 2002; Mintz 1985; Nabhan 2014; Norton 2008; O’Connor 2013; Riello and Parthasarathi 2009; Wu, H. 2021.

⁸ Gerritsen and Riello 2015.

⁹ du Gay et al. 1997.

consumption, and regulation—the authors showed how various human-thing relations and interactions were reflected in the triumph of this electrical device. For archaeological studies, our materials are different from those available to historians and those available to scholars studying contemporary culture. There are some advantages of using archaeological materials, but there are also certain limits.¹⁰ These advantages and disadvantages are described perfectly by Robert Kelly in the introduction of his *The Fifth Beginning*: archaeological materials can provide us with amazing details but only in particular cases (Kelly used the example of Ötzi the Iceman to show this).¹¹ However, as archaeologists, we sometimes also want to (and I personally believe that we should still try to) go beyond historical particularism, and to seek general conclusions of how societies and cultures were shaped in the past.¹² To reach general conclusions from particular cases, we need to see the logic behind and the relations between the particular cases. The historical and contemporary studies I mentioned may not directly answer our archaeological questions, but these studies, by showing us how people engaged with other things, may suggest where the general logic and relations are.

When writing this thesis, I also realised that “taming” may not be a precise word to describe what happened. The word “taming” sounds like it was our human agency which changed metals. In fact, as I will discuss in Chapter 3, human and material agencies both worked on this transformation, while humans and objects were both changed as well. Therefore, our relationship with the metals may have been more similar to a negotiation than a control (see the epigraph of this preface). More importantly, the use (or disuse) of leaded bronze, in my case studies, was not a choice, but a result of many interrelated choices and coincidences, while not all the choices were due to functional reasons, such as to soften the material. But as this title has been with me

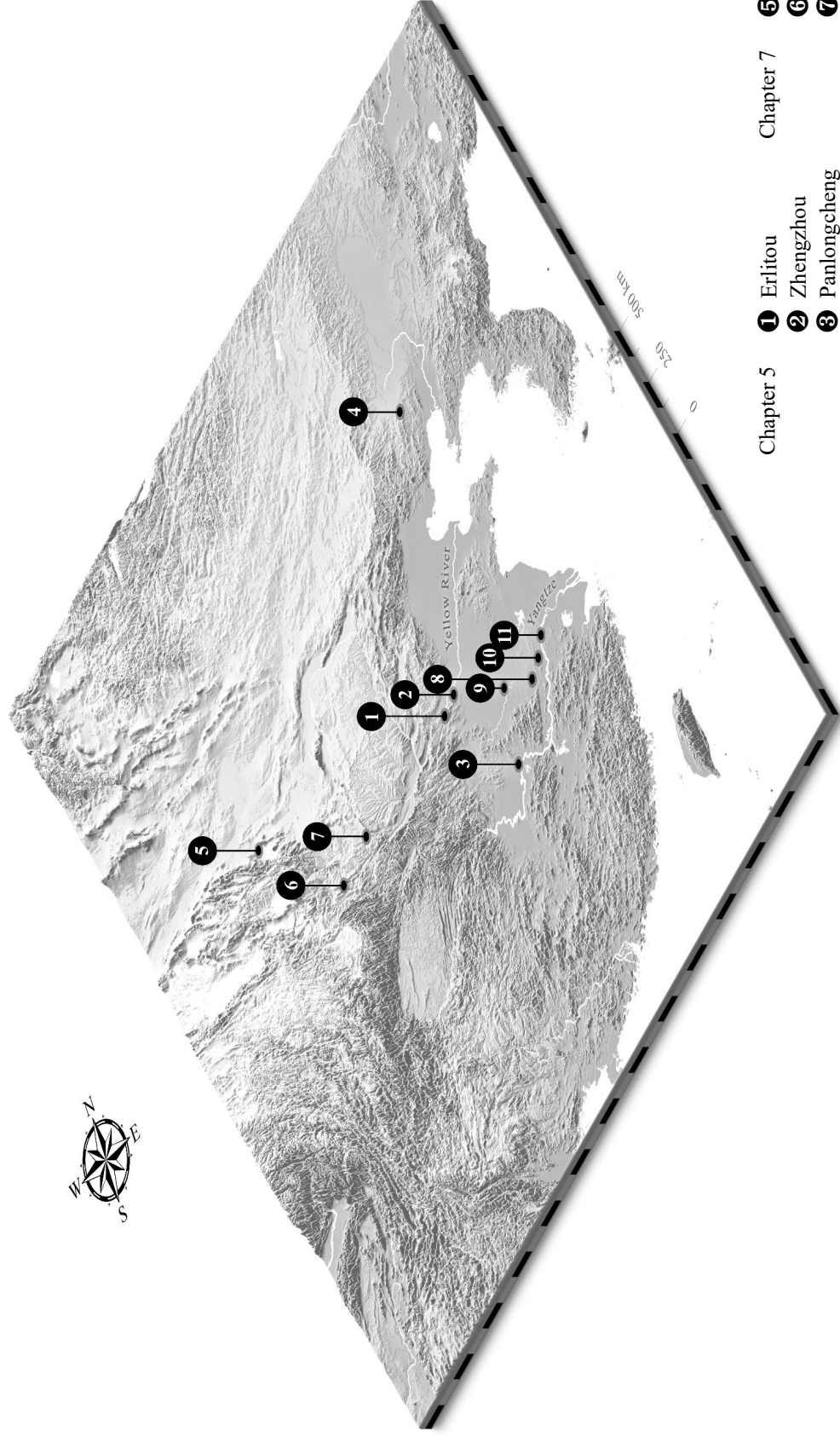
¹⁰ As an archaeological joke says: we do not care what is right; we only care what is left.

¹¹ Kelly 2016: 12–14.

¹² The debate on historical particularism, see Harris 2001: 250–289.

for so many years, through the transfer and the confirmation, I must admit that it is emotionally hard to abandon the title. Therefore, I will still keep this metaphor and remind myself that, for this four-year DPhil research project, the process is more valuable than the result.

As the proverb says, “behind every object, there is a story waiting to be told.” Therefore, here is where my story behind the leaded bronze objects begins.



Taming Metals

Case Studies of Metal-using Communities in Early China, 2000–1250 BC

Chapter 5	Chapter 7	
1 Erlitou	5 Xichengyi	
2 Zhengzhou	6 Mogou	
3 Panlongcheng	7 Xujianian	
Chapter 6	Chapter 8	
4 Dadianzi	8 Dadunzi	
	9 Taijiasi	
	10 Dachengdun	
	11 Beiyinyangying	

PART ONE

Introduction, Background, and Methods

The Metal Age in East Asia

A Leaded Beginning

In the late summer of 2016, I visited Anyang for the first time. To a student of archaeology, Anyang is one of the must-sees for, beneath our feet, there lies the site of Yinxu, the Ruins of Yin, one of the largest and most famous archaeological sites in China. Yinxu is widely recognised as the capital city the late Shang people for about 250 years in the late second millennium BC (more in Chapter 7).¹ As I was wandering among cases full of ritual vessels and oracle bones in the Museum, I finally reached the last gallery, with a gigantic bronze vessel at the centre of the room (Figure 1.1). This rectangular vessel, known by the inscription on it as the *Houmuwu* 后母戊 (or *Simuwu* 司母戊) *ding* 鼎, is probably the best-known discovery from Yinxu. This *ding* in the Yinxu Museum is actually a replica, while the original is now displayed in the National Museum of China in Beijing, the capital city. This arrangement itself tells us something about the importance of the bronze vessel as well as its symbolic meaning even to the modern regime of China. When I stood in front of it, the first thing that shocked me was the sheer scale of the object. On a base in the showcase, the vessel was almost as tall as I am, while

¹ General introduction of Yinxu, see Li, C. 1977; Li, Y. and Feng, C. 2013; Keightley 1999; Tang, J. 2009; Zhongguo 1987; Zhongguo 1994.



Figure 1.1 The *Houmuwu ding* vessel. Top: the replica of (right) in the Yinxu Museum; bottom: the original one in the National Museum of China, Beijing.

the record shows that the object is 133 cm high, with a weight of 833 kg.² A vessel in this size was almost certainly not just for daily cooking.

What is equally amazing are the huge resources devoted to making this bronze. Unlike materials such as stone and wood, bronze, the material used for making this vessel, does not come directly from nature. *Houmuwu ding* was made of an alloy with 84.8% copper, 11.6% tin, and 2.8% lead as its three major components.³ Ores had to be mined. Metals were then extracted from these ores by smelting and mixed together to achieve a certain alloy composition for casting (more in Chapter 3). To cast the *Houmuwu ding*, as some scholars estimate, around 1.5 to 2 tons of bronze was required, while the whole operation may have involved hundreds of people working at the same time.⁴

Putting so much effort into one single metal object may be a quite rare case, but it shows well the significance of metal to some early Chinese communities. This significance has also inspired research on early Chinese bronzes across various fields, such as history of science, archaeology, art history, and anthropology. In archaeology, the studies on early metal objects and metallurgy usually follow two traditions. One tradition, known as “archaeometallurgy”, is to study metallurgy as an early technology through scientifically analysing archaeological materials. This started when pioneers such as John Percy and William Gowland applied scientific techniques to the analyses of metal artefacts in the late nineteenth to the early twentieth centuries.⁵ Working with archaeometallurgy focuses more on the “how” question, that is, how to reconstruct the ways by which the metals were produced in early communities.⁶ In this way, archaeometallurgy shares

² National Museum of China: https://www.chnmuseum.cn/zp/zpml/201812/t20181218_25989.shtml.

³ Yang, G. and Ding, J. 1959.

⁴ Li, W. 2016; Keightley 2012: 23; Yang, G. and Ding, J. 1959; Yu, X. 1964.

⁵ Percy 1861; Gowland 1898; 1899. See also Pollard 2013.

⁶ Cleere 1993; Ehrenreich 1996; Killick 2001; Rehren and Pernicka 2008.

the same research goal with history of science and technology. In the centre of these two disciplines is technology. Archaeometallurgists consider technology in its original Greek meaning, as the “science (-λογία) of craft (τεχνολογία)”.⁷ By studying such as the working surface, microstructure, and chemical composition of an artefact, as well as the people, places, and resources involved in the manufacturing, archaeometallurgy tries to understand how an object was produced and subsequently used.

The other tradition, under the general research interest of “material culture studies”, considers metal objects as part of a universal human-thing relation. Unlike archaeometallurgy and history of technology, material culture studies focus more on the “why” question: why did people use metals or particular forms of metal objects?⁸ Part of the reason is that material culture studies rooted in sociology, anthropology, and museum studies. In these cases, scholars, especially early European scholars, collected many artefacts from indigenous communities around the world. However, the meanings and functions of these objects were unknown to their collectors. So, the first question scholars ask is not how was the object made, but why was it made and used? By borrowing various theories and analytical methods from other social sciences, material culture studies see the production, possession, and distribution of objects as a cultural phenomenon. One example is the study on Sony Walkman by Paul du Gay and colleagues as I mentioned in the preface.⁹ Instead of trying to explain how a Walkman works or how it is assembled, the study emphasizes the social, cultural, and generational factors which contributed to the wide acceptance of this product. Material culture studies also use the term “technology”, but in these

⁷ Oxford English Dictionary (online): <http://www.oed.com>.

⁸ Berger 2014; Hicks and Beaudry 2010; Tilley et al. 2013.

⁹ du Gay et al. 1997.

studies, technology is often defined in a broad sense as a type of human-thing relation, which is not limited to manufacturing. I will elaborate these issues in Chapter 3.

In practice, these two traditions of studying early metallurgy are not incompatible. Archaeologists often use these two approaches together. Especially, around the 1990s, anthropological methods, such as ethnological studies, started having a profound impact on archaeometallurgy, shifting the academic paradigm from the emphasis on finished objects to a more holistic investigation of metallurgical processes, such as mining, smelting, production, and distribution (history of science and technology).¹⁰ To some extent, the new paradigm of a holistic approach echoes the long-lasting idea of viewing metallurgy as both an art and a science.¹¹ The current paradigm of early metallurgy studies also serves the ultimate goal of archaeology, which is to understand not just the objects but the people behind the objects.

One of the materials archaeologists and archaeometallurgists favour in particular is bronze. Bronze is the binary alloy of copper and tin.¹² Due to its remarkable role in our history, people often pay tribute to this metal by naming the whole period when bronze was the most used metal the “Bronze Age”. In East Asia, however, one particular type of metal, which was used by many early communities, was leaded bronze, the ternary alloy of copper, tin, and lead. In our current knowledge, East Asia is one of the very few regions where this alloy dominated the assemblage of early metal objects.¹³ Of course, what we call “leaded bronze” is an idea based on modern science. For an archaeological question, the problem is more complicated. For example, was

¹⁰ Ehrenreich 1991; Goodway 1991; Killick and Goldberg 2009; Muhly 2008; Thornton 2009a.

¹¹ Kuijpers 2013; Thornton 2012; Thornton and Roberts 2014.

¹² In some cases, the word “tin bronze” may be used to emphasis that the metal contains only copper and tin. In this thesis, I use “bronze” or “unleaded bronze” to refer to copper-tin alloys, while “leaded bronze” to refer to copper-tin-lead alloys.

¹³ Examples of leaded bronze use in other regions, see footnote 24.

lead intentionally added to bronze alloys? If so, why did people use this material? How was the material related to the special forms of metal objects created in East Asia?

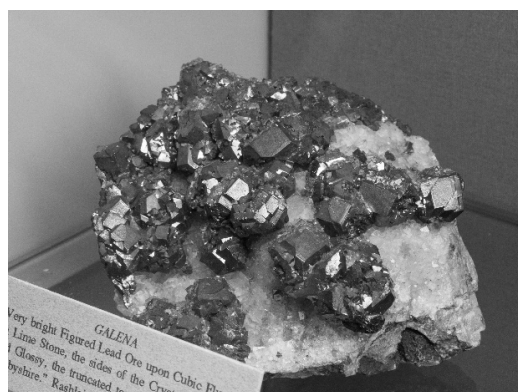
In this thesis, I will take a two-step approach to answer these questions. For the first step, I will review both the cultural issues and the scientific issues of leaded bronze. To investigate these issues, I will rely on methods from both archaeometallurgy and material culture studies. For the second step, I will discuss four case studies on early Chinese communities in which leaded bronze were either used or rejected. As the first chapter of the thesis, I will first review the historical and archaeological records of lead in early China. After that, I will introduce the background of the chemical studies on early Chinese bronzes, which will lead to a summary of the answered and unanswered questions about leaded bronze in early China. In the final section, I will introduce the overall structure of this thesis.¹⁴

China in Eurasia: Lead and Early Societies

Lead is one of the earliest discovered metals by humans. In nature, lead is rarely found in pure form, but often with other minerals. The major type of lead-bearing mineral is galena (PbS), which has a dark grey colour, a metallic lustre, and is often crystalised in a cubic structure (Figure 1.2). Galena ores were often collected by people as a type of gemstone. Small ornamental objects made of galena have been discovered at a few East Mediterranean sites, such as the lead beads at Çatalhöyük, dating to about 6500 BC, as well as in Europe and in North America.¹⁵ It may have been the gleaming appearance of galena ores which attracted people worldwide.

¹⁴ The geographic scope of China will be discussed in Chapter 2.

¹⁵ Çatalhöyük: Mellaart 1964: 111–114; Europe: Glumac and Todd 1987; Henshall 1979: 81–82; North America: Walthall 1981; Walthall et al. 1979: 33–36.



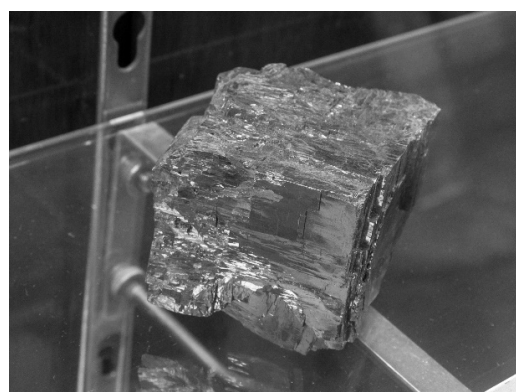
a



b



c



d

Figure 1.2 Samples of galena ores. a: galena on limestone, Derbyshire (Royal Cornwall Museum, Truro); b: galena with quartz, West Chiverton Mine, Cornwall (Royal Cornwall Museum); c: galena on fluorite, Blackdene Mine, Durham (Museum of Natural History, Oxford); d: cubic galena cleavage, Viburnum Trend, Missouri (Missouri Mines State Historic Site).

The earliest evidence pointing to lead smelting, in other words, extracting lead from its ores by firing, appeared in the fifth millennium BC in East Mediterranean.¹⁶ In this region, the earliest copper smelting emerged around the sixth to fifth millennia BC.¹⁷ The slight time difference suggests a possible technological transfer from smelting copper to smelting lead. However, since

¹⁶ A lead object (probably a mace head) with an attached wooden shaft from the Ashelim Cave, Israel is the earliest known object made of smelted lead. The object is dated to the late 5th millennium BC. See Yahalom-Mack et al. 2015.

¹⁷ Lehner and Yener 2014; Radivojević et al. 2010; Yosef et al. 2014.

the facts that lead minerals are often more abundant than copper ones and that lead smelting requires a much lower firing temperature than copper smelting, it is also possible that lead was smelted earlier than copper or the smelting of the two metals was developed as a single technology.¹⁸

During the fifth to the third millennia BC, lead was extracted and exploited by many communities in Western and in Central Asia.¹⁹ In general, most lead-working communities were smelting copper at the same time and producing copper-based objects as well.²⁰ Nevertheless, these two metals are very different in their properties. Copper is hard and shiny, suitable for both small jewels and, especially when alloyed with arsenic or tin, everyday tools and weapons. Lead, by contrast, is soft and with a dull look, as it oxidises easily. Therefore, while copper was often produced for its own sake by early Eurasian societies, the use of lead followed different rationales. On the one hand, lead ores, especially galena, are often argentiferous, or silver-bearing. One way to extract silver from argentiferous galena is called cupellation, in which lead is selectively oxidized and thus separated from silver.²¹ This means that, for people who wanted to produce silver, they may also have got lead as a by-product. According to Nima Nezafati and Ernst Pernicka, the Central Iranian Plateau may be the birthplace of cupellation.²² By the end of

¹⁸ For instance, at the Welsh Bronze Age site Copa Hill in Cwmystwyth, the excavators found that both copper ores (chalcopyrite) and lead ores (galena) were mined and crushed. Although direct evidence for smelting was not found at the site, it is possible that both types of ore were prepared for future smelting. This indicates that copper and lead were processed with the same technology at this site. See Timberlake 2003: 100–102.

¹⁹ Examples of Western Asian sites with early lead objects or evidence for lead smelting: Arslantepe, Turkey: Palmieri and Di Nocera 1999: 180–181; Frangipane 1998; Byblos, Lebanon: Dunand and Cauvin 1937: v. 5, 317; Fatmah-Kalecik, Turkey: Palmieri et al. 1996; Hess et al. 1998; Habuba Kabira, Syria: Pernicka 1990; Pernicka et al. 1998. Examples of such sites on the Iranian Plateau: Anshan: Sumner 2003: 65–66; Arisman: Nezafati and Momenzadeh 2000; Sialk: Ghirshman 1938; Pernicka 2004; Tepe Hissar: Roustaei 2004.

²⁰ Roberts et al. 2009.

²¹ For a general introduction of cupellation, see Craddock 1994: 221–231. For a more detailed discussion from an industrial perspective, see Percy 1870; Eissler 1891.

²² Nezafati and Pernicka 2012.

the third millennium BC, cupellation was widely adopted in Central Asia as well as in the Eastern Mediterranean. As a result, large amounts of lead were probably produced by and circulated among these communities.²³ This is different from the situation in early China as there was no evidence for silver use. I will revisit this point later. On the other hand, lead may also have been produced to be alloyed with copper and other metals. This possibility is suggested by the fact that many early copper and bronze objects contain lead. Although it is often difficult to confirm whether the lead was intentionally added or simply an impurity (see more in Chapter 3), researchers believe that, at least in some cases, lead was deliberately added.²⁴ Nevertheless, in general, the use of leaded bronze was still quite limited in the prehistoric and the ancient world. This is well reflected by a map presented by the FLAME (FLoW of Ancient Metal across Eurasia) project, conducted by an Oxford research team.²⁵ As it shows, copper-based objects with more than 1% lead were relatively rare in other parts of Eurasia. This is very different from the phenomenon in East Asia, where more than half of the analysed metal objects contain more than 1% lead (Figure 1.3).

In early China, historical and archaeological records show us two different yet related pictures of lead. In the case of historical records, a major problem which needs to be raised from the beginning is their dates. The dating issue is related to two types of early texts. One type which I will mainly rely on is those written on objects—oracle bones, ritual bronzes, bamboo and wooden slips, and silk. The dates of these texts are often (but not always) relatively well-

²³ Fragments of litharge, a by-product of cupellation, were found at Fatmalı-Kalecik and Habuba Kabira (see footnote 19) as well as a few Aegean sites, see Papadopoulos 2008.

²⁴ One example is the socketed axes from the Late Bronze Age British Isles, see Brown and Blin-Stoyle 1959; Hughes 1979; Northover 1977: 65; 1980: 235; Northover 1982a; 1982b. See also examples of high-leaded bronze objects from continental Europe: Briard 1965; Butler and Steegstra 2002: 280–282; Craddock 1976; 1979; 1980a; De Lisle 1881; Huth 2000; Montero Ruiz 1993; Montero Ruiz et al. 2003; Nienhuis et al. 2011: 54; Nienhuis et al. 2013; Postma et al. 2011; Trampuz-Orel and Heath 1998; Trampuz-Orel et al. 1998. Another common use of leaded bronze is as coins, see Craddock 1977: 15; Haselgrove 1988; Nriagu 1983: 214–215; Sastry et al. 1983 from Srinivasan 1998.

²⁵ Pollard 2018.

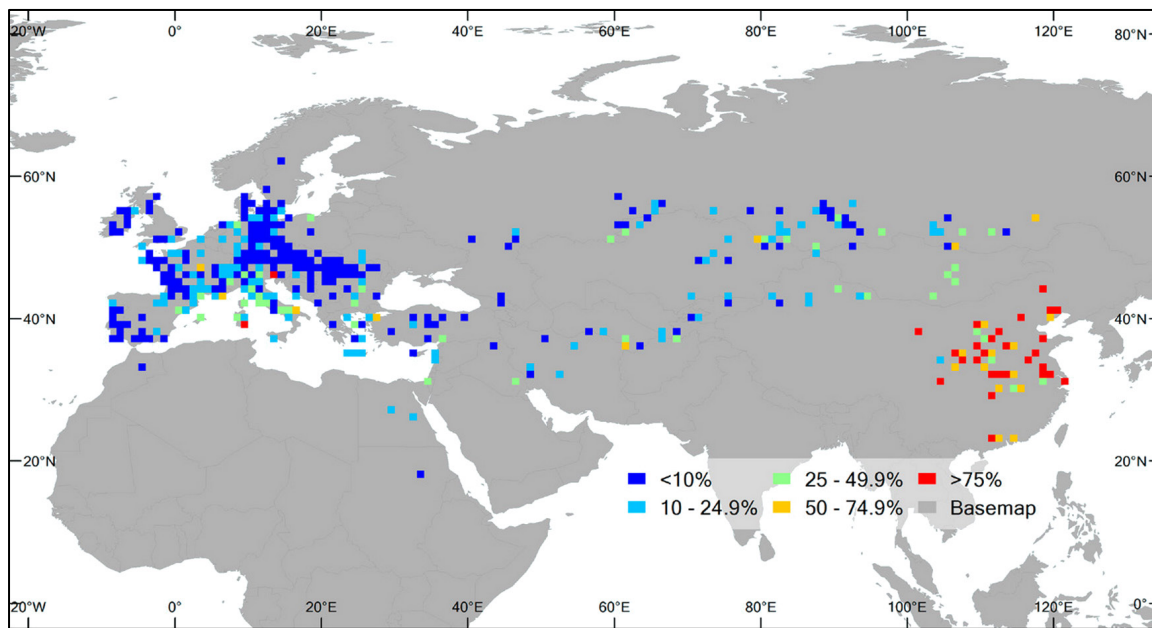


Figure 1.3 Distribution of sites showing the ubiquity of alloys with >1% lead, FLAME Project (after Pollard 2018: 130).

established, since the objects can be directly dated.²⁶ Another type of early text is those passed down through the ages. Some of these texts may already have emerged in the first millennium BC. They were compiled and largely recompiled in the first millennium AD and thus developed through various editions. The earliest editions of these texts as we can see nowadays are usually transcribed or printed in much later eras, especially during the Song (10th–13th centuries) and the Ming (14th–17th centuries) dynasties, as the emperors favoured recompiling old books, also as new printing technologies facilitated their wide copying. An obvious problem with these texts is that they are not contemporary with the events described. When the texts were reedited and recompiled, old narratives were sometimes altered and replaced by the editors and compilers.

²⁶ In some cases, the dates are either written or hinted (usually by people or famous events) in the texts, such as in the case of the vessels of the Lord of Cai, which will be discussed later. Otherwise, we may be able to date the text by the typology of the objects, such as the bronze vessels. Some writing materials, such as papyrus, can also be directly dated by radiocarbon dating. Dating of late Shang oracle bones, see also Keightley 1978: 91–133.

Therefore, the dating of a certain paragraph or a text usually rely on evidence such as writing style.²⁷

In terms of the first type of text, written records about lead or about metals and metallurgy in general were rare before the Han dynasty (202 BC–AD 220).²⁸ The first few references to metallurgy are inscriptions on late Shang (c. 1250–1046 BC) oracle bones and bronzes from Yinxu. These inscriptions mention something called  or  (modern characters: *lǚ* 呂).²⁹ For example, on a bronze *zun* 尊 vessel unearthed near the Liujiazhuang Village in Yinxu, the inscription is identified by the scholars as:

辛丑，亞易彭呂，用作母丁彝。

Xinchou (day 38), Ya awards Peng *lǚ*, (who) herewith makes (this) vessel for his mother Ding.³⁰

The character  itself is likely to be the pictogram of pie-shaped metal ingots. Most discovered early ingots of late Shang and the succeeding West Zhou (1045–771 BC) periods are indeed in this shape (Figure 1.4).³¹ In addition, *lǚ* is often in texts together with *huang*  (黃), meaning “yellow”, as . Some scholars suggest that this yellowish metal is probably bronze.³²

²⁷ Giele 2003.

²⁸ Online database for early texts: “*Lexicon of pre-Qin Oracle, bronze inscriptions and bamboo scripts*” (https://inscription.asdc.sinica.edu.tw/c_index.php). This is a database created by the Institute of History and Philology, Academia Sinica in Taiwan, with free access to the references of most pre-Qin texts.

²⁹ Yao, X. and Xiao, D. 1988: v. 2, 660; 1102; *Zhongguo* 2007c: v. 5, 3671.

³⁰ *Zhongguo* and *Anyangshi* 2008: 28. See also Yan, Z. 2009. English translation by the author.

³¹ Lead pie-ingots found in Yinxu: Tang, J. 2018.

³² Yan, Y. 1973. See also Li, J. and Li, Y. 2010.

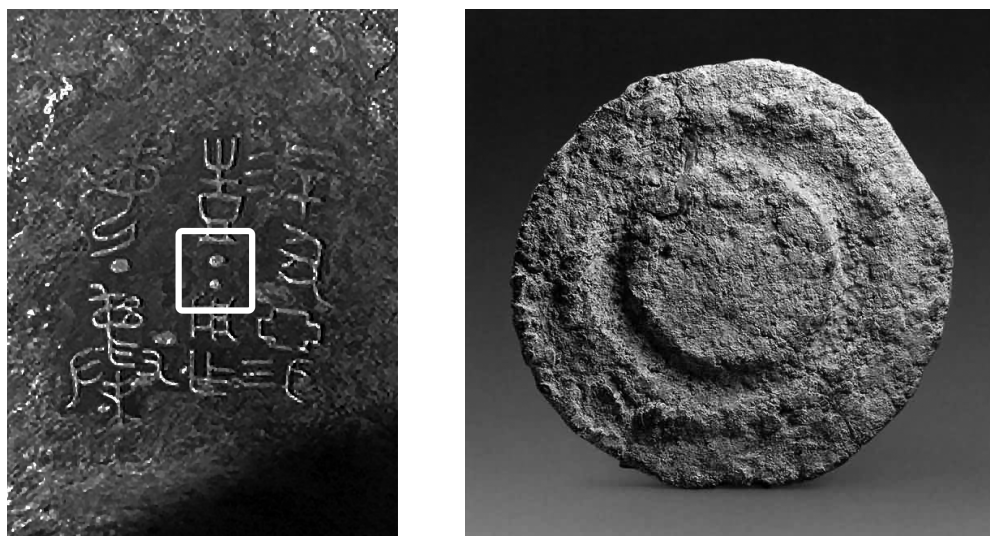


Figure 1.4 The pictograph of metal ingot. Left: inscription of the *Pengzun*, showing the character of 呂 *lǚ* 呂 (after Yan, Z. 2009); right: round shaped Western Zhou copper or bronze ingot found in the Fufeng County, Shaanxi (after Cao, W. 2005: v. 10, 2230).

Another character which is often placed before *lǚ* or *huanglǚ* is 𠩺 or 𠩻. Based on the pictorial resemblance (a human figure or two hands working on a vessel) as well as the contexts, scholars believe that the meaning of the characters is “casting” (*zhu* 鑄).³³

In the Western Zhou and the Spring and Autumn (771–476 BC) periods, the character 𠩺, with two hollow ovals replaced with two solid dots, further developed to 𠩺 or 𠩻.³⁴ In most early contexts, this character, later standardised as *jin* 金, means “metal”, especially copper and copper alloys.³⁵ In addition, the character *jin* is often used with other colour-meaning characters, such

³³ See the first two citations in footnote 29.

³⁴ Zhongguo 2007c: v. 3, 2306; v. 4, 3005. The character 𠩺 also appeared on some late Shang oracle bones. But in those cases, the character did not have a specific meaning related to metals. See Li, J. and Li, Y. 2011.

³⁵ Li, J. and Li, Y. 2011. In modern Chinese, the character *jin*, when used alone, means gold in particular.

as *chijin* 赤金 (red metal) and *baijin* 白金 (white metal). The white metals, *baijin*, as suggested by some scholars, are likely to be silvery metals such as tin and lead.³⁶ One particular inscription is on a set of Spring and Autumn metal bells. It says that the son of the king “chooses good metals to make such bells”, so that they are “neither white nor red (in colour), neither high nor low (in tune)”.³⁷ It is interesting to see that a colour between red and white was considered ideal, as the colour of bronze is exactly between the reddish colour of pure copper, and the greyish colour of tin and lead (see Chapter 4).

A few more characters and words were also used in bronze inscriptions to represent metals. According to their contexts, these characters may represent metals of a silvery colour. One of them is  (*fu* 鑄).³⁸ Scholars suggest that the word *fu* or *fulü* 鑄鋁 represents copper alloys.³⁹

In the inscriptions, *fu* is often used together with *xuanliu* 玄鏐, *liujin* 鑲金, *qiao* 鑄 and *la* 鑛 for casting bronze vessels. These words are likely to represent greyish (suggested by the character *xuan* 玄, meaning “dark”) metals alloyed with copper, especially tin and lead, or their alloys.⁴⁰

The character  or  (*xi* 錫), later reserved to refer to tin (but sometimes also to lead), appeared first on a late Shang oracle bone and on some Western Zhou bronzes, but according to the contexts, this character in those cases means “give/grant”, not “tin”.⁴¹ The first use of *xi* to represent a metal is in a Spring and Autumn bronze inscription, read as “*jindao xixing* 金導錫

³⁶ Li, J. 2010; Li, J. and Li, Y. 2011.

³⁷ Zhongguo 2007c: v. 1, 208–219.

³⁸ Zhongguo 2007c: v. 4, 3003.

³⁹ Cen, Z. 1958; Li, J. and Li, Y. 2010.

⁴⁰ Cen, Z. 1958; Hua, J. 1989; Huang, X. 1995; Li, J. and Li, Y. 2010; Yi, D. 2013a; Li, J. 2016; 2017a; 2017b.

⁴¹ Oracle bone: Yao, X. and Xiao, D. 1988: v. 1, 142; bronze: Zhongguo 2007c: v. 2, 1417; 1447; v. 3, 2268–2269.

行”.⁴² Some scholars suggest that this text refers to the transportation of two metal resources, *jin* and *xi*, between the southern and the northern regions.⁴³ Another character which is related to *xi* is 錫 (*yun* 銑). It is sometimes mentioned together with *xi* as another type of metal.⁴⁴ The character later used for lead, *qian* 鉛, may derive from this old form.⁴⁵

As the contexts suggest, these silvery metals were sometimes alloyed with copper for producing ritual vessels. However, based on these texts, we cannot simply attribute any character to tin or lead. Nor do we know whether tin and lead were considered to be two separate metals. One potential exception is the inscriptions on two late Spring and Autumn bronze vessels, as a pair, commissioned by the ruler Helü of Wu (r. 515–496 BC) and discovered in the tomb of the Lord of Cai.⁴⁶ The inscription shows that King Helü commissioned the bronze vessels as a gift to his daughter, who was probably married to the Lord of Cai. The message also mentions that three components are selected for the casting of the vessels: *jijin* 吉金, *xuanguang* 玄銑 and *baiguang* 白銑. By referring to other bronze inscriptions, we are pretty sure that *jijin* means copper or copper alloys. Then what do *xuanguang* and *baiguang* refer to? Some scholars suggest that the character *guang* 𤝵 is not a particular type of metal, but an alternative form of *kuang* 礦, meaning “ore” or “mineral” in general. *Xuanguang* and *baiguang*, thus, may refer to two types of mineral, one dark (*xuan*) and one white (*bai*).⁴⁷ As we also know, lead and tin were often

⁴² Zhongguo 2007c: v. 4, 3008–3009; object: Fang, H. and Wang, S. 2018.

⁴³ Yi, D. 2013b; 2018.

⁴⁴ Zhongguo 2007c: v. 4, 3003.

⁴⁵ Cen, Z. 1958.

⁴⁶ Text and translation: Zhongguo 2007c: v. 7, 5551–5552. See also Zhu, Z. 2006: 49–54; archaeological background of the object: Anhuisheng 1956: 9.

⁴⁷ Guo, M. 1956; Cen, Z. 1958; Cui, H. 1998: 180.

referred in many ancient languages to as one type of metal but in two colours.⁴⁸ In ancient Chinese, white lead pigment was sometimes called “tin pigment”.⁴⁹ A tenth century AD Chinese text, titled *Taiping Huanyu Ji* 太平寰宇記 (*Universal Geography of the Taiping Era*), notes that “the excellent tin is named lead; lead is white tin.”⁵⁰ Therefore, it is likely that these two types of metal mentioned in the inscriptions are in fact tin and lead.

As in all studies relying on historical materials, we should probably note that textual materials only reflect the ideas and knowledge from the perspectives of certain individuals. In this case, the texts, as they were inscribed on ritual bronzes, mainly reflect the ideas of the commissioners and the metalworkers of the bronzes. These ideas do not reflect how people in the community as a whole, or artisans among metalworking communities but without a writing tradition, thought about the metals. Nevertheless, by reviewing these ancient texts, we can at least suggest that, by the end of the Spring and Autumn period (around the fifth century BC), people in some parts of China used several different metals in casting ritual vessels. Although we cannot exactly match the meanings of the ancient characters to any particular types of metal in our modern sense, it seems that people used at least two types of metal. One was the metal or metals with a golden or yellowish colour, which probably represented copper or copper-based alloys. The other was metals with a greyish or silvery colour. As we know from the texts, “silvery metals” were always used together with the golden ones for casting ritual bronzes. We may further guess that people knew more than one type of “silvery metal”, and tin and lead may have been two of them. However, at least two things remain unclear according to such texts. First, we do not know whether people at that time made clear distinction between different “silvery metals”. Second, we do not know if the “silvery metals” had other uses besides making ritual bronzes. Furthermore,

⁴⁸ Overview, see Nriagu 1983: 1–4.

⁴⁹ A modern example of such a linguistic confusion is “tin foil”. Although those cooking foils have long been made of aluminium instead of tin, the misleading name is still widely used.

⁵⁰ Yue, S. 2007: 3023. English translation by the author.

since the earliest texts can only be dated to the late Shang period, which is after 1250 BC, we cannot learn from the texts how the metals were used before that time. For these questions, I will move to the archaeological records to see if they can provide more information.

Archaeological evidence of early lead objects or lead production, nevertheless, is also extremely rare. So far, only a few lead objects dating to the second millennium BC have been found on the modern territory of China (Table 1.1) (Figure 1.5). Despite the small sample size, these lead objects represent three types of metal use. The first is to make small personal ornaments with lead, such as a mace head and a cowrie-shaped object from Dadianzi, North-east China. In some other cases, people also used other silvery metals to make similar objects, such as several silver and tin personal ornaments (earring, nose ring, etc.) found in the Hexi Corridor and Xinjiang. As I will elaborate in Chapter 6, these objects reflect a wide Eurasian phenomenon of valuing materials with a silvery colour. The second type of lead use is seen in the middle Yellow River Valley, the core area for using ritual bronze vessels. Silvery personal ornaments were probably not used in this area during the first three quarters of the second millennium BC, since such objects have never been found. Lead objects which can be dated to this period are all without regular forms. As scholars have suggested, these lead objects are probably ingots for casting leaded bronzes.⁵¹ Besides these two types of lead use, in the last quarter of the second millennium BC, cast lead ritual vessels and weapons also appeared in Central China,⁵² especially at Anyang. For example, in the tomb M255 of Dasikong, all seven ritual vessels and two weapons

⁵¹ Nie, Z. 2019: 15–16.

⁵² Central China, or the Central Plains, is the geographic region which is loosely defined as the plains in the eastern part of today's China. See more in Chapter 2.

Table 1.1 Artefacts made of silvery metals, c. 2000–1000 BC.

Site	Object	Date (BC)	Reference
Anyang	lead weapons, vessels, ingots	1200–1040	Nie, Z. (2019: 17–25)
Dadianzi	lead mace head and cowrie	1750–1450	Zhongguo (1996: 189; 191)
Erlitou	two lead fragments (ingot?)	1650–1550	Nie, Z. (2019: 15–16)
Huoshagou	silver nose ring	1900–1700	Ma, H. (2013)
Xiabandi	silver earrings	1500–1100	Xinjiang (2012: 13)
Xiaohe	tin earring	1650–1450	Abuduresule et al. (2007)
Zhanglei	lead fragment (ingot?)	1600–1400	Li, H. et al. (2014)
Zhengxiao Zhuang	lead weapons and vessels	1050–1000	Liu, H. (1985)
Zhengzhou	lead fragments (ingots?)	1500–1400	Henansheng (2001: 320; 378)

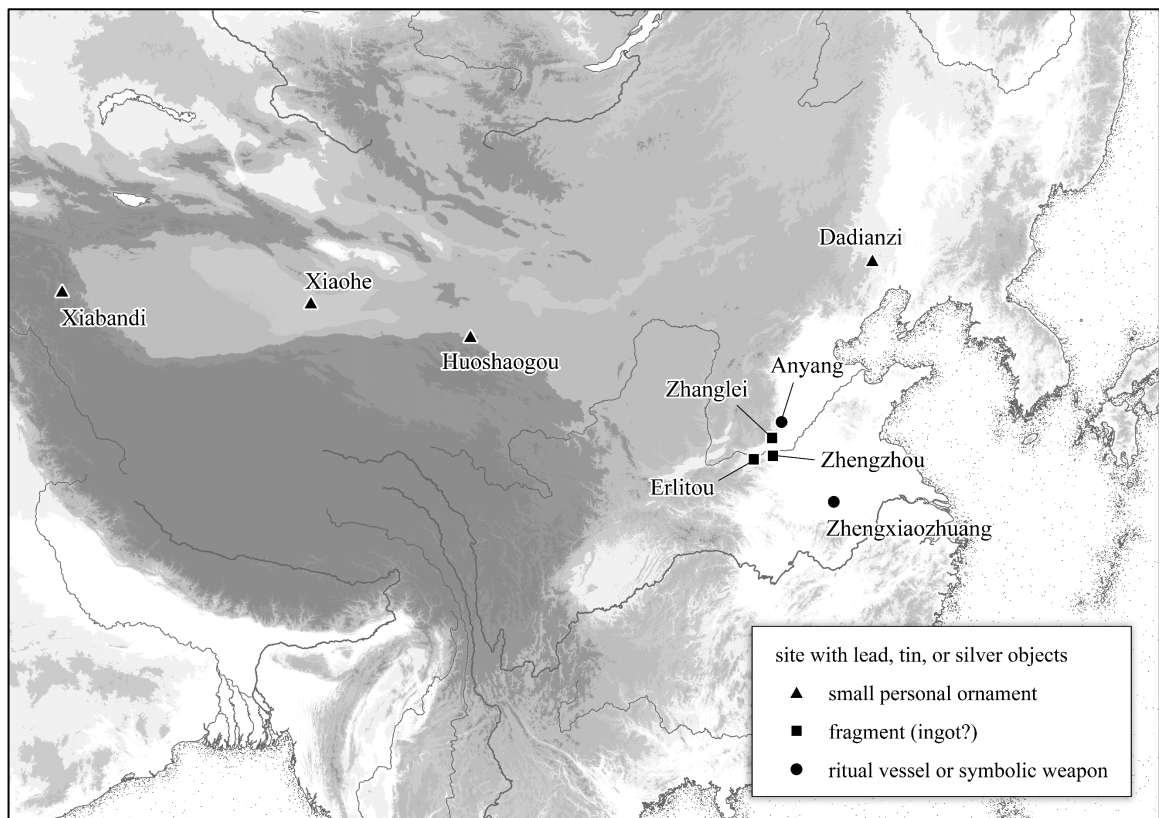


Figure 1.5 Sites with early “silvery” objects on the modern territory of China.

were made of lead.⁵³ Lead objects particularly used as grave goods to imitate bronze ones were also found in later periods, such as Western Zhou.⁵⁴ We will revisit this case in Chapter 7.

In summary, historical and archaeological evidence shows that, for most early Chinese communities, lead was probably considered an “add-on” rather than a “stand-alone” metal. That is to say, people did not commonly use pure lead to make objects, while the only obvious use of lead was to be added to copper and tin for bronze casting. This limited use of lead may be part of a greater divergence between the east and the west during the Early Metal Age, which is seen in the absence of silvery objects in early Central China. Silver was highly valued in most part of Eurasia. As I previously mentioned, the demands of silver were part of the reason for lead to become largely available. Many small lead objects made and used by early Eurasian communities may reflect this phenomenon.⁵⁵ In East Asia, on the other hand, neither many silvery objects nor cupellation was adopted by early communities.⁵⁶ Therefore, making bronze alloys seems to be the only reason for the production of lead. However, even for this single purpose, the scale of leaded bronze casting in early China was extraordinarily large, as I will show in the next section.

The Lead Problem in Chinese Bronzes: A Review

The presence of lead in early Chinese bronzes is a relatively new discovery. Scholars have long been aware of the large-scale metal production in early China, especially during the era from the second to the first millennia BC, or, in the traditional Chinese chronology, the period of the first

⁵³ Zhongguo 2014a: v. 1, 267–268.

⁵⁴ Nie, Z. 2019: 32–34.

⁵⁵ E.g. Nriagu 1983: 103–199.

⁵⁶ The earliest record of cupellation in China is in *Tiangong kaiwu*, see the discussion in Sun, S. 1996.

three “dynasties”: Xia, Shang, and Zhou.⁵⁷ In particular, the word “bronze” and especially its plural, “bronzes”, are sometimes reserved for a specific form of bronze object—bronze food and drink vessels made for ritual purposes.⁵⁸ The use of vessels, first in ceramic and later including bronze, has long been part of the ancestral and afterlife rituals. The production of bronze vessels boomed in the three dynasties, although there were plenty of replicators and followers of those early vessels by the subsequent dynasties. Most early bronzes were buried in tombs or deposited in hoards. Therefore, from time to time, bronze vessels were unearthed, either by serendipity or by deliberate treasure hunting. Meanwhile, how those bronzes were actually made was less understood. In ancient China, knowledge of bronze vessel casting was not well recorded and sometimes even forbidden. An ancient text called *Kaogong Ji* 考工記 (*Artificers’ Record*) is the best-known reference to the knowledge of bronze vessel casting. The current version of the text, dated by its writing style and contents, was probably written in the sixth to the fourth centuries BC and compiled around 50 BC.⁵⁹ In the text, six “mixing ratios” (*liuqi* 六齊) of bronze alloys were listed:

There are six different bronze alloys. *Jin* 金 and *xi* 錫 with a ratio 6:1 are used for the manufacture of bells and ritual vessels called *ding* 鼎; in the ratio 5:1 for the manufacture of hatchets and axes; in the ratio 4:1 for the manufacture of lances and halberds; in the ratio 3:1 for the manufacture of large knives; in the ratio 5:2 for the manufacture of knives to cut bamboo strips for books and of lethal arrows; and in the ratio 2:1 for the manufacture of plane and concave mirrors.⁶⁰

⁵⁷ See e.g. Wang, T. 2018.

⁵⁸ In this thesis, in order to avoid any confusion, I still use the plural form of the term, “bronzes”, to refer to bronze objects in general.

⁵⁹ Guo, M. 1947; Wen, R. 1993: 144–157; Xuan, Z. 1993; Jin, J. 1998.

⁶⁰ Text and English translation: Guan, Z. and Herrmann 2019: 46–47. The oldest remaining version of the text is in the *Kaicheng Stone Classics* (AD 833–837), see *Zhonghua* 1997: v. 1, 635.

The text only mentions two types of metal: *jin* and *xi*. But the real meanings of these two names, as previously discussed, are not clear. As we now know, most bronze vessels were made of alloys of three metals: copper, tin, and lead. In order to coordinate the text and the objects, scholars suggest many interpretations of the text.⁶¹ Two suggestions, which I want to highlight here, consider *xi* as either tin only or the combination of tin and lead. I tend to agree with the first view. The argument is that tin is associated with the mechanical properties of the bronzes, and therefore needs to be precisely controlled. Meanwhile, adding lead is only meant to facilitate the casting, and therefore unnecessary to be recorded in formal recipes.⁶² For the use of lead in ritual vessel casting, I will discuss the issue in the following chapters, especially Chapter 4 (on the properties of lead in casting) and Chapter 5 (on communities producing ritual vessels).

In other crafting guidebooks, the authors sometimes even consider bronze vessel casting a secret. One of these books is Song Yingxing's *Tiangong Kaiwu (The Exploitation of the Works of Nature)*, a prominent encyclopaedia on ancient Chinese technology. This book was first published in AD 1637. In the bronze casting section, Song enumerated detailed methods for casting various objects: bells, cooking pots, statues, cannons, mirrors, and coins. However, in the section of ritual vessel casting, instead of describing the detailed operational procedure, Song wrote something as a mild warning to deter people who may be interested in doing so:

By the Ch'in dynasty (221–206 BC) the ting-tripods of Yu had been lost. ... In later ages there has been a multitude of documents and books, but ting-tripods were never made again. I have therefore noted their history here.⁶³

The story of the lost vessels of Yu the Great, the legendary founder of the Xia dynasty, was well known in ancient China. It is said that, when Qin Shihuang, the first emperor of Qin, united all

⁶¹ Zhang, Z. 1958; Zhou, S. 1978; Su, R. 1998; Lu, D. 1999; Sun, F. 2011; Yang, H. 2015.

⁶² Wu, L. 1986; Su, R. 1998.

⁶³ Sun, E. and Sun, S. 1966: 160.

the lands of the former three dynasties, he tried to retrieve Yu's *ding* vessel from a river. However, he failed in this task. This failure foresaw the ending of his short-lived dynasty.⁶⁴ As the possession of ritual vessels were always associated with the legitimacy of the ultimate political power, it is no wonder than Song did not want to write something about it in his book. Therefore, although bronze vessels were highly revered in ancient China, historical texts do not tell us much about the technology of their manufacturing.

The secret started to be unveiled in the early twentieth century when new archaeometallurgical methods developed and were used to analysed early Chinese bronze objects.⁶⁵ Masumi Chikashige is among the first who adopted these methods and discovered that some mirrors, swords, and bells he analysed contain more than 5% lead.⁶⁶ Later, this phenomenon was also noticed by Liang Jin. Liang further compared the chemical compositions of the objects he tested with the proposed alloy ratios recorded in *Kaogong Ji*. This comparison led him to argue that *xi* in *Kaogong Ji* refers to both tin and lead. However, the actual levels of tin and lead in the objects do not really agree with his suggestion.⁶⁷ In the 1930s, more analyses were done by William Collins and Tsurumatsu Dono.⁶⁸ All those pioneering studies confirmed the surprisingly high and common lead levels in Chinese bronze objects. As Dono summarized:

As for lead which is contained often in considerable quantities in the samples, it is hardly possible to think that it came from copper ores and it must rather be considered that this

⁶⁴ This story is recorded in Sima Qian's *Shiji (Records of the Grand Historian)*, see Watson 1993.

⁶⁵ For the history of chemical analyses of ancient Chinese metal objects, see Liu R. et al. 2015.

⁶⁶ Chikashige 1918; 1920a; 1920b; 1929.

⁶⁷ Liang, J. 1925.

⁶⁸ Collins 1931; Dono 1932; 1933; 1934.

metallic element was artificially added in order to increase the fluidity of molten copper and to make the casting more easy.⁶⁹

In the following decades, the academic understating of lead in early Chinese bronzes continue to improve as more analyses and studies were published. In particular, Noel Barnard collected most chemical data of Chinese bronzes available up till his time and pointed out that lead levels in Chinese bronzes vary with time and with object type.⁷⁰ Also in the 1960s, John Pope and Rutherford Gettens published their studies on the Chinese bronze objects from the Freer Gallery in Washington, D.C. Pope and Gettens' work shows that bronze vessels are in general more leaded than other types of bronze object. Only twelve of the total sixty-eight analysed vessels contain less than 1% lead, while lead content in weapons is relatively lower, but sometimes still exceeds 2%.⁷¹ These studies, as well as those in the following decades,⁷² all contribute to the three general views on leaded bronze which we still hold today. First, leaded bronze is the most popular type of copper-based alloy in early China, while this type of alloy was not commonly used by other early societies around the world. Secondly, in early China, the use of leaded bronze can be traced back to at least the Shang period (c. 1600–1046 BC), although we now know that these alloys may have been used before 1600 BC (Chapter 5). Finally, leaded bronze was commonly used for casting ritual vessels, a very special type of bronze object which were produced on a vast scale in early China.

At the same time, finds from newly excavated archaeological sites also attracted the interests of both metallurgists and archaeologists. The excavation Yinxu is one of them. The first excavation season started in 1928. In 1931, H. C. H. Carpenter was commissioned to analyse four metal

⁶⁹ *Dono* 1932: 352.

⁷⁰ *Barnard* 1961: 169–198. See also *Barnard* 1975; *Barnard and Satō* 1975.

⁷¹ *Gettens* 1967: 33–56.

⁷² E.g. *Bunker et al.* 1997; *Caley et al.* 1979; *Chase and Ziebold* 1978; *Chen, M.* 1954; *Cheng, T.* 1974; *Wang, J. and Yang, G.* 1959.

objects from Anyang and published his finds.⁷³ An obvious advantage of working on newly excavated objects is that scholars usually know more about the archaeological background of the objects, while those in museums and private collections often have questionable dating, provenance and even authenticity. The cooperation between metallurgists and archaeologists also points new directions for archaeological fieldwork, as some metallurgical remains such as smelting wastes—previously unfamiliar to excavators and were often neglected—are now better identified, recorded, and preserved. Ground-breaking work was conducted by the former Beijing University of Iron and Steel Technology (BUIST), the predecessor of the University of Science and Technology Beijing, especially by Sun Shuyun and Han Rubin from the 1970s. In this project, the researchers analysed hundreds of newly excavated objects across China. The results were published in a pioneering paper in 1981.⁷⁴ The works by Sun and Han and their colleagues contributed to a monograph series, starting from 1986, as well as several books.⁷⁵ Recently, archaeometallurgy is included in the state-sponsored “Searching for the Origins of Chinese Civilization” Project, led by Mei Jianjun and joined by three Chinese institutes. Many new research results have been published since the start of the project.⁷⁶

Answered and Unanswered Questions

According to my own review, about 2000 copper-based metal objects dating to the second millennium BC have so far been analysed and the results have been published. These objects are

⁷³ Carpenter 1978.

⁷⁴ Sun, S. and Han, R. 1981. See also Sun, S. and Han, R. 1997.

⁷⁵ Beijing 1978; 1986; Han, R. 2014; Han, R. and Ke, J. 2007; Sun, S. 2015; Sun, S. and Li, Y. 2003.

⁷⁶ Beijing et al. 2011; Linduff and Mei, J. 2009; Mei, J. 2009b; Mei, J. and Zhou, Y. 2016; Mei, J. et al. 2015.

from more than a hundred East Asian sites (see Appendix 2). The chemical data of these objects can provide us with an overall picture of the use of metals in early China.

The first question I want to approach with the data is, how many of the objects were made of leaded bronze? To determine whether the copper alloy is leaded or not, most previous studies suggest using 1% or 2% as the thresholds.⁷⁷ This is due to the fact that lead content above those levels usually brings significant changes to the properties of the metals, and are thus more likely, although still not necessarily, to be intentionally added. In the case of early China, since leaded bronze were very common and the lead content can sometimes be as high as 20%, I use both 2% and 5% as two criteria in order to show whether the objects are moderately or highly leaded. Among the analysed objects in my database, about half of them contain at least 2% lead, while around 30% of the objects have at least 5% lead.⁷⁸

The second question is, when did the use of leaded bronze emerge? This question is hard to answer since knowing the exact date of each object is almost impossible. Therefore, I adopt the following estimation. First, I still use 2% as the threshold to divide all analysed objects into eight chemical groups: pure copper, arsenical copper (with 2% arsenic), bronze (with 2% tin), arsenical bronze (with 2% arsenic and 2% tin), etc. Second, each object is given a time period based on either the dating of its context, or the dating of the object itself (usually by typology). Some objects can be dated quite precisely, indicated by relatively narrow time periods (e.g. 1800–1700 BC), while some objects can only be poorly dated, as the time periods are usually very wide (e.g. 1800–1000 BC).⁷⁹ In order to compare these objects chronologically, I divide the time periods into intervals with a fixed length of fifty years. Therefore, a leaded bronze object

⁷⁷ E.g. Forbes 1972: 51; Northover 1989: 225–227.

⁷⁸ The references to the chemical data are provided in Appendix 2. The data is available in the supplementary materials.

⁷⁹ The issue of dating and chronology will be further elaborated in Chapter 2.

dating to 1800–1600 BC, for instance, is treated as four occurrences of leaded bronze in the intervals of 1800–1750, 1750–1700, 1700–1650, and 1650–1600 BC, each with a relative frequency of 0.25. After this calculation, we can combine the frequencies of each chemical group in every fifty-year interval. This value is then normalized to 100% to compare the percentage that each chemical group contributes to this interval (percentage stacked bar chart). This method is explained in Figure 1.6.

With this method, the result is in Figure 1.7. As the chart shows, before 1600 BC, the major types of metal used by communities in today's China were pure copper (Cu) and bronze (Cu-Sn). There are also about 10% arsenical copper (Cu-As) among the analysed assemblages. Meanwhile, the percentages of copper with lead, either leaded copper (Cu-Pb) or leaded bronze (Cu-Sn-Pb), increased steadily. After about 1500 BC, leaded copper alloys became the majority, while arsenical copper almost disappeared. Due to the dating issue of individual objects, the time periods shown in this result are not likely to be very precise. Nevertheless, the overall pattern suggested by this estimation is still useful since it answers question of when leaded bronze started to be regularly used: around the middle of the second millennium BC.

The third question we may ask is, in which areas of China was leaded bronze mainly used? In Figure 1.8, I plot the sites with their percentages of leaded bronze objects among total metal assemblages. As this map shows, the use of leaded bronze was not a uniform phenomenon in early China. The two major river valleys, the Yangtze and the Yellow River Valleys, are the core areas where most objects were made of leaded bronze. Especially, in the middle Yellow River

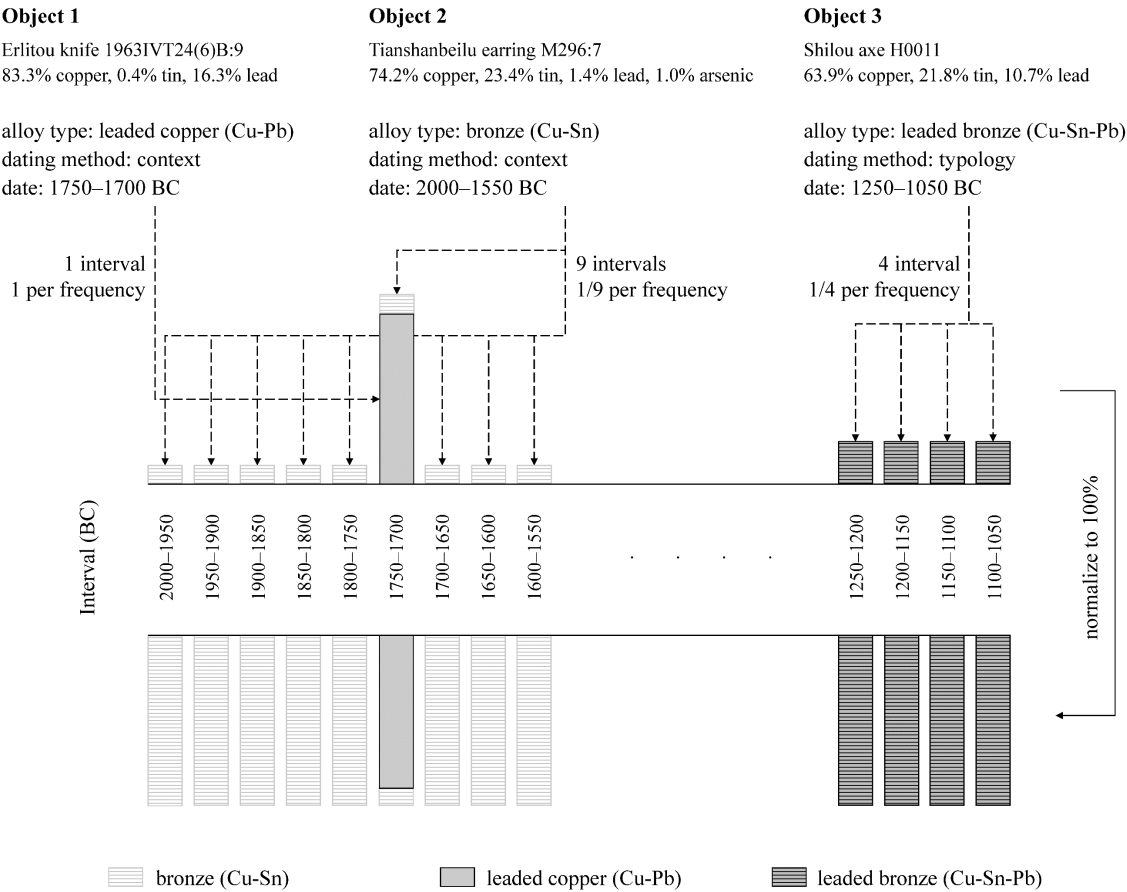


Figure 1.6 The statistical method used to identify the chronological development of metals by alloy type.

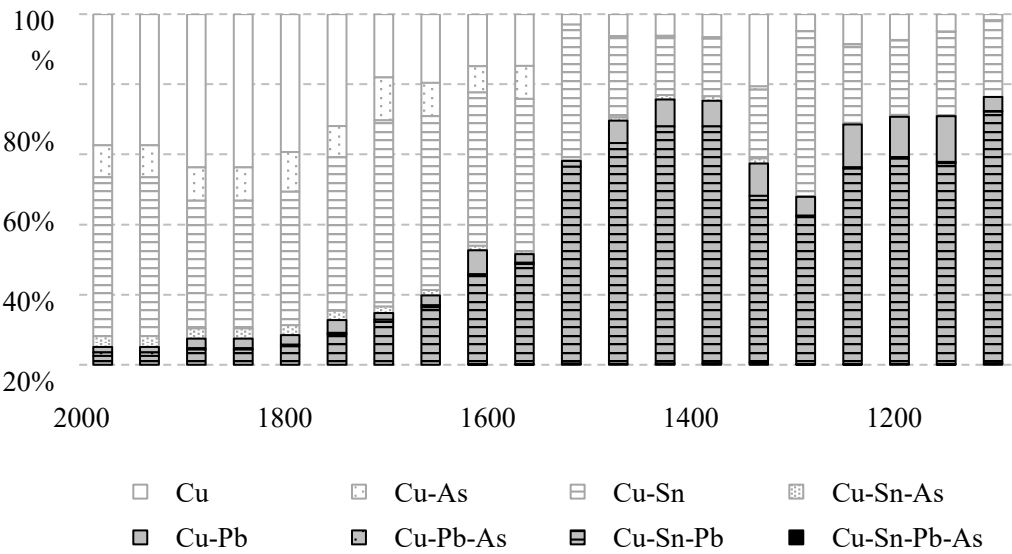


Figure 1.7 Percentage of analysed copper-based objects by alloy type (data: Appendix 2).

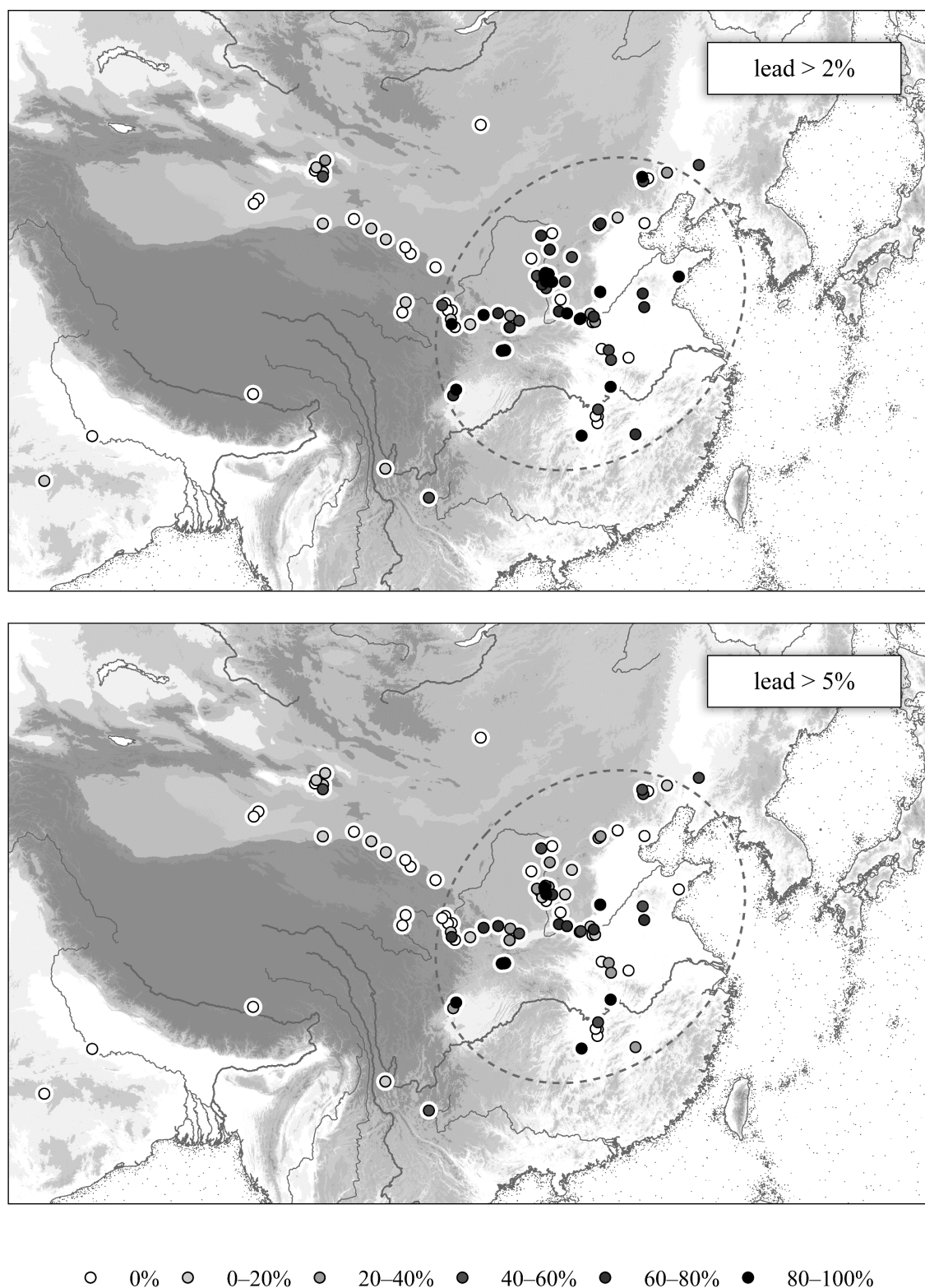


Figure 1.8 Percentages of leaded (over 2%) and highly leaded (over 5%) bronze objects in the metal assemblages, with the core area for the use of leaded bronze in early East Asia, second millennium BC (data: Appendix 2).

Valley, the beginning of the use of leaded bronze echoed the emergence of large settlement sites, such as Erlitou and Zhengzhou, which I will elaborate in Chapter 5. Erlitou, in modern Henan Province, is dated to 1750–1550 BC according to the current chronology established by archaeologists. This was the first time when leaded bronze objects appeared in the region.⁸⁰ Metal objects found in this region prior to Erlitou are all analysed as being made of either pure copper or of arsenical copper. Only one object, a small bell from Taosi in modern Shanxi Province, contains 1.5% lead.⁸¹ Among the analysed copper-based objects from Erlitou, on the contrary, lead is commonly seen and can sometimes be as high as 35% (Figure 1.9, a).

In the first half of the second millennium BC, leaded bronze objects were found among people in the northern Bohai Rim (Figure 1.9, b) and those on the Ordos Plateau, or the “Northern Zone” (c) as well. However, the average level of lead contents is not as high as that at Erlitou. In the case studies (Chapters 5 and 6), I will suggest that the leaded bronze objects used in these three regions were probably produced following different metallurgical traditions and technological choices. In other words, there is no single origin for all the uses of leaded bronze in early China. Instead, leaded bronze may have been produced and used in several areas during the first half of the second millennium BC under very different circumstances.

There is also a clear distinction on the map (Figure 1.8) between the core area, with most objects leaded, and Xinjiang and the Hexi Corridor, with most objects unleaded. If we use 2% as the threshold, about 60% of the total objects from the middle Yellow River Valley, which is roughly the modern Henan Province, are leaded. By contrast, for those from the Hexi Corridor (Gansu and part of Qinghai Provinces) and Xinjiang sites, only about 15% of the analysed samples are

⁸⁰ Zhongguo 1999b; 2014b. See also Chen, G. 2008.

⁸¹ Objects from three sites are analysed: Taosi: Gao, J. and He, N. 2014; Wangchenggang: Sun, S. 1992; Xinzhai: Zhang, X. and Yuan, S. 2008.

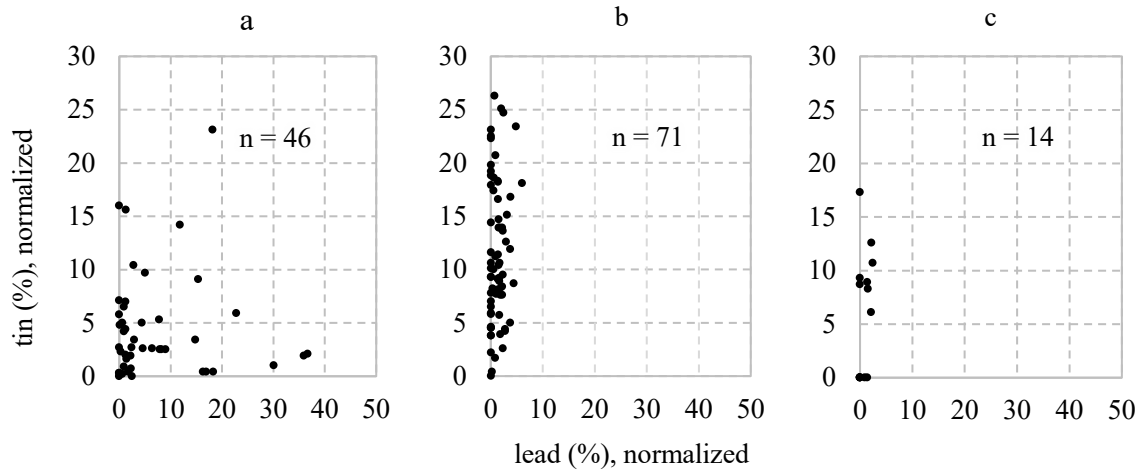


Figure 1.9 Comparison of the chemical compositions of analysed objects from: a: Erlitou; b: the northern Bohai Rim; c: the Northern Zone.

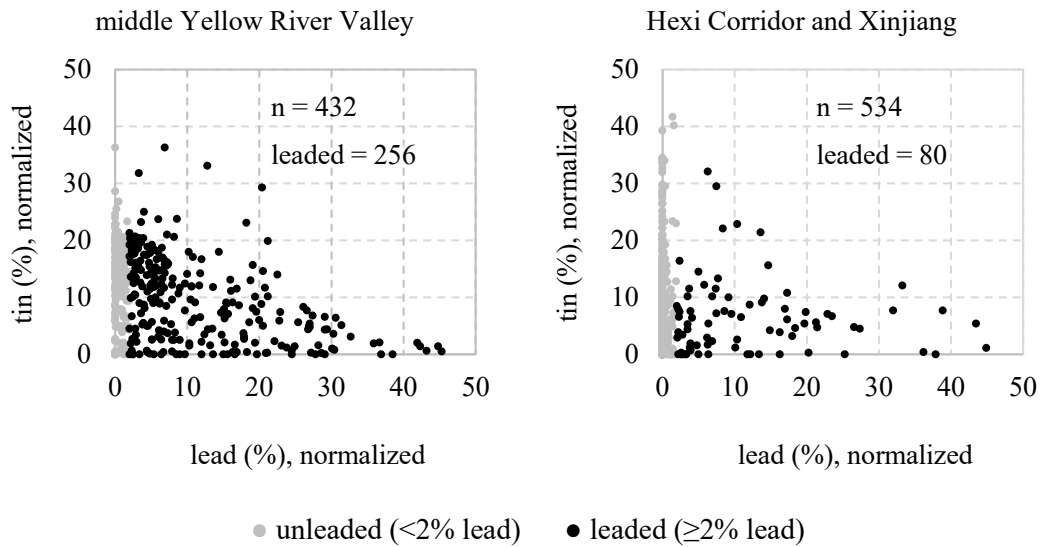


Figure 1.10 Comparison of tin and lead concentration in the copper-based objects from the central and the North-west China.

leaded (Figure 1.10).⁸² This regional difference suggests that not all communities chose to use leaded bronze. As I will show in Chapter 7, when this new material was welcomed in Central

⁸² The geography of China and these regions will be discussed in detail in the next chapter.

China, people in the Hexi Corridor and Xinjiang may have chosen to avoid lead when making their metal objects.

In the second half of the second millennium, the core zone of leaded bronze expanded as more communities in and between the Yellow and the Yangtze Valleys adopted this type of copper alloy in shaping their new material culture. At the same time, cultural contact between different regions may also have pushed this new material into new territories, such as the Sichuan Basin.⁸³

At some sites, the use of leaded bronze became more standardised. Anyang is one of the best examples, as leaded bronze became not only the predominant material for bronze objects, but the level of lead in the objects also became more regular.⁸⁴ Some scholars also argue that the lead level in Anyang ritual bronzes seem to be related to the social status of their owners.⁸⁵ In this thesis, I will not discuss Anyang in detail, except as a comparative case study in Chapter 7. Some recent studies on the alloy practices of this site can be found in Liu Ruiliang's thesis and articles, as part of the FLAME project.⁸⁶

Beyond the modern territory of China, it seems that leaded bronze was not very common in the nearby areas, such as on the Mongolian Plateau, during the second millennium BC. Studies show that, only from the first millennium BC, leaded bronze objects were frequently seen in Mongolia and on the Steppe. As Hsu Yiu-Kang suggested, this is probably due to the recycling of metals from China.⁸⁷ Therefore, based on the current data, the use of leaded bronze seems to have been a phenomenon which originated among a few communities in China's two river valleys and was then adopted by some of their neighbours.

⁸³ More discussion in Chapter 2.

⁸⁴ Li, M. 1982; Ji, L. 1997; Zhao, C. 2004; Uchida and Iizuka 2015.

⁸⁵ E.g. Zhao, C. 2004; Liu, Y. et al. 2007a.

⁸⁶ Liu, R. 2016: 319–323; Liu, R. et al. 2020.

⁸⁷ Hsu, Y. 2016: 228–230; Hsu, Y. et al. 2016; Park et al. 2011.

After reviewing the chronological development and the geographic distribution of the use of leaded bronze, our next question is, why was this material used? Currently, the commonly held argument is that the addition of lead can facilitate casting so as to achieve a better casting result. This view echoes suggestions made by scholars studying early leaded bronze used in other regions.⁸⁸ Scholars supporting this view include Chikashige, Collins, Tsurumatsu, W. P. Yetts, Rutherford Gettens, Thomas Chase, and Katheryn Linduff.⁸⁹ As Linduff summarized:

Although it is still not known exactly how the lead was introduced into the alloy, it is certain that the melting point of the mix was lowered by such addition, that it produced a cleaner cast, and that it made for easier finishing operations, such as removal of ridges and flaws, and for simpler final burnishing. Lead causes this in any mixture. Since the molten material could flow more easily and shrink less rapidly, the addition of lead allowed for the use of more complicated and intricate designs. And even though the exact proportions of the metal were not apparently standardized ... Lead was consciously added in a relatively consistent proportion in Shang and would be included often in higher proportion during the Chou Dynasty, though regional preferences must be considered.⁹⁰

The material science mentioned here will be explained in Chapter 4. These points raised in the above paragraph reflect a functional approach to the use of leaded bronze. That is to say, the material used for an object is partly related to the functions the object is supposed to fulfil. In addition to these functional interpretations, scholars working on early metallurgy in other regions also suggest that the use of leaded bronze, or any type of copper alloy, may have been associated with other properties of the material, such as its colour, touch, taste, and sound.⁹¹ These sensory

⁸⁸ E.g. Craddock 1979; Hyman 1923; Northover and Staniaszek 1982; Staniaszek 1982.

⁸⁹ See footnotes 66; 68; Chase 1983; 1994; Chase and Ziebold 1978; Gettens 1967: 42; Yetts 1931.

⁹⁰ Linduff 1977: 13–15.

⁹¹ E.g. Baker 2013; Busatta 2014; Chapman 2007; Hosler 1994; 1995; Jones 2004b; Keates 2002; Mödlinger et al. 2017; Radivojević et al. 2018.

interpretations remind us that metal objects all had a particular cultural and social context. For early Chinese bronzes, literature from the sensory perspectives is still lacking. This may be a direction for future research. Later in Chapter 4, I will also review some properties of leaded bronze from a sensory perspective.

While both the functional and the sensory approaches assume that lead contents in the bronze alloys were added on purpose, we should not rule out the possibility that lead was introduced unintentionally. To fully understand the process of alloying requires researchers to investigate not only the final products, but also archaeological materials such as ores, reaction vessels, and waste products. This will be elaborated in Chapter 3.

After this brief review, here are what we do and do not know about the use of leaded bronze in early China. First, we know that, as an overall picture, leaded bronze was one of the most used metal materials in early China. What we do not know, however, is whether this ubiquity of leaded bronze had a uniform cause. In other words, did these early communities all adopt leaded bronze for the same reason? Did people all choose the same technology? Or did a few communities produce all the leaded bronze objects and then distribute them in the whole area? To answer these questions, I will choose communities from four different regions in early China to investigate how metal objects were produced and used by them. Some of these communities were relatively big, with large-scale metal production; some were quite small, with only limited use of metal objects. By choosing these communities with diverse geographic and cultural backgrounds, I want to show that there were various reasons for using (or not using) leaded bronze.

Second, the large amount of chemical data published over the past decades makes it possible to demonstrate broad regional patterns, such as the one shown in Figure 1.3. Thanks to these publications, we can now identify the use of leaded bronze as a regional phenomenon. In addition to the data, there are also crucial studies on the metal properties from scientific perspectives,

such as the performance of leaded bronze in casting. The combination of chemical data and material science has offered some potential explanations for the use of leaded bronze. However, most scholars tend to see the addition of lead as driven by functional reasons, that is, to improve certain properties of the alloys. This approach sometimes simplifies the real problem. Objects with the same chemical composition do not always have the same function (e.g. a leaded bronze vessel vs. a leaded bronze earring). Moreover, lead in these early metal objects was not always added to on purpose. Therefore, we need to go beyond the chemical question of leaded bronze and think of the material from both scientific and cultural perspectives. I will further discuss these issues in Chapters 3 and 4.

Finally, no material culture can really be adopted by everyone in a given community. It can only be adopted by some people for some purposes. In other words, to understand the adoption of a material, we need to pay more attention on the particularity rather than on the universality of metal usage. For example, what types of object were commonly made of that material, and what types of object were not? Which group of people in the community was using the material, and which was not? Previously, most research focus was on bronze ritual vessels, as these objects really represent the high achievement in both art and technology. However, since most ritual vessels were owned by people with relatively high social status, what the use of these objects reflects is just views and practices by a certain group of people. Meanwhile, we know very little about people from other social and cultural backgrounds and how their engaged with metals. For this reason, I will try to include metal-using people from different backgrounds in my case studies. In Chapter 5, I will still focus on ritual vessels in order to show how the use of leaded bronze was affected by social and economic factors. In the other three case studies, Chapters 6–8, I will discuss people in communities who did not own bronze vessels.

How This Research Unfolds

In the above discussion, I have already mentioned some topics that will be elaborated in the following chapters. In this section, I want to introduce the whole structure of this thesis and the main content in each chapter. This thesis has two main parts. Chapters 2, 3, and 4 forms the geographic, theoretical, and scientific backbone of the study. These chapters also aim at responding some of the unanswered questions raised in this introduction. As this research focuses mainly on the archaeological finds in China, it is necessary to explain what “China” means. Therefore, Chapter 2 introduces the geographic scope of this research and some important regions in China. Some of the regions, such as Central China and the Hexi Corridor, have already been mentioned in the introduction. Besides, the topic of interregional cultural contact, as related to the early development of metallurgy in East Asia, is also discussed here.

Chapter 3 articulates technological choice as a type of human behaviour which shapes material culture. In this chapter, copper alloys are examined as a particular type of material culture which is influenced by both natural and cultural factors. For human activities involved in the creation of alloys, several possible technological choices are suggested to argue that there are multiple scenarios regarding the formation of alloys. Finally, to supplement the mostly theoretical discussion, an example is given to show the potential for answering technological questions by taking a holistic approach in research.

As the use of a material is partly related to the agency of the material itself, Chapter 4 investigates the properties of leaded bronze reflected in the production and the use-life of the metal objects. By seeing properties as both effects and events, this chapter demonstrates how the properties of leaded bronze may have encouraged the technological choices of whether to use this material.

These chapters are followed by Chapters 5 to 8, which present four case studies on people’s relations with leaded bronze. The case studies cover early metal-using and metalworking communities in Central China, the northern Bohai Rim in North-east China, the Hexi Corridor

of North-west China, and the lower Yangtze Valley in South China. The reasons behind choosing these four case studies are briefly explained in Chapter 2. By comparing the case studies, I argue that people did not simply adopt leaded bronze and add it to their material culture. Instead, different responses can be seen in different communities. This result echoes the theoretical discussion in Chapter 3, as technological choices are not based on single factors, but on an overall effect of human-thing engagements.

In Chapter 9, the discoveries in the case studies are drawn together to support my main argument of this thesis, which is a new explanation for the emergence of leaded bronze use in early China. In this explanation, the production of leaded bronze ritual vessels in Central China, probably driven by socio-economic factors, led to the recycling and reuse of this metal in other regions. Meanwhile, the particular properties of leaded bronze—high castability, low strength and hardness, greyish colour (compared with unleaded bronze)—as well as its close relations with other silvery metals (especially silver and tin) also contributed to technological choices of accepting or rejecting this material. With this enriched picture, the use leaded bronze can be seen as a special example for us to recognise and to appreciate the complexity and diversity of technology and material culture in the early Metal Age of China.

The Geography and the Early Metallurgy of East Asia

For the purposes of this thesis, I define China as the territory of modern China. It lies at the eastern end of the Eurasian continent (Figure 2.1). China occupies the major continental part of what we now call East Asia, which is encircled by the Eurasian Steppe in the north, the Tian Shan and the Pamir Mountains in the west, the Himalayas and the Indian subcontinent in the south-west, the Mainland Southeast Asia in the south, and the Pacific Ocean in the east. About 56 million years ago, Laurasia, one of the two large landmasses derived from the Pangaea supercontinent, started to break into smaller pieces, including the Eurasian plate in the north and the African plate, the Arabian plate, and the Indo-Australian plate in the south. These new-born plates collided with each other, creating a Eurasian landscape with mainly east-west mountain ranges.¹

For East Asia, the collisions of the plates left this region with what I may call two “oceans” on its northern and eastern sides, and a “butte” on the south-western side. To the east, there is the vast Pacific Ocean and different interconnected seas and bays. Seafaring across these waters certainly emerged during the Neolithic and even the Palaeolithic periods, suggested by the early occupation of the islands and the connections in the material culture between the coastal

¹ For this geographic background and its impact on population movement, see Cunliffe 2014: 1–33.

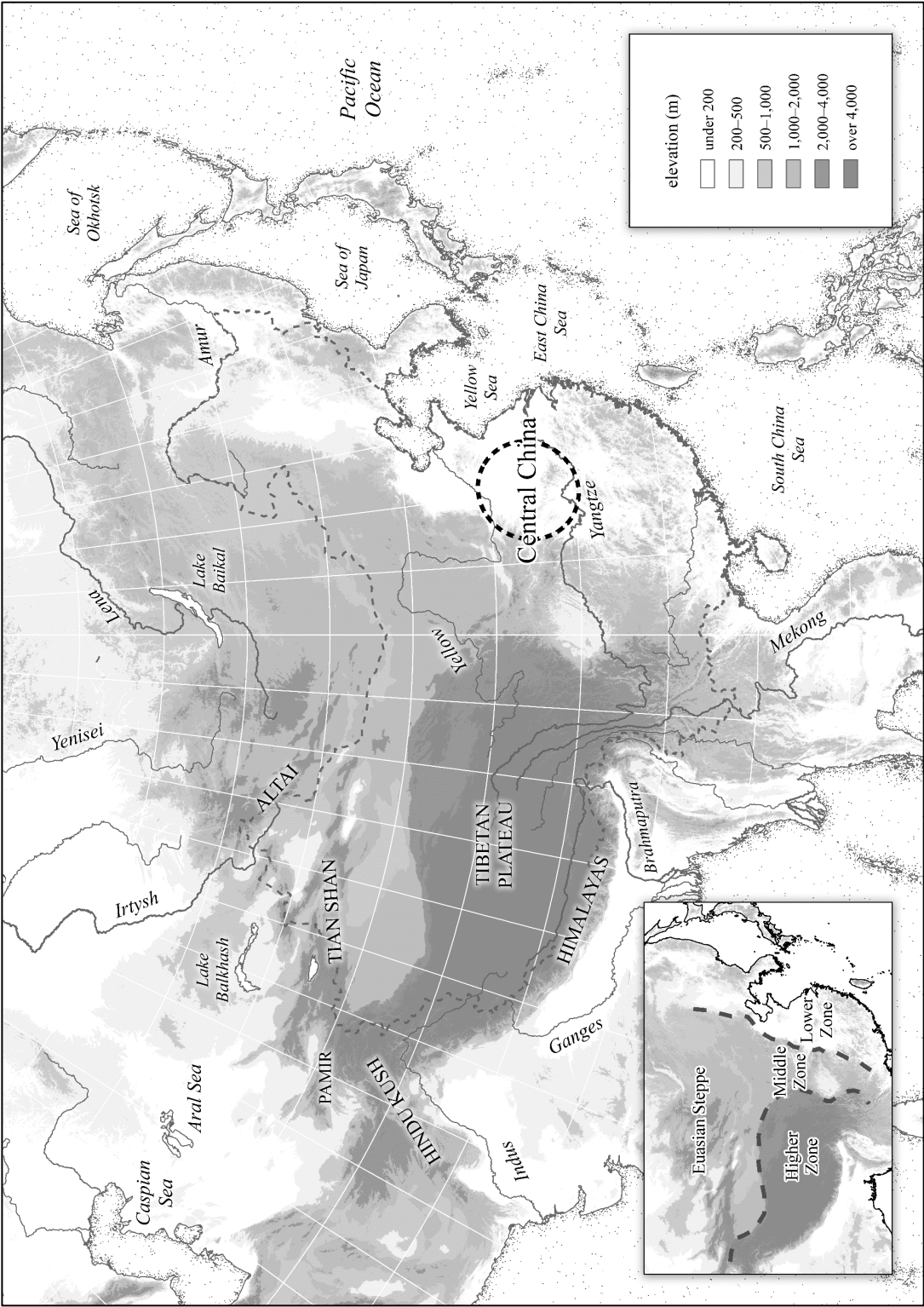


Figure 2.1 The geography of East Asia, the modern territory of China, and the approximate area of Central China (the Central Plains).

communities.² In terms of the development of metallurgy, maritime exchanges also played a role in certain areas, such as the bay area around the Yellow Sea, as we will discuss later in this chapter. On the northern and north-western sides of East Asia, there is another “ocean”—the Eurasian Steppe (also known as the steppes). This is an ocean of endless mountains, grasslands, and deserts. I use ocean as a metaphor since steppe and ocean share one thing in common: for people who are properly equipped, with horses for the former and with boats for the latter, these two types of environment both provide almost unlimited travelling in all directions and usually with fairly high efficiency.³ The movement allowed the wide-spreading objects and ideas in the landscapes. However, just like oceans where little trace was left by people who passed by (provided that the ships did not sink), the steppes are also a challenge to archaeologists, as most archaeological sites tend to be smaller, more sporadic, and “thinner”—with fewer deposits than those in large settled agricultural areas. It is even harder to investigate the use of metal on the steppes since those early metal objects are portable and precious. People tended to carry the objects with them, and to remelt the objects when they were no longer used. Between these two “oceans”, travelling is much more restrained, but not impossible. As I will show in a later section, people may have relied on certain geographic features, such as mountain corridors and river valleys, to move from one area to another.

On the south-western side of East Asia lies the Tibetan Plateau. The Tibetan Plateau has an area of about 2.5 million km², or one fifth of East Asia. Nevertheless, archaeological finds are still very limited due to its extreme condition. The plateau has an average elevation over 4,500 metres, and there are a series of mountain ranges on all edges of the plateau. Climbing onto the plateau from any direction is a difficult job since people need to overcome not only the harsh terrain but also altitude sickness. These difficulties make the Tibetan Plateau like a “butte”. Butte is a

² E.g. Kuo, S. 2019; Wu, C. and Rolett 2019; Palaeolithic seafaring in East Asia: Kaifu et al. 2019.

³ A similar metaphorical term is “steppe highway”, suggested by Di Cosmo 2002.

geomorphological name used for a hill with almost vertical steep sides and a flat top in the Western United States, like the famous Devils Tower in Wyoming. But like most buttes, the Tibetan Plateau is not insurmountable, and it is certainly not a no man's land. Various studies show that, in the second millennium BC as this thesis focuses on, the Tibetan Plateau was already an area where crucial materials and technologies were exchanged.⁴ In particular, the research in the recent decade argues that domesticated crops—millet from western China, wheat and barley from Central and South Asia—all appeared on the Tibetan Plateau.⁵ This suggests that cultural exchange across the plateau may already have been possible during the second millennium BC.

These remarkable geographic features provide the major boundaries of East Asia. Due to the collision of the plates, this area can be divided into three altitudinal zones: the Higher Zone with the Tibetan Plateau, an average elevation over 4000 m, the Middle Zone from Xinjiang, Mongolia and Inner Mongolia to Yunnan, between 1000 and 2000 m, and the Lower Zone below 500 m. As in many other regions of the world, it is usually easier for people to live and to migrate around the same altitude rather than to move to a much higher or lower place. Thus, such a division by elevation often indicate geographic and cultural spheres as how people are more likely to be physically and culturally related.

Calling this vast area by the single name of China is certainly a quite modern political concept. Historically, this area used to be occupied by various ethnic groups and polities. Among these ethnic groups, the Han people, who make of about 97% of the population in the People's Republic of China, lived mainly in the Lower and part of the Middle Zones. Here, two major rivers, the Yellow River in the north and the Yangtze in the south, run west-east across the plains. The region of the middle Yellow River Valley, sometimes extending a bit to its west, east, and

⁴ Aldenderfer 2011; d'Alpoim Guedes and Aldenderfer 2020; Hou, G. et al. 2015; Meyer et al. 2017; Ren, L. et al. 2020; Zhang, D. et al. Zhang et al. 2016.

⁵ d'Alpoim Guedes 2015; Liu, X. et al. 2019; Lister et al. 2018; Stevens et al. 2016.

south, was and still is the most populated area by the Han people. This area is traditionally known as Central China or the “Central Plains”.⁶ The centrality of this area comes from the centrality of the Han culture. Otherwise, the geographic centre of today’s China would be located further west, probably in today’s Shaanxi Province. Since most of the historical records were written by the Han people, the roles of the Han people as well as Central China in shaping the history of the modern territory of China are often overstated.

People living in the second millennium BC certainly did not consider themselves belonging to a single political or social organisation, nor did they hold the concept of China as an identity or a territory.⁷ Although some communities may have felt that they were living at the centre of the world, there was certainly not a culturally core area which was accepted by all these early metal-using communities. Nevertheless, geographic ideas such as China and Central China are still useful for two reasons. First, most communities we are going to study are indeed geographically close to each other. This geographic proximity made cultural contact and exchange possible. Second, it is hard to overlook a core area for high-leaded bronze objects (Chapter 1, Figure 1.8), and much of this area coincides what we may call Central China. For these reasons, China and Central China seem to be convenient terms for us to refer to the regions as I will mention them frequently in this thesis.

In the following part of this chapter, I will first discuss some general questions regarding the relationship between geography and cultural contact. After that, I will briefly review the development of metallurgy in East Asia and how interregional connections may have contributed

⁶ The geographic scope of the Central Plains is ambiguous since the ideas of the Central Plains (or *zhongyuan* 中原 in Chinese) were often involved in the changes of regional political powers. Therefore, I prefer to use “Central China” in this thesis as a more geographic-oriented term.

⁷ Some scholars suggest that a shared identity may have emerged in Central China during the late Neolithic period, see Li, M. 2018; Li, X. 2016. Even this shared identity did exist, it certainly did not cover the modern territory of China, nor was such an identity held by all those early metal-using communities discussed in this thesis.

to this development. In the final section, I will introduce four case studies chosen from some of the East Asian regions. These case studies will be investigated in the second part of this thesis.

Mapping Geography, Time, and Cultural Patterns

To investigate any culture phenomenon, the fundamental questions we may ask are the same, as when we want to understand any problem: who, when, where, what, and why. In archaeology, “who” is about the entity of our discussion, which is often a group of people, such as a community. “When” is about chronology, which depends on various dating methods. “Where” is about the location and translocation of people and objects. “What” is the phenomenon, such as the use of leaded bronze. “Why” is the reason behind the phenomenon, such as cultural contact, as I will elaborate later. In this section, I will discuss four of the WH-questions, except for “what”, from a geographic perspective. In order to do so, I will start with a map from David Anthony’s *The horse, the wheel, and language*, as the suggested migration of the Afanasievo people across the steppes (Figure 2.2).⁸

Archaeological Culture, Community, and The Changing Culture—“Who” and “Why”

Two types of cartographic feature can be clearly seen on this map. One is cluster. A cluster is a contour line marking a certain area. On this map, the cluster represents an archaeological culture, the Afanasievo culture. Some other cultures such as Glazkovo and Botai are also marked on the map. Archaeological cultures are often used to represent the entities (“who”) in the archaeological discussion. The idea of archaeological culture was first proposed in the early twentieth century. According to Gordon Childe, one of the pioneers advocating this concept, an

⁸ Anthony 2007.

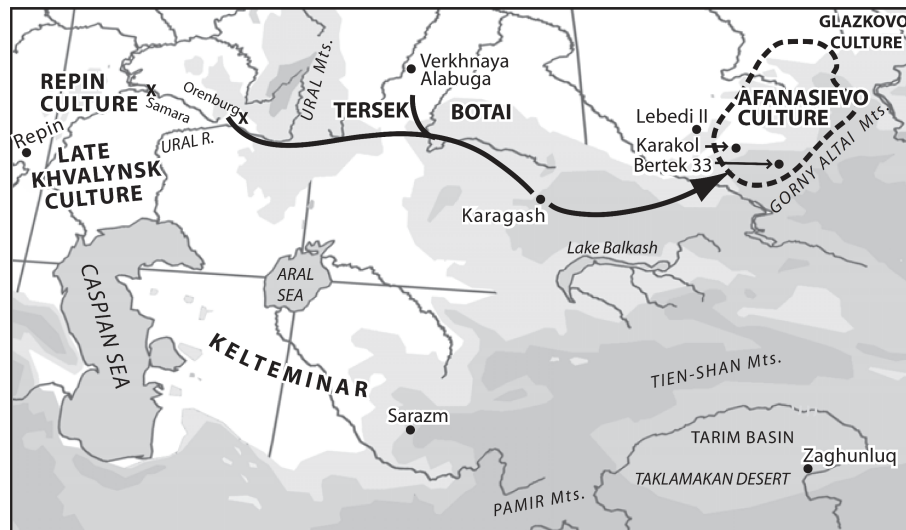


Figure 2.2 The migration of the Afanasievo culture, an example of a map with clusters and arrows (after Anthony 2007: 308).

archaeological culture is defined by certain types of remain which “constantly recurring together”.⁹ For Neolithic and Early Bronze Age cases, archaeological cultures are often defined by ceramic types, as ceramics are durable and widely available at most sites. Sometimes other cultural practices, such as a uniform burial pattern, are also used to define an archaeological culture. In the example of the Afanasievo culture, Anthony suggested that it derived from the Repin culture which was in the Don-Volga region since Afanasievo pottery “has Repin traits”.¹⁰

The concept of archaeological culture was proposed in the early twentieth century to argue that each group of people has its own distinctive way of life.¹¹ In humanities and social sciences, scholars also use concepts such as “culture area” or “culture region” which represent a similar approach, but focus more on the homogeneous non-material cultural traits, such as language and religion.¹² Although these analytical tools are commonly used in various academic fields, many

⁹ Childe 1929: v–vi. See also Roberts and Linden 2011b.

¹⁰ Anthony 2007: 309.

¹¹ For the discussion, see Trigger 2006: 232–241.

¹² E.g. Withers 1988; Yorgason 2003.

scholars have expressed their concerns over the misuse and misinterpretation of these concepts.¹³ Subjectivity is certainly an issue of these theories. As in Anthony's example, whether the Afanasievo pottery really shared "Repin traits" is a subjective judgment. Besides, grouping people into "a people" based on their cultural traits is also a problematic approach to many scholars. This may reflect the debate between structuralism, which argues that what people do, think, and feel are mainly determined by the social and cultural structures, and post-structuralism, which suggest that people are not just culturally different, but individually different. As the objectors of the ideas of culture group may argue, a culture group or culture area always exaggerates the cultural differences between people in the group and people out of it, while understating the cultural differences between people in this group.

In archaeology, there are two questions which the theory of archaeological culture cannot answer very well in particular. The first question is why did some people share the same cultural traits? To answer this question, we need to investigate how people influenced each other. The ways of cultural influences usually rely on certain forms of social organisation. In the modern cases, these social organizations facilitating cultural exchange may be schools, fan clubs, and social media platforms. In archaeology and anthropology, a particular type of social organisation which is often chosen as a manageable unit to be studied is local community. A local community can be defined, according to Thomas Eriksen, as "a relatively bounded local environment, (in which) most inhabitants know each other personally ... They participate in, and reproduce, a social system characterised by face-to-face contact."¹⁴ For archaeological cases, a settlement site (either a village or an urban environment) or a few adjacent sites are often considered a local community. To understand a certain type of material culture, I suggest that we need to focus on

¹³ For example, see papers in Roberts and Linden 2011a.

¹⁴ Eriksen 2015: 74. Anke Hein also proposed a differentiation between archaeological culture or cultural group (a group of people with similar cultural traits) and community (a group of people living and acting together): Hein 2017: 16.

the communities rather than on the whole archaeological culture as a single entity. The reason is that the idea of archaeological culture does not reflect how people were socially related to each other. For example, to understand how metal objects were produced and used in a village, we need to know how the community was organised. Was there a division of labour? Was the society highly stratified based on wealth and power? How were the craftspeople trained? All these questions need to be investigated on the community level. By contrast, grouping people into archaeological cultures based on their pots does not really help us understand any of the above questions.

The other issue which the idea of archaeological culture cannot fully explain is why cultural patterns change. The theory of archaeological culture was initially proposed in opposition to “hyperdiffusionism”, which argues that all ideas and technologies were initially invented by one group of people and then “diffused” to other areas.¹⁵ The ideas of archaeological culture rejected diffusionism and argues that a cultural trait appearing in a new area is due to people with that cultural trait migrating to that area (as the suggested migration of the Afanasievo culture).¹⁶ In reality, neither diffusion nor migration all possible scenarios. For the case of the Afanasievo culture, people in the west may have migrated to the east with their pots. Alternatively, some people may have brought those pots and given them or sold them to the eastern communities. It is also possible that a community learned pottery production from a neighbour and borrow their design ideas.

¹⁵ Roberts et al. 2009; Thornton and Roberts 2014.

¹⁶ Migration in archaeology has been intensively discussed and debated: e.g. Adams et al. 1978; Anthony 1990; 1997; 2006; Burmeister 2000; Chapman and Dolukhanov 1992; Dergachev 2002; Duke 1978; Frachetti 2011; Lee 1966; Rouse 1986. Briefly speaking, although most scholars acknowledge the role of migration in cultural development, they disagree widely on what archaeological evidence can be used to identify migration, and on how types of migration can be related to types of cultural pattern. In recent years, a new trend is to identify migration by genetic studies. Although ancient DNA may indeed suggest the translocation of people, how genetic groups can be associated with cultural patterns (such as language groups) is still a question. See e.g. Damgaard et al. 2018; Haak et al. 2015; Racimo et al. 2020.

To better reflect these possibilities, I would like to borrow the terms by Valentine Roux. According to her, one scenario is what she calls “distribution”, which refers to the transferring of products from the producers to the users. The other is “circulation”, meaning the moving the objects together with the users.¹⁷ Roux’s definitions can be expanded to include not just objects but also ideas such as knowledge. Therefore, I define distribution as the action to give objects or ideas to others, while circulation is defined as the moving of objects and ideas through people migration. It must be pointed out that the ideas of distribution and circulation do not reject the possibilities of diffusion and migration. When objects were distributed, certain ideas (like how the objects should be properly used) also diffused. For the circulation of objects, migration may have been a main reason behind it. Nevertheless, I prefer these two terms since they reflect all the scenarios covered by diffusion and migration, while avoiding potential ambiguities (such as what really “diffused”?).

While distribution and circulation explain some cases of the changing patterns of cultural traits, new ideas and new types of material culture may also grow in a community either simultaneously or as responses to external stimulation. To study cases in the first scenario, we may rely on interdisciplinary theories such as innovation.¹⁸ For the second scenario, studies on cultural contact may shed some light.¹⁹ Since these topics are quite new to archaeology and are still developing rapidly, I do not want to discuss them in detail here. Briefly speaking, the studies of innovation and cultural contact show us that people are not just passively affected by cultural influence, they actively interact with the external agencies and participate in the shaping of new culture. To the particular topic of early metallurgy, I would like to adopt a theoretical framework proposed by Chen Kunlong and Mei Jianjun which separates “exogenous technological

¹⁷ Roux 2019: 289–293.

¹⁸ Leeuw and Torrence 1989; Elias 2012; Stockhammer and Maran 2017; Spataro and Furholt 2020.

¹⁹ Silliman 2001; Cusick 2015. An overview of the issue of cultural contact, see Hein forthcoming.

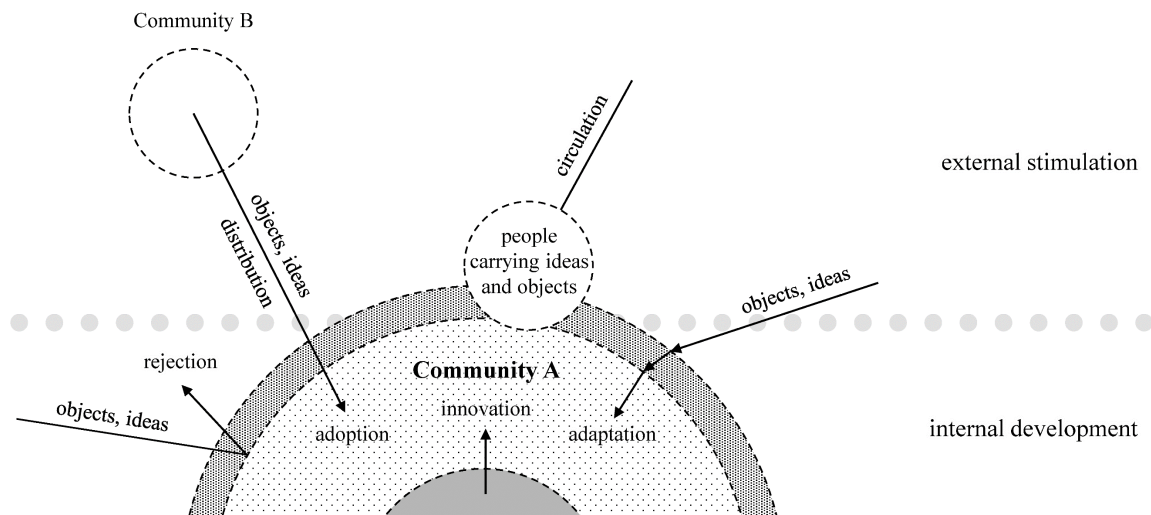


Figure 2.3 A model demonstrating scenarios of external stimulation and internal development.

stimulation” (I will call it “external stimulation”) from “local adoption and adaption” (I will call them “internal development”) (Figure 2.3).²⁰ As Chen and Mei argued, although exogenous stimulation was often a driving force of the spread of metallurgy, local adoption, adaption, and innovation also played an important role in the establishment of metal production in a community.²¹ In the later case studies, more detailed investigation is needed to identify both the external stimulation and the internal development.

Matching Space and Time—“When” and “Where”

The other feature on Anthony’s map is the line arrow. A line arrow usually indicates some sort of translocation of the entities or cultural traits, with certain directions.²² In an archaeological case such as the Afanasievo one, the direction of the arrow is often based on the chronological order of the phenomenon. For instance, if a type of ceramic vessel first appeared at site A around 4000 BC and at site B around 3500 BC, scholars sometimes suggest that people at site B either

²⁰ Chen, K. 2016; Chen, K. et al. forthcoming.

²¹ Chen, K. et al. 2019; Mei, J. 2003b; Mei, J. and Takahama 2003.

²² Fuller 2002.

obtained the objects from people at site A, or adopted the material culture through the exchange of ideas. To determine the chronological order, we need to know the date of the object or cultural trait at each site. Two ways of dating are used by archaeologists. One is absolute dating which dates the object or its direct context. Radiocarbon dating is the most widely used absolute dating method. Usually, this method can provide a date with a range from a few decades to a few centuries. However, there are still two problems. First, since personal biases remain in the process of radiocarbon dating from the selection and pre-treatment of samples to the interpretation of data, there may be remarkable discrepancies in terms of dating results from different researchers and projects (see, for example, the dating issue of Erlitou in Chapter 5). Second, metal objects usually cannot be dated directly since these objects do not contain carbon. Instead, researchers often date the archaeological remains which are obtained from the same contexts of the metal objects, such as charcoal, seeds, and animal or human bones.²³ The dates of these remains may suggest when the metal objects were placed or disposed in the contexts. However, these dates cannot suggest when the object was produced since it may have been used and passed down from generation to generation for centuries before the object was finally disposed.

An alternative way is to date the object based on its style. This, called relative dating, is achieved by comparing the typology of objects and the stratigraphy of archaeological sites. If objects from two sites look similar, we assume that they are from roughly the same period of time. If one object is found in a lower cultural layer than the other, we assume that the former is older than the latter. To know the real dates, relative dating still relies on at least one object or context, as a benchmark, to be absolutely dated. For artefacts which have clear changes in style through time, relative dating is often a good way to decide when the artefacts were made. Besides,

²³ Dating with charcoal has as particular problem as the wood used in an archaeological context (such as a tome) may be much older than the creation of that context. This is known as the “Old Wood Problem”. See e.g. Schiffer 1986.

relative dating is much less costly than absolute dating and does not rely on the condition of the archaeological contexts (such as whether datable carbon remains can be extracted). In the archaeology of China and some other regions, a widely used method is to combine relative dating with archaeological culture, that is, to date a few type sites of an archaeological culture with radiocarbon dating and then to give these dates to other sites of the same archaeological culture. Cost saving is certainly one of the main reasons to use this method. Considering that hundreds of sites are excavated in China every year by often understaffed archaeological institutes, the use of relative dating by archaeological culture seems to be the only way to provide a rough chronology for all these sites. Nevertheless, problems with this method are also obvious. This method is prone to subjectivity as the identification of typology, stratigraphy, and archaeological cultures are all subjective. In addition, since relative dating relies on absolute dating to provide benchmarks, the errors of absolute dating as previously mentioned are actually inherited by the other related sites. From this perspective, relative dating is almost inevitably less precise than absolute dating since two types of error and subjectivity are accumulated.²⁴ Furthermore, unlike absolute dating, relative dating can only determine when an object was produced. If a tomb is full of objects which are relatively dated to, for instance, 1000 BC, we cannot know if the tomb was also constructed around 1000 BC, since the objects may already have been antiques to the tomb owner at that time. Therefore, which dating methods to be chosen depends on conditions of the samples and the sites as well as the research questions. But no matter which method is used, dating remains a big problem which may affect our interpretation of an archaeological case.

When the archaeological questions are about a vast region, such as the Afanasievo “migration”, we also need to consider the relationship between time and space. Even with the best radiocarbon dating, the dates of most prehistoric sites can only be narrowed down to around a few decades

²⁴ Currently, many new dating projects adopt the Bayesian statistical modelling. This method uses stratigraphical sequences to narrow the range of radiocarbon dates. In future, this method should be used more if the archaeological contexts have clear stratigraphy. See Bayliss 2009; Bronk Ramsey 1995; 2008.

or a few hundreds of years. Meanwhile, even without any advanced means of transportation, travelling from the coast of Shandong to the deserts in Xinjiang may only take a few months.²⁵ Therefore, it is almost impossible for us to put the movements of the people and the objects in a clear time order. It is even more unreliable if we try drawing certain routes by putting the dates of the groups of sites in order, since, for a time period of a few centuries, people almost definitely did not only move in one direction.

In the above discussion, I use a map and two types of feature on the map—cluster and arrow—to discuss some fundamental issues, such as archaeological culture, cultural contact, and dating. The discussion also reminds us that we need be careful when reading a map. It is also necessary to point out how I deal with the location and dating issues on the maps in this thesis. This will be explained in the next section.

Methods Used in This Thesis

In this thesis, most locations marked on the maps are archaeological sites where the objects and remains have been found. The locality of a site is often described in its publications as a modern address, such as the nearby village or town. In Appendix, I convert these addresses to GPS coordinates (latitude and longitude). Although the locations are often not very precise, it is good enough for our descriptive purpose.

However, one type of bias remains as almost all archaeological finds depend on serendipity. As a result, how archaeological finds are distributed does not necessarily reflect the distribution patterns of people and material cultures in the past. For example, in China, the national surveys of archaeological sites show that there are many more archaeological sites in Central China than

²⁵ The distance is about 4500 km, the same as the Pacific Crest Trail from Mexico to Canada. It usually takes less than six months to finish the trail on foot.

in the border provinces such as Xinjiang and Tibet. In addition, there are also many more sites located on plains or in river valleys than in, for example, high-altitude areas.²⁶ This may lead to a conclusion that the geography of Central China was and is more suitable for living. However, such a result may be biased since archaeological institutes in relatively more populated and richer provinces in Central China may contribute more efforts to those surveys, while vast lands in Xinjiang and Tibet are not well surveyed. Meanwhile, as most surveys only cover areas which are relatively easy to access by modern modes of transportation, many high-altitude areas—though possibly settled in the past—are not fully investigated.

For sites at which metal remains were found, we also need to separate two situations. On the one hand, if metallurgical remains, such as slags, crucibles, and furnaces were found at a site, we usually can confirm that people used to conduct metalworking activities, such as smelting and casting, at the site. On the other hand, metal objects, especially finished products, are often found in residential areas and in burials. In the first case, the metal objects were usually disposed intentionally or by accident. In the second case, the objects were usually placed as grave goods. The existence of these objects does not mean that the local communities were involved in metalworking, but we can usually confirm that people living in those communities were using metal objects (we may call them were “metal-users”). However, materials found at the sites may not reflect the full range of people who possess them. Many people may all have possessed metal objects, while only some of them left these objects in their settlements or burials. This also means that even metal objects have never been found in a certain area, people who used to live there may also have been using metals.²⁷ In addition, in some cases, metal objects were found without

²⁶ The result of the second national surveys has been published as a series of *Atlases of Chinese Cultural Relics* (*Zhongguo wenwu dituji*), see those in the bibliography under Guojia Wenwuju. The provisional report of the third national surveys can be seen in Guojia 2009. See also Liu, A. 2018; Yi, Y. and Chen, Y. 2021.

²⁷ One example, as I will mention later, is the Mongolian Plateau during the late second millennium BC. One a few metal objects have been found there, but most scholars believe that people at that time, often

clearly identified archaeological context. These objects are called “stray finds”. Stray finds usually cannot provide us with much information about the metal use and metalworking in the local communities. However, if the question is about a very large scale, such as the whole Eurasian continent, we may use the presence of all types of metal object as a proxy for the adoption of metallurgy in certain regions. I will introduce some maps drawn with this assumption.

Regarding the dating, as previous discussed, different dating methods often suggest different results. For any particular case in this thesis, I will discuss its dating problems in detail. Meanwhile, for a large-scale, interregional comparison, such as the map of early metal sites which we will discuss in the next section, the dates I use may come from one of the three methods. The first is the direct, relative dating based on the style of the metal objects. The second is the indirect, absolute (radiocarbon) dating based on the datable remains in the same archaeological contexts of the metal objects. The third is the relative dating of the contexts based on the typology and the stratigraphy. As we can see, this method is often not very reliable. I will only use this when dates by the first two methods are not available, and when the goal is to understand the general situation of a region. Archaeological culture may also be used for the dating purpose if other dating methods are not available.

As previously discussed, the chronological order of sites does not always suggest how people actually moved from one place to another. Routes drawn in this way are therefore not always reliable. However, I think one type of route may be helpful, which is ancient trade route. Behind these routes are often geographic reasons which have remained almost the same for thousands of years. For example, the Hexi Corridor, partly in today’s Gansu Province, is a narrow passage between the northern slope of the Tibetan Plateau and the deserts. For people who travel between the upper Yellow River Valley and Central Asia, the Hexi Corridor was and still is one of the

associated with the Ulaanzuukh-Tevsh culture, were metal-users: Honeychurch 2015: 109–156; Ma, J. 2015.

few possible routes. Nevertheless, relying on these ancient routes also introduces possible biases. Although some geographic features, such as mountains, may remain almost unchanged for millennia, there are also some changes which are crucial for the movement of people. One example is the change of vegetation cover. With the same terrain (topographical relief), a nice hike through a land with low grass can become very difficult and even impossible if the land is full of tall grass and shrubs. As these features may change rapidly (especially from an archaeological perspective),²⁸ we cannot simply assume that a historic or modern route was also available in prehistory. Ideally, we need to investigate whether a route was really accessible on a case-by-case basis. This often means that we need to take other information into account. In the case of the Hexi Corridor, we can assume that it was used in prehistory since many archaeological sites dating to that time have been found along this route. Also, material culture at the sites shows clear evidence of influence from both Xinjiang, on the north-western side of the corridor, and the upper Wei River Valley, on the south-eastern side. Moreover, studies based on paleoclimate data also suggest that the Hexi Corridor was arable and crossable in certain periods in prehistory.²⁹ If we put all these information together, we can almost confirm that this traditionally recognised route was really available to people in the past.

After the discussion of these fundamental issues, in the following section, I will review the early development of metal use and metallurgy in East Asia as this provides a background for the emergence of leaded bronze.

²⁸ A land can change from with low grass to with tall grass in a few months.

²⁹ See Chapter 7 for more discussion of the environment of the Hexi Corridor and the archaeological sites. For the paleoclimatic studies, see Dong, G. et al. 2017; Feng, Q. et al. 2019; Zhou, X. 2012.

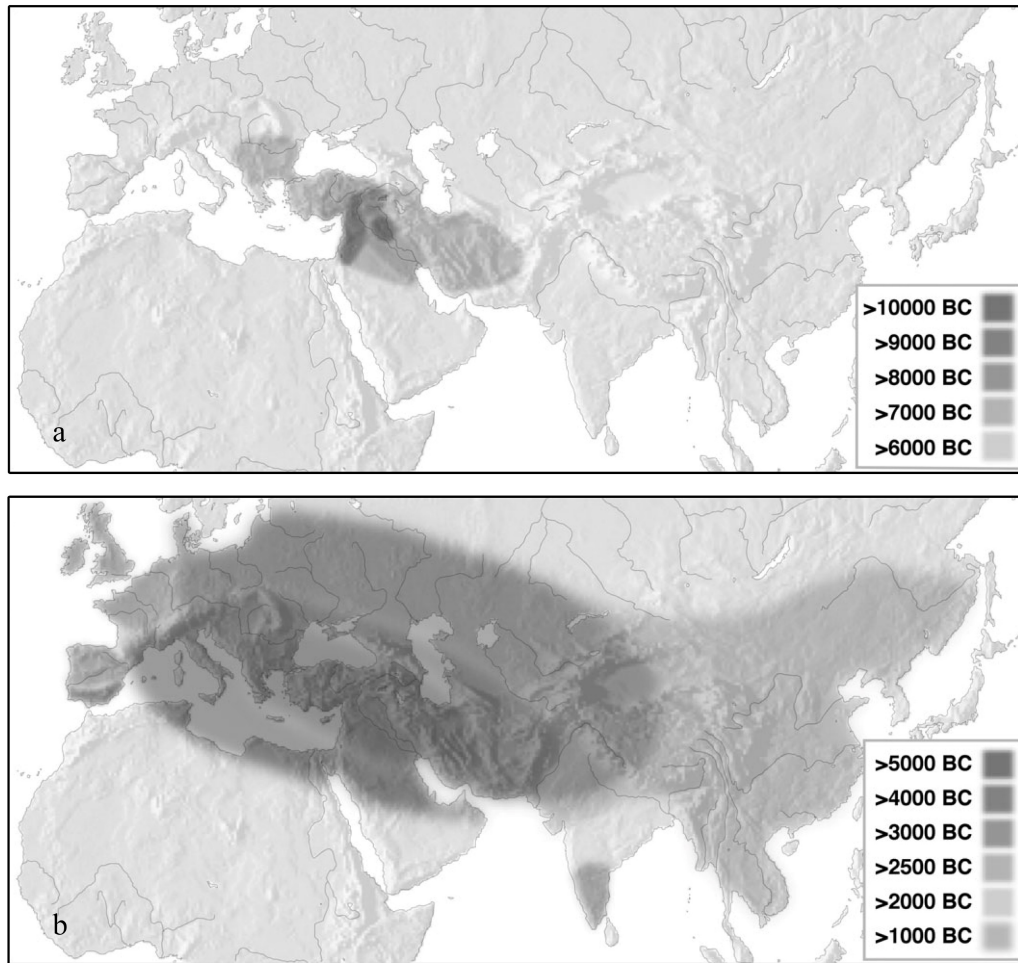


Figure 2.4 The spread of the exploitation of copper ores (a) and copper smelting technology (b) (after Roberts et al. 2009).

East Asia and Its Early Metals: Beyond a Diffusion Model

Based on the current understanding, in Afro-Eurasia, both the earliest use of metals and the earliest smelting—extracting a metal from its ore by firing—appeared in the area of South-west Asia and South-east Europe before the fifth millennium BC. East Asia only caught up with this trend in a much later period, around the second millennium BC. Across the regions, there seems to have been a spatial-temporal sequence in the emergence of metallurgy as suggested by

scholars such as Benjamin Roberts (Figure 2.4).³⁰ This sequence of development is also suggested by Evgeny Chernykh as he grouped the early metal-using communities in Eurasia into several regions which he calls “Metallurgical Provinces” (Figure 2.5). Communities in the same Metallurgical Province were not just geographically close to each other, but they also shared some cultural traits in their metallurgical practices. Therefore, the idea of Metallurgical Province can be seen as a model influenced by the concept of archaeological culture, as each Province represent one to several local archaeological cultures.³¹ Another important study on the early development of metallurgy across Eurasia is by Lorenz Rahmstorf, shown as Figure 2.6. In this study, Rahmstorf provides not only a map with sites where bronze objects prior to 2200/2100 BC have been found, but also list of the sites with detailed information in the appendix.³² This is a very reader-friendly method as scholars in future can rely on not just the conclusions in this study, but also the data to do further research.

When I started this DPhil project, I also began to record the information of sites with evidence of metal use or metalworking. My initial goal was to have a database of mostly Chinese sites with objects dating between 2000 and 1250 BC, but I then realised that, to understand the emergence of metals, I also needed to see it as a pan-continental phenomenon. To do so, I started to put sites from other regions into my database as well. Due to the limit of my research scope, it is not possible to make a full list of all archaeological sites with early metal remains, but I try to cover as many areas as possible. Also, for some regions, such as Japan, no metal remains prior to 1250 BC has been found. In these cases, I choose to add a few sites which are later than 1250 BC but can represent the earliest stage of metal-using in these regions. As a result, Figure 2.7 shows these metal sites I collected in these years. The dates of the sites, shown in different

³⁰ Roberts et al. 2009.

³¹ Chernykh 1992; 2014; Chernykh et al. 1991; 2000.

³² Rahmstorf 2017. See also Rahmstorf 2011.

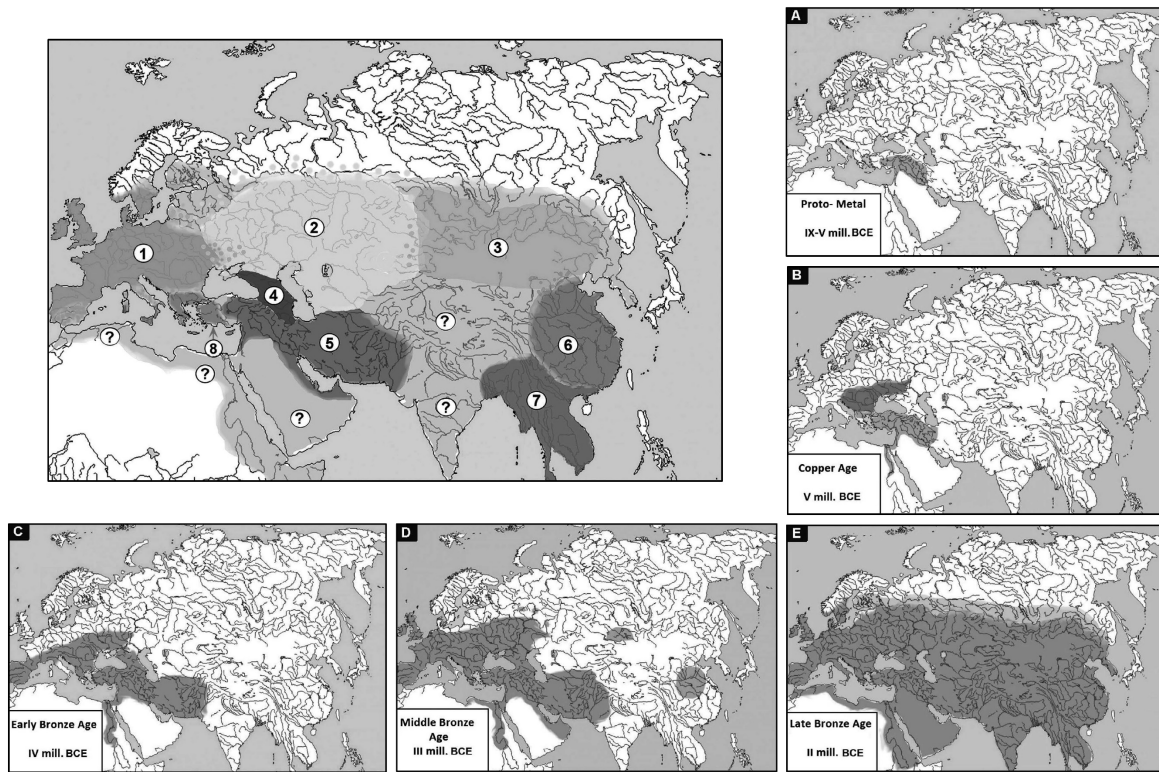


Figure 2.5 Metallurgical Provinces in the Late Metal Age Eurasia (top left) and the “territorial leaps” of metal-using cultures from the proto-Metal Age to the Late Bronze Age (after Chernykh 2014).

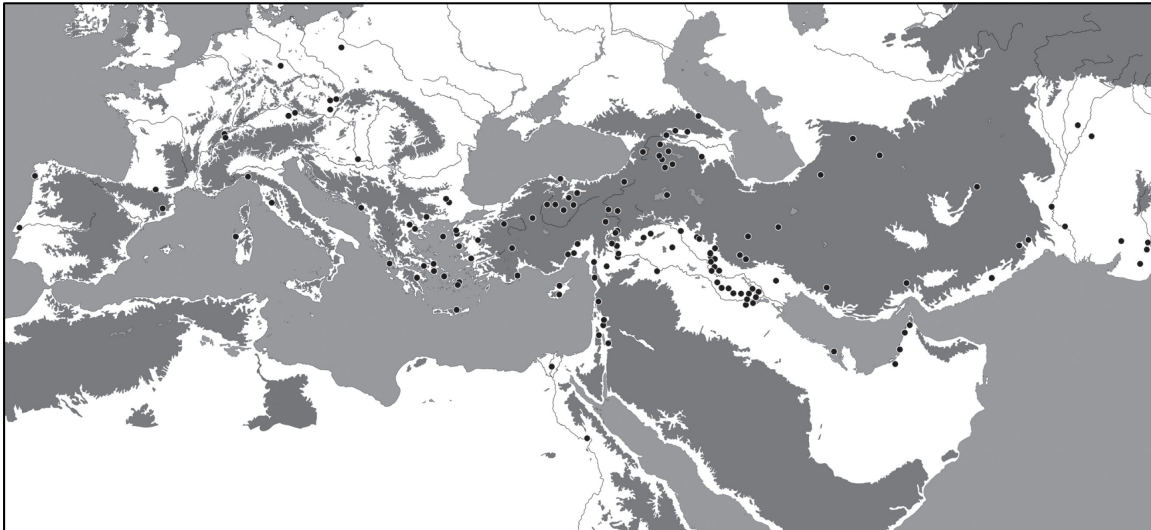


Figure 2.6 Distribution of sites with bronze objects before 2200/2100 BC (after Rahmstorf 2017).

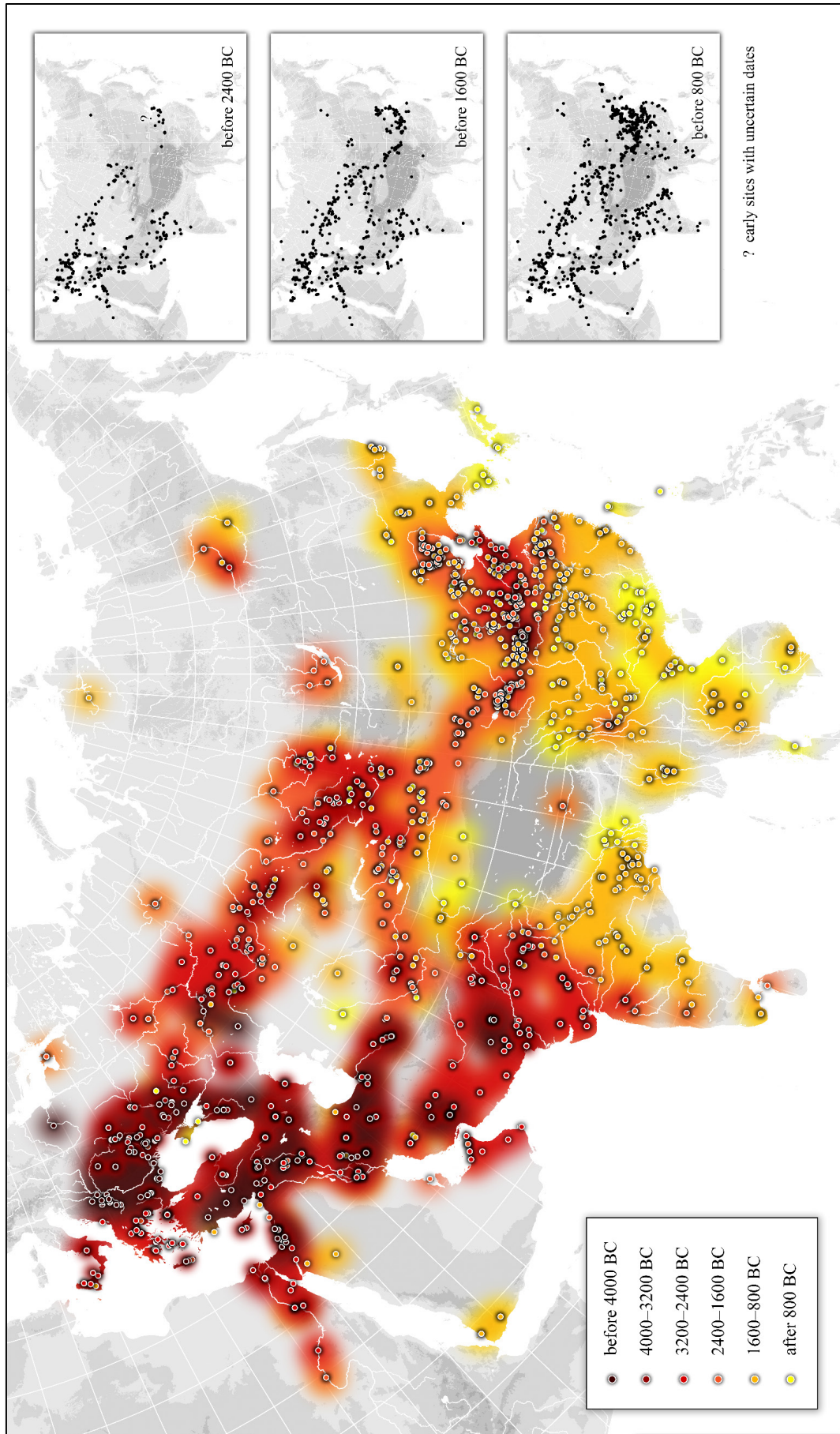


Figure 2.7 The emergence of metallurgy in eastern Eurasia based on the dating of earliest metal finds across the region (data source see Appendix 1).

colours, are the dates of the earliest metal-yielding contexts at each site. In this way, I want to show the approximate time when metals were first used in each area. Of course, my personal biases and oversights in the selection of the sites seem to be inevitable, especially when, in certain regions such as Russian, most studies are not published in English or Chinese. Nevertheless, by collecting a large number of sites, I hope “big data” can reduce the biases to an acceptable level, so the result can reflect a general spatial-chronological pattern of the development of metallurgy. The data and further discussion can be found in Appendix 1.

All these maps seem to confirm the west-to-east development of metallurgy in Asia, as what has already been pointed out. This sequential development was sometimes used to support the diffusionist view of copper metallurgy, that is to say, the technology was once invented in West Asia and East Europe and was then transmitted gradually to regions in the east.³³ In my view, although this general trend may be true, there are something missing in such an oversimplified diffusion model.

One issue of this model, as previously mentioned, is that it cannot take various scenarios of external stimulation and internal development into account. Metallurgy is not just a single technology, it is a complex system with many ideas, beliefs, and practices. In each technology, there are also many options to achieve the same result (see more in Chapte 3). We can take smelting as an example. The map by Roberts and colleagues (Figure 2.4, b) seems to suggest that copper smelting technology spread from West Asia to East Asia. However, even smelting itself is not a single technology. To smelt copper ores, people needed to have heating facilities, such as furnaces. In each community, these furnaces may have been developed long before the use of metals. If a community wanted to start metal smelting, people may have relied on their

³³ The single vs. multiple origins of early metallurgy is still a hotly debated topic starting from the 1960s: Wertine 1964; Renfrew 1969. See also Muhly 1988; Amzallag 2009 (and also the comment: Thornton et al. 2010); Roberts et al. 2009.

existing furnaces or have improved their furnaces to fit smelting better, such as to increase the firing temperature. Alternatively, they may have introduced the furnace technology together with smelting from other communities. For early metalworking communities, different technologies of heating are well reflected by archaeological remains, such as various types of bellow and blowpipe.³⁴ Therefore, even the idea of smelting was really originated in West Asia and was transferred to the rest part of Asia, we cannot really say that the smelting technology diffused from the west to the east. More precisely, as in the case of the furnaces, we need to identify what ideas and objects in the technological system were transferred, and what ideas were the responses and innovations by the local community under the external stimulation.

Furthermore, according to the diffusion model, new technology usually just “entered” a new area. Such an approach overlooks the different reactions and choices by communities and individuals. When a new technology first appeared in an area, people living there may or may have been aware of its arrival, and, for those who were aware of, some people may have chosen to adopt the new technology, while others may have chosen to turn it down. In archaeological cases, such differences between individuals may not always be noticeable, but we still need to keep these possibilities in mind. In the second part of this thesis, some of my case studies show clearly that the adoption of certain metal materials varied among communities in the same region (Chapter 8) and among people with different socio-economic status (Chapter 5) and cultural identities (Chapter 6).

After the general review, I will now move on to East Asia. Due to the fact that the earliest metal remains here appeared much later than those in the west (Figure 2.7), most scholars nowadays accept the hypothesis that metallurgy in East Asia emerged under the influence from the west.³⁵

³⁴ Huang, X. and Qian, W. 2013; Juleff 1996; Rehder 1994.

³⁵ Bai, Y. 2002; Lin, M. and Xiang, L. 2017; Linduff 1997; 2000; 2002a; 2002b; 2006; 2015; Linduff and Mei, J. 2009; Mei, J. 2003a; 2004; 2009a; Mei, J. and Shell 1999; Mei, J. et al. 2012; Tang, L. 1979.

However, according to our previous discussion, I argue that, first, we should see metallurgy as a group of ideas and technologies to discuss what exactly was transferred (or locally developed). Second, we should also see East Asia as a region with many communities. Instead of all being influenced by a coming wave of metallurgy, each community may have developed its own trajectory of adopting, and even rejecting, metallurgy. In this section, I will first follow the chronological order to revisit most major archaeological finds related to early metallurgy. For the next section, I will choose a few regions to discuss how metallurgy may have developed under both external stimulation and internal development.

What is the earliest metal use in East Asia? In two recent papers, Guo Jingyun and colleagues raised the issue of copper-bearing minerals found at several middle Yangtze Valley sites, especially at Qujialing and Shijiahe (Figure 2.8). The contexts with these minerals are dated to the fourth to the third millennia BC. Some of the minerals appear to have been heated. The excavators also found what they interpret as smelting remains.³⁶ The reliability of these materials and the interpretations are still questioned by most scholars. In my view, the possible scenario was that, like in many other regions, people in the Yangtze Valleys may have collected copper-bearing green stones and even have tried heating these stones—just like what people always did to clays.³⁷ Strictly speaking, people who collected and fired the minerals did not consider metal as a new material from what they had already known. Also, these practices seem to have been sporadic and discontinued after the abandonment of these sites. So far, there is no evidence to show that the knowledge and know-how obtained from these practices were transferred to the later development of metallurgy in East Asia. Besides these finds of copper minerals in South China, the earliest known metal objects in East Asia are all found in North China. Some of the

³⁶ Guo, J. et al. 2018; 2019.

³⁷ Some of the earliest ceramics in West Asia are figurines which were put into fire, probably during ritual ceremonies. See Rice 1999; Hommel 2014. The use of copper-bearing “green stones” in other regions, see e.g. Bar-Yosef Mayer and Porat 2008; Coutts 1971; D’amico 2005.

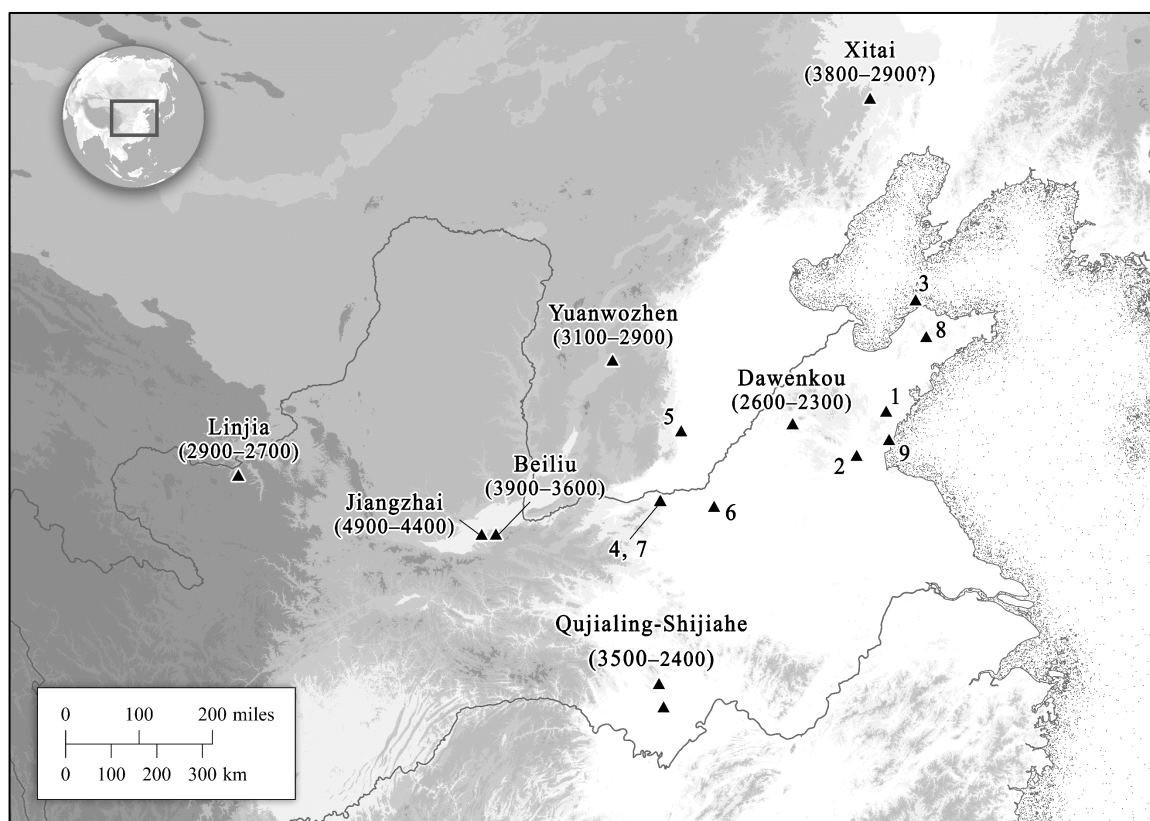


Figure 2.8 Sites with metal-related finds before 2400 BC. The dates provided here may not be generally agreed (see footnotes 38 and 39). Other sites: 1: Chengzi; 2: Dafanzhuang; 3: Dianzi; 4: Dongzhai; 5: Hougang; 6: Lutaigang; 7: Niuzhai; 8: Yangjiaquan; 9: Yaowangcheng (see also Figure 2.10).

objects are probably prior to 3000 BC (and even before 4000 BC), but such finds are extremely rare and often with questionable dates.³⁸ Thus, these finds may not suggest a clear adoption of metallurgy in this region as well.³⁹

The majority of early metal objects are dated to around the second half of the third millennium BC. They are mainly found in two areas. One area is on the northern border of the Tarim Basin, or around the Aitai and the Junggar Basin (Figure 2.9). Those metal-yielding sites often show

³⁸ A review of some early metal-bearing sites and their dates, see Xu, H. 2016a.

³⁹ Sites with early metal objects: Jiangzhai: Xi'an et al. 1988: 148; Beiliu: Zhang, R. 1986: 122; Yuanwozhen: Wajima 1962.

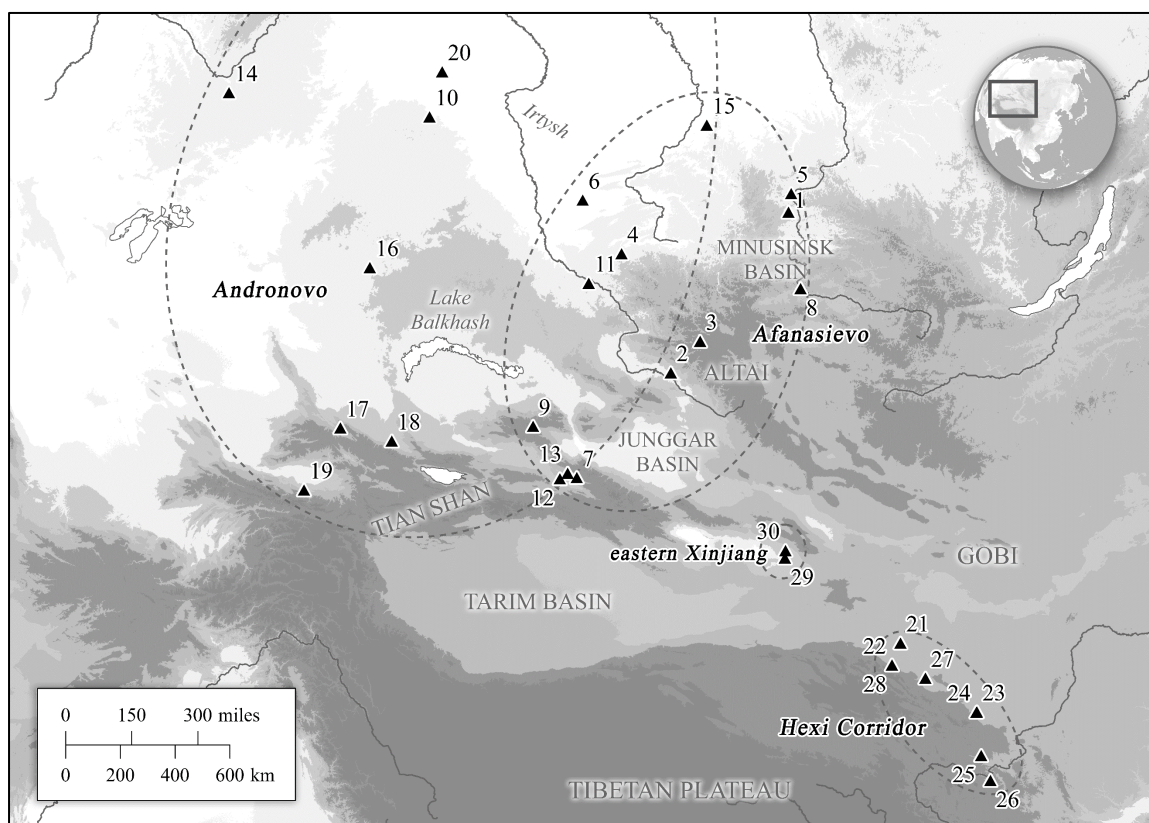


Figure 2.9 Metal-bearing sites in Xinjiang and the Hexi Corridor, c. 2400–1800 BC, with the Afanasievo and Andronovo sites in the nearby region. Afanasievo: 1: Afanasieva Gora (Russia); 2: Ayituohan; 3: Bertek 33 (Russia); 4: Karakol (Russia); 5: Karasuk III (Russia); 6: Lebedi II (Russia); 7: Nilka; 8: Toora-Dash (Russia); Andronovo: 9: Adunqiaolu; 10: Alekseevka (Kazakhstan); 11: Dzhartas (Kazakhstan); 12: Gongliu; 13: Jirentai Goukou; 14: Kupukhta (Russia); 15: Malyj Mys (Russia); 16: Sangru (Kyrgyzstan); 17: Tash-Tyube (Kyrgyzstan); 18: Tegermen-say (Kyrgyzstan); 19: Vuadil (Uzbekistan); 20: Yavlenka (Kazakhstan); Hexi Corridor: 21: Ganggangwa; 22: Gaomuxudi; 23: Haizangsi; 24: Huangniangniangtai; 25: Jiangjiaping; 26: Linjia; 27: Xichengyi; 28: Zhaobitan; eastern Xinjiang: 29: Fuzhisuanchang; 30: Tianshanbeilu.

Afanasievo cultural traits, such as certain types of ceramics, metal objects, and burial patterns.⁴⁰ It is through this relation that most of the metal objects are dated. Around 1800 BC, another group of metal-yielding sites appeared in western Xinjiang, near the ridge of the Tian Shan Mountains. These sites are often linked with the Andronovo culture, a widespread cultural

⁴⁰ Li, S. 2018a; Liu, H. et al. 2018.

phenomenon from the east of the Urals to the edge of the Tarim Basin.⁴¹ Nevertheless, no evidence suggesting the presence of local metal production dating to this period has been found in Xinjiang. Meanwhile, we know very little about the lifestyle or subsistence economy of the local communities. Therefore, it is unclear whether the metal objects were locally made, obtained from other regions, or carried to Xinjiang by migrants.

On the eastern side of this area, in the Hexi Corridor, the earliest metal objects and evidence relevant to metal production are dated to around 2000 BC. The emergence of metallurgy in this area appears to have been quite abrupt, since, from its very beginning, metal production in the Hexi Corridor had already shown a certain level of complexity, with a variety of product types (knife, awl, mace head), techniques (casting, forging, cold working), as well as the use of different alloys (pure copper, arsenical copper, later tin bronze).⁴² In Xinjiang, no contemporaneous site demonstrated the same level of metal production. These finds have triggered heated debate over how metal production began in the Hexi Corridor, as I will discuss in the next section. Between western Xinjiang and the Hexi Corridor metal sites, there were also metal-using communities in eastern Xinjiang. Some of these communities lasted for quite a long period, while the earliest remains can be dated to around 1800 BC.⁴³ The metal assemblages from eastern Xinjiang sites shared a chemical characteristic with those at the Hexi Corridor sites: the presence of arsenical copper, which is very rare among Andronovo metal objects.⁴⁴ This is often used to suggest that either the objects were originally made in the Hexi Corridor, or the technologies were transferred from the Hexi Corridor to eastern Xinjiang.

⁴¹ Anthony 2007: 448–451; Jia et al. 2017; Kuzmina 2004; Mei, J. and Shell 1999; Shao, H. 2009; Shao, H. and Zhang, W. 2019; Yang, J. et al. 2016: 93–110. A summary of the new discoveries, see Han, J. forthcoming.

⁴² Chen, G. 2017b; Dodson et al. 2009; Li, Y. 2015.

⁴³ Liu, C. et al. 2020; Wang, T. et al. 2019.

⁴⁴ Hexi Corridor: Chen, G. et al. 2015a; eastern Xinjiang: Liu, C. et al. 2020; Qian, W. et al. 2001; Andronovo: Chernykh 1992: 213; Wang, L. 2019a.

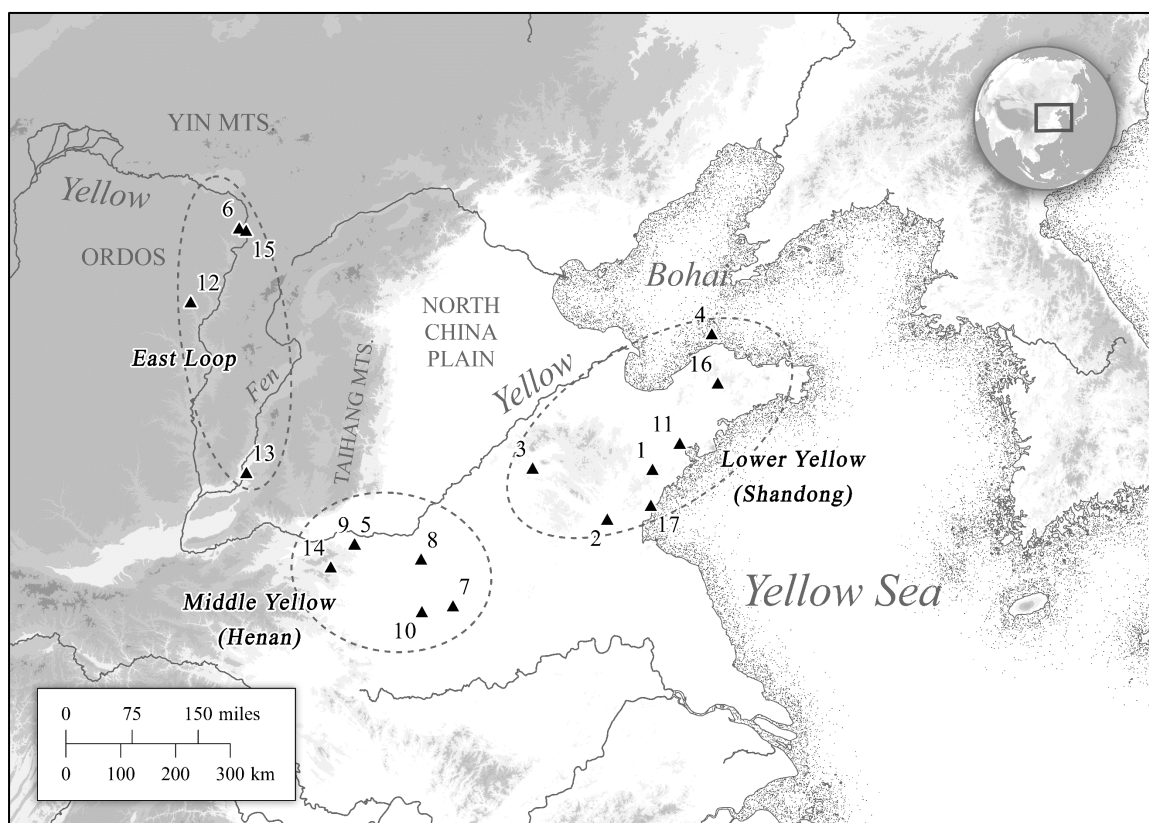


Figure 2.10 Metal-bearing sites in the eastern part of North China during the second half of the third millennium BC. 1: Chengzi; 2: Dafanzhuang; 3: Dawenkou; 4: Dianzi; 5: Dongzhai; 6: Erliban; 7: Luntai; 8: Lutaigang; 9: Niuzhai; 10: Pingliangtai; 11: Sanlihe; 12: Shimao; 13: Taosi; 14: Wangchenggang; 15: Xicha; 16: Yangjiaquan; 17: Yaowangcheng.

The other area where earliest metal objects have been found is the middle to the lower Yellow River Valley (Figure 2.10). The river valleys and the mountain corridors along the rivers may have been used by travellers as highways in the past. In recent years, one particular area which has attracted much attention is the eastern side of the large northern bend (the “Great Bend”) of the Yellow River, known as the “East Loop” or the “Front Loop”. The most important site in this area is Shimao in modern Shaanxi Province, which is currently under excavation.⁴⁵ A few radiocarbon dates suggest that Shimao was occupied around 2300–1900 BC.⁴⁶ At Shimao,

⁴⁵ Sun Z. et al. 2013; 2018; metals: Su, R. 2019.

⁴⁶ Dating issues: Sun, Z. et al. 2017; Xu, H. 2019.

copper or bronze knives and stone moulds have been found at Huangchengtai. The excavators suggested that the objects are no later than 1800 BC.⁴⁷ The metal objects found at Shimao are typologically similar to those from the steppes, indicating a possible direction of cultural connection.⁴⁸ Taosi, a site further south, is dated to 2400/2300–1700 BC.⁴⁹ Four Taosi metal objects, dating to Phases II–III (2100–1700 BC), have been analysed, among which one was made of almost pure copper; two were made of arsenical (2–4%) copper; one was made of leaded (1.5%) copper.⁵⁰ Also around 2000 BC, there were sites with small metal objects in the Middle and the Lower Yellow River Valley, or roughly today's Henan and Shandong Provinces. The connection between these areas and the East Loop was probably through the Yellow and the Fen Rivers as well as the along the Taihang Mountains. Most objects found at Henan and Shandong sites do not have clear archaeological contexts, nor have they been carefully analysed. However, one exception is two fragments from one original object, probably a drill, discovered at Sanlihe. The cultural layers in which these fragments were found are dated to 2400–1800 BC.⁵¹ As the samples were analysed, they were made of copper with zinc (20.2–26.4%), lead (1.8–4.3%) and tin (0.4–2.2%).⁵² This “brass” object, by the modern term of metallurgy, seems exceptional since zinc, with its relatively low melting and boiling points, was unlikely be to intentionally alloyed with copper by people at that time.⁵³ As scholars have pointed out, the object was probably produced by either melting or hot forging a polymetallic mineral.⁵⁴ The problem with

⁴⁷ However, based on the typology of the objects, Su Rongyu argued that some metal objects may be from a much later period, about 1000 BC: Su, R. 2019.

⁴⁸ Jaang, L. 2018; Rawson 2017b.

⁴⁹ Shao, J. 2020; Xu, F. 2014.

⁵⁰ Gao, J. and He, N. 2014. See also *Zhongguo & Shanxisheng* 2015: 666–667; 898–900.

⁵¹ *Zhongguo* 2010: 839.

⁵² *Zhongguo* 1988: 21; 199.

⁵³ Other early copper-zinc objects are discovered at Jiangzhai and Beiliu: Xi'an et al. 1988: 148; Zhang, R. 1986: 122.

⁵⁴ Sun, S. and Han, R. 1981; Fan, X. et al. 2012.

technological choice behind the chemical composition will be further discussed in the next chapter. The limited finds of metal objects suggest that the acceptance of this new material may still have been very low by the end of the third millennium BC.⁵⁵

In the next few centuries, evidence for large-scale metal production appeared in the middle Yellow River Valley, especially at the site of Erlitou in modern Henan Province. The earliest of these remains are dated to around 1700–1600 BC. Some scholars suggest that people in the middle Yellow River Valley learned metallurgy from their western neighbours in Gansu.⁵⁶ Around 1500 BC, smelting and casting activities also emerged in the Middle Yangtze Valley. The object typology and other evidence suggest that the metal production in this area were connected with the communities in the middle Yellow River Valley, as people in the south may have been sending their metal resources and even finished products to the north (see more in Chapter 5). Another area with clear evidence for local metal production is the West Liao River Valley, north of the Bohai Bay, as mining, smelting, and casting remains were identified at multiple sites here. These metallurgical remains are dated to as early as 1900 BC. It is still unclear how metal production was established here. Some objects from the West Liao River sites look similar to those from the middle Yellow River Valley, suggesting a potential cultural contact which may also have contributed to the transmission of metallurgical technologies. Nevertheless, it is more likely that people in the West Liao River Valley learned metallurgy directly from the steppes rather than from their southern neighbours (Chapter 6). In the lower Yangtze Valley and South-east China (e.g. Jiangxi), there are also scattered finds of

⁵⁵ Besides these objects and sites, there are also a few spearheads, most as stray finds, from North China: Gao, J. 2015; He, D. 2016; Lin, M. 2016; Liu, X. 2015; Liu, X. and Liu, R. 2016. These spearheads are often attributed to the Seima-Turbino phenomenon, and thus dated accordingly. Lin Meicun suggested that these objects are dated to 2100–1750 BC: Lin, M. 2015; 2016. This dating, however, is not widely accepted. See also Chernykh 1992: 215–233; Marchenko et al. 2017; White and Hamilton 2014. Due to the problem of dating, I will not include these spearheads in my following discussion of early metal finds. See also the further discussion: Liu, X. 2021; Shao, H. 2021.

⁵⁶ Fitzgerald-Huber 1995. See also the discussion in Mei, J. 2003b.

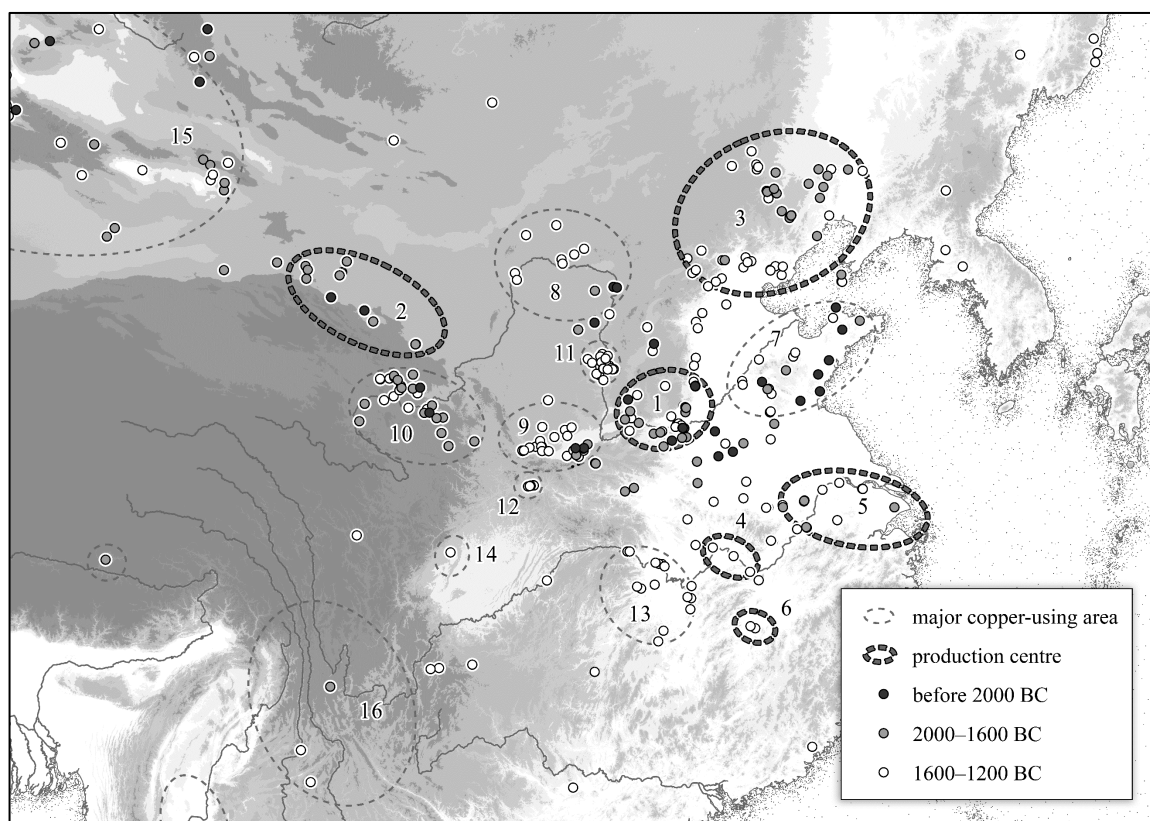


Figure 2.11 Early metal-bearing sites and metal-using centres in East Asia. 1: middle Yellow River; 2: Hexi Corridor; 3: northern Bohai Rim (West Liao River); 4: middle Yangtze; 5: lower Yangtze; 6: Jiangxi; 7: Shandong; 8: Northern Zone; 9: Guanzhong; 10: upper Wei River; 11: Shilou; 12: Hanzhong; 13: Yueyang; 14: Sichuan; 15: Xinjiang; 16: Yunnan.

metallurgical remains, especially ceramic and stone casting moulds, dating to the second half of the second millennium BC.⁵⁷ These finds suggest that this area may have been conducting metal production as well. Besides these production centres, copper objects were also found in other areas, especially in several major areas as marked on the map (Figure 2.11). Communities in some of these areas, such as Hanzhong and the Northern Zone (the Ordos Plateau), may also have adopted local metal production since metal objects in large quantities have been found.

⁵⁷ Lower Yangtze Valley, see Chapter 8; Jiangxi: Dayangzhou: Jiangxisheng 1997; Wucheng: Jiangxisheng 2005. See also Kane 1974; Peng, M. 2005; Zhang, L. 2006.

In South-west China, two major early metal-bearing sites are Sanxingdui (site: 2800–1000 BC; metal: 1400–1100 BC) and Jinsha (1200–600 BC).⁵⁸ At both sites, there are two groups of metal objects with strikingly different styles. One type comprises ritual vessels which share a similar form with those used in the Yellow River and the Middle Yangtze Valley. Lead isotopic analyses also suggest that these vessels were probably made in Central China or made locally with metals imported from Central China.⁵⁹ In the other group are some unique objects which are not seen in any other part of China, such as bronze and gold face marks, bronze trees with birds, and human-like figures.⁶⁰ Beyond the Sichuan Basin, only a few metal objects dating to the second millennium BC have been found. Especially, excavations in recent years have confirmed that the earliest bronze objects from Yunnan are dated to around 1500 BC, and therefore chronologically close to the metal objects from Sanxingdui.⁶¹ On the Tibetan Plateau, the only known early metal-bearing site is Qugong. The early layers of the site were previously dated to 1750–1500 BC and recently re-dated to around 1400 BC.⁶² The single metal object found at the site is a bronze arrowhead (83.7% copper with 12.5% tin).⁶³ All early metal objects found in Yunnan and Tibet are small objects such as axes, awls, arrowheads, fishhooks, knives, and bracelets. It is still hard to confirm whether these objects were locally made or imported, but the ideas and technologies behind these objects are likely to have come from either the Sichuan Basin or South and Southeast Asia, as I will discuss in the next section.

Metal objects and metallurgical remains have also been found in some other East Asian regions. On the Korean Peninsula, the earliest metal objects are dated to the second half of the second

⁵⁸ Sanxingdui: Falkenhausen 2003; Sichuansheng 1999; Jinsha: Chengdu and Chengdu 2017; Zhang, Q. et al. 2002.

⁵⁹ Cui, J. and Wu, X. 2013; Jiang, Z. 2006; Jin, Z. et al. 2004; Li, H. et al. 2019b; Liu, X. et al. 2018.

⁶⁰ Sichuansheng 1999; Zhang, Q. et al. 2002.

⁶¹ Li, K. and Chen, G. 2013: 59–70; Li, K. and Min, R. 2011; Tzehuey 2009; 2018.

⁶² Gao, Y. et al. 2021; Zhongguo and Xizang 1999: 219.

⁶³ Zhongguo and Xizang 1999: 142; 251.

millennium BC. These objects are all found around the Korean Bay area. Later, metal objects also appeared in South Korea (650–100 BC) and in Japan (100 BC–AD 100).⁶⁴

On the modern territory of Mongolia, the situation is complicated. Metal objects, though very rare, appeared around the late forth to the early third millennia BC. Sites yielding these objects are usually associated with the Afanasievo culture (c. 3000 BC) or the Chemurchek culture (c. 2500–1800 BC).⁶⁵ Meanwhile, some sites attributed to these two cultures have also been found in south central Mongolia.⁶⁶ Since these sites are geographically close to, and chronologically close to or prior to most early metal-bearing sites in North China, Linduff and colleagues argue for a potential route through which metallurgical knowledge was transmitted from south central Mongolia directly to the Great Bend of the Yellow River (northern Shanxi), such as Shimao and Taosi (Figure 2.12).⁶⁷ However, most of the early metal-bearing sites in Mongolia, as the map shows, are all located in the Mongolian Altai region, while metal objects have not been found in most Afanasievo- and Chemurchek-related sites in south central Mongolia. Therefore, Strong evidence for a metal-using tradition in south central Mongolia before 2000 BC is still lacking. During the second millennium BC, there was still no large settlement site in Mongolia. Metal objects were only found as stray finds or in some burials. Scholars suggest that the metal objects in this period are associated with the so-called Ulaanzuukh-Tevsh (U-T) culture, characterised by stone-structured burials.⁶⁸ The radiocarbon dates show that the U-T culture existed around 1400–1000 BC.⁶⁹

⁶⁴ North Korea: Chaoxian 1983: 72–74; South Korea: Barnes 2015: 255–284; Japan: Mizoguchi 2013: 140–142.

⁶⁵ Honeychurch et al. 2021; Kovalev 2014; 2015; Kovalev and Erdenebaatar 2009.

⁶⁶ Honeychurch et al. 2021; Kovalev and Erdenebaatar 2009.

⁶⁷ Linduff et al. 2017: 5; 52–60.

⁶⁸ Honeychurch 2015: 109–156. See also Ma, J. 2015; Rawson et al. 2020.

⁶⁹ Honeychurch 2015: 125.

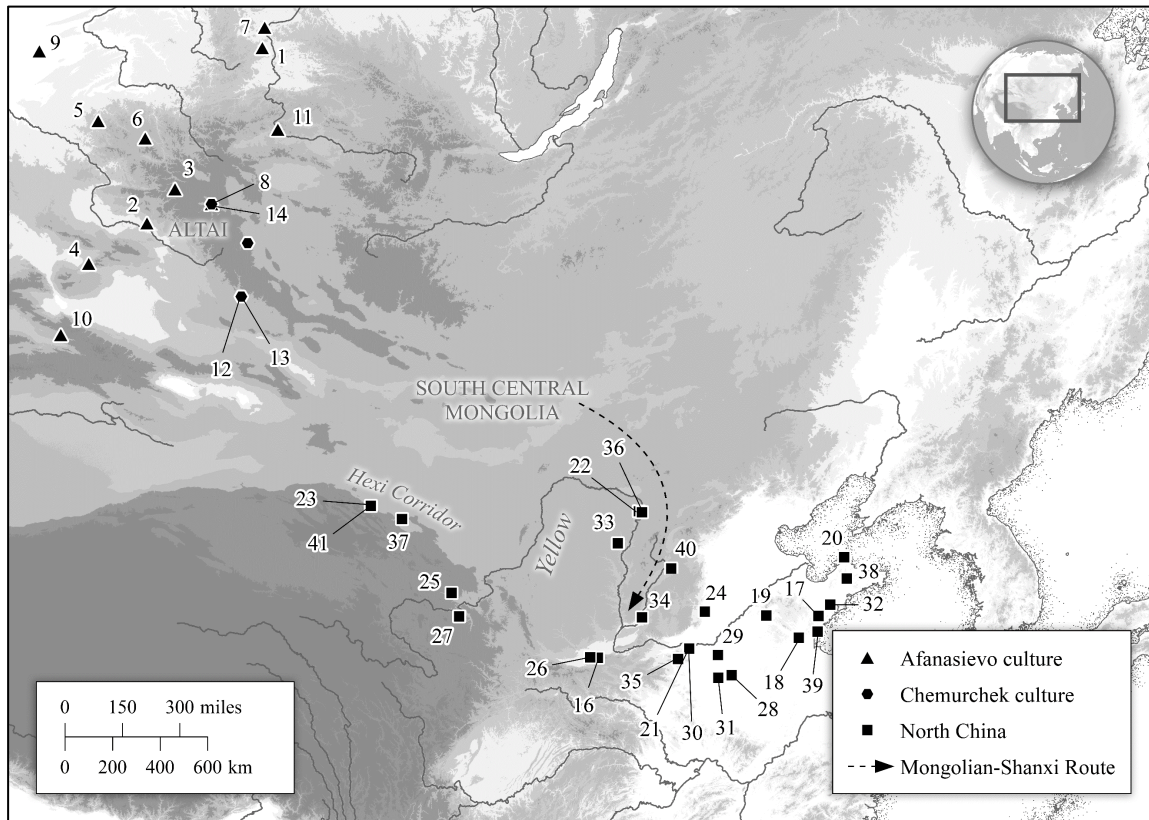


Figure 2.12 Metal-bearing sites in Mongolia and its potential connection with the metal-bearing sites in North China, before c. 2000 BC. 1: Afanasieva Gora; 2: Ayituohan; 3: Bertek 33; 4: Huoji'erte; 5: Inskoy Dol; 6: Kara Koby; 7: Karasuk; 8: Khuurai-Gov' 1; 9: Lebedi II; 10: Nilka; 11: Toora-Dash; Chermurchek culture: 12: Iagshiin Khödöö 1; 13: Iagshiin Khödöö 3; 14: Kumdi govi; 15: Ulaan Khudag 2; sites in North China: 16: Beiliu; 17: Chengzi; 18: Dafanzhuang; 19: Dawenkou; 20: Dianzi; 21: Dongzhai; 22: Erliban; 23: Gaomuxudi; 24: Hougang; 25: Jiangjiaping; 26: Jiangzhai; 27: Linjia; 28: Luantai; 29: Lutaigang; 30: Niuzhai; 31: Pingliangtai; 32: Sanlihe; 33: Shimao; 34: Taosi; 35: Wangchenggang; 36: Xicha; 37: Xichengyi; 38: Yangjiaquan; 39: Yaowangcheng; 40: Yuanwozhen; 41: Zhaobitan. The route from south central Mongolia to northern Shanxi is proposed by Linduff et al. (2017).

In further north, the earliest metal objects in the Russian Far East can be traced back to the second half of the third millennium BC, while the earliest evidence relevant to bronze production appeared around the first half of the second millennium BC.⁷⁰ I will revisit this area in the next section to discuss its potential cultural contact with North-east China.

⁷⁰ Dyakonov et al. 2019.

In summary, during the third to the second millennia BC, multiple communities in different East Asian areas started to use and produce metal objects. However, I argue that the emergence of metallurgy in East Asia was probably not a single phenomenon. That is to say, we should not see East Asia as a single region which learned metallurgy from a single direction, because different communities in East Asia may have been facing various types of external stimulation from different directions. These directions may have included the steppes, Central Asia, South Asia, and Southeast Asia. In the next section, I will focus on three particular areas. To some extent, these areas are all near the border of the modern territory of China. By choosing these areas, I want to show some potential interregional cultural contact which stimulated the early metallurgy in the local communities.

Interregional Cultural contact and Stimulation

Hexi Corridor in North-west China

North-west China, as previously discussed, is one of the earliest areas in East Asia where metal objects and metallurgy emerged. The relation of early metallurgy between the steppes and North-west China has long been discussed by scholars. Chernykh considered China part of the “East Asia Metallurgical Province”. He argued that the west-east connection was through the steppes, or the “steppe belt”.⁷¹ However, Chernykh did not describe how the cultural contact happened. In recent decades, as the discovered early metal-using communities grew in numbers and the dating of these sites was greatly improved, some scholars tried to identify specific routes through which the metal objects and metal-related ideas from the west came into East Asia, triggering

⁷¹ Chernykh 2008a; 2008b; 2014.

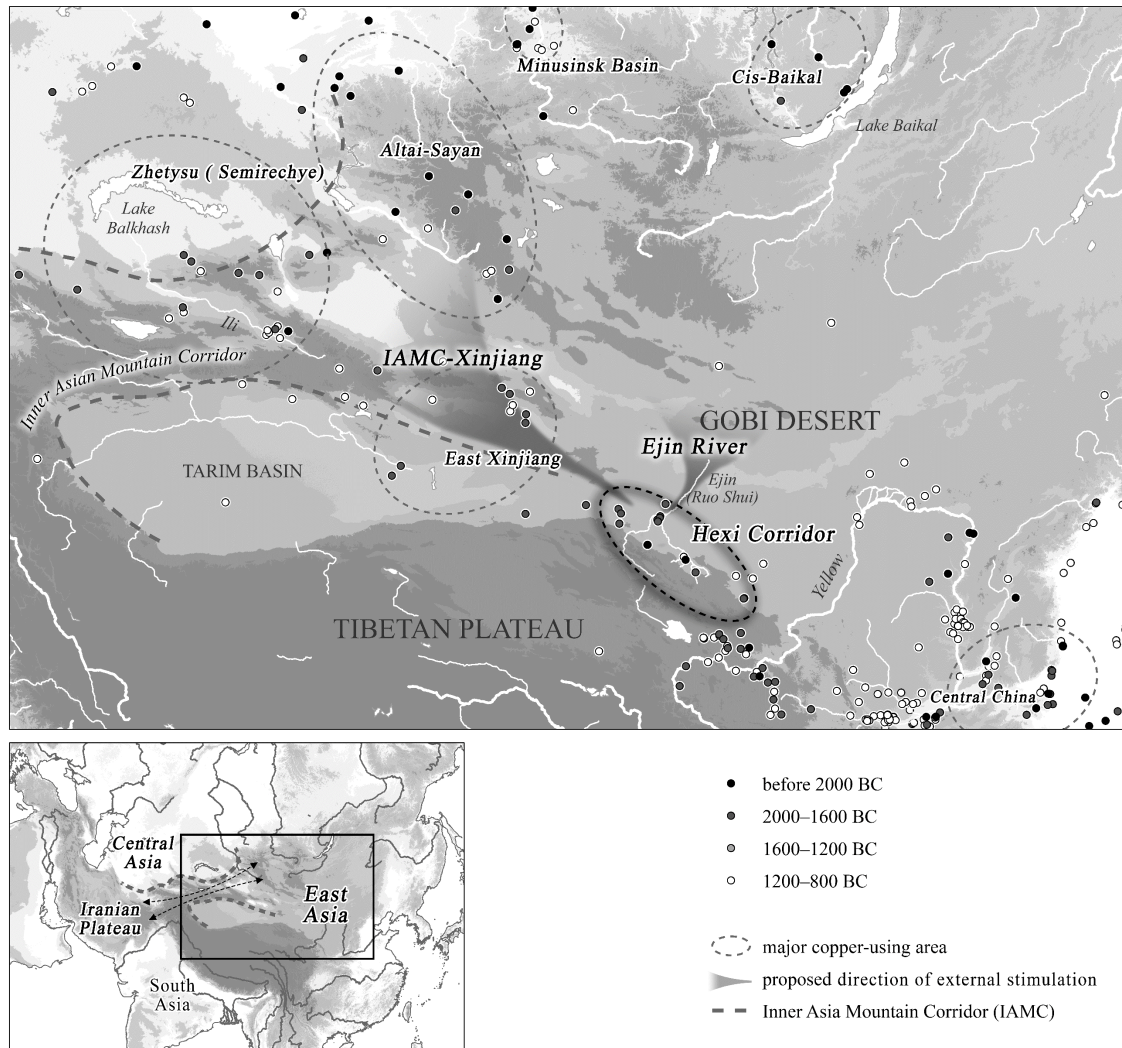


Figure 2.13 Metal-using communities between East Asia and Central Asia, the possible directions of external stimulation, and the Inner Asian Mountain Corridor (after Frachetti and Bullion 2018).

the development of metallurgy in this region.⁷² The early metallurgy in the Hexi Corridor, in particular, may have been stimulated by the cultural contact from two directions (Figure 2.13).

The first direction is from the Altai-Sayan region to Central China through Xinjiang and the Hexi Corridor.⁷³ This hypothesis reflects not only the discoveries of early metal objects in the region, as previously discussed, but also a historic view based on the route connecting Central China to

⁷² Borrowing the idea of the Silk Roads, these routes are sometimes called the “Metal Roads”. See Yang, J. 2016; Yang, J. et al. 2020.

⁷³ An, Z. 1993; Li, S. 2005; 2006; Liu, X. and Li, W. 2014; Mei, J. 2009a.

Central Asia through the Hexi Corridor and Xinjiang, famously known as the Silk Road. It seems reasonable to suggest that the same route may also have played a vital role in prehistory. In recent years, the importance of this route has been further highlighted by the idea of the Inner Asian Mountain Corridor (IAMC). Michael Frachetti defined IAMC as the high-altitude mountain ranges including the Hindu Kush, the Pamir, Tian Shan, and the Dzhungar mountains. As Frachetti argued, communities living in these highland areas were not isolated from each other. Through the cultural exchange between these communities, IAMC connected Central and South Asia on the one side, and East Asia on the other side.⁷⁴

However, all metal objects discovered in Xinjiang are small, finished products, there is no evidence of metal production, such as smelting and casting. Therefore, it is hard to confirm whether people in Central China really acquired metallurgy from the communities in Xinjiang. The favour of the Xinjiang-IAMC hypothesis is also challenged in the recent decade by the discovery of the metal-producing communities in the middle part of the Hexi Corridor, especially the Xichengyi site.⁷⁵ The Hexi metal objects and metallurgical remains show some characteristics which are later seen in the Yellow River Valley, such as casting with moulds and the use of multiple alloy types. Also, the radiocarbon dates from Xichengyi suggest that metal production started at the site about 2000 BC.⁷⁶ This dating puts Xichengyi ahead of most middle Yellow River metal-production communities, especially Erlitou, which only started around 1750–1650 BC. By contrast, most eastern Xinjiang metal objects can only be roughly dated to the first half of the second millennium BC. Therefore, the chronology seems to support the hypothesis that metallurgy came to the Hexi Corridor first and was then introduced to the Middle Yellow region. Some recent studies further suggest a possible role played by the Ejin River (or

⁷⁴ Frachetti 2012; 2014; Frachetti and Bullion 2018. IAMC and the dispersal of domestic crops: Liu, X. et al. 2017; Spengler et al. 2014; Stevens et al. 2016; Wang, W. 2020.

⁷⁵ Chen, G. 2017b; Chen, G. et al. 2015b; Wang, H. et al. 2015. See more in Chapter 7.

⁷⁶ Li, Y. et al. 2015a; Zhang, X. et al. 2015.

Ruo Shui 弱水, “weak water”) in the introduction of metallurgy from the north into the Hexi Corridor. Ejin starts in the Qilian Mountains and flows northward into the Gobi Desert. Most early metal-producing sites are located near the valley where river crosses the Hexi Corridor. Therefore, some scholars suggest that the knowledge of metallurgy was transmitted by people moving from the steppes into the Hexi Corridor through the Ejin River Valley, as the river forms a few oases in this relatively drought area.⁷⁷ Any route further north beyond this point is vague since almost no trace of human activities survive in the desert.

Both hypotheses reveal some important external stimuli which triggered the early metal use and metallurgy in the Hexi Corridor. However, there are also missing links in both explanations, as mentioned above. For these reasons, I agree with Mei Jianjun’s suggestion as we should shift the research focus from looking for certain directions or routes to understanding the whole “interregional exchange”.⁷⁸ The earliest metalworking technologies in the Hexi Corridor—extracting metals from ores by smelting and shaping metals into objects by casting and forging—were used by people in Central Asia and those on the steppes for centuries before they appeared in North-west China. Early metal objects in North-west China, such as small tools (knives, awls, etc.), personal ornaments (rings, bosses, etc.), and objects which may have had symbolic meanings (such as maces) are also similar to the objects in those two regions. Therefore, the suggestion that communities in the Hexi Corridor learned metal-using and metal production from their northern and western neighbours seems convincing.⁷⁹ Nevertheless, for those neighbours, were they all using the same type of metal object and metalworking technology? Was there any difference between the metal-use and metalworking practices between the IAMC communities and the steppe communities? Did the early metalworking technologies used by people at

⁷⁷ Jaang, L. 2015; Janz et al. 2020.

⁷⁸ Mei, J. 2003b; 2016.

⁷⁹ Fitzgerald-Huber 1995; Li, S. 2002; 2006; Mei, J. 2003a; Mei, J. et al. 2017. See Chapters 6 and 7 for more discussion.

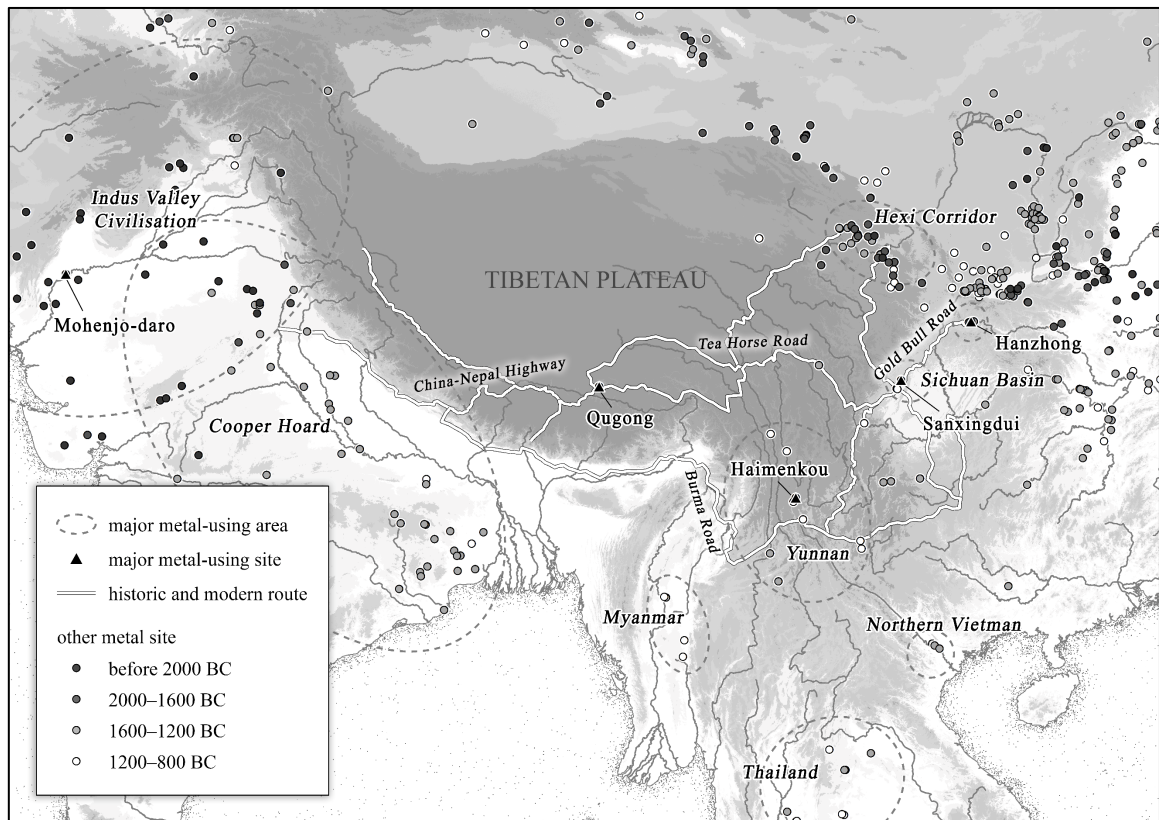


Figure 2.14 Metal-using communities and the possible routes connecting South Asia with East Asia.

Xichengyi all come from one direction, or, did they come from several communities from both Central Asia and the steppes? So far, there are no clear answers to these questions as previous studies all focus on the typological comparison of the metal objects (e.g. to associate metal objects to archaeological cultures, such as Afanasievo and Andronovo). In future, more studies on the metal production in Central Asia and on the steppes are needed in order to identify the specific technological transfers from these regions to North-west China.

South-west China Beyond the Sichuan Basin

I choose South-west China as my second example to discuss the possible roles of cultural contact in the development of early metallurgy. South-west China is a region with two major geographic areas (Figure 2.14). On the eastern side is the lowland mountainous area which is adjacent to the relative flat plains around the middle Yangtze Valley. One particular feature is the Sichuan Basin.

Access to the basin has always been very challenging since it is surrounded by mountains in almost all directions. Nevertheless, the Sichuan Basin is also a fertile land suitable to agrarian communities. Beyond the Sichuan Basin, elevation abruptly climbs to over 4000 metres as western Sichuan is actually part of the Tibetan Plateau. A rugged mountainous terrain transitioning the basin and the plateau is called the Hengduan (literally means “blocking”) Mountains. On the southern side of the basin is another plateau called Yunnan-Guizhou (or Yungui) Plateau. Across this plateau is today’s Mainland South-east Asia.

For this area, my question is, was it possible to be certain external stimuli which contributed to the early metallurgy in South-west China? To answer this question, I will divide it into two parts. First, who were the metal-using and metalworking people outside South-west China, and what were the metal objects and metallurgical technologies they had?

On the southern side of the Tibetan Plateau is the Indian subcontinent. Copper and bronze have been used here since at least the late fourth millennium BC.⁸⁰ Many copper-based objects dating to both before and during the so-called Indus Valley Civilisation (IVC, also known as Harappan) period, c. 3300–1300 BC, have been analysed. The results show that tin is the major element besides copper, but lead, iron, nickel, and arsenic are also identified in some objects. In addition to IVC, another important type of metal-bearing site is the “Copper Hoard”. These hoards are mainly located in North and North-east India. They often contain unstratified metal finds which can only be roughly dated to the second half of the second millennium BC.⁸¹ Like those from the IVC sites, most Copper Hoard copper/bronze objects are unleaded, but there are indeed some objects with significant (>2%) lead content.⁸² In most cases, scholars cannot confirm whether small amounts of lead was deliberately added to the copper alloys, but evidence suggests that

⁸⁰ Overview: Hoffman and Miller 2014; Chakrabarti and Lahiri 1996; Kenoyer and Miller 1999.

⁸¹ Agrawal and Kharakwal 2003: 195–206; Chakrabarti and Lahiri 1996: 77–90; Yule et al. 1989.

⁸² Yule et al. 1989: 262–263.

people may have intentionally chosen high leaded bronze when casting objects with the lost-wax method. This method first appeared on the Iranian Plateau and was adopted by the IVC communities around 3000 BC.⁸³ One example is a metal weight, often known as the “Leopards Weight” due to its motif of two leopards, found at Shahi Tump, Pakistan, c. 2600 BC. The jacket of the weight was made of copper with 12% lead and 3.5% arsenic. The filling of the weight is almost pure (>99.5%) lead.⁸⁴ To make the motif in such detail, using this high leaded copper alloy was a reasonable choice. Besides these copper-based objects, lead objects have also been found at almost all excavated IVC sites.⁸⁵ At Mohenjo-daro, a small piece of lead has been found together with copper minerals. The excavators suggested that lead may have been used to assist smelting by lowering the melting point.⁸⁶ Evidence pointing to lead smelting has not been found at the IVC sites. As argued by Heather Miller, lead was probably imported to the area in the form of ingots or scrap metals.⁸⁷ In all, it is clear that both copper and lead were being used in North India in the third to the second millennia BC.

In Southeast Asia, there are also some sporadic finds of lead objects in prehistoric contexts. For example, Li Kunsheng and Chen Guo mentioned that they once analysed a piece of lead wire which is believed to be from northern Vietnam.⁸⁸ This object is attributed to the Phung Nguyen (Phùng Nguyên) culture, which existed roughly in the first half of the second millennium BC. The authors suggest that the lead wire may have been used as a raw material for casting leaded bronze, but this is only a hypothesis. One major problem with the early metallurgy in Southeast

⁸³ Thoury et al. 2016: 6.

⁸⁴ Mille et al. 2005.

⁸⁵ Mohenjo-daro: Mackay 1937: v. 1, 450; 453; 472; 476; Marshall 1931: v. 1, 30; 227; v. 2, 464; Harappa: Dales and Kenoyer 1990: 147; Kenoyer and Miller 1999: 119; Vats 1940: v. 1, 158; Chanhudaro: Mackay 1943: 188; Lothal: Lal 1985: 656–658.

⁸⁶ Mackay 1937: v. 1, 41; 54.

⁸⁷ Miller 1999: 266.

⁸⁸ Li, K. and Chen, G. 2013: 270.

Asia is its dating. For the metal-bearing sites in today's northern Thailand and northern Vietnam, some archaeologists date them to the first half of the second millennium BC, while others insist that these remains belong to the second half of the second millennium BC. Scholars supporting the earlier dates also argue that the early metallurgy in Southeast Asia was transmitted from the Altai through the Hexi Corridor, while scholars supporting the later dates believe that metallurgy arrived in Southeast Asia from the Yellow and the Yangtze Valleys.⁸⁹ Because of these issues, I leave this for future studies.

Therefore, we can confirm that, at least in South Asia, people were using and producing metal objects prior to the emergence of metallurgy in South-west China (e.g. the Sichuan Basin). My next question will be, how far east may this South Asian metallurgical tradition have extended?

The bronze arrowhead found at Qugong on the Tibetan Plateau is a potential candidate. This arrowhead was found in the 1990s excavation seasons.⁹⁰ At that time, there were not many materials suggesting the cultural contact with communities in other areas. However, a recent survey at the site discovered evidence of millet, wheat, and barley agriculture.⁹¹ As scholars generally agreed, millets were domesticated in northern China before appeared at Qugong, while wheat and barley were domesticated in the Fertile Crescent and were introduced into South Asia during the IVC period.⁹² Based on genetic studies, scholars argue that the barleys on the Tibetan Plateau are likely to have been introduced from South Asia.⁹³ If domestic crops from both side of the Tibetan Plateau can have appeared at Qugong, we may assume that other objects and ideas,

⁸⁹ Early 2nd mil. BC: White and Hamilton 2014; late 2nd mil. BC: Higham et al. 2011; Higham et al. 2020; Pigott and Ciarla 2007. See also Pryce 2014.

⁹⁰ Zhongguo and Xizang 1999.

⁹¹ Gao, Y. et al. 2021.

⁹² Millet: Deng, Z. et al. 2018; Yang, X. et al. 2012; wheat and barley: Fuller 2006; Riehl et al. 2013.

⁹³ Lister et al. 2018.

such as those related to metallurgy, can also been exchanged between South Asia and South-west China through routes across the plateau.

However, unlike North China where people can usually travel through the open lands, around the Tibetan Plateau, following a suitable route is crucial for both travel and survival. There are some routes that were either used in the historical eras or built in the last century. The locations of these routes may suggest relatively easy ways in this overall challenging area. The most famous historic route is the so-called “Tea Horse Road”. As the name indicates, it is said to be the route through which tea and horses were traded between Sichuan, Yunnan, and Tibet. However, like the Silk Road, many parts of the Tea Horse Road are not well identified, so what we really have is not a route or routes, but a possible network connecting several important stops.⁹⁴ Some routes in this network may be connected with routes on the other side of the Himalayas through mountain passes (such as the one passed by the modern China-Nepal Highway). Another famous road in this region, although with a much shorter history, is the Burma Road, it was constructed during the World War II by the Allies in order to guarantee the flow of suppliers between South-west China and the British colonies in South and South-east Asia. This road chose a route from Kunming to North Myanmar and North-east India along the southern slopes of the Himalayas.⁹⁵ Besides these two routes, there is actually a third, indirect option. People from South Asia can go to Central Asia, and then enter Xinjiang and the Hexi Corridor through the IAMC. A route connecting the Sichuan Basin and the Hexi Corridor through Hanzhong, historically known as the “Gold Bull Road”,⁹⁶ can be used for the last part of the journey.

⁹⁴ See e.g. various papers in Liu, Q. 2006. The eastern part of the network in the Hengduan Mountains is also called the “Zang-Yi Corridor”, first proposed by Fei Xiaotong, see Shi, S. 2009.

⁹⁵ Tan, P. 1945.

⁹⁶ Li, J. 2015: 355–480.

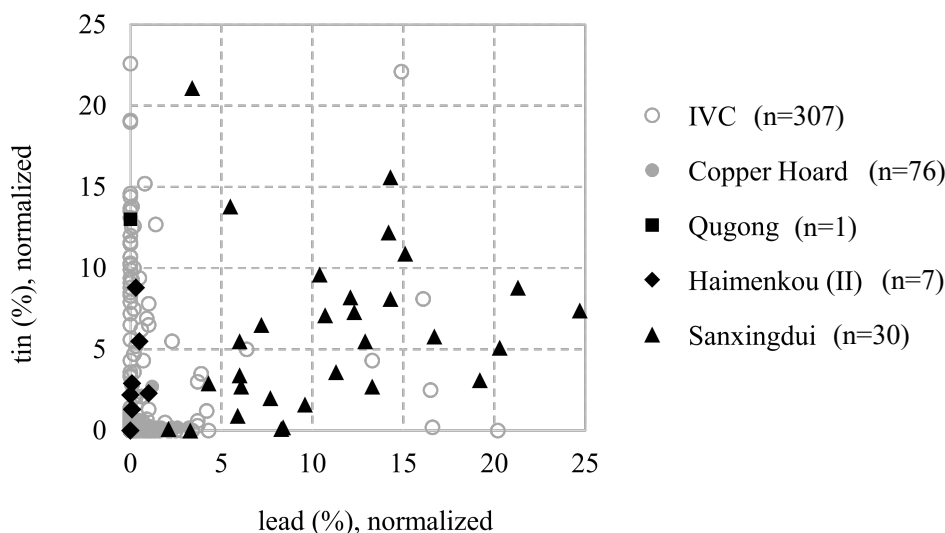


Figure 2.15 Distribution of tin and lead in the copper-based objects of the Indus Valley Civilisation (data: Chakrabarti and Lahiri 1996: 45–60).

Due to the existence of these routes, some scholars suggest that communities in the Sichuan Basin may already have established cultural contact with South Asia during the second millennium BC. One of their arguments is that some cultural traits reflected by the Sanxingdui bronze assemblage, such as the favour of face masks, sceptres, seashells, and gold objects, can also be found in South Asia.⁹⁷ In my opinion, it is too early to draw such a conclusion. From the perspective of metal objects, there is no evidence to show that the characteristics in the material culture of Sanxingdui came from South Asia, even some of the characteristics existed in both areas. The bronze and gold masks from Sanxingdui and Jinsha, for instance, were much earlier than any similar masks found in the Himalayas. Although there seems to have been no previous tradition of making similar masks in the Sichuan Basin or anywhere else in China, we cannot rule out the possibility that such a tradition did exist but left no archaeological evidence.⁹⁸ Some other cultural characteristics proposed by scholars, such as the use of gold and sceptres (maces),

⁹⁷ Duan, Y. 2007: 302–331; Shi, J. 2017. See also various papers in Duan, Y. and Fan, X. 2016.

⁹⁸ Jessica Rawson reminded me that some details on the Sanxingdui masks may look similar to those on objects made of wood. Therefore, there may have been wooden masks which were used before the metal ones, but not preserved in archaeological contexts (personal communication).

can also be found in the Hexi Corridor. Therefore, it is not necessary for Sanxingdui to be connected with South Asia in order to have such objects.⁹⁹ Meanwhile, if we look at the alloy types of the Sanxingdui bronzes, most Sanxingdui objects have much higher tin levels than objects from earlier and contemporaneous sites in South Asia (IVC: 2600–1500 BC; Copper Hoards: 1500–1000 BC), as well as samples from Tibet (Qugong) and Yunnan (Haimenkou) (Figure 2.15). As the use of high-leaded bronze was a very typical practice in early China, the chemical compositions of the Sanxingdui bronzes suggest that the early metallurgy in the Sichuan Basin was more likely to be influenced by people from the north and east, rather than by those from the south and west.

In conclusion, although there may have been cultural contact between South Asia and the metal-using communities in South-west China during the second millennium BC, there is still no clear evidence suggesting that the early metallurgy in the Sichuan Basin was affected by stimulation from that directly. However, as new excavation is ongoing at Sanxingdui, there may be new discoveries which will change our understanding.

Yellow Sea Rim and North-east China

The third example of possible external stimulation which had potential impact on early metallurgy is through the north-eastern part of China, especially around the Yellow Sea Rim (Figure 2.16). The Yellow Sea is the water body between China and the Korean Peninsula. It has two major bays, the Bohai Bay, and the Korea Bay. The Yellow Sea is also where a few major rivers empty out, including the Yellow River and the Liao River. For prehistoric human activities in this region, communication must have been particularly facilitated by seafaring. Especially, studies show that during the third and the second millennia BC, there was a major transgression

⁹⁹ See more in Chapter 6.

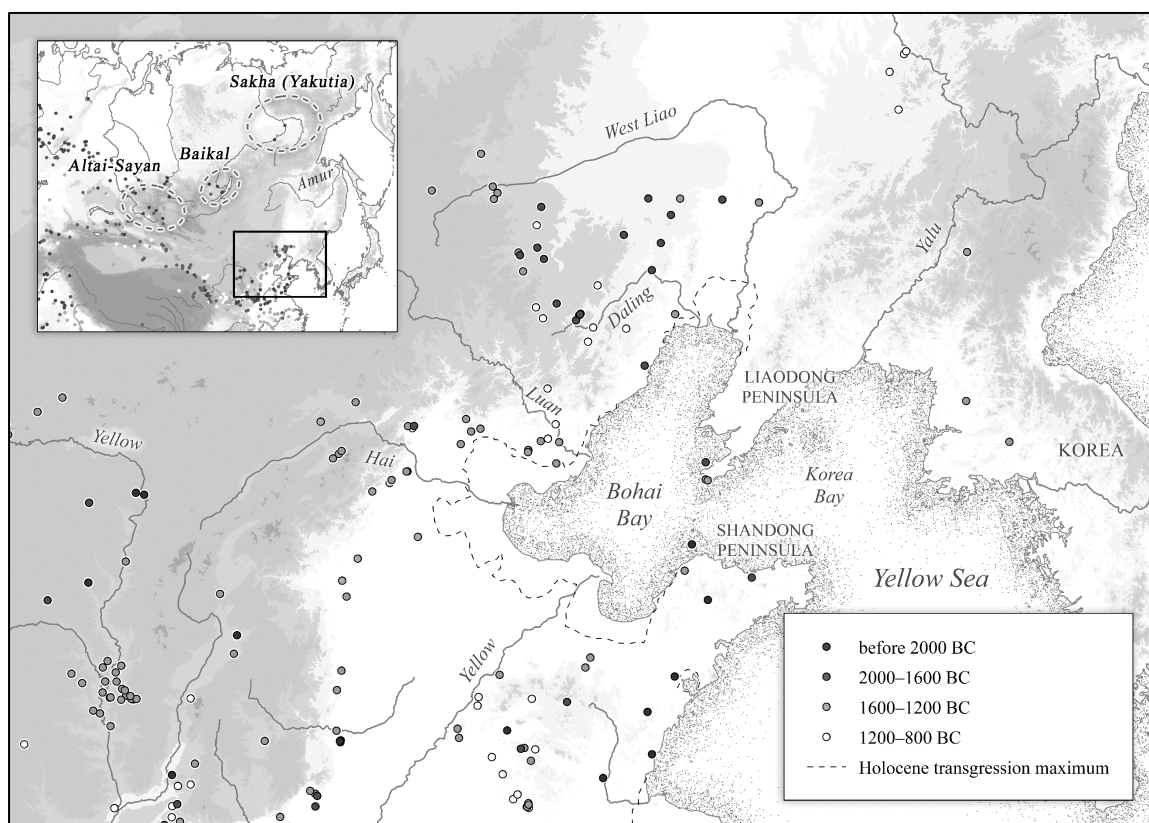


Figure 2.16 Metal-bearing sites in the Yellow Sea Rim and the reconstructed Holocene shorelines.

of the Yellow Sea, as many parts of today's land may have been covered by water.¹⁰⁰ Therefore, prehistoric communities in that area may have an even more sea-based lifestyle than people living there today.

On the southern side of the Bohai Bay is the Shandong Peninsula. As previously discussed, metal objects and possible metallurgical remains dating to the third millennium BC are found in this area. On the north side of the Bohai Bay, however, evidence of metal use is rather thin. One candidate of the earliest metallurgical remains is the ceramic moulds found at Xitai, a settlement site between the Daling River and the West Liao River. The excavators suggested that the moulds were probably used for casting small metal ornaments.¹⁰¹ There is no radiocarbon date from the

¹⁰⁰ Guo, X. 1979; Li, S. 1962; Xue, C. 1993; 2002; Zhongguo 1999a: 183–185; 1977. According to these studies, the highest sea level was about five meters above the modern level.

¹⁰¹ Yang, H. and Lin, X. 2010.

context of the moulds. The only suggestion of their date comes from the ceramic vessels in the context. These vessels are attributed by the excavators to the middle phase of the Hongshan culture, or around 4000–3500 BC.¹⁰² The reliability of this date is questioned by many scholars.¹⁰³ Similarly, a few furnace fragments and a small copper ring have been found at Niuheliang, an adjacent site on the bank of the Daling river. These objects used to be dated to the fourth millennium BC as well. Recently, based on clearer stratigraphic evidence and new thermoluminescence dates, scholars now agree that the objects should be no earlier than 2000 BC.¹⁰⁴ That is to say, based on the newest dating, metal objects may not have been used or produced in the northern part of the Bohai Rim during the third millennium BC. However, one particularly notable find is a blade-like metal object found at Dazuizi, which is on the tip of the Liaodong Peninsular. The cultural context of the object is dated to around 2000 BC.¹⁰⁵ The composition of the object is copper with tin, lead, and arsenic.¹⁰⁶ Considering the location of the site, it is likely that people came to this site by sea rather than from the land.

The evidence for wide adoption of metal-using in the northern part of the Yellow Sea Rim appeared in the first half of the second millennium BC, as a dozen of sites with very similar types of metal object appeared in the north of the Bohai Bay. Although metal production remains discovered in this area are very limited, lead isotopic analysis suggests that the objects were probably made locally (more in Chapter 6). The origin of this metal tradition is still unclear, but scholars have pointed out that it is more likely to come directly from the steppes rather than from the Yellow River Valleys.¹⁰⁷ The evidence of metal remains in the eastern steppe is very thin

¹⁰² Zhongguo 2010: 821–822.

¹⁰³ Ren, S. 2004; Xu, H. 2016a. Xu Hong suggested that the date may be around 3800–2900 BC.

¹⁰⁴ An, Z. 2003; Li, Y. et al. 1999; Xu, H. 2016a.

¹⁰⁵ Object and dating: Dalianshi 2000: 108; 269.

¹⁰⁶ Dalianshi 2000: 295.

¹⁰⁷ Liu, H. 2013: 34–43.

due to the difficulties in conducting large-scale fieldworks in the harsh environment. So far, two areas which show signs of relatively early metal-use and metalworking are the northern and western sides of Lake Baikal (Cis-Baikal) and the middle Lena Valley, also known as Sakha (Yakutia).

In Cis-Baikal, most early metal objects are associated with the contexts of the late Neolithic–Early Bronze Age Serovo-Glazkovo culture.¹⁰⁸ For instance, at the Kurma XI cemetery, ten metal objects (nine of copper and one of silver) have been found in eight of the total twenty graves. These objects include several knives, a needle, a pendant (medallion) and a ring.¹⁰⁹ According to the radiocarbon dates, the burials where earliest metal objects are found are about 2400–1800 BC.¹¹⁰ However, since the date of the burials is only the date when the objects were disposed, we do not know when the objects were produced, nor do we know whether they were produced locally in Cis-Baikal.

To the further east of Lake Baikal, the known evidence of metal objects and metal production is very limited. In a recent review article, Viktor Dyakonov and colleagues highlight the middle Lena Valley as a potential area for further investigation.¹¹¹ Metal objects as stray finds were discovered over the twentieth century. These objects usually cannot be dated accurately. One exception, however, is a small piece of oxidised copper or bronze object, originally around the skull of an individual in a burial at Ymyyakhtakh Diring-Yuryakh. The radiocarbon date obtained from the human bone is 2464–2146 BC.¹¹² In addition, the earliest evidence for bronze casting in this region is some fragments of ladles found at the Ulakhan-Segelennyakh site. The

¹⁰⁸ Link and Weber 2001; Weber 1995.

¹⁰⁹ Metcalf 2006: 91.

¹¹⁰ Metcalf 2006: 46; 155–156; for the dating of the Serovo-Glazkovo culture, see Weber et al. 2005; Weber et al. 2006.

¹¹¹ Dyakonov et al. 2019.

¹¹² In Dyakonov et al. 2019: Fedoseyeva 1988; Mochanov 2017.

radiocarbon dates of the context show that the ladles were used around the first half of the second millennium BC.¹¹³ Both the Baikal and the Sakha regions are still quite far away from the Yellow Sea Rim, so it is unlikely that the two regions were the direct external stimuli to the emergence of metallurgy in the latter. Nevertheless, the spread of metal objects and metal production in the eastern steppe suggests that people living and moving on this vast land during the third and the second millennia were metal-users and even metal-producers. Therefore, it is possible that communities around the Yellow Sea Rim in East Asia obtained metal objects and metal-related knowledge via this direction.

Leaded Bronze and People: The Case Studies

The scope of China discussed in this chapter covers a wide swath of land with various early communities and heterogeneous culture. However, there are still some shared characteristics which hold the discussion of early metallurgy in this region together. All early Chinese metal-using communities seem to have received the essential knowledge set of metallurgy (such as smelting, casting, and alloying), either directly or indirectly, from the west. The wide distribution of metal deposits, especially copper and lead, also made it possible for communities in different Chinese regions to establish their local metal production. Meanwhile, we also need to take the material agency of metal into account. When people work with a certain material, such as leaded bronze, the properties of this material may also contribute to the establishment of some general human-thing relations (Chapters 3 and 4). The aim of this thesis is to show how a material engaged with people from different social and cultural backgrounds, and thus led to different technological choices and material culture.

¹¹³ Site: Alekseyev 1996: 71; dating: Alekseyev and Dyakonov 2009: 35.

For this purpose, I choose four metal-using communities or regional groups in China as examples to be studied in the second part of the thesis (see also the colour plate). People in these case studies all had some understanding of lead as a metal material, nevertheless, the ways they engaged with this material were very different. In some cases, people added lead to copper alloys to make leaded bronze, while in other cases, the idea of using lead in alloying was ignored or rejected. For those who favoured leaded bronze, Erlitou in Chapter 5 is a good example to be studied. This site and its successors in Central China systematically used leaded bronze for a particular purpose—casting ritual bronzes. As I will show in this case study, the use of leaded bronze by Erlitou and its followers may have been driven by the wishes to make more affordable ritual vessels. Such a preference also made lead one of the most used metals, together with copper and tin, in early China.

In the northern part of the Bohai Rim, we meet a different material culture of lead and leaded bronze. As demonstrated in Chapter 6, people at Dadianzi were buried with metal ornaments made of both leaded bronze and lead. By investigating the objects, the local metal deposits, as well as the cultural connections, I argue that the people in the northern Bohai Rim, who adopted a steppe tradition of metallurgy, did not intentionally add lead to copper alloys. Rather, lead and bronze (without high lead contents) may have been recognised as two types of metal by their different colours.

After these two case studies, Chapter 7 examines various communities in the Hexi Corridor. Around 2000 BC, people started to participate in metal production, probably under the external stimulation from the Steppe. Lead resources are abundant in this area, but for a long time, people tried to avoid lead in their metal products by confining themselves to lead-free ores in smelting. However, when cultural exchange between the Hexi Corridor and Central China strengthened in the middle of the second millennium BC, leaded bronze began to appear in the south-eastern part of the Hexi Corridor. Through this change from unleaded to leaded bronze objects, we can see

how the material culture of the Hexi Corridor communities responded to the changing interregional relations.

For the final case study, the area of the lower Yangtze Valley in Chapter 8 shows the parallel of two types of metal production. In this area, some communities were participating in the production of ritual bronzes as those in Central China, while other communities were only using metals in a very limited way. For people in the latter case, I argue that the omnipresence of lead in the metal resources may have discouraged their interest in metallurgy.

The case studies I choose cover some of the major metal-using areas in early China, but there are some other areas with leaded bronze use, such as the Northern Zone, Jiangxi and Hunan in the middle Yangtze Valley, and the Sichuan Basin, which are not examined in this thesis. The reason not to include sites in these areas is mostly due to the lack of sufficient information, such as evidence of local metal production. Therefore, the conclusions we reach by studying our examples may only represent some but not all of the reasons why leaded bronze was (or was not) adopted.

Engaging Changes

Alloys from Materials to Material Culture

“*Endeavour*’s life starts in an unrecorded time, in a subterranean space several inches deep.

There, as summer faded into autumn, an oak tree begins life as an acorn.”¹

This is the beginning paragraph in Peter Moore’s *Endeavour: The Ship and the Attitude that Changed the World*. In this *The Sunday Times* bestseller, the most remarkable sentence to me is this beginning, as it shows how a historically important object (in this case, a ship) started from a very material-oriented perspective—an acorn which ultimately became the building material of the ship. This is not a metaphor, but a reminder that, for any discussion of a cultural phenomenon, we should think of how the particular materials are transformed into the material cultural.

Like stone, ceramic, fabric, and wood, leaded bronze is basically a material which, in some cases, people utilise. In research fields such as material science, a material is defined as a matter out of which people can make things.² In other words, whether a substance (or a group of substances) can be considered a material is cultural-related, as this depends on how people perceive matters

¹ Moore 2018: 15.

² Ashby et al. 2019: 3.

in this world and how people make things out of matters. Those human-made things are called objects or artefacts, as those two words are often interchangeable.³ In archaeology and anthropology, the studies on artefacts are often put under the name “material culture studies”, while the same term is also used by other disciplines such as material history, cultural geography, and sociology.⁴ Regarding its definition, most scholars suggest that material culture is the culture based on tangible objects, as opposite to “nonmaterial”, symbolic culture, such as symbols, art, and beliefs.⁵ However, some scholars also use the term “material culture” to refer to intangible things, like sounds and languages.⁶ In this thesis, I will use the first definition since it is more widely accepted.⁷

For a natural substance to become part of material culture, or for one form of material culture to become another, a transformation has to take place in which certain human activities are involved. In this chapter, I will first discuss these processes of transformation and the particular human activities which we may call technologies. Next, I will discuss the technologies involved in the creation and transformation of metal objects, especially the multiple ways of creating alloys. In the final part of the chapter, I will use a case study of a site on the Iranian Plateau to show how we may recognise the technological choices in early metallurgy.

³ Berger 2014: 16–18.

⁴ Hicks and Beaudry 2010.

⁵ Woodward 2007: 14–16.

⁶ E.g. Aronin et al. 2018: 25–26; Miller 2010.

⁷ Nevertheless, I should probably point out that the separation of material and nonmaterial worlds itself is a cultural-related idea. See e.g. Brown and Walker 2008; de Castro 1998.

Material Culture, Technological Choice, and Chaîne Opératoire

To transform a natural thing to form part of a material culture, the simplest way is by noticing the object. As soon as we lay our eye on a natural thing, that thing is no longer purely natural. We can think of a collection of mineral specimens. The collected minerals, probably due to their aesthetic or scientific value, certainly fall within the scope of material culture. Although the rocks themselves may be mostly still in their natural state, the way we separate these things from their natural environment and reorganise them in a new context establishes new human-thing relations. It is these relations which transform the natural objects into what we may call artefacts (Figure 3.1).

What follows noticing is often a state of craving. People choose to engage with things not only because they are there, but because those things are appealing and desirable. Desire is important to our discussion since it is related to the idea of value. Value is a particular type of human-thing relation. The social theories of value are complicated and will not be elaborated in this thesis.⁸ What I want to point out here is that the concept of value provides people not only with a reason to obtain and produce something, but also with a way to compare two objects or two types of material and, if necessary, to exchange them. The latter may have been part of the reason behind activities such as circulation and distribution, as we have already discussed in Chapter 2.⁹

From this perspective of demand, we can compare those major metals used in early China: copper, lead, and tin. On the modern territory of China, the distribution of these metal resources is quite uneven. While copper and lead deposits are common in many areas, tin deposits,

⁸ Graeber 2001; 2005; Papadopoulos and Urton 2012; Wijngaarden 1999.

⁹ More discussion of exchange, see Dillian and White 2009; Miyazaki 2010.

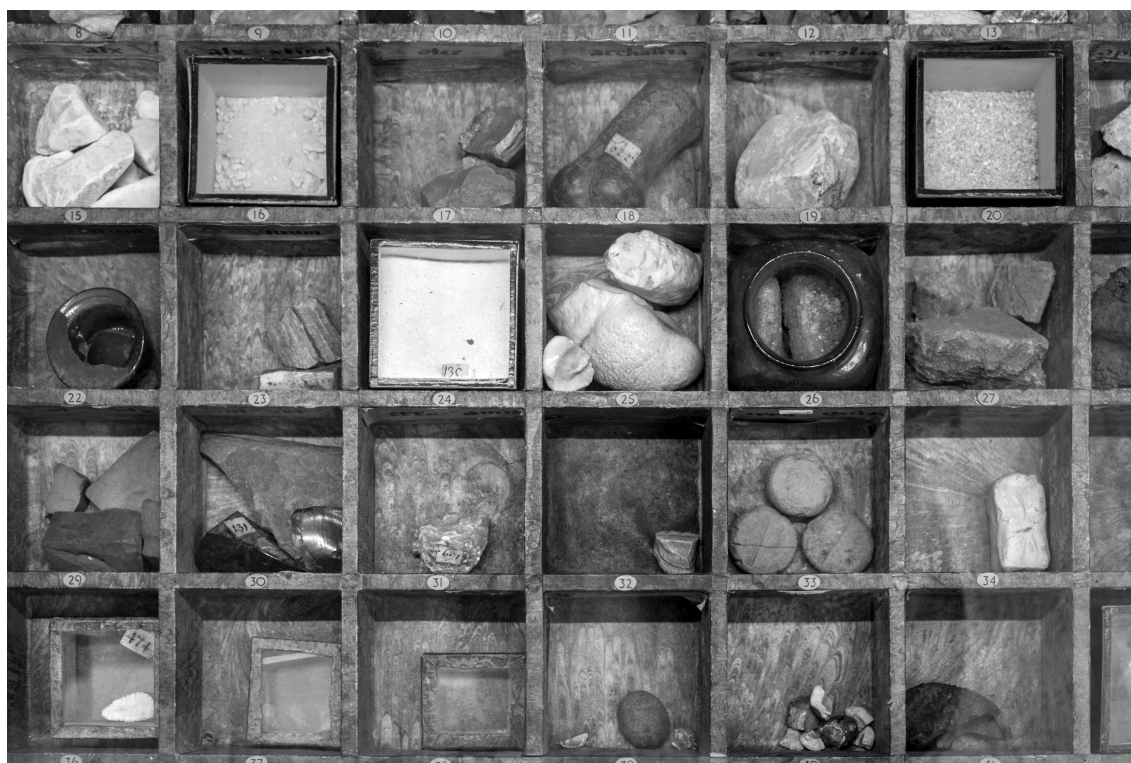


Figure 3.1 A drawer of Sir Hans Sloane's mineral collection, British Museum, London.

conversely, are much more narrowly distributed, as most large tin mines are all in south China (Figure 3.2).¹⁰ That is to say, to many metal-using communities in North China, especially the Yellow River Valleys, people did not have good access to tin unless they could find a way to obtain the resources from somewhere else.¹¹ Meanwhile, as I will explain in Chapter 4, for certain purposes such as casting ritual vassels, tin and lead can sometimes be used as substitutes for each other. However, tin is probably a better choice than lead due to the potential issues of the latter in casting. As tin had both a more limited supply and a better result in use than lead, we can imagine that the exchange value of tin may have been higher than the exchange value of

¹⁰ Globally speaking, lead is more available than tin. According to the United States Department of the Interior, the average abundance of lead in the crust is 15 ppm, while the abundance of tin is just 2–3 ppm: Brobst and Pratt 1973: 317; 641.

¹¹ So far, there is still no certain conclusion regarding the provenance of the tin which facilitated the large-scale bronze production in early China (especially the middle Yellow River Valleys). See the discussion in Chen, K. 2012; Liu, S. et al. 2018; Tian, J. and Ma, J. 2017; Yi, D. 2013b. For the distribution of tin and lead in China, see also Chen, Z. et al. 2015; Zhang, C. et al. 2014.

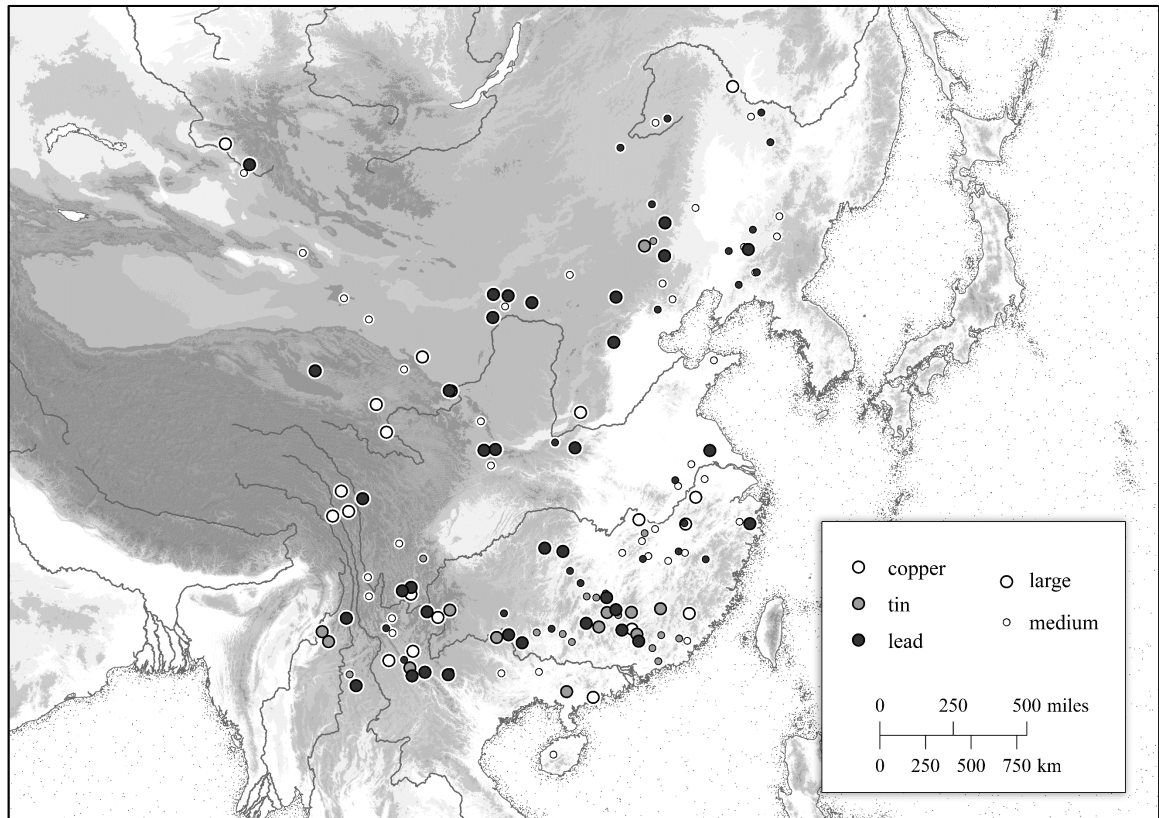


Figure 3.2 Distribution of major copper, tin, and lead deposits in China (after Liu, L. and Chen, X. 2003: 38–41).

lead.¹² In the case study of Erlitou (Chapter 5), I will argue that this difference in exchange value may have affected several technological choices, leading to the acceptance of leaded bronze vessels.

As people want something, they often try to obtain it. Like noticing and craving, possession is also a transformation of material culture. To own something means that the object is moved to a new cultural sphere, as the person now have control over the object. In a society, ownership means that other people all agree to give up their rights to control over the same object. Possession changes not only the object but also the subject—the owner. As the mineral

¹² The law of supply and demand is used in microeconomy as a model of price determination. In the case of early China, I do not want to use the term “price” as it indicates a condition of a market economy which may have not existed at that time.

specimens are collected, the person becomes a rock collector, or even an amateur geologist. Our interpretation of some aspect of the owner's knowledge and personality is also affected. This resembles the way by which we try to interpret or recognise people today from their clothing and cars (just think of the stories of Sherlock Holmes).

The control over an object also enables the owner to further transform it. One thing people can do to an object is to utilise it, or, in other words, to consume it.¹³ As the object is used or consumed, it is not just culturally changed, but often physically changed as well. Archaeologists are excited with the physical changes because we can rely on use-wear analysis to tell us how the object was used. More complicated ways of transforming objects include, for example, making minerals into jewels, or extracting metals from the minerals. One particular case is to transform several objects into a new object. We may call the formers raw materials, while the latter products.¹⁴ To create a product requires a special set of knowledge and know-how. In this thesis, I use "metalworking" to indicate the skill set of producing metal objects. Archaeologically, the capability of metalworking is suggested by the presence of metal producing remains, such as ores, slags, crucibles, and tools. Meanwhile, I use the word "metal-using" to indicate the presence of metal objects without evidence of metal production.

All these means of transformation involve some human-thing engagements. In particular, some of the engagements, especially those involved in production, are often called "technologies". The term technology is commonly used in archaeology, while the exact meaning often varies in different contexts. Here, I use the term to describe certain types of human activity which transform objects (e.g. metallurgy) or beings (e.g. horse domestication) physically or culturally. For the first part of the definition, I adopted the suggestions made by scholars such as Heather

¹³ Dant 1999; Dietler 2010.

¹⁴ Economists use more precise definitions of these terms. In economy, the term raw material means only unprocessed materials, while processed materials can be either finished products or intermediate materials.

Miller to consider technology a set of actions, or the ways people do things.¹⁵ This is to distinguish technology from things which do not necessarily involve actions, like knowledge, concepts, or cultural beliefs. The second part of my definition of technology may be different from some scholars' suggestions. According to their view, a technology does not necessarily involve physical objects. For example, Ursula Franklin argued that prayer and storytelling are also technologies just like pottery making.¹⁶ In my definition, I limit the discussion of technology to the interaction with physical objects and beings in accordance with the definition of material culture I use. However, I agree with Franklin's view that technology is "ways of doing" rather than "ways of making".¹⁷ Therefore, in my definition, a non-physical transformation can also be considered a technology. Nevertheless, I should also admit that not all these technologies are archaeologically researchable since, as one of the limits of archaeology, we are only able to study human activities with physically traceable evidence.

For most technologies, there is also more than one way to achieve a certain result. I will use the term "technological choices" to represent these possibilities. In social sciences, the term "technological choice" was first used by French scholars in the 1960s and fully developed into a theory in the 1980s, especially by Pierre Lemonnier.¹⁸ When observing the practices of the Royal Air Force pilots, Lemonnier noticed that some of their flying habits, led by "a mixture of tradition, bravado, and ill-conceived military regulations", are inefficient and even dangerous, but people still continue using them.¹⁹ Lemonnier noted that these seemingly unnecessary habits are also commonly seen in the development of technologies. At that time, the studies on technology were dominated by utilitarian and evolutionary approaches. That is to say, scholars

¹⁵ Miller 2007: 3–7.

¹⁶ Franklin 1992.

¹⁷ For example, Rowan Flad considered the process of urbanism as a technology: Flad 2018.

¹⁸ Lemonnier 1986; 1992; 1993b.

¹⁹ See, in particular, Lemonnier 1993a.

believed that any technological habit can be explained by functional reasons, so the habit can survive in natural selection.²⁰ Lemonnier, on the other hand, argued that choices in technology do not necessarily have functional reasons. Instead, these choices are influenced by social and cultural factors which may not be directly related to technology. The theory of technological choice was soon introduced into archaeology. One of the important publications is a book edited by Lemonnier, titled *Technological Choices: Transformation in Material Cultures since the Neolithic*, published in 1993.²¹ In this book, a study on the Neolithic Jura Mountains (north of the Western Alps) communities by Pierre Pétrequin gives an example of how this theory can be applied in archaeology. Pétrequin noted that the transmission of some types of artefact were intentionally blocked, but the rejection of these artefacts were not because that they were useless, but because that they did not fit into the local culture.²²

Furthermore, a type of material culture, such as bronze, often involves multiple technological choices in a certain sequence. To investigate these choices, we first need to reconstruct the whole life cycle of the material culture. Arjun Appadurai called this cycle the “social life of things”, while Chris Gosden used the term “cultural biography”.²³ An analytical method which is now widely used by archaeologists is *Chaîne opératoire*.²⁴ A common *chaîne opératoire*, according to Michael Schiffer and James Skibo, includes not only the activities of production, such as the procurement of raw materials and manufacturing, but also other parts of the overall life cycle of an artefact (distribution, use, reuse, discard).²⁵

²⁰ For a review, see Hicks 2010.

²¹ Lemonnier 1993b

²² Pétrequin 1993.

²³ Appadurai 1986; Gosden and Marshall 1999.

²⁴ Cresswell 1990; Edmonds 1990.

²⁵ Schiffer and Skibo 1997.

We can use the *chaîne opératoire* of ritual bronze vessel as an example (Figure 3.3). The life cycle of a bronze vessel can be divided into two parts. The first is what we may call production. The second is what we may call the use-life of the object. In both parts, multiple activities and technological choices are involved. For example, if craftspeople want to cast a bronze vessel, they can choose bronze ingots with predetermined alloy compositions. Alternatively, they can also use copper and tin ingots as raw materials and create an alloy during casting. In the first scenario, alloying is a technological choice in the stage of raw material selection. In the second scenario, alloying is part of the manufacturing techniques. In both cases, the selection of materials also affects other technological choices, such as moulds and the firing temperature. The technological choices related to alloying will be discussed in the next section. As Bill Sillar and Michael Tite concluded, there are five main areas in which technological choices can be made: raw materials, tools, energy sources, techniques, and sequence. Meanwhile, a technological choice tends to be influenced by two spheres (without a hard line between them): material influences (the properties of the material) and cultural influences (economy, politics, ideology, etc.).²⁶ To understand why a certain technological choice is made, we need to study not just its relationship with other technological choices, but also the material and cultural influences behind the choice. For a particular material, material influences are often reflected in what we may call the “properties” of the material. In the case of leaded bronze, how these properties may affect the technological choices will be discussed in the next chapter.

Another question on technological choice is its agency. When we use the word “choice”, we inevitably assume that the decision is made by someone or something with agency. For most previous studies on technology, especially before the 1960s, scholars focused on technological choices made by human agency. This view is challenged by agency theory developed through the 1970–80s as part of “practice theory”, especially after 1980 as the theory started to emphasize

²⁶ Sillar and Tite 2000.

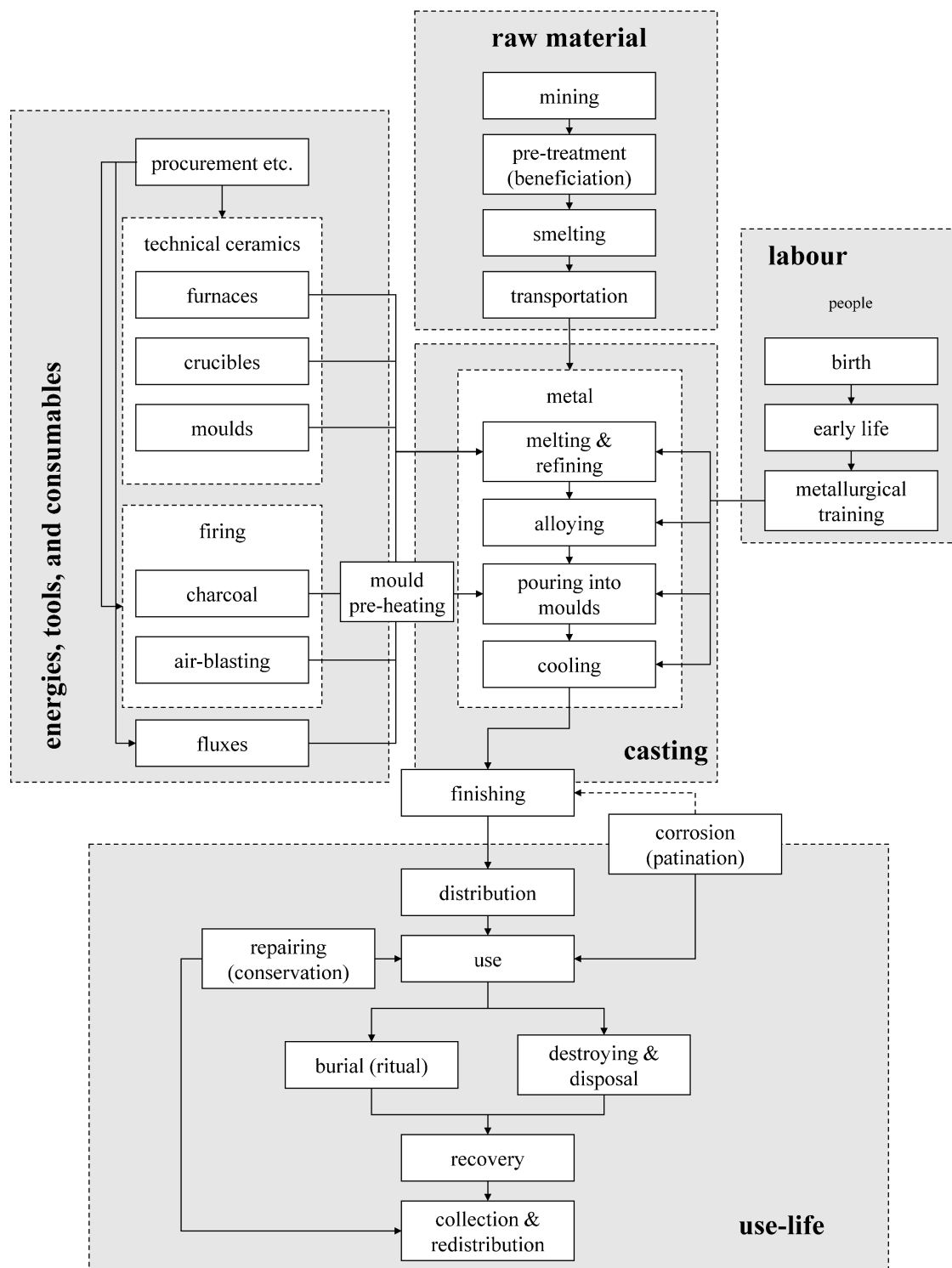


Figure 3.3 *Chaîne opératoire* of a cast ritual bronze vessel (modified from Chase 1983: 101; Hoffman and Miller 2014: 701).

agency of objects.²⁷ According to agency theory, things can sometimes act in a human-like way, such as establishing relationships with each other, as well as with humans.²⁸ The recognition of “material agency” leads us to think of technology and social relations from the perspectives of objects.²⁹ In technological choices, material agency can be reflected in the co-dependency of choices, as the choice of one technology may lead to the choice of another (such as a certain raw material can only fit a certain type of mould).

For human agency, there is also a particular issue of individual vs. collective human agencies. This is because that, in many technologies, it is impossible to figure out which individual or individuals made the technological choices. Rather, the choices seem to have been made collectively. The logic behind a collective choice-making may be different from that of an individual choice-making. One particular example is tradition. Traditions often have strong impacts on any new technological choice. In such a case, we cannot say that the technological choice is made by any individual, but only by traditions as collective human creations. Some scholars use the term “path dependence” to describe such an effect. Our modern QWERTY keyboard design is an example of path dependence in technological choice.³⁰ To incorporate this discussion in my research question, the making of leaded bronze, as I will show in the following section, almost always involve more than one person. Therefore, I will consider the use of leaded bronze as a collective choice rather than an individual choice.³¹ That is to say, I will focus on the social acceptance of leaded bronze, rather than the new idea itself. This is because that, in reality, any individual may have had an idea to use a new material. If the individual did not leave

²⁷ Barrett 2001; Bourdieu 1977; Dobres and Robb 2000; Giddens 1979; Johnson 1989.

²⁸ Gosden 2005.

²⁹ Kohn 2013; Malafouris and Knappett 2008; Robb 2004.

³⁰ David 1985; Hall et al. 2011.

³¹ By contrast, the use of materials by modern artists more often reflects, although not always, individual choices, see the artwork by Anselm Kiefer in Chapter 4 (Figure 4.2) as an example.

us any historical record, it is impossible for us to understand why the individual made that decision.³² However, if leaded bronze was widely used in a community over a period of time, we may be able to make some suggestions of why this material was widely adopted. In other words, if a community was using leaded bronze, my real research question is not why people used leaded bronze (which may have been an individual decision) , but why the use of leaded bronze was adopted by the community (which must have been a collective choice).

In addition, making a technological choice requires not only agency (who) and motivation (why), but also means (how). In order for a person to work with an object or a material, the person needs to be equipped with two things: knowledge and know-how (or “body knowledge”). Knowledge decides what people want to do, while know-how decides what people really do, or they may even “unconsciously do”.³³ The difference between knowledge and know-how has been discussed in many archaeological and anthropological studies. For example, in his study on the Late Neolithic flint production in Scandinavia, Jan Apel noticed that the production of flint daggers relied on two types of human-thing engagement. On the one hand, the craftsperson must have learned the knowledge part, that is, the step-by-step process of reducing the raw material to a dagger. On the other hand, the craftsperson also needed to develop a certain muscle memory, or the know-how, in order to control the gestures. In this case, the morphology of the final products reflected both the knowledge and the know-how of the craftsperson.³⁴

In summary, technology is a form or a method of transformation. An object is being transformed throughout its lifecycle, which can be seen as a *chaîne opératoire* with a series of interrelated technological choices. Each of the choices is likely to be made by a group of interrelated people

³² Just think of social taboos. Usually, the reasons behind a taboo can only be understood either by interviewing the people, or by studying their written records. But neither of these two methods are available in archaeological cases.

³³ Kuijpers 2013.

³⁴ Apel 2008.

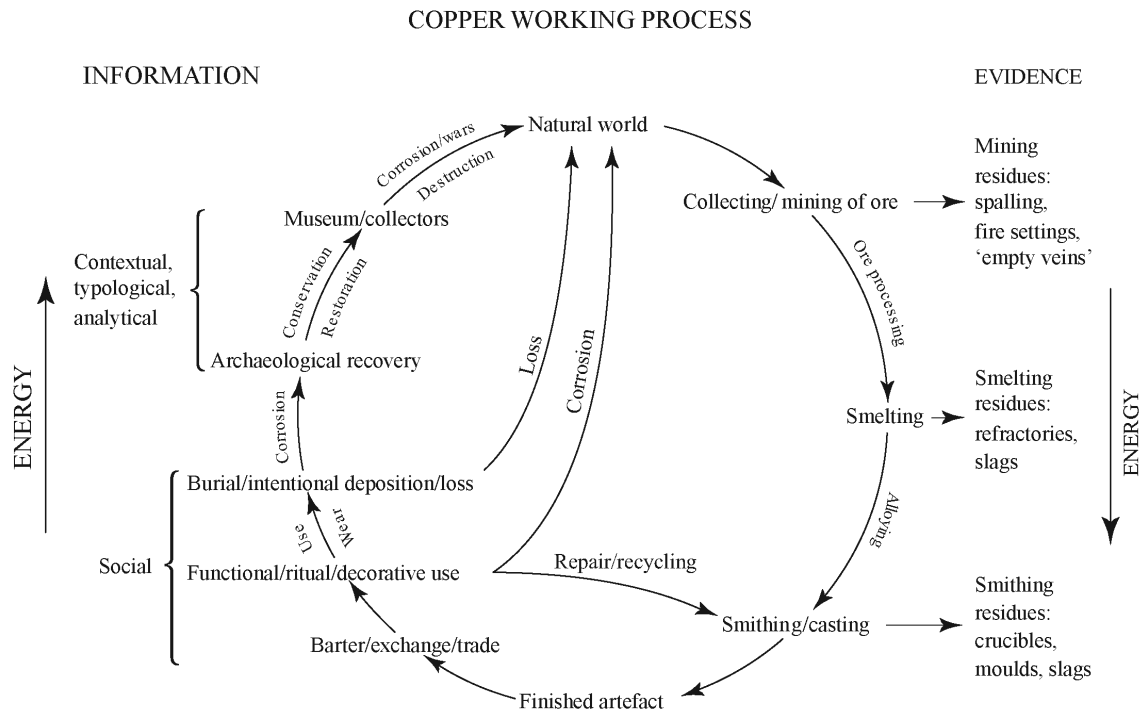


Figure 3.4 Metal cycle representing the production and working of copper (after Ottaway 2001).

(human agency) and objects (material agency), rather than by one individual or one object. The choices are made with certain motivation (material and cultural influences) and capability (from a human perspective, knowledge and know-how). For my research question, alloy type itself may not be a technological choice, but a result a series of technological choices. I will discuss this in the next section.

The Metal Cycle and the Creation of Alloys

To understand the use of leaded bronze, we may also begin with the life cycle of the material. One concept proposed by scholars is “metal cycle” or “metal flow”. This can be seen as an alternative type of *chaîne opératoire*. Figure 3.4 shows a metal cycle by Barbara Ottaway. At the top of the circle is the metal in its natural state, while at the bottom is the finished metal artefact. As the right side shows, the natural metal can be transformed into an artefact through a series of activities including mining, smelting, and casting. On the left side, the artefact can also

turn back into the nature through processes such as destruction and corrosion. Meanwhile, many metals may keep their forms as artefacts for indefinite periods, such as in burials, hoards, or, after discovered by archaeologists, in museums.³⁵

Unlike *chaîne opératoire*, which usually focus on the life cycle of objects, a metal cycle puts metal elements (copper, iron, lead, etc.) at the centre.³⁶ The advantage of this approach is that it reflects something fundamental about these elements. When an object is disposed of and destroyed, the certain “object identity” (as the quality of being the same object) may be permanently lost, as a car broken up into a scrap metal is no longer a car. However, the iron and other metal elements in that car are surprisingly stable,³⁷ no matter how many times they are recycled and reused. Between the metal elements and the metal objects are something we may call metal materials. Copper is both a metal element and a metal material, while bronze (copper-tin) and steel (iron-carbon) are only metal materials but not basic metal elements. The “bronze identity” is created when copper and tin are mixed, while the material can also lose its “bronze identity” due to processes such as corrosion. Leaded bronze, an admixture of copper, tin, and lead, is also a metal material. Its identity as leaded bronze only exists when these three elements are mixed. In other words, the process of mixing, or what we may call alloying, is what creates the identity of leaded bronze.

Therefore, we can imagine that copper, tin, and lead are all in their own metal cycles. At a certain point, these three cycles have an intersection, creating this metal material. This material can then be used to make certain objects. If we borrow the words used in a paper by the FLAME project, authored by Peter Bray and colleagues, the metal cycle of each element can be seen as a “flow”,

³⁵ Ottaway 1994; 2001.

³⁶ Bray et al. 2015; Ottaway 2001; Pollard 2018: 43–45.

³⁷ Most metals in our discussion are stable nuclides, which means they have sufficiently long half-lives.

while a metal material, or a metal object, can be seen as a “form” created by one or several flows.³⁸

How, then, do the flows of copper, tin, and lead flow together to form leaded bronze? Generally speaking, “alloy” is a concept based on modern chemistry, which identifies materials as the combination of chemical elements. From this perspective, to describe the alloy type of ancient artefacts, modern researchers usually agree on a certain threshold, like 1% or 2%, to distinguish an alloy from an impurity.³⁹ Hence, copper without significant amount of other metal elements is called pure copper, while copper with more than 1% or 2% tin is called bronze. The use of 1 or 2% as a threshold is based on the practical experience in modern industries, since additional elements beyond this level usually bring significant changes to the properties of the material. However, for archaeological cases, such a definition of alloy is not enough, as it does not reflect whether people were aware of a material as an alloy, or what kind of human behaviour (“technology”) was involved in creating the alloy. In order to understand this, we need to first differentiate two types of alloy. The first is what I call “naturally co-occurring” (Table 3.1, scenario 1). This usually happens with gold, silver, copper, and platinum group metals. Electrum is an example of a natural alloy of gold and silver. The wide use of this metal in the ancient Mediterranean region was recorded by Pliny the elder in his *Natural History* (*Naturalis Historia*), written in the first century AD.⁴⁰ Another type of natural alloy is the iron-nickel alloy found in iron meteorites. This material was also exploited by some communities as a pre-Iron-Age source of iron.⁴¹ For these natural alloys, no particular human act is involved in changing the chemical

³⁸ Bray et al. 2015.

³⁹ E.g. Forbes 1972: 51. See also Northover 1989: 225–227.

⁴⁰ Pliny 1938: 63.

⁴¹ E.g. Jambon 2017.

Table 3.1 Five scenarios of the creating an alloy. A, B, and C stand for three metallic elements.

Scenario		Description
1	naturally co-occurring	native metal (A, B)
2	smelting	polymetallic ore (A, B) $\xrightarrow{\text{smelting}}$ alloy (A, B)
3.1	co-smelting	metallic ore (A) } $\xrightarrow{\text{smelting}}$ alloy (A, B) metallic ore (B) }
3.2		metallic ore (A) } $\xrightarrow{\text{smelting}}$ alloy (A, lead) flux (lead or lead ore) }
4.1	co-melting/alloying	native metal (A) } $\xrightarrow{\text{melting and mixing}}$ alloy (A, B) native metal (B) }
4.2		metal ore (A) $\xrightarrow{\text{smelting}}$ ingot (A) } $\xrightarrow{\text{melting and mixing (alloying and casting)}}$ alloy (A, B) metal ore (B) $\xrightarrow{\text{smelting}}$ ingot (B) }
4.3		ingot (A) } $\xrightarrow{\text{alloying}}$ alloy. ingot (A, B) $\xrightarrow{\text{casting}}$ alloy. product (A, B) ingot (B) }
5.1	recycling	alloy (A, B) $\xrightarrow{\text{remelting}}$ alloy (A, B)
5.2		alloy (A, B) } $\xrightarrow{\text{remelting and mixing}}$ alloy (A, B, C) alloy (A, C) }

* The percentages of the alloys in the recycled metal may be different from those in the original one.

compositions of the materials. The technologies of transforming these materials to material culture are reflected in activities such as mining and shaping (making the metal into an object).

The opposite is what we may call “artificial alloy”, which means that the creation of the alloy requires certain technologies. Artificial alloys can be created in one of the several steps in the metal cycle. The first scenario is creating alloys by smelting. Normally, smelting is used to obtain relatively pure metals, but this method can also produce alloys when the raw materials are polymetallic ores—ores that are composed of more than one metals (Table 3.1, scenario 2). As an example of producing alloys through direct smelting, Heather Lechtman and Sabine Klein

suggested that arsenical copper (Cu-As) can be produced by smelting olivenite ores ($\text{Cu}_2\text{AsO}_4\text{OH}$).⁴² In terms of lead, polymetallic lead deposits were commonly used in early metallurgy. In Song Yingxing's *Tiangong kaiwu*, the author mentions several types of lead deposit. One of them is what he calls *tongshanqian* 銅山鉛, or “copper-mine lead”,⁴³ which, from the modern perspective, may be a type of polymetallic deposit composed of a combination of galena (PbS), sphalerite ($(\text{Zn}, \text{Fe})\text{S}$), and chalcopyrite (Cu_2FeS_4).⁴⁴ People smelting ores from this type of deposit are very likely to get lead with significant copper content. Argentiferous galena is also a type of polymetallic ore, which, when smelted, may result in lead-silver alloys.⁴⁵

Another way to produce alloys by smelting is to co-smelt two or more types of ore together (Table 3.1, scenario 3.1).⁴⁶ As scholars suggest, co-smelting can produce many types of alloy, including bronze (copper-tin).⁴⁷ In particular, a common practice in early copper smelting is to add lead ores or metallic lead as a “flux”, an agent to lower the melting point (scenario 3.2).⁴⁸ Strictly speaking, such a practice can be seen as co-smelting lead and copper.

A problem with alloys produced by these smelting methods is that the ratios of the alloy components cannot be controlled precisely. If people want to have alloys with more uniform chemical compositions, the only choice is to melt and mix relatively pure metals (or metals which already have uniform chemical compositions). This can be further divided into two scenarios. The first is when the original metals are native metals. That is to say, they are not

⁴² Lechtman and Klein 1999.

⁴³ Sun and Sun 1966: 252.

⁴⁴ Zhou, W. et al. 2014.

⁴⁵ Eissler 1891; Patterson 1971; Percy 1870.

⁴⁶ For example, Lechtman and Klein point out that arsenical copper can also be produced by co-smelting copper oxide ores (CuCO_3) with copper or iron sulpharsenide ores (e.g. enargite Cu_3AsS_4 or arsenopyrite FeAsS): Lechtman and Klein 1999.

⁴⁷ Oudbashi and Davami 2014; Rovira et al. 2009; Rovira and Renzi 2017.

⁴⁸ See, e.g. the example of Hissar in the next section.

extracted by smelting. The mixture of native gold and silver is one of the examples. Such a process is known as co-melting (Table 3.1, scenario 4.1).⁴⁹ The second scenario is what we may call alloying in the narrow sense. In modern metal industries, alloying is defined as a technology in which relatively pure metals are first extracted from ores by methods such as smelting. Those ingredients are then mixed in certain ratios in order to create an expected alloy. This can happen either during (scenario 4.2) or before (scenario 4.3) the casting process. I put co-melting and alloying in one big category since the technological differences involved in these activities are often indistinguishable in real archaeological cases. For example, many metalworking communities in early China did not do smelting themselves.⁵⁰ Instead, they often acquire metal ingots from other people. In this way, whether the original metals were native or extracted from ores did not really matter. The only technological choice was whether to use one type of ingot or to mix multiple types of ingot during casting.

To consider all possible scenarios in the use of alloys, we should also take recycling into account. The proportion of recycled metals to total metal resources used in the past is often debatable, and the answer may vary in each case.⁵¹ For metal use in early China, a series of papers published by the FLAME project reinvestigate the chemical compositional analyses and lead isotopic studies done on early Chinese bronzes. Based on the reviews, the authors argue that the use of recycled metals was not rare in Central China during the second millennium BC.⁵² In his dissertation, Cao Dazhi also suggests (based on lead isotopic characteristics of the objects) that communities living on the Loess Plateau during the second half of the second millennium BC

⁴⁹ E.g. Lechtman 2014: 373–374.

⁵⁰ See the example of Erlitou (and the new interpretation by Liang Honggang) in Chapter 5.

⁵¹ E.g. Pernicka suggested that recycling happened more often in declining economics than in expanding economics: Pernicka 2014. See also Bradley 1988; Bray 2020; Bray and Pollard 2012.

⁵² Liu, R. et al. 2020; Pollard and Liu 2021; Pollard et al. 2017a; 2017b; 2019.

may have recycled metal objects obtained from Central China to make bronze weapons.⁵³ To further discuss the practice of metal recycling, I suggest that we separate it into two sub-categories.⁵⁴ The first is what we may call “sorted recycling” or “multi-stream recycling”. In this practice, only those objects considered to be made of the same metal material are remelted together. In other words, people do not remix metals in recycling (Table 3.1, scenario 5.1). A simple example of sorted recycling is when a flawed cast was made, the craftspeople put the object back to the furnace, melt it, and cast the object again. In reality, sorted recycling does not always mean that the chemical composition of the recycled metal is exactly the same as the original one. This is for of two reasons. First, to decide whether objects are made of the same type of metal, and thus can be recycled together, depends on the judgement of the recyclers. In the past (as in most modern cases), sorting waste metals by chemical composition was not really practicable. Alternatively, people may have sorted unwanted metal objects by the types of the object. However, since the same type of object may not all have the same chemical composition, recycled metals produced in this way may still have varied chemical compositions. Second, during remelting and re-casting, each metal element in the composition has a different loss per unit weight, due to reasons such as oxidation and volatilisation.⁵⁵ This means that if people remelt and recast the same alloy several times, without involving other metals, they still get a different chemical composition each time. Nevertheless, even if we take these two possibilities into account, overall, metals produced by sorted recycling may still have a more uniform chemical composition than those produced by unsorted, “single-stream recycling” (scenario 5.2). Single-stream recycling means that different types of metal are mixed and remelted together. As in nowadays, single-stream recycling is relatively easier to participate in, and more flexible about

⁵³ Cao, D. 2014: 160–161.

⁵⁴ This idea and the following terminology come from the modern industry of recycling. See e.g. Pires et al. 2018: 312–313.

⁵⁵ Bray and Pollard 2012; Pollard et al. 2015.

what can be recycled. However, the quality of the outputs is usually much lower, so the materials often have more limited uses.⁵⁶

In some case in early China, primary metals (produced from ores) and recycled metals may have been used to make same type of object but for different groups of consumers. For example, in a case study by Liu Ruiliang and colleagues, the authors showed that both primary metals and recycled metals were used in casting ritual vessels in Yinxu. However, people with a higher social status (in the paper, the “high elites”) tended to be buried with ritual vessels mostly made of primary metals, while those a lower social status (the “low elites”) tended to have more vessels made of recycled metals. This distinction also suggests that the Yinxu craftspeople were quite aware of the types (and the qualities) of the metals they were using.⁵⁷

In Table 3.1, I put all these scenarios together to show that what we observe in the final product of the technology, such as chemical composition, is affected by multiple co-dependent technological choices. Those shown in the table are some typical scenarios, but there are certainly more possible ones. Especially, the scenario of recycling suggests that the alloy composition of an object may also reflect the technological choices in the life cycle of the previous objects. From this perspective, we may say that alloying, like many other technologies as we previously discussed, also has a certain level of path dependence. Mark Pollard and colleagues used “karmic cycle” as a metaphor to describe this phenomenon, as the previous lives of the objects “may have an influence on the form that such reincarnation might take”.⁵⁸

Besides the technological choices which affect the materials chemically, the alloy composition of a metal object is also affected by post-production factors, such as the use-life, the preservation

⁵⁶ Pires et al. 2018: 312–313.

⁵⁷ Liu, R. et al. 2020.

⁵⁸ Bray et al. 2015.

condition. Also, researchers may draw different conclusions on the chemical composition of the same object if different sampling and testing methods are used. As this thesis is mainly based on reviewing the test results from previous studies, I am often unable to examine the condition of the objects or the quality of the published data. What I can do is to try my best to exercise “dual diligence” by selecting the most reliable data if possible.⁵⁹

In a real archaeological case, it is often difficult to determine the technological choices based on the analysis of the objects alone, since different technological choices may achieve similar results. Therefore, it is necessary to adopt a holistic approach, as suggested by Christopher Thornton and Benjamin Roberts, to investigate “all material remains from ancient technical practice”. As they point out, these remains include not only finished artefacts, but also fuel (e.g. charcoal), mining sites (e.g. ores and hammerstones), reaction vessels (e.g. crucibles and furnaces), tools (e.g. moulds and lithics), and waste products (e.g. slags).⁶⁰ In the final section of this chapter, I will briefly introduce the studies at Tepe Hissar, an early metal-using community in Iran (established around 5000 BC) by Thornton. With this example, I would like to show how we may be able to identify different technological choices by a holistic study on the archaeological materials.

How Did They Do It? An Example

On the Iranian Plateau, the earliest evidence for copper smelting can be dated back to the early fifth millennium BC, while the earliest evidence for lead (galena) smelting can be dated to the second half of the fourth millennium BC. Besides the smelting remains, many silver and lead

⁵⁹ For the chemical data used in the case studies, I will provide information such as the methods of analyses together with the results. A general discussion of the methods can be found in Pollard and Bray 2014; Pollard et al. 2007.

⁶⁰ Thornton and Roberts 2014.

objects dating to the same period of time have also been found on the Iranian Plateau as well as around the mountain range of Kopet Dag in modern Turkmenistan.⁶¹ Based on these finds, scholars such as Nima Nezafati and Ernst Pernicka suggest that the Central Iranian Plateau may be the birthplace of cupellation, as silver and lead were both extracted and then separated from argentiferous galena ores.⁶²

Tepe Hissar, a Chalcolithic to Bronze Age settlement, emerged in this context. The excavated parts of the site include three main locations: the “North Flat”, the “Main Mound”, and the “South Hill”. According to the latest chronology, the site started to be occupied around 4300 BC, and was finally abandoned around 1650 BC. This whole period is divided into three major phases (I, II, and III), and each phase is further divided into sub-phases (such as IA, IB, etc.). The earliest cultural layers with metal remains are dated to about 4000–3700 BC, corresponding to Phases IC–IIA.⁶³

I choose this site as an example since the metal remains have been thoroughly studied by Christopher Thornton and published in his PhD dissertation and papers. Thornton examined twenty-four slags from the “South Hill” and noticed that there are three types of slag. The first type of slag is the by-product of copper smelting since they contain copper prills only. The second types of slag, containing lead prills only, are left by lead (and silver) smelting. In addition, there are also eight slag samples which contain both copper and lead prills. To identify what activities created these slags, Thornton further compared the slag-forming oxides in all the slag samples. As some background information, a slag consists of silica (SiO_2) and various other oxides (CaO , Al_2O_3 , FeO , etc.) which come from both the ores and any fluxes added. Meanwhile,

⁶¹ Frame 2004; Pigott and Lechtman 2003; Thornton 2014.

⁶² Nezafati and Pernicka 2012. Cupellation, see Chapter 1 footnote 20.

⁶³ Excavation reports: Schmidt and Kimball 1937; Dyson and Howard 1989; metal finds and metallurgy: Pigott et al. 1982; Roustaei 2004; Thornton 2009b: 154–158; 2014: 682; chronology: Gürsan-Salzmann 2016.

the chemical composition of a slag is also affected by the condition of the smelting operation, such as the firing temperatures. For most prehistoric and ancient smelting remains, FeO, SiO₂, CaO, and Al₂O₃ usually contribute to most of the slag's bulk chemistry. Thus, archaeometallurgists often use the levels of these four oxides to suggest whether slags are created under similar conditions.⁶⁴ In Thornton's analysis, the oxides in the copper-lead slags tend to cluster more closely with the copper-only slags, rather with the lead-only slags (Figure 3.5). Thus, Thornton suggested that the copper-lead slags and the copper-only slags were probably created in one type of smelting operation, while the lead-only slags were created in another type of smelting. This means that people may have smelted lead-bearing copper ores just like normal copper ores for copper production (as scenario 2 in Table 3.1). A different explanation, as some scholars suggest, is that people may have added lead-bearing ores during copper smelting, either as a flux to lower the melting temperature (scenario 3.2) or for other purposes (scenario 3.1).⁶⁵

To further investigate which technological choices led to the slags, Thornton also analysed the metal objects from the South Hill to see if the chemical composition of the products aligns with these three types of smelting activity. The first group is silver-based objects (rings and beads). As Thornton showed, these objects usually contain 0–1% lead. This suggests that the silver was probably produced by cupellation.⁶⁶ The second group is thirty copper-based objects from the South Hill. Most of these objects are not leaded (Figure 3.6). However, several objects do contain more than 1% lead. Especially, an object (perhaps a handle) contains 4.1% lead. Since the lead levels are not very uniform, Thornton suggested that these objects were not produced by

⁶⁴ Hauptmann 2014.

⁶⁵ Thornton 2009b: 154; Bourgarit et al. 2005: 30.

⁶⁶ Thornton 2009b: 123; App. I.B.

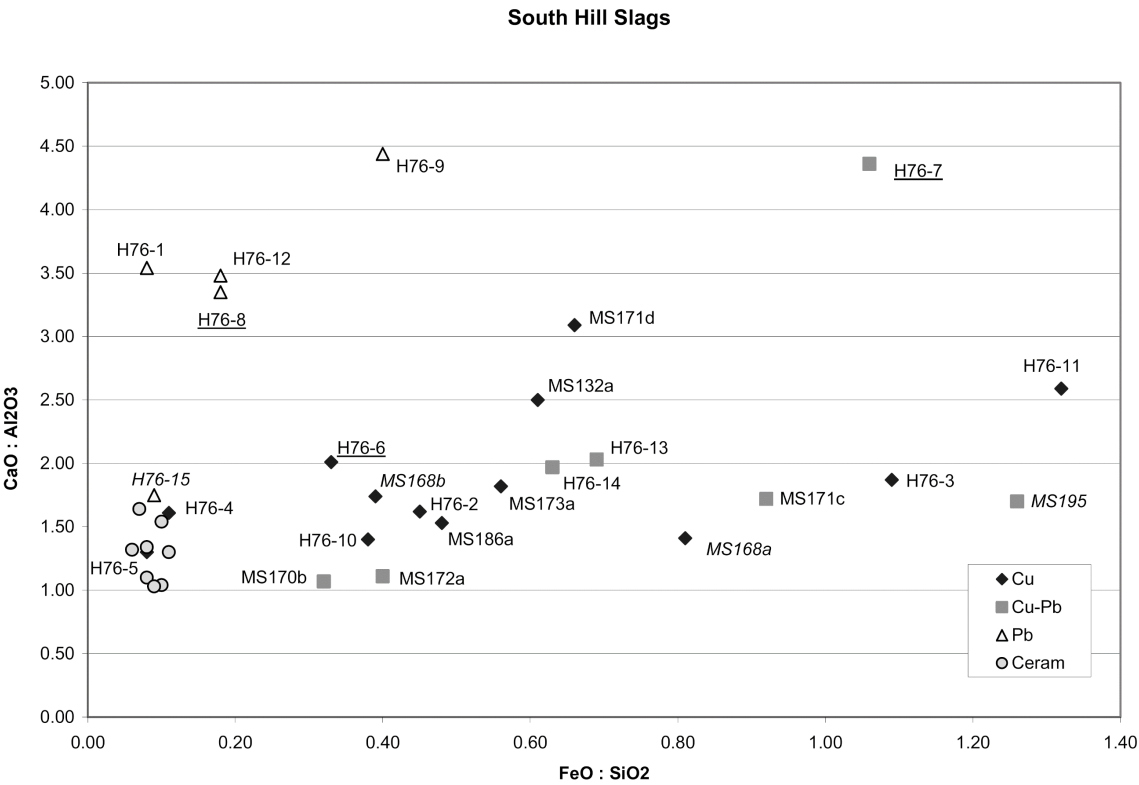


Figure 3.5 Slag-forming oxides in the South Hill slag samples, Hissar (after Thornton 2009b: 182).

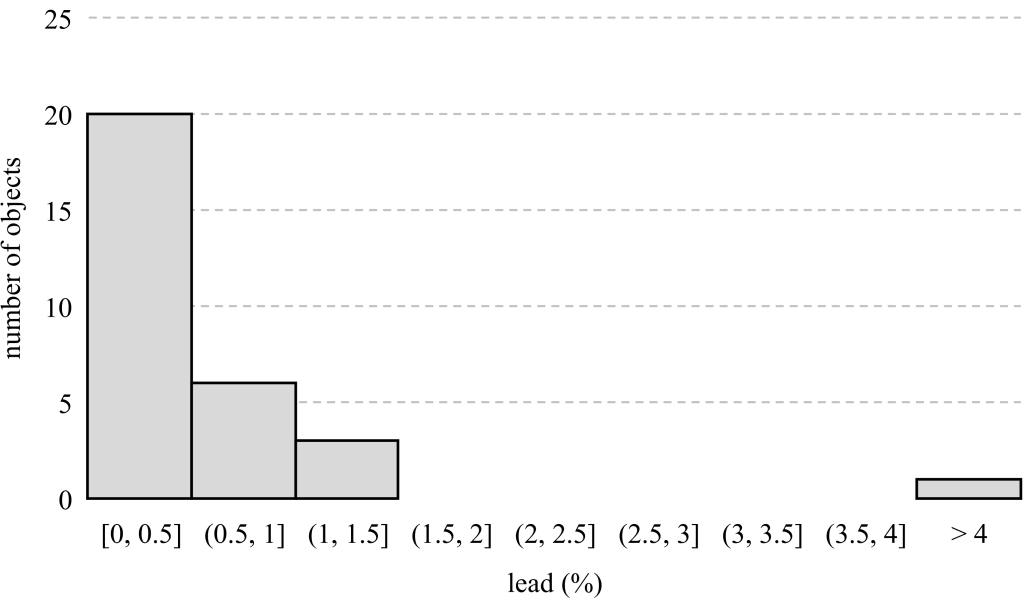


Figure 3.6 Distribution of lead in the South Hill copper-based objects (data: Thornton 2009b).

controlled alloying (scenario 4.2; 4.3). More likely, they were made of copper-lead alloys produced by the above copper-lead smelting.⁶⁷

Was the leaded copper produced intentionally? Thornton argued that it was. As he noted, for the analysed anthropomorphic and zoomorphic figurines from the other location, the Main Mound, most of them have high levels of lead (>4%), while most other objects are unleaded. Thornton suggested that, since copper alloys with more than 4% lead are more castable than unleaded copper, this material may have been intentionally used for making objects with many details, such as the figurines.⁶⁸ In the next chapter, I will discuss the relationship between lead level and castability. As my conclusion of that discussion, bronze with 4–10% lead is indeed more castable than unleaded bronze.

In summary, Thornton argued that the leaded copper used in this case was produced by either smelting polymetallic copper-lead ores or co-smelting copper and lead ores.⁶⁹ As previously mentioned, unlike the normal way of making alloys by mixing pure copper and lead, alloys produced by smelting and co-smelting usually do not have uniform chemical compositions. However, as this case study shows, behind the seemingly random lead levels, there may still be intentional technological choices. In Thornton's words, "uncontrolled alloying" does not mean "unintentional alloying".⁷⁰

This case study, although very brief, shows how different types of archaeological material can be used together to answer the questions of technological choice. I think this holistic approach is promising and should be used in more archaeometallurgical studies. For my own case studies, I will also try to consider materials in as many respects as possible so as to have a reach a

⁶⁷ Thornton 2009b: 124.

⁶⁸ Thornton 2009b: 124.

⁶⁹ We may be able to further identify the technological scenarios if ores from the site are also investigated.

⁷⁰ Thornton 2014: 677.

comprehensive understanding. However, for future research, it is also important to adopt a holistic approach when doing the fieldwork, such as excavation. Some seemingly trivial finds at a site, such as slags, fragments of crucibles, and even soil, may provide us with evidence which is more important than that from metal artefacts.⁷¹ If the archaeological information is not well obtained and recorded in the fieldwork, such information may be missing forever.

⁷¹ An example of using soil to answer archeometallurgical questions, see Liu, R. et al. 2021.

Lead Matters:

The Properties of Leaded Bronze

In the late 1960s, a group of Japanese artists started to explore opportunities of making sculptures with new materials. Instead of aiming to “create” an artwork out of the materials, these artists tried to reveal the properties of the materials by minimizing the interventions. The movement was later known as “Mono-ha”, or “School of Things”.¹ In the 1970 Tokyo Biennale, Mono-ha artworks were displayed to fit into the theme of the exhibition, *Between Man and Matter*. This time, Mono-ha won its world recognition and became a source of inspiration for artists from Europe and North America.² Some artworks in the Biennale were later obtained by the Tate Modern in London, becoming part of its permanent exhibition “Materials and Objects”. Even today, some questions explored by the Mono-ha artists are still astonishing (Figure 4.1). These artworks show vividly how knowing and appreciating the materials help the art expression. As Sheela Gowda, a contemporary artist who also has her artworks displayed in the exhibition once said, “Handling a material makes me understand its limitations and its potential ... Proximity to

¹ Groom 2001.

² Tomii 2011.

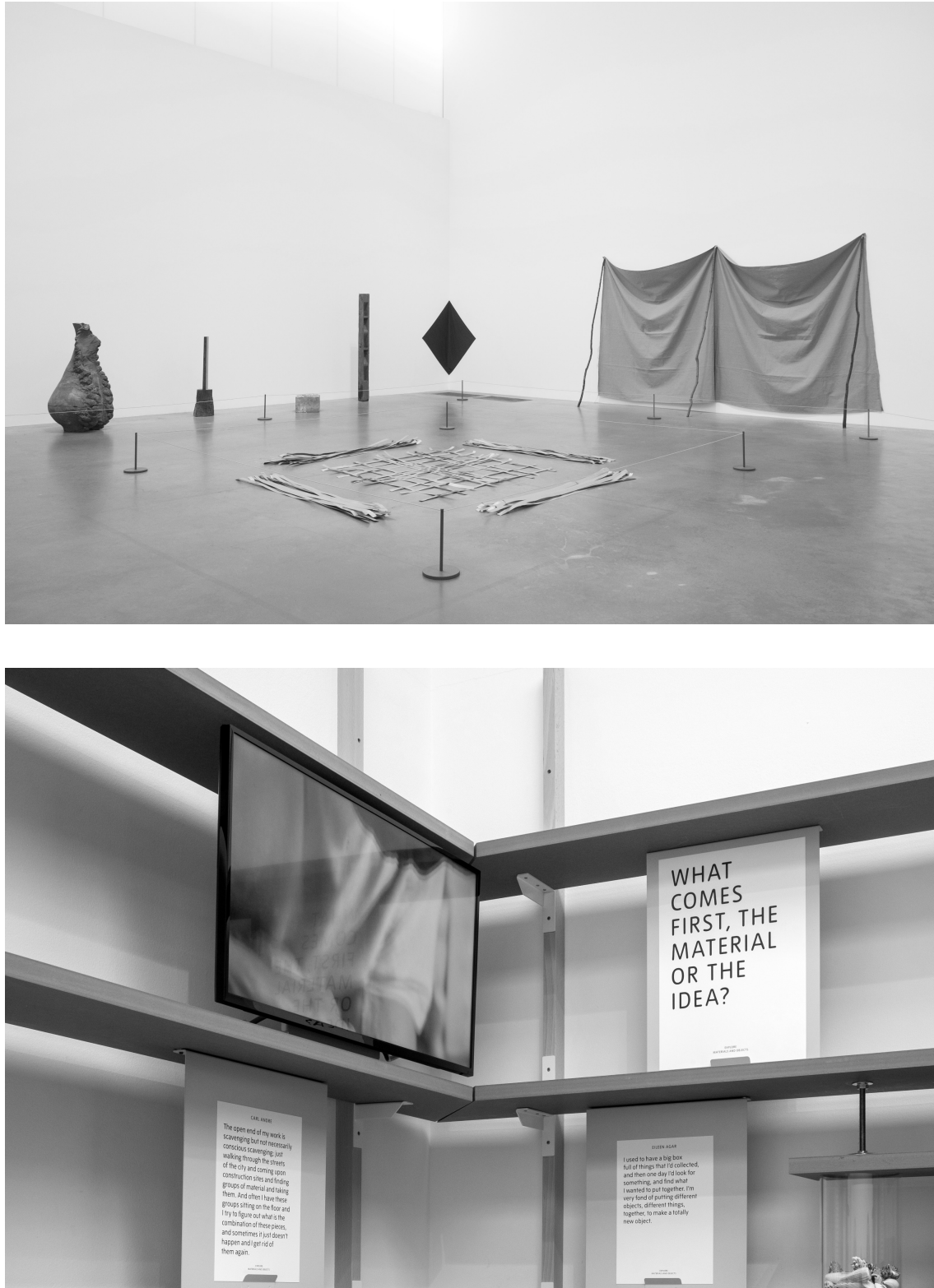


Figure 4.1 Displays of the “Material and Objects” gallery, Tate Modern, London.

the material defines the formal aspects of the work and its tangibility. I therefore do not outsource the physical aspect of art-making.”³

When trying to understand how a new material was added to the existing material culture, we often find ourselves asking the same question: what particular nature of that material makes it so appealing to people? As to archaeology, one of its main topics is how people create, use, and dispose of objects. However, for a long time, the discussion of materials was framed in an evolutionary view, as new and superior supposedly materials emerged to replace old ones. Consequently, the adoption of a new material, such as metal, or a new technology, such as the steam engine, is considered a technological advancement. Particularly, artefact typology was used to demonstrate a way of “evolution of culture”.⁴ From the middle of the twentieth century, the archaeology mainstream shifted away from this evolutionary approach and reoriented the studies of objects and technologies towards a cultural approach, that is, to consider the use of a material or an object as the result of a special relation established between the material/object and the particular group of people. Within this trend, “material culture” replaced “artefact” and even “technology” to become the centre of discussion.⁵ One particular term which became popular among scholars in humanities and social sciences in the 1990s is “materiality”. Since then, the theory has been both widely adopted and widely debated among archaeologists.⁶ Materiality theory argues that material relations (human-object, object-object) are comparable to social relations (human-human).⁷ From this perspective, artefacts are not “a mere reflection or product of society”.⁸ Rather, they are active in establishing and maintaining social

³ This quote is displayed in the galley of Tate Modern.

⁴ E.g. Morgan 1877; Pitt Rivers 1875; discussion: Gosden et al. 2007.

⁵ A review of this history, see Hicks 2010.

⁶ For the early use of this term in anthropology, see Taylor 2009: 299.

⁷ Gosden 1994: 82; Jones 2004a.

⁸ Thomas 1996: 141.

relationships through “materialisation”, that is, a process of transforming “ideas, values, stories, myths, etc. into a physical reality (symbolic objects, monuments, ceremonial events or writing systems)”.⁹ Colin Renfrew further expanded the theory by including the discussion of symbols. He suggested that any idea, be it a technology or a form of government, needs to rely on material forms, such as idols and sculptures, so as to be effective. Meanwhile, the materialised ideas, technologies or social structures also create a certain foundation, favouring the development of new materials and new ideas in certain directions.¹⁰

However, some problems with the concept of materiality has also lead to intense criticism. One of the most criticised issues is that, although the theory argues how the material world may think or act, at the same time, it also separates such activities from human thinking and actions. In other words, the materiality theory implicitly assumes that nature and culture are separated. From the 1990s, this nature-culture dualism became hotly debated among scholars in various research fields. Many argued that the idea of a distinction between nature and culture is itself a cultural view.¹¹ In a study of native Americans, Eduardo Viveiros de Castro pointed out that the contemporary Western view of naturalism, i.e., one nature, multiple cultures, does not apply in his case. The native Americans he studies hold a multi-naturalistic world view (one culture, multiple natures). Therefore, he argued that the definitions of nature and culture, as well as their distinction, are based on the “ontology” of the observers.¹² The relationship between nature and culture is also reflected in the theory of personhood in archaeology.¹³ As this theory suggests, not only can people and materials both be agents, but also human and nonhuman agents are de

⁹ DeMarrais et al. 1996.

¹⁰ Renfrew 2001b. See also Renfrew 2001a.

¹¹ Literature on this issue is numerous, here is just a brief list of some of them: Boivin 2004; de Castro 1998; Descola 2013; Gosden 2008; Knappett 2004; Kohn 2013; Malafouris 2013; Olsen 2010; Webmoor and Witmore 2008.

¹² de Castro 1998.

¹³ Fowler 2016; 2004; Kohn 2013.

facto indistinguishable.¹⁴ If nature and culture are inseparable, to consider material objects as independent entities in expressing their “materiality” seems to be fundamentally flawed.

To solve this nature-culture dilemma in the theory of materiality, some scholars recommend an integrated framework to combine both material and social relations. One of these new theories is “material engagement”, proposed by Colin Renfrew and Lambros Malafouris.¹⁵ Material Engagement Theory, or MET, rests on three legs. The first leg is the objection of that culture-nature dualism, as what many scholars have argued. The second leg is the idea of material agency. MET argues that people and things can both act as agents.¹⁶ However, MET rejects the traditional, anthropocentric view of the agency theory, and supports an integrated view of both human and material agencies. As Chris Gosden also argued, both brains and objects in archaeology are plastic. “People and materials bring out the characteristics of each other in particular cultural context.”¹⁷ The third leg is the rejection of Cartesian “mind-body” dualism and the 1950s psychological theory of cognitivism. According to cognitivism, the mind is constrained in our brain which stores and processes all information.¹⁸ In opposition to this, MET argues that it is philosophically impossible to define a clear boundary between mind and body.¹⁹ One of the vivid examples is a blind man with his stick. In this case, the mind (or the blind man’s self) extends beyond the man’s head to the stick and through the tip of the stick to the things he “touches”. In MET, this idea is known as the “extended mind”.²⁰ The third leg is the rethinking

¹⁴ Brown and Walker 2008.

¹⁵ Renfrew 2001b; 2004; Renfrew et al. 2004; Malafouris 2004; Malafouris and Knappett 2008; Malafouris and Renfrew 2010.

¹⁶ Malafouris 2013: 174.

¹⁷ Gosden 2008.

¹⁸ Mithen 1998; Gardner 1985.

¹⁹ Boivin 2004; Clark 1997. To argue this point, MET also relies heavily on the development of neuroscience and the concept of intelligence, see Clark 2003; Malafouris 2013: 57–59.

²⁰ Bateson 1972: 318; Malafouris 2008. See also Adams and Aizawa 2010; Clark and Chalmers 1998; Menary 2010.

of the relationship between nature and culture. Like the objection of the mind-body dichotomy, many scholars also argue that the separation between nature and culture (or humans and things) is cultural-related.

As of 2021 when I am writing this thesis, there is a continued discussion around these theoretical issues. The discussion and debate also affect how material culture is studied. In a review article written for *The Oxford Handbook of Material Culture Studies*, Dan Hicks suggests that things should be seen as both “events” and “effects”.²¹ This view, also focusing on the relations that material culture is able to establish, is probably the closest to a new paradigm which we have in this discipline. In the next section, I will introduce this idea and relate it to the study on material properties. Nevertheless, as archaeology used to be and is still heavily relying on positivism, any theories need to go through the tests of real case studies. For ideas such as materiality and material engagement, we need to see what practical problems these new theories can help answer, and whether those answers are more convincing than the previous ones. After all, the best arbiter of the material theories is the materials themselves.

Properties as Effects, Properties as Events

One thing which has already been changed by the new theories of material culture is our view on the properties of physical things. This also goes back to the discussion of objectivity in sciences.²² Traditionally, a material is seen as having certain properties which are intrinsic and objective, such as strength, density, and chemical stability. These properties, and the underlying natural laws determining these properties, are not affected no matter when, where, by whom, and for what purpose the properties are measured. In other words, a property is a natural thing,

²¹ Hicks 2010.

²² Daston and Galison 1992; 2007; Lakatos 1980; Latour 1996; Sattaur 2012.

not a cultural thing. However, according to the new theories just mentioned, any given property of a physical object is defined and perceived by humans in a cultural way. Hardness, for instance, is defined as a property for any solid material denoting its ability to resist plastic deformation. From a micro perspective, hardness is determined by one of the fundamental interactions (forces) between atoms, which certainly follows natural laws.²³ However, the same fundamental interactions also decide many other things, from the colour to the density of the material and to whether it can dissolve in water. We choose to pay attention to hardness (and colour, density, etc.) only because we, as humans, can perceive this property when engaging with the material. For the same reason, we do not describe how hard a gas is since we cannot simply determine this based on our own experience (even though such a property is totally definable).²⁴ Therefore, properties do not describe what an object or a material is, but what it can do. As Karen Barad concluded, properties are not something pre-determined, they are just the perspectives from which we choose to see in things (“things-in-phenomena”).²⁵ If we borrow Hick’s words in that review article, we may say that properties are “effects”.

In addition, material properties are not timeless. For a metal, its form is constantly changing as I have discussed in Chapter 3. The changing form of the metal also means that the way in which people engage with it is also changing constantly. For example, during smelting, the melting point of the metal is important. However, when the metal is turned into the form of a sculpture, people may no longer pay attention to its melting point, but instead see other properties, such as weight and colour, as important. If, unfortunately, the sculpture is later destroyed, the same metal

²³ This is only an abridged and perhaps imprecise view from a physics perspective.

²⁴ My supervisor Professor Mark Pollard, a former physicist, reminded me that, in quantum mechanics, the measured results can be affected by the mode of observation. This may be a good analogy to what we are discussing here. A discussion between Professor Pollard and one of my examiners, Professor Chris Gosden on this issue can be found online: <http://podcasts.ox.ac.uk/universe-sentient-and-what-implications-might-have-archaeology>.

²⁵ Barad 2007: 19; 140.

goes into a new cycle and may one day return as part of a car or a utensil. In those forms, people will focus on other properties of the metal. Again, if we use Hicks's term, we can see properties as a series of "events" happening in the life cycle of the metal.

From the perspectives of effectness and eventness, we may also rethink the usefulness and attractiveness of a material. What makes a material useful or attractive? From a human-thing engagement perspective, usefulness rests not only upon the properties of the material, but also upon how humans sense the material. A good example is the case study of the emerging smart fabrics. Susanne Küchler showed how smart fabrics, as a new type of textile, create new properties of the whole fibre group. Smart fabrics are a hybrid of both traditional fabrics, as a type of "artificial second skin", and computer science such as artificial intelligence and robotic machinery. For example, with displaying devices such as LEDs, clothes with smart fabrics can show messages and thus communicate with people and AI devices directly. Some other types of smart fabric are able to change their stretchability. They can be used as heart supports.²⁶ These new applications do not change any existing laws in physics, chemistry, or biology. However, smart fabrics certainly go beyond the artificial skin. They establish new relationships between clothes and people. New properties, which are previously never involved with fabrics, are now introduced into this scope.

In all, the essential point suggested by this new view of material culture is that, instead of taking properties as something inside the material or the object, we need to consider properties as a set of human-thing relations. In terms of lead and leaded bronze, how can we use effectness and eventness to help us understand the materials? First, I argue that, following the above discussion, we need to see their properties as relations between the materials and humans. For people making

²⁶ Küchler 2008.



Figure 4.2 Two objects made of lead suggesting different human-thing relations. Left: a lead votive vase with an image of Bes, Thonis-Heracleion, c. 500–1 BC. The ancient Egyptians often associated lead with death. This is probably because of the fusibility, high density, and high resistance to corrosion of lead (2018 “Sunken Cities” exhibition, Saint Louis Art Museum); right: “Breaking of the Vessels”, by Anselm Kiefer, 1990. The artist used lead sheets to represent the sacred folios which are destroyed (Saint Louis Art Museum).

a bronze knife, they may pay attention on the strength and hardness of the material. Nevertheless, if bronze is used for a sculpture, people may focus on other properties, such as its castability and colour (Figure 4.2). For leaded bronze used in early societies, we need to put it into the special human-thing relations to discuss the properties of the material.

Furthermore, I suggest that we consider the properties of leaded bronze in a relation with the properties of other materials available to people in early China, such as other metals, ceramics and clay, stone, wood, and bone, especially when the materials are all made into the same type of object. By taking this approach, I do not assume that people were really choosing among these available materials. Instead, my reason is that the objects in the same type but made of different materials were often involved in similar human-thing relations. Therefore, the comparison with

other materials may suggest what properties of leaded bronze were valued. For example, in early China, the materials of stone, ceramic, wood (with lacquer), and bronze were all used to make ritual vessels. This suggests that these metals may share properties which make the material “effective”, such as water tightness. In the category of metals, two types of metal were also widely used in early China besides leaded bronze (Chapter 1, Figure 1.7). One is unalloyed, almost pure copper. Copper started to be used in East Asia around the late third millennium BC (Chapter 2). The special plasticity, colour, as well as its potential to be remelted and transformed through fire, must have shocked people at that time. The other metal which was also widely adopted is bronze, or copper-tin alloys. Unlike lead which is much more evenly distributed, tin resources only exist in some part of East Asia (Chapter 3, Figure 3.2). Thus, for most early metal-using communities, tin would be something they needed to import all the time. In most cases, tin was not used alone, but was alloyed with copper to make bronze.²⁷ One characteristic which makes this combination desirable is the significantly improved mechanical properties of bronze over copper. In addition, bronze also has a yellowish, almost gold-like colour. Meanwhile, unlike these copper-based metals, gold and silver were rarely used in early China. There are only a few cases which will be mentioned in the case studies (especially Chapter 6). Compared with these metals, leaded bronze is different in many ways as we will discuss in this chapter. By focusing on these differences, we may find a way to explain the use of leaded bronze. Also, we should not forget that there are many other available materials at the time. Some of these materials are common in all early communities, such as stone, ceramic, and animal-based materials (bone, horn, tooth, skin, etc.), some had their particular uses in East Asia, such as jade and lacquer. The relations (comparisons) between these materials and leaded bronze also need to be considered.

In the next section, I will first examine the properties of leaded bronze reflected in the production processes, especially the use of lead to facilitate casting. Then, I will focus on the properties

²⁷ However, tin objects, although rare, have been found at some sites: Nie, Z. 2019: 15–35.

related to the use-life of leaded bronze objects, such as colour, hardness, and density. The division into these two aspects is only for the convenience of the discussion. Also, as properties are related to certain effects, I will only discuss the properties of leaded bronze which may have affected people's engagements with the material in early China. More general discussion of copper-lead alloys from a scientific perspective can be found in the literature listed below.²⁸

Lead and Casting: A Flawed Choice

In metal production, one of the key processes is to make a metal into a wanted shape. For most early Chinese bronzes, this was almost always done by casting, while forging was only used under special circumstances.²⁹ Hence, in this section, I will focus on the properties of leaded bronze reflected in casting. Normally, metal casting involves several steps (see also Chapter 3, Figure 3.3). First, raw materials, sometimes in the form of metal ingots, are melted. This is usually done by placing the ingots in a crucible and then heating them in a furnace. During the melting process, people can also refine the metal by removing unfavourable elements. One of the ways to do so is by adding fluxes.³⁰ After that, the molten metal needs to be tapped into a transport vessel (a ladle) so as to be poured into a mould. This can also be done by moving the crucible directly. In the next step, molten metal is poured into a mould (either a solid single one or several sections of split patterns). To fill the mould more efficiently, vacuum filling is commonly used in modern foundries, but in the past, people can only have relied on gravity to pull the molten metal into the mould. When the filling is done, the caster leaves the metal to cool

²⁸ E.g. Chattopadhyay and Srikanth 1994; Korniyenko 2007; Predel 2012.

²⁹ Discussion and examples of forging, see Huang, K. 1992; Li, Y. 2017.

³⁰ Lead is a common type of flux. Since adding lead as an alloy and adding lead as a flux are two similar technological scenarios (see Chapter 3, Table 3.1, s3.1 and s3.2), researchers usually do not differentiate them. In this thesis, I will not specifically discuss lead as a flux, but this is perhaps a very important point to the start of the use of lead as an alloy: Mark Pollard, personal communication.

法同鍾朝

圖鼎鑄

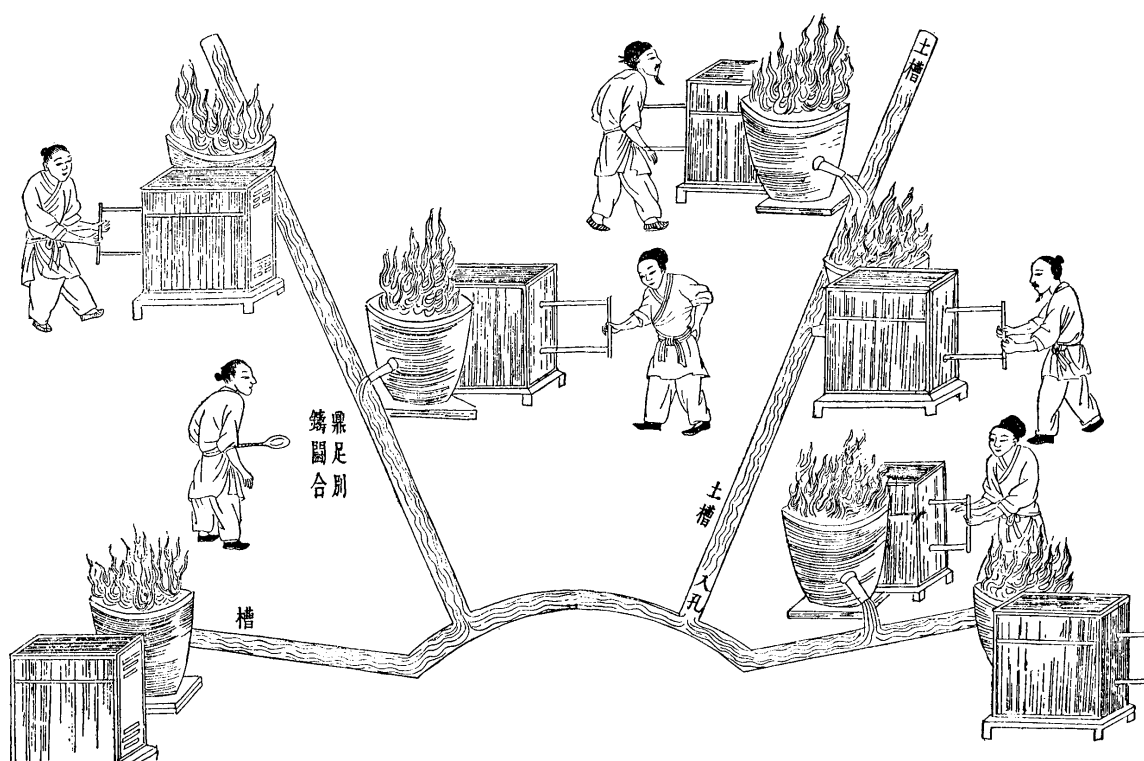


Figure 4.3 Casting a bronze vessel in *Tiangong Kaiwu*. The figure shows that multiple furnaces are operated simultaneously to fulfil the need of molten bronze (modified from Sun, E. and Sun, S. 1966: 161).

and solidify in the mould, until the cast can be removed from the mould. The metal object is thus produced.³¹ Alloying is sometimes involved in casting as multiple metals are melted and mixed to reach the expected alloy composition (Chapter 3, Table 3.1). For early craftspeople, they may have used very different tools and methods during their casting operations, but the basic procedure was usually the same as described above. In ancient China, casting usually required the collaboration of multiple people. A depiction in Song Yingxing's *Tiangong Kaiwu*, although from a much late era (17th century), gives us an impression of such an operation as several groups of people (and furnaces) were working together (Figure 4.3).

³¹ For more detail of casting, see e.g. Black and Kohser 2011.

One major concern of casting is how and how fast the molten metal cools and solidifies in the mould. Liquidus and solidus are used to describe two key temperatures in this process. Above the liquidus temperature (T_L), the material is completely liquid; below the solidus temperature (T_S), the material is completely solid. When the temperature drops below T_L , the metal gradually turns into solid depending on the cooling time and condition. If we define the temperature of the molten metal in the furnace as the firing temperature T_F , a successful casting relies on whether the metal can fully fill the mould before the temperature drops from T_F to somewhere between T_L and T_S . Therefore, with the same furnace technology (T_F), the lower T_L and T_S are, the more easily the casting can be done.³²

When working with an alloy, T_L and T_S are determined by the relative proportion of each alloying element. This is often illustrated by phase diagrams. For binary alloys bronze (copper-tin) and leaded copper (copper-lead), their phase diagrams are shown as a and b in Figure 4.4. According to the diagrams, both tin and lead can decrease the T_L (represented by the uppermost curves in the diagrams) of the copper alloys, although adding tin would be more efficient than adding lead. Since leaded bronze is a type of ternary alloy, its phase diagram is much more complicated.³³ Figure 4.4, c is one version of the phase diagram, provided by Ernst Jänecke. Briefly speaking, in the copper-rich corner ($> 70\%$ copper), T_L decreases with the increase of tin and lead. In the modern copper industry, organisations such as industry associations also provide properties of various copper-lead-tin alloys. For example, Table 4.1 shows the data released by

³² For alloying materials, T_L and T_S are not the same. However, to simplify the discussion of a ternary system, I will only use T_L here as this is the starting point for a molten alloy to solidify.

³³ E.g. Blumenthal 1932; Chattopadhyay and Srikanth 1994; Dies 1967: 508–510; Giolitti and Marantonio 1910; Jänecke 1937: 333–335; Korniyenko 2007; Sabahi Namini et al. 2016; Veszeka 1932.

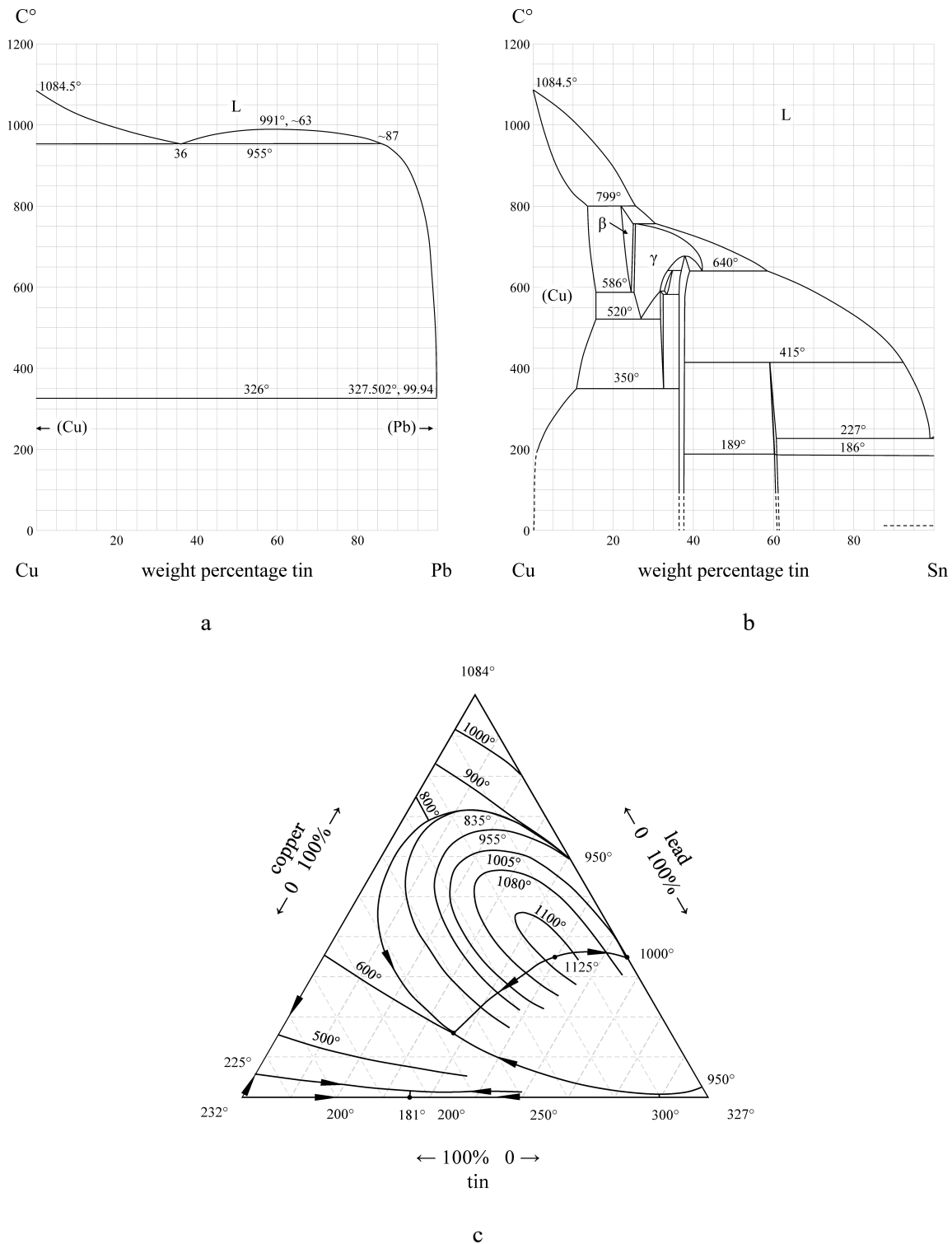


Figure 4.4 Phase diagrams of the alloys. a: copper-lead, b: copper-tin (after Lyman 1973: 296; 299); copper-tin-lead (liquid miscibility gap at each temperature) (after Jänecke 1937: 334).

Table 4.1 The melting points of alloys with different levels of tin and lead (data source: Copper Development Association).

ID	Cu (%)	Sn (%)	Pb (%)	Melting point (T_L / T_S , °C)
C10100	≥99.99	≤0.005	≤0.0002	1082.8 / 1082.8
C90200	91.0–94.0	6.0–8.0	≤0.3	1046.1 / 875.6
C90700	88.0–90.0	10.0–12.0	≤0.5	998.9 / 831.1
C90900	86.0–89.0	12.0–14.0	≤0.25	977.8 / 818.3
C91100	82.0–85.0	15.0–17.0	≤0.25	950.0 / 818.3
C91300	79.0–82.0	18.0–20.0	≤0.25	888.9 / 818.3
C92700	86.0–89.0	9.0–11.0	1.0–2.5	982.2 / 843.3
C92800	78.0–82.0	15.0–17.0	4.0–6.0	954.4 / 818.3
C93600	79.0–83.0	6.0–8.0	11.0–13.0	937.8 / 843.3
C93700	78.0–82.0	9.0–11.0	8.0–11.0	929.4 / 761.7
C93800	75.0–79.0	6.3–7.5	13.0–16.0	943.3 / 854.4
C94400	Rem	7.0–9.0	9.0–12.0	940.6 / 787.8

Other elements in the alloys are lower than 1.0%.

the Copper Development Association (CDA).³⁴ In general, the data corresponds to Jänecke's phase diagram as alloys with more tin and lead have lower melting points.³⁵

For early metalworkers, the lowering of the melting points by adding tin and lead can have brought great benefits. Most prehistoric metalworking relied on bonfires and simple furnaces to melt the metals. The maximum firing temperatures of these devices were about 900–1200 °C.³⁶ When the crucible filled with the molten metal leaves the furnace, there is only a short period of time before the metal cools down and solidifies again. During this time, the caster needs to take the crucible out, bring it to the mould, and pour the still-liquid metal into the mould. These actions need to be done as quickly as possible. Compared with pure copper, the lower melting

³⁴ Copper Development Association: <https://alloys.copper.org/>.

³⁵ However, alloys with higher tin and lower lead levels do not always have lower melting points than alloys with lower tin and higher lead levels (e.g. C92800 vs. C93700; C91300 vs. C93600).

³⁶ Common clays used for furnaces and crucibles can usually withstand temperatures in that range, but not much above it. See Martín-Torres and Rehren 2014.

points of leaded bronze means that this material takes longer time to solidify, giving a caster more time to complete the pouring.

In addition to the lowering of melting points, another advantage of adding lead is that lead improves the fluidity of the metal. Lead is much less soluble than tin in copper. When a ternary alloy of copper-lead-tin cools, liquid lead is separated from copper-tin as the latter solidifies. Lead starts to solidify into separate globules, which are distributed in the copper-tin structure, only when the temperature drops below the eutectic temperature of copper-lead system, or 326 °C.³⁷ This phenomenon is illustrated by the metallographs in Figure 4.5. Due to the presence of the undissolved lead liquid, leaded bronze is more fluid than unleaded bronze. For casting, this also means that leaded bronze is more likely to fill the mould, especially when the inner space of the mould has a complex shape (such as those moulds used for ritual vessels).³⁸ However, there may also be an upper limit of this benefit, that is to say, the addition of lead beyond a certain level may not improve the fluidity any further. So far, there is no agreement among researchers upon what this upper limit is.³⁹ Before any further experiment clarifying this point, I can only assume that, for a bronze alloy with more than 10% lead, the further increase of the lead level may not benefit the fluidity of the metal remarkably.⁴⁰

Another benefit of leaded bronze in casting is also connected with the insolubility of lead in copper-tin. Kurt Dies illustrated that, during the cooling process, copper-tin crystals grow in the

³⁷ Briesemeister 1931; Klein and Hauptmann 1999.

³⁸ Chase 1983; Wan, C.1991; Young 1975.

³⁹ Judith Young suggested that the addition of lead beyond 15% has no significant effect on improving the fluidity. In fact, only 2–3% lead is almost enough to maximise the fluidity: Young 1975: 28–30. See also Philip 1991. A copy of Young's unpublished BSc dissertation can be found in the British Museum Library. In contrast, Bourgarit and Thomas cited an unpublished conference paper by Mille and colleagues which suggests that lead may have no significant effect on fluidity at all. As the authors admit, the results rely heavily on the setup of the experiment: Bourgarit and Thomas 2012.

⁴⁰ Another important factor about improving the fluidity is the preheating of moulds in order to avoid the sudden cooling of the molten alloys: Gettens 1967: 29.

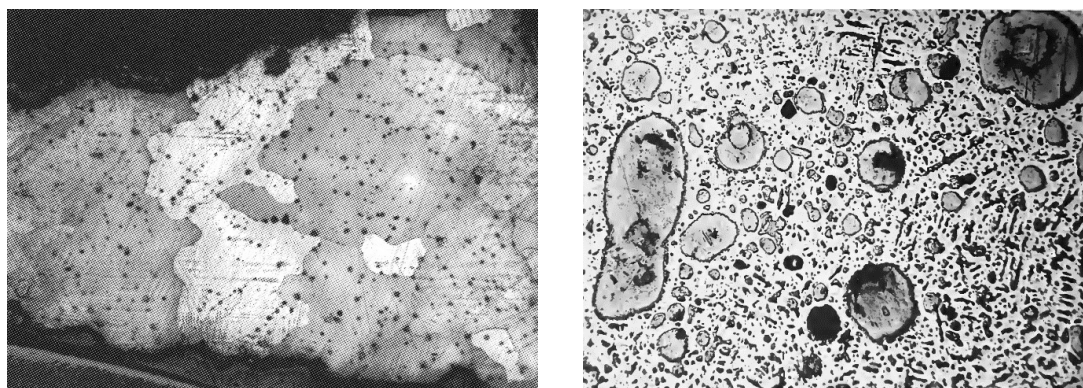


Figure 4.5 Lead in cast bronzes. Left: drops of lead (black) are evenly distributed in the of the α -phase crystal. Alloy: 85.5% Cu, 11.4% Sn, 2.2% Pb (after Sun, S. et al. 2011: 74); right: lead globules in the copper-tin with some dendritic structure. Alloy: 69.4% Cu, 11.0% Sn, 15.9% Pb (after Gettens 1967: 126).

form of dendrites (slow cooling) or equiaxed grains (fast cooling). In either case, the crystal structures are relatively porous, with lots of empty spaces.⁴¹ When lead is involved, the still liquid lead can fill these spaces and thus reduce the porosity. This effect is reflected by the lower gas absorbing ability of leaded bronze than that of unleaded bronze. As Hanson and Pell-Walpole's data shows, at 1250 °C, the gassing indices of a copper alloy with 5% tin and 20% lead are about 20% lower than those of an alloy with 10% tin and 10% lead.⁴² For casting, features like low air absorption and low porosity are beneficial since these features lead to fewer cavities ("air bubbles") in the cast. This is especially helpful if the cast is a drinking vessel—such as in the cases of many Chinese bronzes—since those vessels are expected to be impermeable. As an analogy, in pottery making, potters often mix different types of clay or add tempers to clay to control the porosity of the ceramics.⁴³ These technologies are also seen in China before the Metal Age.⁴⁴ Therefore, is it possible that there was a transfer of ideas and even

⁴¹ Dies 1967: 615.

⁴² Hanson and Pell-Walpole 1951: 137.

⁴³ Eramo 2020; Lippi and Pallecchi 2017.

⁴⁴ E.g. Womack et al. 2019.

technologies from tempering in pottery making to adding lead in casting? This may be an interesting direction for future studies.

Nevertheless, the benefits of leaded bronze also come with costs. One major problem is the segregation of lead in copper-tin due to its delayed solidification. The higher the lead content is, the more likely lead segregates.⁴⁵ For casting a large object such as a ritual vessel, a particular type of segregation is gravity segregation (also known as density segregation). Since lead with relatively higher density solidifies later than copper-tin during cooling, lead tends to flow downwards and sink to the bottom of the cast. As a result of lead segregation, the lead-rich part is often fragile and easy to break off from the rest. This problem is well reflected in the Panlongcheng bronzes, as I will discuss in Chapter 5 (see also Figure 5.24). A probably more serious problem with leaded segregation is that it deteriorates the mechanical properties of the cast. This will be discussed in the next section.

In all, the introduction of lead has some clear benefits, but these benefits may not justify the defects. Especially, if a cast has very high lead contents, the problem with lead segregation may actually increase the possibility of casting defects. Therefore, we may conclude that adding a low amount of lead may facilitate casting. For objects with very high lead contents, such as over 10%, there must be other factors that contribute to those choices. However, it is also worth noting that the above discussed benefits and disadvantages of lead in bronze casting are all based on a positivist approach. In reality, any human practice, no matter how science-oriented it is, contain certain cultural aspects.⁴⁶ To understand these cultural aspects requires us to put more effort in

⁴⁵ Segregation in casting, see Craddock 1980b; Harrison et al. 1981; Scott 2011: 53.

⁴⁶ These issues are one of the main topics in the interdisciplinary field of science and technology studies (STS), see especially Pickering 1992.

reconstructing and investigating the manufacturing operations, especially the practices which, in our views, did not serve practical purposes.⁴⁷

Leaded Bronze in Use

In this section, I will continue to discuss the properties of leaded bronze but from a user's perspective. As discussed in Chapter 3, new human-thing relations are established when people use metal objects. In these new relations, some other properties of metals become "effective". A user of a bronze object may not be aware of the issues mentioned in the last section, such as the melting points and fluidity of leaded bronze. Instead, what become important are the properties of the material which can be perceived when the user interact with the object. In other words, to a metal-user, the cognition of metals, such as the ability to differentiate copper, bronze, and leaded bronze, comes from senses. The studies on senses and their roles in ancient technology and material culture have developed into an interdisciplinary field called archaeology of the senses, or sensory archaeology.⁴⁸ Traditionally, there are five senses, sight, hearing, taste, smell, and touch, but scholars have pointed out that there are probably more as the recognition of senses as culture-dependent.⁴⁹ The foundation of sensory archaeology is "our shared human corporeality". That is to say, biologically, the fully functioning sensory organs of any human today or in the past sense in the same way.⁵⁰ As Christopher Tilley summarized, sensory

⁴⁷ A good example is provided by Pamela Smith in her study on the production of a bronze-gilt altarpiece in the 1580s in Augsburg. The artisans recorded in their account book butter together with other raw materials. According to the texts left by the artisans, they believed that butter could have protected them from the "evil smoke" of metalworking. In this case, the consumption of butter was certainly part of the manufacturing operation which cannot be explained from a positivist perspective. To understand such a practice, therefore, requires us to understand the craftspeople culturally: Smith 2014.

⁴⁸ Day 2013b; Hamilakis 2011.

⁴⁹ E.g. Classen 1990.

⁵⁰ Day 2013a; Yates 1993. An opposite view is held by phenomenology and its applications in archaeology (a.k.a. phenomenological archaeology). In phenomenological archaeology, sensory experience is defined not only culturally but also individually: Kuijpers 2013. I will not elaborate this

archaeology is to scrutinise “culturally constructed individuals whose personhoods differ while possessing a universal body”.⁵¹

The approach of sensory archaeology has been adopted by some studies as a way to understand prehistoric metalworking. For example, in her study on the pre-Columbian bronze bells from the Valley of Mexico, Dorothy Hosler noted that people used several types of copper alloy (including leaded copper) to produce these bells so as to give them different colours and sounds.⁵² Hosler argued that bells with certain colours and sounds were further associated with the expression and control over social power. Another example of explaining metal alloys from a sensory perspective is the study of an Early Bronze Age necklace from Gegharot, Armenia. Khachatur Meliksetian and colleagues discovered that some beads of the necklace were made of copper-arsenic-lead alloys. Such alloys were not commonly used in this region. The authors argued that this material was deliberately chosen for its grey, “silvery” colour, so the beads can contrast with other reddish and yellowish ones made of other copper alloys.⁵³

To understand how the properties of leaded bronze affect people who use it, I will start with our senses to discuss the visual characteristics, the smell, the taste, and the touch of this material. In the final part, I will also discuss the durability of leaded bronze as it is also related to how people use the metal.

debate here. More discussion about it can be seen in Brück 2005; Hamilton et al. 2006; Desjarlais and Jason Throop 2011.

⁵¹ Tilley 2010: 487.

⁵² Hosler 1994; 1995.

⁵³ Meliksetian et al. 2009.

Visual Characteristics

The first property to be discussed is colour, or, more generally, the visual characteristics of leaded bronze objects. Visual characteristics played and still play a crucial role in shaping people's ideas of metal materials.⁵⁴ Before elaborating my argument, I need to point out that the visual perception of a metal object has two aspects: colour and lustre. Besides, various surface treatments, such as polishing, painting, and patination can change the original colour and lustre of a metal. What we see of a metal reflects the overall result of all these factors.

In terms of the original colour, most metals used in the Bronze Age can be divided into two colour systems. In the first group are gold and gold alloys, or the so-called coloured gold, especially gold-silver-copper (Figure 4.6, a).⁵⁵ Copper gives gold alloys a reddish colour, while silver makes them whitish or greenish. In many societies, people are intrigued by the colours of these metals and the symbolic meanings attached to them.⁵⁶ In early China, gold and silver were rarely used. However, people may still have valued the golden colours, as I will argue in Chapter 6. The second metallic colour system is based on copper and its alloys, especially copper with tin, lead, and arsenic.⁵⁷ Copper-based alloys may have some different colours from those in the gold-silver-copper system. For example, Figure 4.6, b shows the colour diagram of copper-tin-arsenic alloys. At the arsenic-tin end, the alloys can achieve a distinctive bluish-grey colour. Also, as the ternary plot shows, copper mixed with certain levels of tin can sometimes imitate the colour of gold.

⁵⁴ For a few examples, see Jones and MacGregor 2002; Jones 2004b; Morphy 1989; Pinney and Thomas 2001.

⁵⁵ Scientific colour standardisation of the gold-silver-copper ternary system started in the mid twentieth century: Cretu and Lingen 1999; Grimwade 2009; Leuser 1949; Roberts and Clarke 1979; Shiraishi and Tilley 2014.

⁵⁶ E.g. Falchetti 2003; Oliver 2000.

⁵⁷ Scientific colorological studies: Bourgarit 2003; Chase 1994; Fang, J. and McDonnell 2011; Mödler et al. 2017; Radivojević et al. 2018.

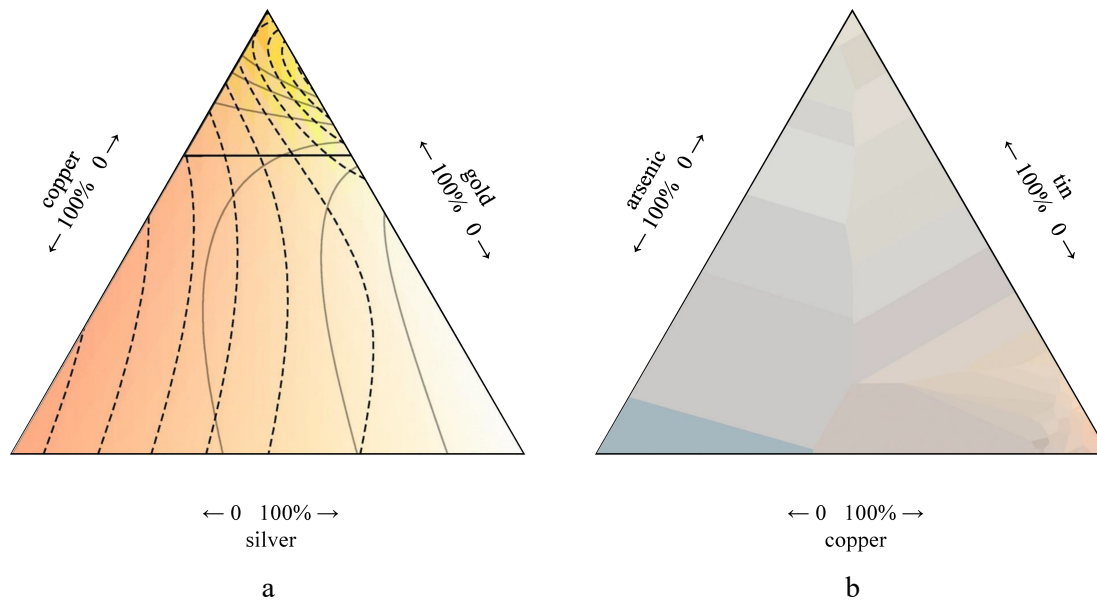


Figure 4.6 Ternary plot of colours of two metal alloying systems. Left: gold-silver-copper alloys (after Manas 2018: 210); b: copper-tin-arsenic (Cu-Sn-As) alloys (after Radivojević et al. 2018: 114).

So far, there is still a lack of studies on the colours of leaded bronze. One exception is the research by Thomas Chase and colleagues which suggests that leaded bronze may have varied colours from “light yellow” to “yellowish grey”. A more detailed colorological study has been published by Chase and Ruth Johnston-Feller. In this study, ten copper-tin-lead samples were created. The researchers argued that the hue of the samples changes mainly along with the levels of tin, while lead has little effect on the colour (Table 4.2). From the perspective of microstructure, this is probably due to the fact that lead is not soluble in copper-tin alloys. Therefore, as Chase suggested, lead only “decreases the intensity” of the metal colour instead of “changing its hue”.⁵⁸

In addition to the effects on colour, alloying elements can also change the brightness, or lustre, of the metals.⁵⁹ Lustre refers to the amount of light, or the luminance, a metal surface can reflect,

⁵⁸ Chase 1983.

⁵⁹ In some early cultures, the brightness and the colour of a material may have been considered the same property as colour: Plato 2008: 66. The confusion with colour and lustre in ancient Greek texts led to the

Table 4.2 Composition of bronze alloy samples and their sRGB colours. Original colorimetric data from Johnston-Feller (2001: 161); Chase (1994: 95). The transformation from CIE XYZ to sRGB is based on International Electrotechnical Commission (1999).

Sample	Cu (%)	Sn (%)	Pb (%)	CIE XYZ colour	sRGB colour	colour
1	100	-	-	56.96, 51.57, 36.85	231,178,149	
2	90	10	-	65.33, 63.88, 50.58	235,199,161	
3	90	7	3	69.34, 67.73, 54.31	244,207,168	
4	80	10	10	69.85, 69.23, 57.18	236,209,178	
5	77.5	22.5	-	63.15, 63.58, 55.86	222,206,182	
6	76.5	12.6	10.9	63.19, 63.63, 56.48	222,206,183	
7	75	15	10	63.35, 62.89, 51.22	227,201,171	
8	71	26	3	63.18, 63.99, 63.12	215,207,195	
9	70	27.5	2.5	61.21, 62.19, 62.86	212,204,192	
10	65	2.5	32.5	66.44, 63.52, 53.44	239,197,168	

as well as the way in which light is reflected (specular or diffuse).⁶⁰ Generally speaking, leaded bronze does not have a high reflection since the insoluble lead globules tend to decrease the total reflectance of the material surface. Also, since lead globules often disperse throughout the whole cast body, polishing a leaded bronze object usually cannot improve its gloss effectively.⁶¹ However, in some particular cases, the lacklustre surface of leaded bronze may be what people want. Researchers have already noted that, in both ancient China and Rome, many mirrors were

debate that whether the Greeks were colour blind, mainly by William Gladstone. Nevertheless, there is no evidence that the ancient Greeks were biologically different from us in eyes or brains. A more likely explanation is that the Greeks understood colours in a different way: Bradley 2009; Roberts-Austen 1886.

⁶⁰ Sometimes transmit light can also affect the total luminance from the object, such as in the case of polarization.

⁶¹ Paul Craddock, personal communication.

made of high-tin and high-leaded bronze alloys. Those mirrors often have very reflective, silvery-lustrous surfaces even after being buried for thousands of years.⁶² In one study, G. M. Ingo and colleagues analysed two Roman mirrors and discovered that they both contain around 24% tin and 9% lead. The authors suggested that the lustrous surfaces are due to the inverse segregation (sweating) of tin.⁶³ The analysis also shows that lead is distributed as small round globules in the copper-tin cast structure, but the authors do not explain the presence of lead in detail.⁶⁴ I think that the use of such high-leaded bronze is to make the surfaces of the mirrors darker, so the reflections can be clearer. Scholars also suggest that, in some Chinese contexts, black mirrors were associated with special symbolic meanings. Therefore, people may have intentionally used mirrors with a darker colour—achieved by the addition of lead—for certain burial or magical purposes.⁶⁵

Besides colour and lustre, surface treatments are also important to the overall visual characteristics of metal objects. Surface treatments include various techniques, such as painting,⁶⁶ inlay, gilding, patination, as well as dozens of modern ways of coating (electroplating, thermal spraying etc.). The chemical compositions of the alloys play a crucial role in some of these treatments. In this section, I will mainly focus on patination.⁶⁷

Patination is a process in which a thin layer of various chemical compounds is generated on the surface of a metal. Strictly speaking, patination is a type of corrosion. Metals are often replaced

⁶² Meeks 1986; Chase and Franklin 1979; Chikashige 1929; Gettens 1934; Chase 1977.

⁶³ Inverse segregation is a process in which a component is pushed towards the surface of a cast during cooling. This is also called vividly as “sweating”. The inverse segregation of tin is very common in bronze objects, while lead sometimes also segregated in this way. See Craddock 1980b; Harrison et al. 1981.

⁶⁴ Ingo et al. 2006.

⁶⁵ Chase and Franklin 1979.

⁶⁶ Bronze painting is a technique in some ancient traditions. However, painting on early Chinese bronzes is rare. The only example I know is the bronzes from Sanxingdui: Zhu, D. 2018. Therefore, I will not elaborate this point in this thesis. Examples of painted bronze in other cultures, see e.g. Born 1990.

⁶⁷ Other surface treatments, see Chase and Franklin 1979; Chase 1994.

by their oxide, hydroxide, and sulphide in this process. In general, copper turns green when corroded in the air since copper reacts with carbon dioxide and water, forming three compounds: malachite ($\text{Cu}_2(\text{CO}_3)$), azurite ($\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2$) and brochantite ($\text{Cu}_4\text{SO}_4(\text{OH})_6$). The colours of these three compounds are from green, blue to purple, giving copper patina its green colours.⁶⁸ For bronze, the additional tin may also oxidise and form tin oxide (SnO_2), giving the object a smooth greyish-green patina.⁶⁹ Leaded bronze, on the other hand, often turns into a dark brown colour when corrodes, since lead oxides (such as PbO , Pb_3O_4 and PbO_2) have various colours from orange-red to black. Besides, when lead oxidizes, it gradually falls off from the metal substance. The spaces originally occupied by lead globules are gradually refilled by cuprite (Cu_2O), whose colours are dark red to black.⁷⁰

This dark brown colour of leaded bronze patinas may increase the attractiveness of this material. In his *Naturalis Historia*, Pliny the elder mentioned that when copper, tin and lead are mixed in the ratio 100:10:5 (or 87% copper, 9% tin, 4% lead), the alloy has a colour which he called “Graecanic”, after the Greek.⁷¹ This coral-brown colour reminds us another type of bronze also mentioned in *Naturalis Historia*, the “*hapatizon*” (“liver-like”) Corinthian bronze. According to Pliny, this bronze was highly valued for uses such as making statues because of its colour.⁷² One more suggestion by Pliny is that “the addition of lead to Cyprus copper produces the purple colour seen in the bordered robes of statues.”⁷³ Based on our previous discussion, it is likely that

⁶⁸ Scott 2002.

⁶⁹ Bannister 1926; Caley 1941; Gettens 1949; Smythe 1940. For a more detailed introduction and discussion of products in copper corrosion, see Vernon and Whitby 1929; 1930. See also Chapter 2 to 8 of Scott 2002.

⁷⁰ Gettens 1967: 177; Lyon 2010; McCann et al. 1999; Quaranta et al. 2014.

⁷¹ Pliny 1938: 197.

⁷² Pliny 1938: 129. Pliny considered the formula of this Corinthian bronze a mystery and “produced by luck”. Some modern scholars believe that this bronze is produced by adding silver and gold to bronze: Giumlia-Mair and Craddock 1993; Craddock and Giumlia-Mair 1993; Jacobson and Weitzman 1995.

⁷³ Pliny 1938: 201.

Table 4.3 Examples of ancient to modern leaded bronze sculptures and their chemical compositions.

Name	Alloy composition				Reference
	Cu (%)	Sn (%)	Pb (%)	others (>1%)	
Statuette of an Archer, c. 600 BC J. Paul Getty Museum, Los Angeles	79.4	3.7	7.5	-	Scott (2011: 219)
Statuette of a Kouros, c. 490 BC J. Paul Getty Museum, Los Angeles	77.1	6.2	14.4	As: 9.0	Scott and Podany (1990)
The Cleveland Apollo, c. 350 BC The Cleveland Museum of Art, Cleveland	76.1	6.2	13.3	-	Snyder et al. (2017)
The Getty Herm, c. 200–100 BC J. Paul Getty Museum, Los Angeles	69.1	12.7	17.3	-	Scott and Podany (1990)
Bernward Doors, c. 1015 Hildesheim Cathedral	77.2	8.6	8.5	Zn: 5.0	Mende (1983: 34–40)
<i>Mars</i> , after Giambologna, c. 1587 The Cleveland Museum of Art, Cleveland	90.4	6.0	2.8	-	Bewer (1996)
Statue of Henry IV, 1818 Pont Neuf, Paris	84	3.5	5.5	Zn: 4.9	Celle and Usai (2012)
Rodin's Clenched Hand, 1884–5 Smart Museum of Art, Chicago	86.8	4.6	6.3	Zn: 2.0	Ganio et al. (2014)

these appealing brownish colours described by Pliny are the colours of leaded bronze patinas. More recently, Chandler Roberts-Austen suggested in his Cantor lectures that “the addition of ... a certain amount of lead to tin and copper confers upon the metal copper the property of receiving, when exposed to the atmosphere, varying shades of deep velvety brown, characteristic of the bronze which has from remote antiquity been used for artistic purposes.”⁷⁴ For early Chinese bronzes, there is no direct textual evidence discussing such a brownish colours. However, in traditional Japanese metalwork, a type of alloy with a normal formula is 71–79% copper, 2–8% tin and 5–15% lead is called *Karakane* 唐金, literally means “Chinese metal”. This metal is said

⁷⁴ Roberts-Austen 1888.

to have a brown to greyish-green colour.⁷⁵ This special colour may also be the colour of the leaded bronze patinas. Besides these suggestions, many famous European sculptures, from ancient to the 20th century, were also made of leaded bronze (Table 4.3). Although we do not really know why these sculptors all chose leaded bronze as their material, such a common choice indicates that leaded bronze must be considered visually appealing to these artists' eyes.

Taste and Smell

Taste and smell were once crucial to people when working with metals. In Agricola's *De re metallica* (On the Nature of Metals), the author noted that "the taste of copper is very bitter and unpleasant, that iron less so while the taste of tin is the weakest of all metals."⁷⁶ Agricola's statement was for a very practical reason: for the miners to find the metal ores by following the taste of water. Nevertheless, the taste and the smell of metals may also have had symbolical meanings. For example, medieval alchemist Jean de Roquetaillade (c. 1310–1368) claimed that demons love the matters "which were complexed with Mars, Saturn, and the moon, such as lead and bad smelling things".⁷⁷

For quite a long time, lead, although nowadays recognised as a toxic material, was part of people's daily diet.⁷⁸ When in the form of lead (II) salts, such as lead(II) acetate ($\text{Pb}(\text{CH}_3\text{COO})_2$), lead has a sweetish taste.⁷⁹ The ancient Romans produced lead (II) acetate by boiling lead in acetic acid. The product, also known as "the sugar of lead", was widely used by the Romans as a type of sweetener for food and for wine, and was even reintroduced in the Medieval period by

⁷⁵ Gowland 1895; 1915; Hughes and Rowe 1982.

⁷⁶ Agricola 1955: 8.

⁷⁷ Halversen 1998: 52.

⁷⁸ For the toxicity of lead, see e.g. Nriagu 1983; Winder 1984.

⁷⁹ Casas Fernández and Sordo 2006: 29–32.

some tricksters (deceitful people) to adulterated wines.⁸⁰ In the work by Columella (4–c. 70 AD), the author also noted that the Romans made a sugar syrup, known as *defrutum*, by boiling grape juice in lead pots to concentrate it. Columella insisted that the boiling should be in lead vessels instead of in brass ones, since “brazen vessels throw off copper-rust and spoil the flavour of the preservative”⁸¹. Pliny also recommended using copper vessels coated with *stagnum* (here means alloys of silver and lead), so as to “have a more agreeable taste”.⁸² The Romans seem to have believed that vessels made of lead and lead alloys can improve the taste of wine and cover the unpleasant taste of copper.

In early China, one of the main uses of leaded bronze was indeed vessels for cooking and drinking. Meat and wine were supposed to be cooked and boiled in such vessels during ritual feasts. Therefore, we may wonder, did early Chinese also value the taste brought by leaded bronze? As there is no written record about this, we have no direct evidence. Nevertheless, according to an experiment by Qin Yin and colleagues, food and wine heated in two leaded bronze vessels, reconstructed with 2% and 10% lead, are clearly polluted with lead.⁸³ Another experiment by Woolf and colleagues also confirms the lead contaminant in the wine heated in leaded bronze vessels.⁸⁴ Although we do not know how the food and wine may taste like (they definitely should not be tasted), the taste may indeed be different from what produced by unleaded vessels.

⁸⁰ Ancient Rome: Retief and Cilliers 2006; Waldron and Wells 1979; Medieval: Beckmann et al. 1846: 252–253.

⁸¹ Columella 1941: 229–233.

⁸² Pliny 1938: 243.

⁸³ Qin, Y. et al. 2005.

⁸⁴ Woolf et al. 2010.

Besides the unfavourable taste, copper and many copper-based metals are also “smelly”.⁸⁵ The mysterious smell of copper has puzzled scientists for centuries. Only in recent decades did people start to understand its mechanism. Precisely speaking, the special odour of copper is not the smell of the metal itself, but the smell of our body due to the chemical reaction between the metal and our skin.⁸⁶ The odour of leaded bronze is not well studied. What I suggest is that leaded bronze is perhaps less odorous than copper due to both the low rate of reaction between lead and our skin and the oligodynamic effect of lead—the effect of heavy metals which kills odour-producing bacteria.⁸⁷ Hence, lead may be added to de-odorize copper. For the daily use of bronze vessels, taste and smell are often inseparable. If people did not like the taste nor the smell of their vessels, it is possible that they may have added lead to mitigate the taste and the smell of copper. The difficulty in such research is that sometimes the results cannot be tested with scientific methods, as people may simply believe that vessels made of certain alloys can improve the taste and smell of food and drink.⁸⁸

Touch

Another important way for people to establish relations with a physical object is through the sense of touch (our somatosensory system). Unlike the previously discussed senses (relations), the sense of touch usually requires physical contact with the material. But, for an object made of a certain material, how we feel the material is also related to the way we use the object. For

⁸⁵ In Chinese, the word *tongchou* 銅臭 (“copper smell”) is often used to describe the negative feelings toward the rich. Despite this class discrimination, the unfavorable smell of copper is well reflected by this term.

⁸⁶ Glindemann et al. 2006. Interestingly, it is said that when the son of Vespasian (r. 69–79) complained about the urine tax imposed by his father, the Roman emperor replied, “Pecunia non olet (money does not stink).” After all, it seems that Vespasian was right: Suetonius 1911: 460.

⁸⁷ Müller 1985. Copper itself is a well-known bacteriostatic agent: Grass et al. 2011.

⁸⁸ One modern example is the enthusiasm on cooking with cast-iron pans: Anke Hein, personal communication.

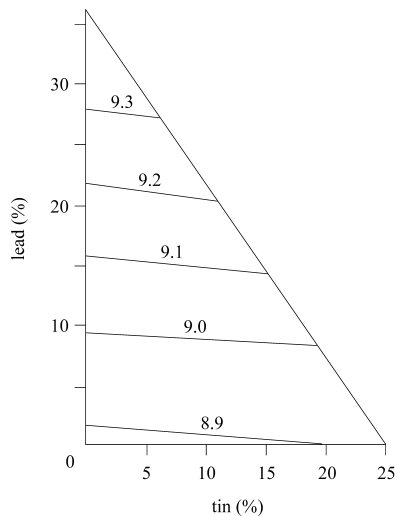


Figure 4.7 Density of leaded bronze (g/cm^3)
(after Hanson and Pell-Walpole 1951: 253).

example, the weight, the texture, and the temperature may be something we recognise when using a bronze vessel. However, if the bronze is in the form of a knife, people who use it may pay more attention on its hardness and sharpness.

For a metal object in any form, one property which is often noticeable is the heaviness of the object. This is mainly decided by the size and the density of the metal of which the object is made. Compared with other commonly used metals, lead is much heavier. The density of lead at room temperature is $11.34 \text{ g}/\text{cm}^3$, which is much denser than copper and tin.⁸⁹ When lead is added to bronze alloys, the density of the alloys also increases along with the percentage of lead (Figure 4.7).⁹⁰ In prehistoric and ancient times, this property of lead was sometimes utilized by people as they used lead and leaded bronze for various objects, such as standard weights, sling bullets, and even “halteres” (hand-held weights to increase the leaping distance) for ancient Olympic long jump athletes.⁹¹

⁸⁹ Sutherland et al. 2011.

⁹⁰ The industrial data can also offer a reference. C93800 leaded bronze (78% copper, 15% lead, 7% tin), for example, is almost 5% denser than C90200 unleaded bronze (93% copper, 7% tin). See footnote 34.

⁹¹ Alberto and Luca 2002; Nriagu 1983: 256–262. Photos of some of these items can be found in the preface.

For early Chinese ritual vessels, heaviness may have been a preferred quality. Ancient Chinese texts suggest that the size and weight of ritual vessels were linked with the power and status of their owners, especially the legitimacy of the rulers. The best-known example is recorded in the *Zuozhuan* 左傳 (*The Zuo Tradition*), originally composed around 4th century BC. In a story, the Lord of Chu asked the official of the King of Zhou how heavy the King's bronzes are—a clear intention of usurpation. The official replied: “With (sovereign's) virtue, vessels are heavy despite small; without virtue, vessels are light despite big.”⁹² Some early ritual bronzes are indeed very weighty, such as the *Houmuwu ding* (see Chapter 1). However, early craftspeople may have had more complicated goals in addition to increasing the weight. Such a case will be discussed in Chapter 5 when we encounter the ritual vessels from Zhengzhou.

When a material is used for vessels, especially when the vessels are used for serving hot food, we also need to consider its ability to absorb and transfer heat. Pure copper has a very high thermal conductivity, 401 W/(m·K) at room temperature. When alloyed with tin, bronze has a much lower thermal conductivity, usually below 100 W/(m·K).⁹³ The thermal conductivity of pure lead is even lower, which is 35.3 W/(m·K).⁹⁴ Since lead is insoluble in copper-tin, leaded bronze is expected to have lower thermal conductivity than unleaded bronze. The industrial data shows that, in some cases, adding a small amount of lead can really lower the thermal conductivity (e.g. C90200 vs. C93600), but the relation between lead level and thermal conductivity may not be linear and there may be an upper limit of this effect (e.g. C93600 vs. C93800) (Table 4.4). When leaded bronze is used for vessels, its relatively low thermal conductivity means that, to the sense of touch, leaded bronze vessels may have a milder feel compared with unleaded ones. This can be a favourable quality in two ways. First, those vessels

⁹² Durrant et al. 2016: v. 1, 601–603.

⁹³ With at least 5% tin: Griffiths and Schofield 1928. See also Hanson and Pell-Walpole 1951: 254–255.

⁹⁴ Madelung and White 1991: 38.

Table 4.4 The thermal conductivity (at room temperature, 20°C) of alloys with different levels of tin and lead (data source: Copper Development Association).

ID	Cu (%)	Sn (%)	Pb (%)	Thermal conductivity (W/(m·K))
C10100	≥99.99	≤0.005	≤0.0002	390.8
C90200	91.0–94.0	6.0–8.0	≤0.3	62.3
C90700	88.0–90.0	10.0–12.0	≤0.5	70.6
C92700	86.0–89.0	9.0–11.0	1.0–2.5	47.0
C93600	79.0–83.0	6.0–8.0	11.0–13.0	49.3
C93700	78.0–82.0	9.0–11.0	8.0–11.0	46.9
C93800	75.0–79.0	6.3–7.5	13.0–16.0	52.2
C94400	Rem	7.0–9.0	9.0–12.0	52.2

Other elements in the alloys are lower than 1.0%.

are easier to handle. Second, food and drink can also be kept warm for much longer. In the context of early China, I may further suggest that, as most pre-bronze ritual vessels were made of ceramic, people who wished to imitate the feel of ceramic vessels may have chosen leaded bronze for this mild feel.

Another property which can be sensed when the metals are used for vessels, but more perceptible in the cases of metal tools and weapons, is the toughness of the material. As previously discussed, lead exists in a segregated form in a copper-tin-lead alloy. This structure weakens the mechanical properties—including tensile strength, ductility, elongation, toughness, and hardness—of the material (Figure 4.8).⁹⁵ Also, since lead clots and copper-tin crystals are not bonded strongly, a leaded bronze object is very easy to break into pieces if we hammer it. This means that leaded bronze tools and weapons are usually not suitable to be forged.⁹⁶ However, these seemingly

⁹⁵ Chase 1983: 104–105; Dies 1967: 549; French et al. 1928; Hanson and Pell-Walpole 1951: 248. See also Northover and Staniaszek 1982.

⁹⁶ Chase 1983: 103. However, forging a leaded bronze object was still possible. For example, a bronze weapon from Huoshiliang, Shaanxi, containing 1.3% lead, was forged: Chen, K. et al. 2009b. Objects which do not need to be very strong/hard (such as personal ornaments) may be more tolerate to high lead levels. For example, several Dadianzi rings and earrings, containing 2–5% lead, were forged: Li, Y. et al. 2003.

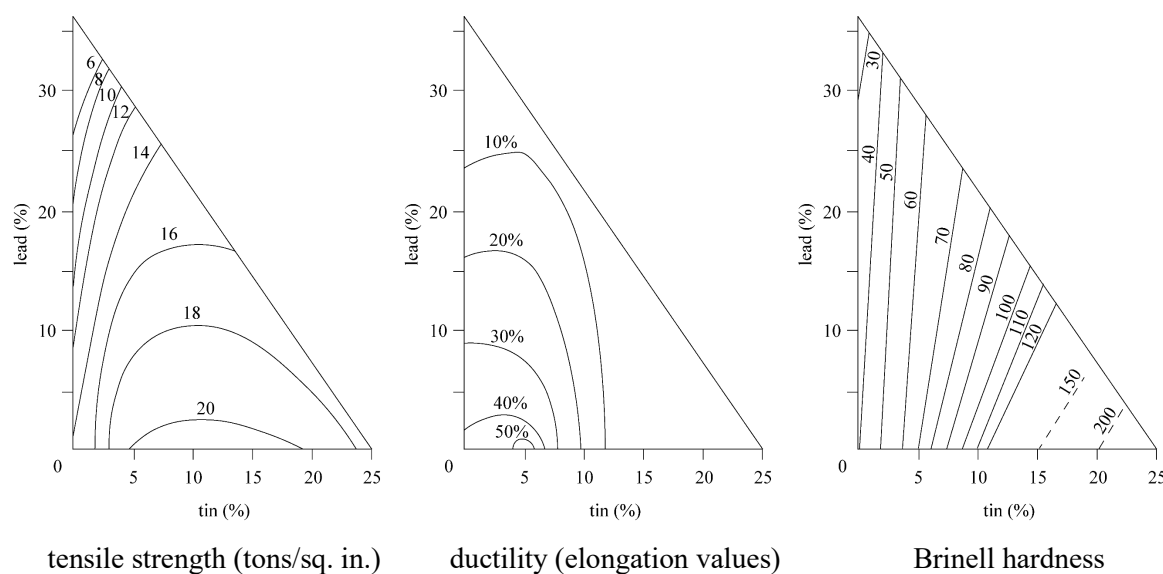


Figure 4.8 Mechanical properties of leaded bronze (after Hanson and Pell-Walpole 1951: 248).

disadvantages do not mean that leaded bronze cannot be used for everyday tools. If we compare leaded bronze with other materials which were often used to make those tools, such as stone and bone, leaded bronze is at least as good as those alternative options. For example, the Brinell hardness of high-leaded bronze C93800, with 13.0–16.0% lead, is about 55, which is of course lower than that of unleaded bronze C90200, 70.⁹⁷ However, this leaded bronze alloy is still harder than pure copper, which is about 35, or 3 in Mohs hardness. In comparison, the Mohs scales of two types of lithic material commonly by early Chinese communities, dolomite and sandstone, are between 3.5 to 7.⁹⁸ Meanwhile, materials like bone, tooth, and antler are about 2.5 to 5 in Mohs scale.⁹⁹ This suggests that, for people using these materials, bronze tools, even with quite high lead contents, can still have a hardness level similar to bone ones. Therefore, from the perspective of hardness, the idea of using leaded bronze as everyday tools seems to be acceptable, but leaded bronze is also not mechanically superior to the lithic and organic materials.

⁹⁷ Copper Development Association: footnote 34.

⁹⁸ E.g. Webb et al. 2007.

⁹⁹ Samsonov 1968: 432.

In Chapter 8, we will see some examples of leaded bronze tools from the lower Yangtze Valley. I will also argue that this lack of outstanding mechanical properties may have been a reason for the limited acceptance of leaded bronze in that region.

Durability

For a metal object, the durability is mainly about how easily the object corrodes, and in what way it corrodes. When a metal object corrodes, a thin layer of patina grows on its surface, giving the object a special colour as previously discussed. In the process of patination, metals are replaced by their oxides, hydroxides, and sulphides. This usually means that the original metal bodies deteriorate. However, patinas may also provide chemically more stable coverings, so the objects are actually protected from further corrosion.¹⁰⁰

In the case of early Chinese leaded bronze objects, their special patinas are often called “mirror-black” (for those on bronze mirrors) or “water patina” (for those on ritual vessels).¹⁰¹ The patinas of leaded bronze are very resistant to further corrosion, but, in fact, the key component in corrosion resistance is not lead, but tin. As some corrosion experiments show, adding lead to bronze has little effect on resisting corrosion by water. Nevertheless, lead does help strengthen the acid resistance of the bronze alloys.¹⁰² In an experiment with vinegar, the researchers suggest that bronze alloys with 8–10% tin and 6–10% lead have the overall best resistance to acid.¹⁰³ This quality of leaded bronze was probably meaningful in the early Chinese cases as bronze vessels were used for alcohol.

¹⁰⁰ An obvious example is stainless steel in which chromium oxidises and protects iron: Mark Pollard, personal communication.

¹⁰¹ Chase 1977; Gettens 1967: 42–43; Liang, Z. et al. 2021; Liu Wei and Chen Jianli 2019; Soto et al. 1983.

¹⁰² Kareem et al. 2016; Quaranta et al. 2014; Hanson and Pell-Walpole 1951: 254–259.

¹⁰³ Mrak and Le Roux 1932.

Lead itself is a material with very high corrosion resistance. For this and other reasons, lead was widely used for water pipes, net-sinkers, standard weights, and grave goods.¹⁰⁴ This property of lead may also give lead a certain connection to ideas such as long-lasting and anti-corrosion. In other words, lead probably made itself a symbol for corrosion resistance in some cultures. When people wanted to prevent metal objects from corrosion, they may have tried to introduce such a property by adding lead. One example is lead votive objects which were commonly used in the ancient Mediterranean, such as the one in Figure 4.2. As Jerome Nriagu pointed out, the ancient Egyptians often associated lead with Osiris, the god of the dead. This is probably because of the fusibility, high density, and high resistance to corrosion of lead.¹⁰⁵ In early China, lead objects such as ritual vessels, weapons and figures were sometimes also put in tombs. Nevertheless, without textual records, it is very hard for us to investigate whether such a concept of lead also existed in early China.

Conclusion

As mentioned earlier in this chapter, for the archaeological questions asked in this thesis, I adopt the approach to investigate material properties based on their relations with humans. An alternative, and more traditional approach would be to discuss the properties from a purely mechanical/scientific perspective.¹⁰⁶ These two approaches are not disconnected. In my discussion, I have also relied on the studies of the physical and chemical properties of leaded bronze, such as its melting points, strength, and oxidation. Nevertheless, unlike other research fields such as material science which aims to find new useful materials, archaeologists ask different questions, such as why certain materials were used? That is to say, what we want to

¹⁰⁴ E.g. Nriagu 1983: 200–268. See also photos in the preface.

¹⁰⁵ Nriagu 1983: 35.

¹⁰⁶ E.g. Collins 1899; Percy 1870; Isbell 2011.

know through studying the properties is not just how good a material is, but how good a material may have been considered by people in their contexts. Therefore, taking the human-thing relations into account seems to be a necessary way.

With this approach, I reviewed the properties of leaded bronze as well as some potential uses of this material based on these properties. Leaded bronze has a good castability, especially when the lead contents are not too high. Objects made of leaded bronze also tend to have special visual characteristics and touch, compared with objects made of other metal materials. In addition, there may also be culinary reasons behind the use of leaded bronze, as food and drink may have a more appealing taste and smell (from a modern perspective, this definitely should not have been practiced). When used for tools such as knives and awls, the mechanical properties of leaded bronze lie between pure copper and almost all other alternative materials. A leaded bronze awl, for example, is probably as good as a stone or bone one, but not as good as an unleaded bronze one. All these reasons may have led to the adoption or rejection of this material.

Nevertheless, studying the properties of a material as human-thing relations forces us to make assumptions based on our understanding of human behaviour. This can sometimes introduce cognitive bias.¹⁰⁷ The properties discussed in this chapter are mainly based on our current understanding of how the bronze objects were used in early China. In the following case studies, I will revisit some of these properties in different contexts (human-thing relations). As I mentioned earlier in this chapter, the properties do not determine what a material is, but what it can do.

¹⁰⁷ Even for a contemporary case, such as the right artwork in Figure 4.2, it is sometimes difficult to know the creator's intention of choosing certain materials.

PART TWO

Leaded Bronze and People

Making Vessels with a New Material

Erlitou and Its Leaded Bronzes

The archaeological site of Erlitou lies in the middle Yellow River Valley, which is traditionally considered part of the “Central Plains” in Chinese culture. The site is on a small floodplain called Yiluo or Luoyang Basin, named after the city Luoyang, which is about 25 km to the west of Erlitou. For our investigation of leaded bronze in early China, Erlitou is important since it is the earliest site with clear evidence of workshops for ritual vessels and for their burial. It is also the site where the earliest leaded bronze vessels have been found. In this case study, I will discuss the possible reasons behind the use of leaded bronze here, with a view to suggesting that one purpose was to make ritual vessels at relatively low economic costs. At Erlitou, these socio-economic factors probably turned people from making unleaded bronze vessels to making leaded ones during the last period of the settlement. After Erlitou was abandoned around 1500 BC, this idea of making leaded bronze vessels did not disappear along with the site. On the contrary, the Erlitou metalworking tradition, as well as the making of leaded bronze vessels, was carried on by later communities and was thus taken up in a much wider territory. In this chapter, I will discuss how this socio-economic choice was initially established at Erlitou, and how it was continued and developed by the successors of Erlitou.

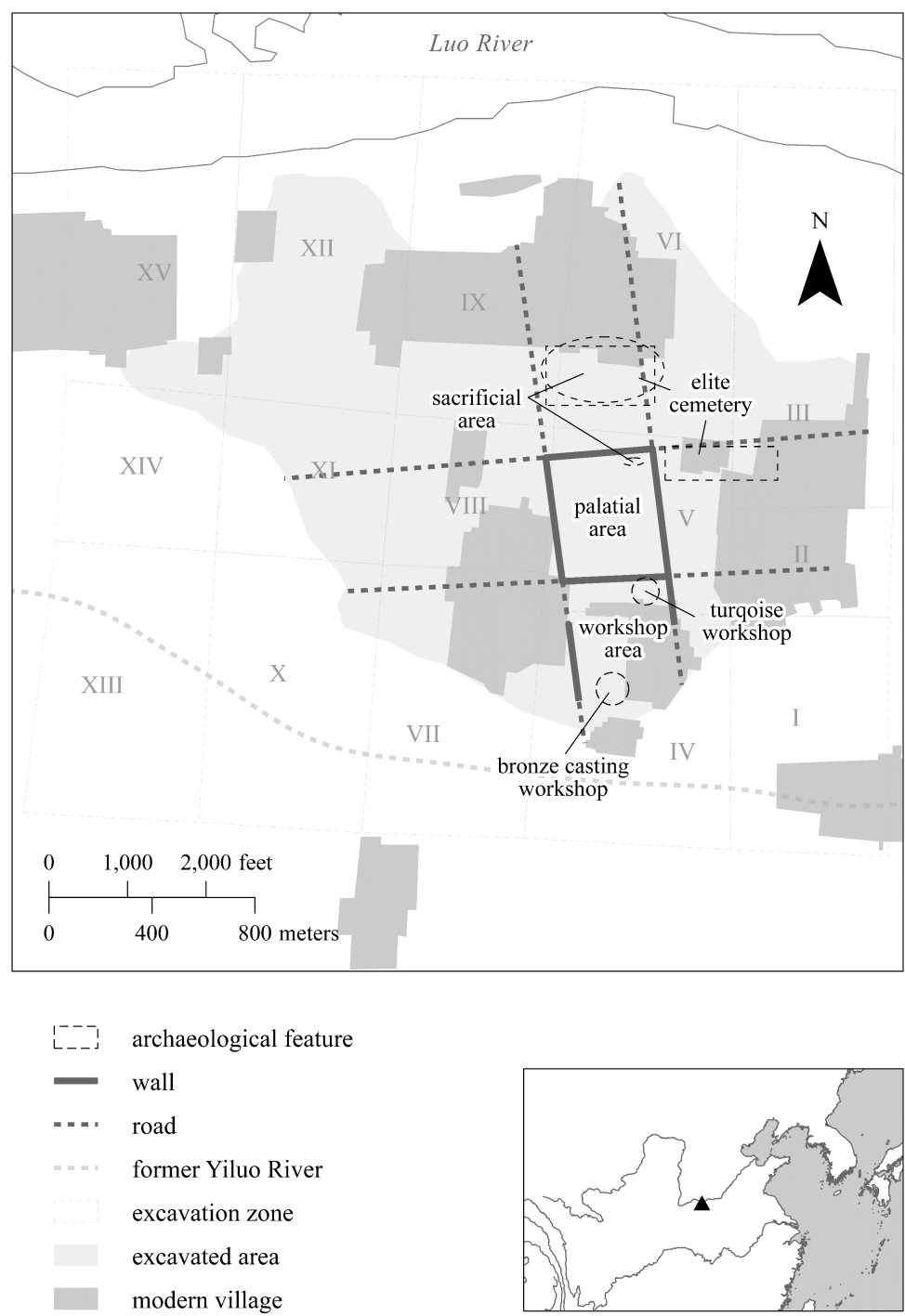


Figure 5.1 Plan of the Erlitou site and the distribution of the archaeological features (modified from Zhao, H. 2020: 110; Zhongguo 1999: 13; 2014: v. 1, 11).

*Erlitou and Its Region***The Erlitou Site**

In the academic history of Chinese archaeology, Erlitou (Figure 5.1) has always been a special site. It was discovered in 1957 during a survey aiming to locate the capital of the Xia dynasty. The Xia dynasty is recorded in various classical texts as the first dynasty in Chinese history. The earliest of these texts was probably composed around second half of the first millennium BC.¹ Therefore, from the beginning of its discovery, Erlitou was considered to be a crucial site, with efforts by both academic and political players, in order to demonstrate the long and splendid history of the Chinese civilisation.² Since the discovery of the site, ongoing excavations have been revealing more and more detail. People started to realise that the importance of Erlitou does not depend solely on its connection with the legendary first dynasty. The first reason to highlight this site is its size. Up till the 2020 season, excavators have uncovered about four hectares (40,000 m²) of the site, while the original site is believed to be around 300 to 400 hectares in area, with probably a population of 20,000 to 30,000 people in its heyday. This makes Erlitou undoubtedly the largest site in the middle Yellow River Valley of its time, and probably the largest East Asian site in the first half of the second millennium.³

In addition to the scale, the archaeological finds also suggest diverse social and manufacturing activities at Erlitou. The site is divided by its excavators into fifteen working zones. In Zone V,

¹ Overview of the issue of the Xia dynasty: Chang, K. 1999: 65–73; early texts, see Shaughnessy 2019; Zhan, Z. 2007: 19–42.

² Zhao, H. et al. 2019; Zhongguo 2019. For a brief English introduction of the site, see Liu, L. and Chen, X. 2012: 263–274; Xu, H. 2013.

³ Xu, H. 2017: v. 1, 140–165; Zhang, C. et al. 2019. The population estimate was provided by Liu Li by referring to the population density based on the number and size of residential shelters at Dongxiafeng, a nearby contemporaneous site; see Liu, L. 2006.

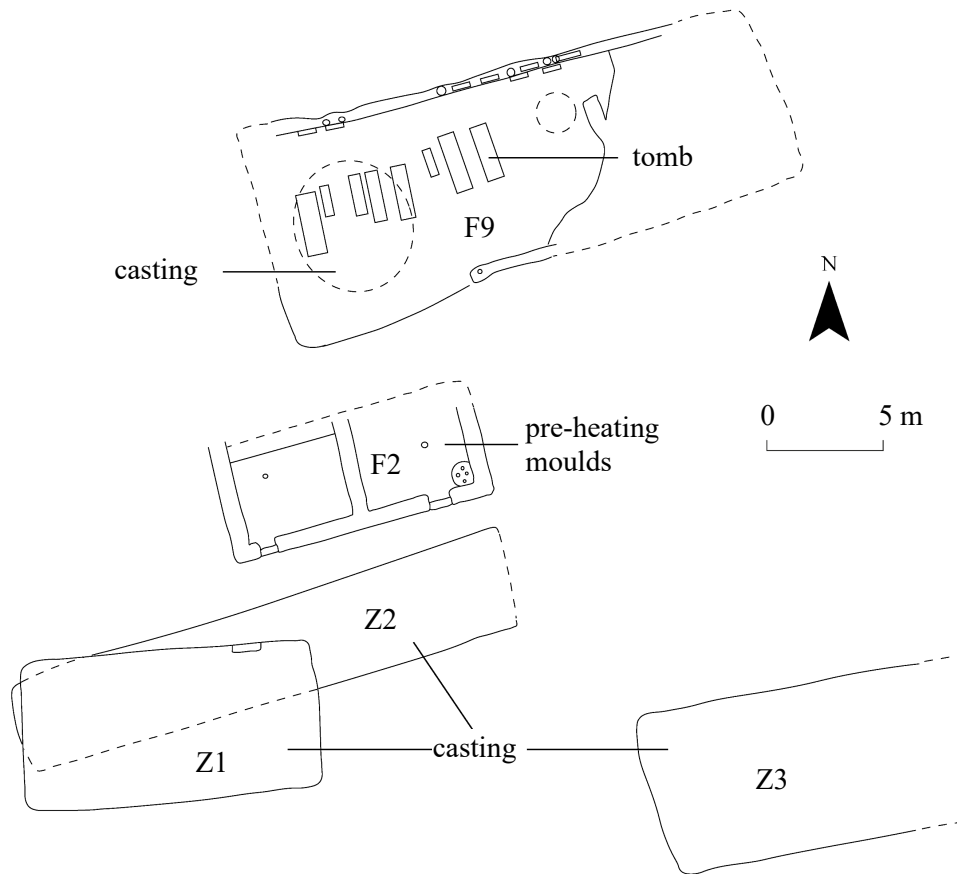


Figure 5.2 Plan of the Erlitou bronze workshop (modified from Du, J. 2020).

a rectangular, walled area has been found with foundations for two large buildings. This is interpreted as the “palatial area” by the excavators.⁴ This palatial area was created in the middle of the occupation of the Erlitou site, or in Phase III (we will discuss the chronology later). To the north of this walled area, in Zones VI and IX, there is an area with some special constructions and tombs, thought to be for sacrificial rituals.⁵ To the south of the palatial area, several houses have been found, with large quantities of manufacturing remains, such as raw materials, tools, and waste products. The excavators suggested that these are workshops which emerged in Phase II, including one for bronze production.⁶

⁴ Xu, H. and Zhao, H. 2004; Xu, S. et al. 2014.

⁵ Du, J. 2019.

⁶ Chen, G. 2014; 2016; Zhongguo 2014b: v. 1, 295–464.

At Erlitou, most metallurgical remains, including slags, moulds, crucible fragments, and metal scraps, were found within a small area (1.5–2 ha) in Zone IV (Figure 5.2); especially, massive casting remains have been located on the floors of several buildings (F9, Z1, Z2, Z3). Scholars suggest that these buildings were probably the place where bronze objects were cast. In F9, there are also dozens of people buried. The adults were laid at the centre of the room, while the children were buried close to the northern wall. Next to F9, there is also a building, divided into two rooms, with multiple heating facilities, probably for pre-heating ceramic moulds.⁷ This bronze workshop is probably the earliest casting workshop identified in East Asia. The stratigraphy suggests that the workshop was primarily used from Phase II through Phase IV. Some metallurgical remains have also been found right within the “palatial area”, especially during Phase IV (Figure 5.3).⁸ In contrast with the massive casting remains, copper ores and smelting slags have rarely been found at Erlitou.⁹ This leads most scholars to believe that only the casting stage was done at Erlitou (unless the smelting is somewhere else in the unexcavated area of Erlitou).¹⁰ The spatial distribution of cemeteries and graves at Erlitou is still not very clear. The discovered tombs are all sporadically located in different zones. Among them, some tombs are clearly more sumptuous than others, based on the tomb size, quantity of grave goods, as well as the presence of some particular types of grave goods, such as metal and jade objects.¹¹ As many scholars have argued, the burial practices and the material expressions in the burials may, though

⁷ Du, J. 2020.

⁸ Zhongguo 1999b: 15; Chen G. 2006; 2016.

⁹ Li Jinghua suggested that some turquoise ores may have been used to smelt copper: Li, J. 2004.

¹⁰ A different argument is made by Liang Honggang. By examining the furnace fragments and slags, Liang suggested that both smelting and casting were done in the Erlitou workshop: Liang, H. 2019. Since Erlitou is still under excavation. This may become clearer in future.

¹¹ Li, Z. 2008; Xu, H. and Zhao, H. 2010; Zheng, R. 1994.

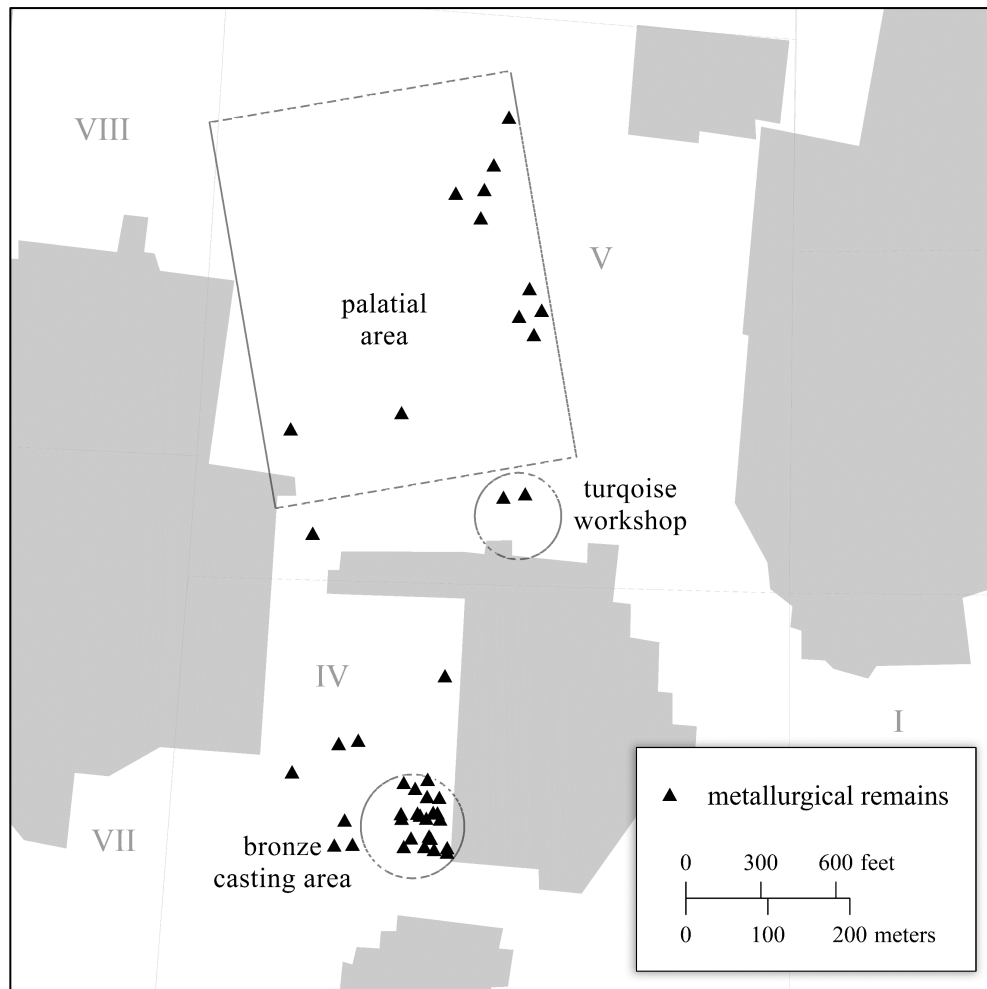


Figure 5.3 Metallurgical remains at the Erlitou site (modified from Chen, G. 2016).

not always, indicate wealth and political power.¹² If we adopt this as our working hypothesis, the tombs with larger sizes, more grave goods, and more types of extraordinary object may have belonged to individuals who enjoyed extra wealth and political power in the community. I will use the term “elite members” to refer to these individuals.¹³ In my context, I define an elite member partly based on Jon Abbink and Tijo Salverda’s suggestion from an anthropological perspective as an individual who belongs to a relatively small group within the societal hierarchy

¹² E.g. Dong et al. 2019; Flad 2001. Sometimes, other evidence such as diet may be used together with burial patterns to suggest the status and identities of the buried individuals: Budd et al. 2020; Linderholm et al. 2008; Kim 2015.

¹³ The term “elite” is often ill-defined and mis-used, see the discussion in Luley 2016.

based on power, wealth, or command over others¹⁴ In the case of Erlitou, the extra efforts and costs reflected in constructing a larger tomb and filling it with more grave goods may imply the criteria of belonging to an elite—whose members are recognised by “power, wealth, or command over others”. Accordingly, I will use the term “high-status objects” to refer to objects which, on most occasions, exclusively belonged to tombs of elite members.¹⁵ I will use a few examples to illustrate these objects later.

A further issue we need to consider is the relationship between the elite members—the main owners of bronze objects as I will show later—and the metalworkers. In the book *Artisans versus nobility*, the editors Ann Brysbaert and Alexis Gorgues collect a number of papers on this topic and argued convincingly that, during craft production, different social groups (such as elite members and artisans) try to form and reconfirm their multiple identities through actively engaging in the productive process.¹⁶ At Erlitou, as I previously mentioned, the palatial area is close to the workshops, while most artefacts which may have been produced by the workshops, such as bronze and the turquoise objects, were also found in the tombs around the palatial area.¹⁷ This suggests that the workshops may have played an important role in “forming and reconfirming” the social power. As some scholars may even argue, the elite members probably wanted to put the workshops under their direct control by closely monitoring the raw materials

¹⁴ Abbink and Salverda 2013: 1. In Abbink and Salverda’s original definition, an elite also “aims to preserve and entrench its status thus acquired”. In the case of Erlitou, our understanding of its social structure is still quite limited, so I do not think that we have sufficient evidence to show whether the Erlitou elite members were able to preserve their status.

¹⁵ The term is also used by other scholars, such as Dubreucq 2017; Sörman 2017. Although I should point out that objects themselves do not have “high status”. It is the high status of the individuals the possession of the objects may infer. In this research, I assume that the material wealth reflected in the burials is related to the social status of the deceased. Discussion and debate of this assumption, see e.g. Binford 1971; Brown 1971; Chapman 2013. See also the case study in Sørensen 2004.

¹⁶ Brysbaert and Gorgues 2017; introduction: Brysbaert 2017.

¹⁷ Li, Z. 2008: 39–51. The most outstanding tomb ever discovered in the palatial area is probably 2002VM3, with bronze, jade, and turquoise objects, as well as a turquoise mosaic “dragon”: Xu, H. 2005; Zhongguo 2014b: v. 2, 998. See also Xu, H. 2016b.

and the manufacturing in these workshops.¹⁸ From this perspective, it is possible that the manufacturing activities at Erlitou were not only on a relatively large scale, but also centrally organised. Therefore, to understand the metal production in the workshop, I suggest considering both the rulers and the craftspeople as a connected “metalworking community”, since many decisions, such as the selection of the raw materials and the form of the products, were probably influenced by both sides. However, by using the term “metalworking community”, I still recognise that the elite members, as the consumers of most high-status objects, and the craftspeople, as the producers of these objects, must have had different identities as argued by Brysbaert and Gorgues. However, these different identities need to be revealed by future studies. The relationship between the elite members and the craftspeople is critical for us to understand the use of bronze and then leaded bronze in the Erlitou society, as we will elaborate later in this chapter.

The most widely accepted chronology of Erlitou is based on the stratigraphy and ceramic typology. The whole Erlitou site is divided into five periods, with a further later, “historic period”. The first four periods, named as Phases I–IV, are considered to be the main occupation of the site, while the archaeological finds of the fifth phase are very limited. Since the ceramic types of the Phase V remains are similar to those from the nearby Zhengzhou site, with some of its earliest discoveries around a village called “Erligang”, Erlitou Phase V is sometimes called the “Erligang phase”. The relationship between Zhengzhou and Erlitou will be discussed later in this chapter. Archaeological features, which do not have clear stratigraphic contexts, such as some tombs, are usually dated by comparing the ceramics found with these features with the “standard ceramics” established by those with clear stratigraphic information. As in other archaeological cases, the subjectivity of ceramic typology is always an issue. Nevertheless, these phases still offer us a convenient and generally accepted tool to discuss the changes of the material culture

¹⁸ Chen, G. 2014; 2016.

Table 5.1 Absolute dates of Erlitou phases (based on Zhongguo 2014b: v. 3, 1215–1238).

Phase	Absolute date (BC)
I	1750–1700
II	1700–1650
III	1650–1600
IV	1600–1550
V	1600/1550–1400

and technologies at Erlitou in a roughly correct chronological order. Meanwhile, radiocarbon dating has also been used to determine the absolute date of Erlitou. Those attempts reach different results, of which two of them are generally supported. One result is presented in the report of the “Xia-Shang-Zhou Chronological Project”. This result, based on the radiocarbon dates of eighteen bone and charcoal samples, dates Erlitou Phases I–IV to 1880–1520 cal. BC.¹⁹ The other result is published in the latest Erlitou report of the 1999–2006 excavation seasons. This time, some new samples were dated, while the previous dates were also reviewed. The result dates Erlitou Phases I–IV to 1750–1550 cal. BC, while each phase is around 50 years. Erlitou Phase V probably overlaps Phase IV. It is dated to 1600/1550–1400 cal. BC.²⁰ The main difference between these two proposals is the beginning of the Erlitou site. In this thesis, I will use the chronology from the excavation report (i.e., starting from 1750 BC) simply because this is the most recent result (Table 5.1).

The Luoyang Basin and the Zhongtiao Mountains

Ceramic vessels analogous to those from Erlitou Phases I–IV contexts have also been found at about two hundred sites in Erlitou’s hinterland, especially in the Luoyang Basin (Figure 5.4).

¹⁹ Xia Shang Zhou 2000: 76–77.

²⁰ Zhongguo 2014b: v. 3, 1228. See also Zhang, X. et al. 2007. The overlap of Phase IV and V: Xu, H. and Zhao, H. 2010; Xu, H. et al. 2004.

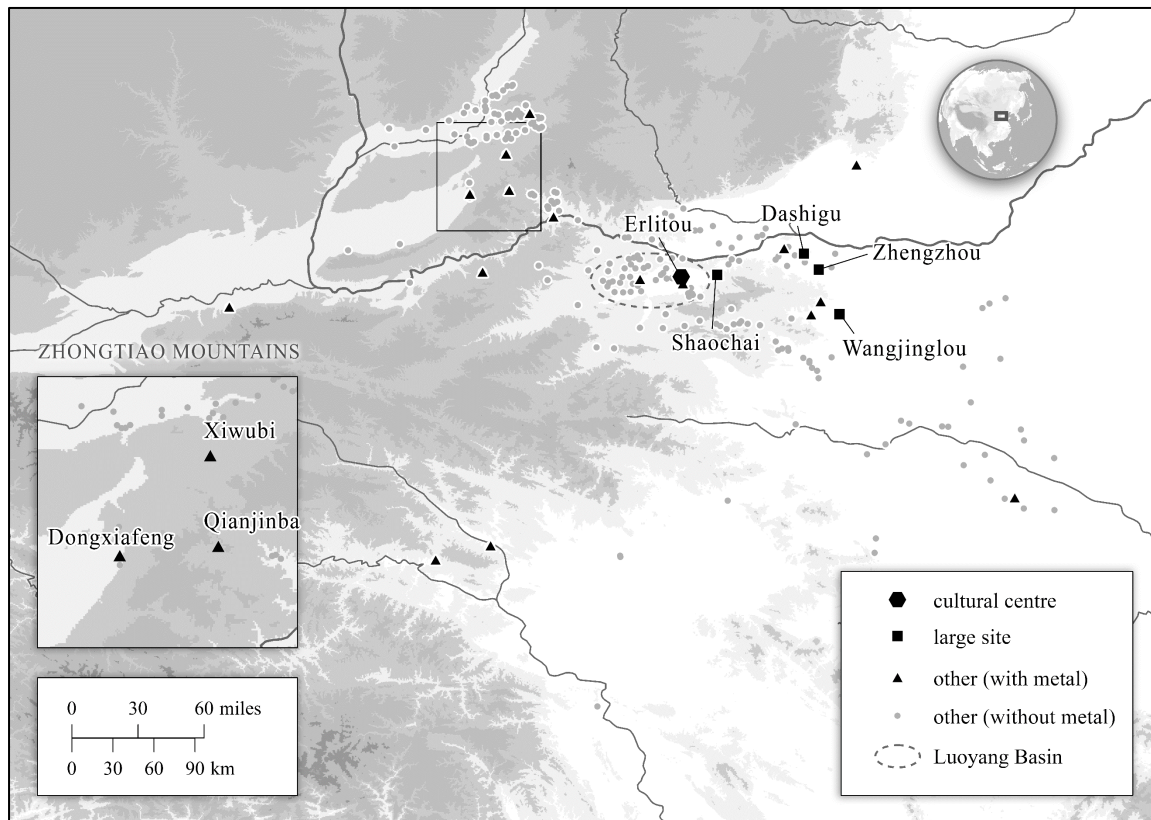


Figure 5.4 The Luoyang Basin and its surrounding areas, with the distribution of sites with Erlitou ceramics (site data: Xu, H. 2017: v. 2, 383–384; Zhongguo 2003: 82–88).

Among these sites, Erlitou is by far the largest settlement, as well as the only settlement over 300 hectares in the area. There were also a few relatively large settlements, including Wangjinglou (168 ha), Zhengzhou (80 ha during the Erlitou period), Shaochai (60 ha) and Dashigu (51 ha). In most tombs at these sites, there were only a few ceramic vessel, while jade, metal, and turquoise objects like those found in Erlitou tombs are very rare. Besides these relatively large sites, there are also some small sites, but with defensive facilities such as walls and moats. Based on the homogeneity of the ceramic typology and the diverse types of settlement site, some scholars suggest that an early model of a state-level polity had emerged with Erlitou as its cultural and political centre, while other scholars are more cautious about the claim.²¹ For

²¹ Area studies: Liu, L. et al. 2004; Qiao, Y. 2007; Chen, G. 2019; craft production: Liu, L. et al. 2007; Bonomo 2018; site fortification: Xu, H. 2017: v. 1, 142–151; 2018. The debate on whether Erlitou was a state: Liu, L. and Chen, X. 2002; 2003; Allan 2007; Xu, H. 2015.

this thesis, whether Erlitou was a state is perhaps beyond my topic. However, the existence of those contemporaneous sites shows clearly that Erlitou was not an isolated community. The Erlitou elite members, as well as the developed craft production at the site, must have benefited from the cultural and material exchange with those nearby sites.

About 200 km west of Erlitou, the Zhongtiao Mountains are particularly important for Erlitou's metal production. Nowadays, the Zhongtiao Mountains are still one of the richest mining areas in North China, with various types of copper and lead deposit.²² Besides, the terrain is covered in forest, providing timber resources suitable for on-site smelting.²³ A few archaeological sites with Erlitou-period remains have been discovered in the Zhongtiao Mountains. At one of the excavated sites, Dongxiafeng in modern Shanxi Province, metallurgical remains suggest that the site was mainly used as a mining and smelting site, with a limited capability of casting small tools such as axes and awls. In the 2017–18 season, new excavations started at two other sites, Xiwubi and Qianjinba, both with abundant remains of mining and smelting activities.²⁴ At Xiwubi, the preliminary analysis of the ore and slag samples indicates that the ores are mainly oxide ores, while the smelting products are relatively pure copper.²⁵ Based on the ceramic types and radiocarbon dates, the contexts with the earliest metallurgical remains at Dongxiafeng and Xiwubi are dated to Erlitou Phase III, or around 1650–1600 BC.²⁶ Although there is still no direct evidence for metallurgical activities in this area which can be dated to the early periods of Erlitou, the Zhongtiao Mountains remain our best candidate for supplying Erlitou with the metal resources. Tin deposit, however, has not been found in the Zhongtiao Mountains region, or

²² Zhongguo 1996a: v. Henan, map.

²³ Li, J. 2011; Li, Y. 1993; Shi, T. 2021; Tong, W. 2012.

²⁴ Xiwubi: Zhongguo 1988: 75–76; Dai, X. and Tian, W. 2020; Dai, X. et al. 2020; Qianjinba: Li, G. 2017; Tian, W. 2020.

²⁵ Dai, X. 2020.

²⁶ Dongxiafeng: Zhongguo 1991: 29–32; Xuwubi: Dai, X. 2020.

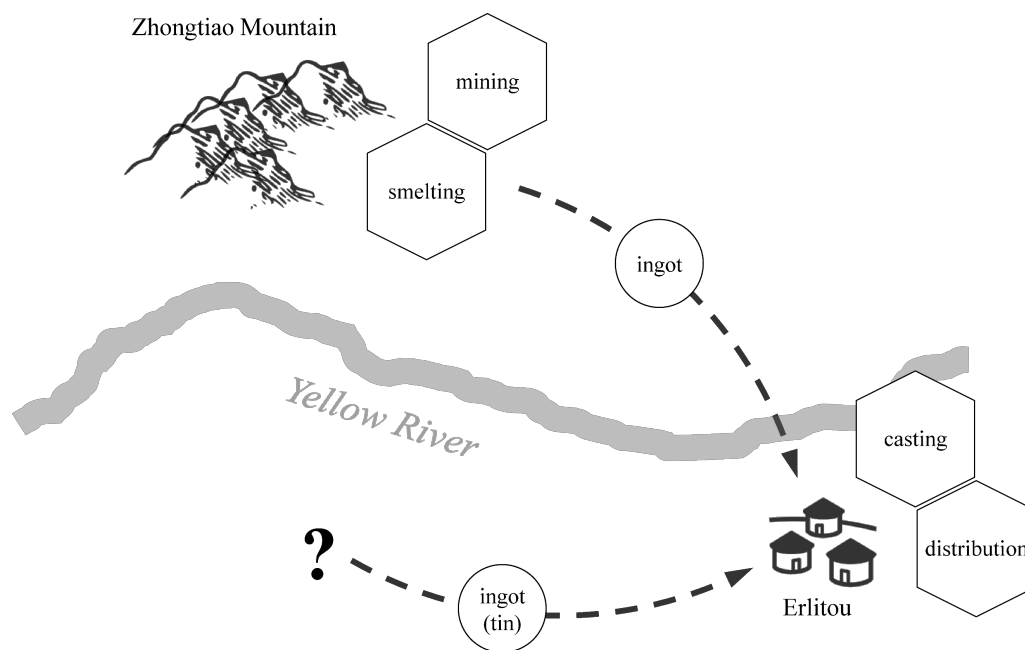


Figure 5.5 One of the possible models of the metal production in the middle Yellow River Region.

anywhere near the middle Yellow River Valley (see Chapter 3, Figure 3.2). The provenance of the tin resources used at Erlitou is still unclear. Based on later textual records, some scholars suggest that there may have been small tin deposits in the middle and the lower Yellow River Valley which were depleted before the modern era.²⁷ But the textual records are also questionable, especially due to the common issue of the tin-lead confusion in early texts (see Chapter 1). Other scholars suggest that tin may have come from the Wei River Valley or South China as early as in the Erlitou time.²⁸ In any case, I think we can agree that the Erlitou metal resources probably came not only from the Zhongtiao Mountains, but also from other places.

In summary, the whole manufacturing model of the Erlitou bronze industry may be what Figure 5.5 illustrates. On the one hand, mineral ores are likely to have been mined and smelted in the

²⁷ For example, Shih Chang-Ju counted that there are at least seventeen locations of tin deposits in Henan, Hebei, Shandong, and Shanxi Provinces mentioned in early texts. Shih, C. 1955: 95–129.

²⁸ For example, at Panlongcheng, as we will mention later in this chapter, some early contexts can be dated to around 1700 BC. This suggests that some sites in the middle Yangtze Valley—close to abundant tin deposits—may already have been settled in the Erlitou time. Erlitou may have been able to import tin from the south. See also the discussion by Liu, L. and Chen, X. 2003: 73–79.

Zhongtiao Mountains. Those sites in the mining area were mainly involved in producing metal resources in the form of ingots, rather than producing metal end products (although some small products for everyday use may have been produced locally). The metal ingots were then sent to Erlitou for the major casting activities there.²⁹ We do not really know how many types of metal ingot were provided by the Zhongtiao Mountains smelters; I will try to discuss this issue later when we observe the metallurgical remains. On the other hand, metal ingots, especially those with tin (either relatively pure tin ingots or tin alloyed with copper or lead) may have come from a different source (or multiple sources). On the production side, Erlitou is so far the only known site of its time with the capacity for large-scale metal production. The Erlitou workshops may have primarily served its own local community. However, a few bronze objects, especially bronze ritual vessels, were also discovered outside Erlitou.³⁰ This suggests that Erlitou may also have played a role in distributing its metal products in the region.

Bronze Vessels: A New Material and a New Material Culture

Pre-Vessel Metal Production

So far, not many metallurgical remains belonging to the two early phases of Erlitou have been found. Therefore, what we can learn from the limited materials is still very preliminary. Metal objects attributed to Phase I only comprise two bronze knives (Figure 5.6, a and b) and a slag.³¹ Both knives are highly corroded, with their original shapes impossible to determine. However, the curved edges on the fragments remind us of knives from the Northern Zone, the Hexi

²⁹ Gao, J. 2019. See also Liu, L. and Chen, X. 2000; 2001.

³⁰ Chen, L. and Ma, D. 1991; Cheng, L. 2014; Du, J. 2007; Henan1981: Pl. 10; Hennansheng and Zhongguo 1992: 155; Xue, W. 1981; Zhao, Q. and Wang, Y. 1981; Zeng, X. et al. 2003.

³¹ Zhongguo 1999b: 41.

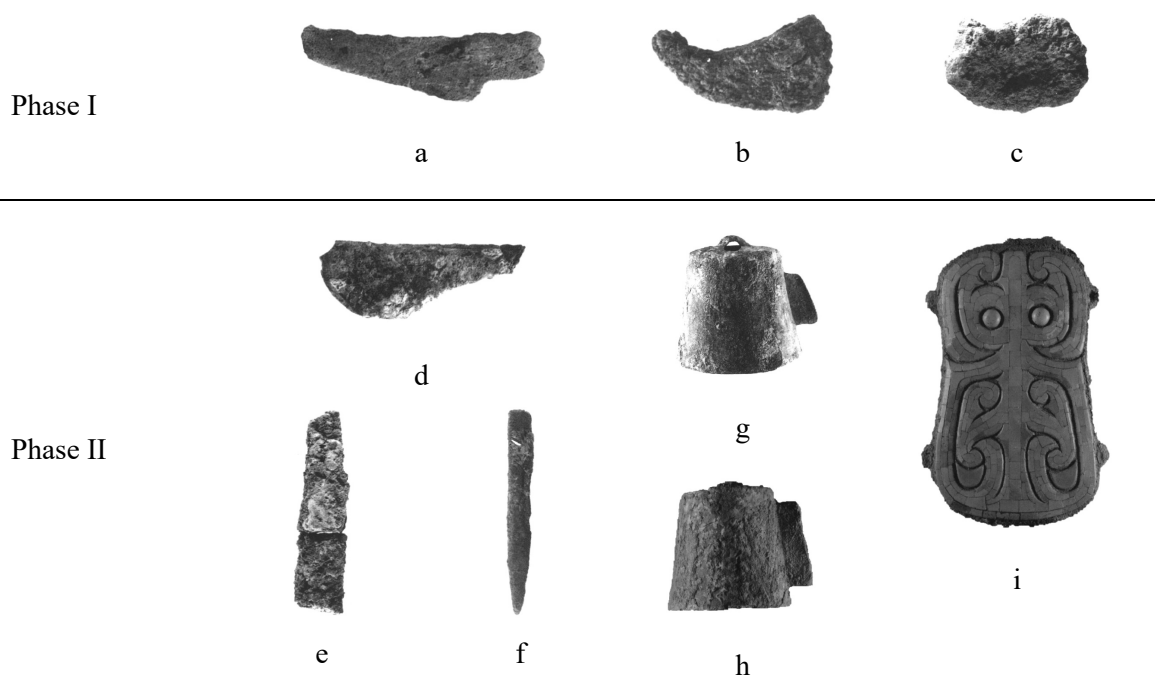


Figure 5.6 Metal objects and metallurgical remains from Erlitou Phases I–II. a, b: knives; c: slag; d: knife; e: chisel; f: awl; g, h: bells; i: plaque with turquoise inlay (after Yang, G. 1984: Pl. 4; Zhongguo 1999: Pl. 3; 28; 62).

Corridor, and the steppes.³² Since many knives from these areas are dated to periods much earlier than Erlitou Phase I, it is likely that the beginning of metallurgy at Erlitou was, as previously discussed in Chapter 2, under certain external stimulation. The Phase I slag (Figure 5.6, c) is a “crucible slag”, which was left by activities such as melting, refining, or casting, rather than smelting. It is analysed and found to be with 98.4% copper and 1.4% tin.³³ The existence of this slag indicates that bronze casting may have started in this period.

Some new types of bronze object appeared in the Phase II contexts. Among them, several small bells and bronze-framed, turquoise inlay plaques (e.g. Figure 5.6, g–i) are of particular interest. Near a hundred small ceramic bells have been found in various Neolithic sites in Central China, along with a metal one (97.9% copper, 1.5% lead) from Taosi, indicating a long tradition of

³² E.g. Shimao: Su, R. 2019; Linjia: Gansusheng 1984.

³³ Zhongguo 1999b: 399.

using these bells prior to the Erlitou period.³⁴ The Taosi bell belonged to a medium-sized burial whose occupant had no other grave goods remaining.³⁵ However, in the case of Erlitou, four published Phase II tombs with metal bells are all grander than the average tombs in terms of their sizes and grave goods.³⁶ The bronze plaques are also extraordinary objects which, at Erlitou, have only been found in grand tombs.³⁷ These plaques show not only an intricate design, but also a high level of technical competence. Some scholars suggest that the origin of this type of object came from the Hexi Corridor.³⁸ Therefore, most early metal objects used by the Erlitou community—the knives, the bells, and the plaques—may all have been the result of cultural exchange with Erlitou’s northern and western neighbours.³⁹ The contexts of these objects also suggest that metals were probably considered materials with high value, as metal objects were almost exclusively used by people with a high status in the society, or, as I previously defined, the elite members.

Among the Phases I–II metal objects, five have been analysed. The results show that there is one relatively pure copper object (a hairpin), a knife with a fairly high (16.3%) lead content, an awl with a moderate (4.5%) arsenic content, a knife with a moderate (4.2%) tin content, and a knife fragment with a low (1.2%) arsenic content.⁴⁰ However, since four of the five analyses were done using X-ray fluorescence (XRF), a method often proved to be problematic in compositional

³⁴ Ceramic and bronze bells, see Chen, G. 2018; Kubota 2014; Miyamoto 2014; chemical composition of the Taosi bell, see Gao, J. 2014.

³⁵ *Zhongguo and Shanxisheng* 2015: v. 2, 666–667.

³⁶ Liu, Z. and Du, J. 1985; Yang, G. 1984; *Zhongguo* 1999b: 397.

³⁷ Chen, G. 2017c; Wang, J. 2001; Wang, Q. 2014; 2019.

³⁸ Fitzgerald-Huber is probably the first scholar to argue such a western connection of Erlitou: Fitzgerald-Huber 1995.

³⁹ As Ge Yun suggested, the technology of piece-mould casting, which was used for casting the bells as well as some early ritual vessels, may also have been developed on the steppes: Ge, Y. 2018; 2019. See also Cai, J. 2014; Miyamoto 2014.

⁴⁰ Jin, Z. 2000; *Zhongguo* 1999b: 399; 2014: v. 3, 1515.

studies (the low-arsenical knife was analysed by SEM-EDS),⁴¹ the accuracy of the results, especially the particular levels of the alloying elements, may not be very reliable.⁴² Meanwhile, some slag samples, as analysed by Li Yanxiang and Xu Hong, also contain tin, lead, or arsenic.⁴³ Li and Xu suggested that metal resources probably arrived at Erlitou in two forms. One was as relatively pure copper ingots. The other were ingots with the alloys of tin, lead, and arsenic, probably produced by smelting polymetallic ores bearing these three elements (see also Chapter 3). Some objects may have been cast with pure copper, while others were made by mixing copper and the tin-lead-arsenic alloys.

However, a potential problem with this explanation is that, if the objects were really made by mixing copper with pre-alloyed tin-lead-arsenic, we may expect to see objects with high contents of more than one of the three added metals, such as objects with both high tin and high lead levels. However, none of the analysed objects contain more than one significant metal (either tin, lead, or arsenic) besides copper. For this reason, I argue that ingots from the smelting sites may have been either relatively pure tin and lead (as two separated types of ingot), or the ingots of pre-alloyed copper-lead, copper-tin, and copper-arsenic.⁴⁴ Although this suggestion cannot be directly confirmed by current archaeological finds or textual materials, one case study of the alloy practice of pre-Qin (before 221 BC) coins, done by Mark Pollard and Liu Ruiliang, may shed some light on this possibility. In that study, the authors review the published chemical data of the coins and draw the conclusion that, instead of using separate copper, tin, and lead ingots

⁴¹ SEM-EDS stands for “scanning electron microscopy and energy dispersive X-ray spectroscopy”. Introduction of the analytical methods, see Pollard et al. 2007.

⁴² See e.g. Pollard and Bray 2014. In general, I think that results by XRF can be used to suggest the presence or absence of each alloying element, but not its precise level.

⁴³ Li, Y. and Xu, H. 2007.

⁴⁴ Metallic arsenic is not likely to have been made at that time because of its volatility, so, for arsenic, the ingots were probably copper-arsenic alloys (speisses) (Mark Pollard, personal communication). The discussion of arsenical copper in early China can be found in: Chen, K. et al. 2017a; Li, W. and Li, Y. 2014; Qian, W. and Sun, S. 2009; Qian, W. et al. 2000.

as the raw materials, minters actually started with two types of alloy: one containing copper-tin-lead and the other containing copper-lead.⁴⁵ This case study reminds us that, for the metallurgy in early China, how people thought of alloying and how they controlled the target composition may have been quite different from our modern concept of alloying, which is based mainly on separate chemical elements. Meanwhile, since the levels of tin, lead, and arsenic are not related to any specific type of object, I further suggest that the Phases I–II craftspeople at Erlitou may have considered these metals (or their alloys with copper) a group of “silvery metals” which could be added to copper during casting, probably to make the casting easier (as discussed in Chapter 4).

The Earliest Bronze Vessels

The metal use and metal production in Erlitou Phases III–IV has been better studied since more archaeological materials from these later phases have been found and analysed. In terms of the production, two finds are especially important for our interpretation of the alloying technology. The first is a metal fragment, which is close to a 3.5x3.5 cm square sheet, mostly made of lead (95.9%, with 2.1% copper and 2.0% tin).⁴⁶ Since this fragment was found in a “trash pit”, together with a few ceramic vessels, the excavators dated the lead fragment to Phase III based on the vessel types. We do not know whether this lead fragment was from a finished product, or, as some scholars speculate, a lead ingot. The disposal seems to suggest that lead was not considered very precious, otherwise the metal would have been at least recycled. However, the existence of this lead fragment shows that people at that time had had access to relatively pure lead. The other find is a crucible fragment. Li and Xu analysed this fragment and noticed that this crucible had been used several times. Each use left one layer of metal slag on its inner surface.

⁴⁵ Pollard and Liu, R. 2021.

⁴⁶ Zhongguo 1999b: 240; 399. The thickness of the sheet is not measured, but it is said in the report to be “very thin”.

These metal layers are sandwiched by layers of refractory (clay). The SEM photos show that, among the metal layers, one was with unleaded copper-tin, while another was with untinned copper-lead.⁴⁷ This indicates that at least two types of alloy, copper-tin and copper-lead, had been melted in this crucible separately. These two finds suggest that the Erlitou craftspeople had access to tin and lead resources as separate metals (instead of pre-alloyed tin-lead ingots). This understanding is fundamental for us to investigate how different copper alloys were used for ritual vessels.

At Erlitou, six bronze vessels dating to Phase III have been found (Figure 5.7).⁴⁸ These vessels are all of the same type, commonly called a *jue* 爵 in Chinese (Figure 5.7). The basic components of a *jue* vessel are an egg-shaped container with a long spout, a pointed rear, a handle, and three legs. The *jue* vessels appeared first in a ceramic form in the first two phases of the Erlitou culture (Figure 5.8). A normal Erlitou ceramic *jue* is about 15–20 cm high, a little taller than a modern-day teacup. Regarding the use of the *jue*, most scholars suggest that the *jue* vessels were used mainly for wine-drinking, and occasionally for wine-heating or wine-pouring.⁴⁹ In the burials, the *jue* vessels were usually accompanied by other vessels, especially tall cylindrical cups called the *gu* 觚 (sometimes made with lacquer),⁵⁰ and three-legged, teapot-like vessels called the *he*

⁴⁷ Li, Y. and Xu, H. 2007: 68–69.

⁴⁸ In fact, it may be more accurate to call them “copper-based vessels” since, without analysis, we cannot confirm whether they were really made of bronze, or just copper. However, since all analysed Erlitou vessels contain tin, we may assume that these are bronze vessels instead of copper ones.

⁴⁹ Wine heating: Sun, J. 2019. Elizabeth Childs-Johnson argued that the *jue* was simply a pouring vessel: Childs-Johnson 1987. The problem with this argument is that, in the Erlitou context, there was no other type of drinking vessel placed together with the *jue* in tombs (Table 5.2).

⁵⁰ Yan Zhibin suggested that the lacquer *gu* vessel, the handle-like jade object, and the small ceramic disk form a set which were used for a special ritual purpose: Yan, Z. 2020. The presence of these objects, therefore, also demonstrates the relatively high social status of the buried individual.

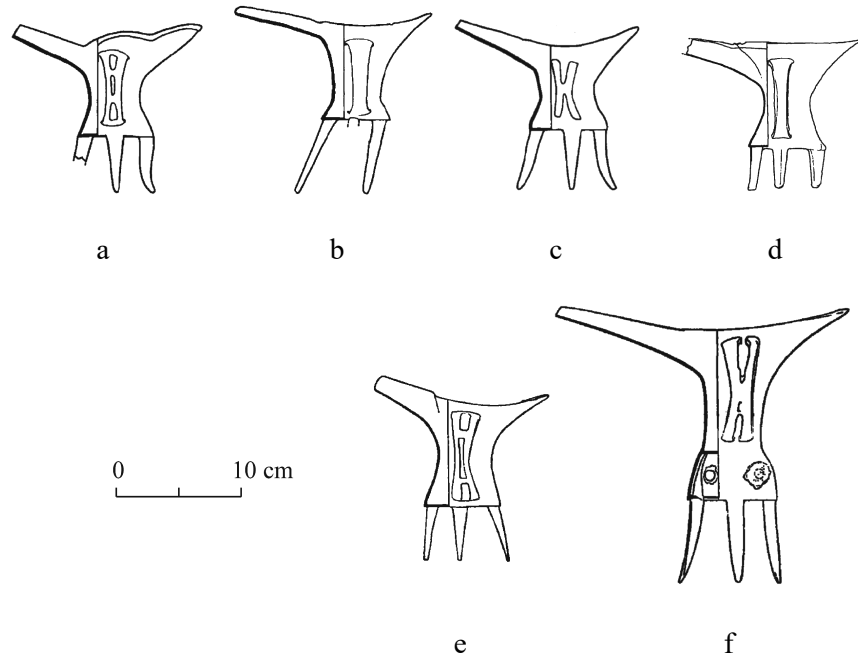


Figure 5.7 Phase III Bronze *jue* vessels from Erlitou: a: 1975VIKM3:4; b: 1978VKM8:1; c: 1975IIHKM6:1; d: 1973VIIT22(3):6; e: 1980IIIM2:1; f: 1980IIIM2:2 (after Yang, G. and Liu, Z. 1983: 203; Zhongguo 1999: 195; 252; 299).

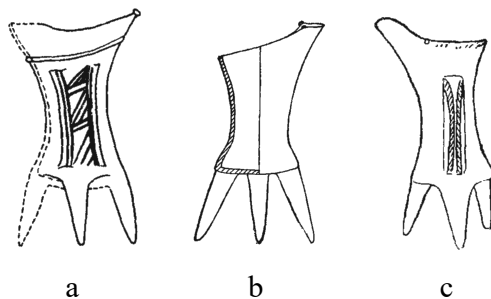


Figure 5.8 Early ceramic *jue* vessels from the Henan Province, Erlitou culture. Left: a: Erlitou II-VM54:7, (after Zhongguo 1999: 72); b: Nanzhai M3:4 (after Yuan, G. 1996: 38); c: from Yucun (after Du, J. 1990: 520); right: an Erlitou *jue* vessel (photo taken in the Henan Provincial Museum).

盞. In the Phase III tombs, the predominant combination was of a pouring vessel and the cup, or a *he* and a *jue*, although their numbers do not always match (Table 5.2).

Who owned those earliest bronze *jue* vessels? For those six Phase III *jue* vessels, five were found in four tombs (one tomb has two vessels). Among them, one was totally disturbed without a trace of its original size, but the other three were all larger than 2 m² in area. According to Li Zhipeng's

Table 5.2 Combination of wine-related vessels in Erlitou tombs.

Phase	Season	Zone	Tomb	Vessel type, quantity, and material						
				● ceramic			■ bronze		▲ lacquer	
				<i>jue</i> 爵	<i>jia</i> 斚	<i>bei</i> 杯	<i>gu</i> 觚	<i>hu</i> 壶	<i>he</i> 盃	<i>gui</i> 鬲
I	1959–78	II.IV	M54	●			●			
I	1959–78	II.IV	M57					●		
I	1959–78	IV	M26				●	●		
II	1959–78	IV	M6	●					●	
II	1959–78	IV	M8						●	
II	1959–78	IV	M9	●			●			
II	1959–78	IV	M11	●●					●	
II	1959–78	IV	M14	●					●	
II	1959–78	IV	M18				●		●	
II	1959–78	IV	M19				●			
II	1959–78	V	M15	●			●		●	
II	1959–78	V	M22	●			●			●
II	1959–78	V	M23	●					●	
II	1959–78	VI	M8	●					●	
II	1981	V	M5				▲		●	
II	1982	IX	M2*	●					●	
II	1982	IX	M3*	●			●●			
II	1982	IX	M10	●						●
II	1982	IX	M12			●	●			
II	1982	IX	M15	●					●	
II	1982	IX	M20*	●						●
II	1987	VI	M43	●			●●			
II	1987	VI	M49	●			●●▲			●
II	2000–06	V	M1	●●				●		
II	2000–06	V	M3	●			▲		●●●	
II	2000–06	V	M4	●					●	
II	2000–06	V	M5	●			▲▲		●●	●
III	1959–78	III	KM2*						●	
III	1959–78	III	KM6*	■					●	
III	1959–78	IV	M17	●					●	
III	1959–78	V	KM8*	■						
III	1959–78	VI	KM3	■					●	
III	1959–78	VI	M7	●					●	
III	1980	III	M2	●■					●	
III	1980	V	M3	●					●	
III	1981	V	M1*	●					●	
III	1981	V	M3	●						

Table 5.2 (*continued*)

Phase	Season	Zone	Tomb	Vessel type, quantity, and material						
				● ceramic	■ bronze	▲ lacquer				
				<i>jue</i> 爵	<i>jia</i> 斚	<i>bei</i> 杯	<i>gu</i> 觚	<i>hu</i> 壶	<i>he</i> 盃	<i>gui</i> 鬲
III	1981	V	M1*	●					●	
III	1981	V	M3	●						
III	1982	IX	M1*	●					●	
III	1982	IX	M5*						●	
III	1982	IX	M7*						●	
III	1982	IX	M8*	●		●●			●	
III	1982	IX	M14	●					●	
III	1987	VI	M28	●			▲		●	
III	1987	VI	M44	●			▲		●	
IV	1959–78	II	M101						●	
IV	1959–78	IV	M12	●					●	
IV	1959–78	IV	M20			●			●	
IV	1959–78	V	M21				●			
IV	1959–78	VI	M11					●		
IV	1959–78	VII	KM7*	■						
IV	1980	VI	M1				●			
IV	1980	VI	M6						●	
IV	1984	VI	M6	■					●	
IV	1984	VI	M9	■	■		●		●	
IV	1984	VI	M11	●■					●●	
IV	1987	VI	M57	■					●	
IV	2000–06	V	M8							●
IV	2000–06	V	M11				●			●
IV	2000–06	V	M17							●
V	2000–06	V	M14	●						●

* disturbed

References: 1959–78 seasons: Zhongguo (1999b); 1980 season: Yang, G. and Liu, Z. (1983); 1981 season: Yang, G. (1984); 1982 season: Liu, Z. and Du, J. (1985); 1984 season: Yang, G. and Zhang, G. (1986); 1987 season: Du, J. (1992a); 2000–06 seasons: Zhongguo (2014b: v. 2, 991–1027).

statistics, of the ninety-five Erlitou Phase III tombs, there are only thirteen larger than 2 m².⁵¹ In other words, the tombs with bronze vessels were some of the largest tombs of their time. Tomb 1975VIKM3, for example, was 2.3 metres long and 1.3 metres wide.⁵² This was probably the most elaborate Phase III tomb.⁵³ It was a rectangular shaft tomb with secondary ledges on three sides (Figure 5.9). The floor of the tomb was covered by cinnabar pigment. Although the body was not preserved, the grave goods were extremely rich. Besides a bronze *jue* (Figure 5.9, f) and a ceramic *he* (g), there were also two delicate bronze weapons, a *ge* 戈 or halberd (a) and a *zhang* 璋 or sceptre (b). The jade objects (i–l) were also among those of the highest quality found at Erlitou. A large stone slab, which, as suggested, may have been a chime, was also the only one of its type seen at Erlitou. In these respects, we can conclude that the individual buried here, a bronze *jue* owner, must have been one of the elite members at Erlitou.

Another example is Tomb 1980IIIM2 (Figure 5.10). This is also the only case where two bronze *jue* vessels were found in the same tomb.⁵⁴ The individual was buried with two bronze weapons (Figure 5.10, g, h), a ritual jade (f), and at least one lacquerware (fragment, i). Interestingly, there were overall four vessels in this tomb. Besides two bronze *jue* vessels (a, b), there were also a ceramic *jue* (c) and a ceramic *he* (d). According to the description in the excavation report, both ceramic vessels are white to light grey. Ceramics in this colour were in the minority of ceramic assemblage at Erlitou as a whole. They are often called “white pottery” in order to distinguished them from the majority of the ceramics, which have either a red-orange or a dark grey colour.⁵⁵ As Liu Li has pointed out, like jade and bronze, white pottery was also a symbol of a high social

⁵¹ Li, Z. 2008.

⁵² Zhongguo 1999b: 241.

⁵³ Xu Hong suggested that Tomb 75VIKM3 may be around the transitional period from Phase III to Phase IV, according to his understanding of the ceramic typology. See Xu, H. and Zhao, H. 2010: 46–48.

⁵⁴ Yang, G. and Liu, Z. 1983.

⁵⁵ Erlitou white pottery, see Li, B. 2010; Lu, X. et al. 2011; 2012; Zheng, G. 1995.

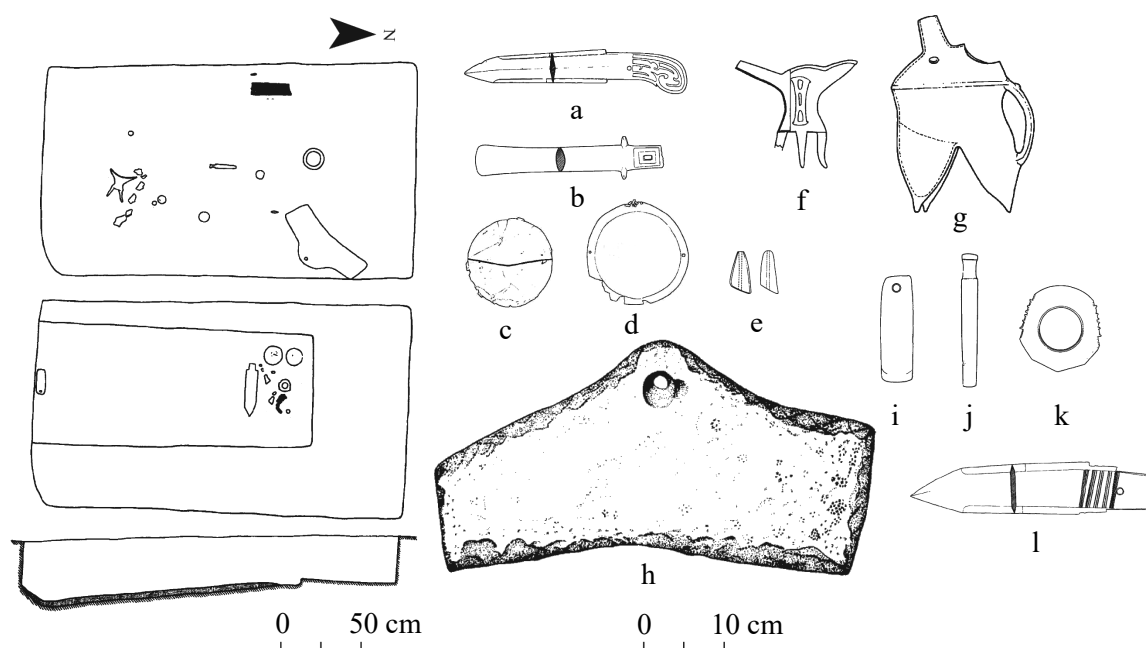


Figure 5.9 Plan of Tomb VIKM3 and its grave goods. Metal: a: *ge* blade; b: *yue* blade; c, d: round decorations; f: *jue* vessel; ceramic: g: *he* vessel; turquoise: e: beads; jade: i: axe; j: handle-like object; k: axe-disk; l: *ge* blade; stone: h: sounding stone (chime) (after Zhongguo 1999: 242; 249–258).

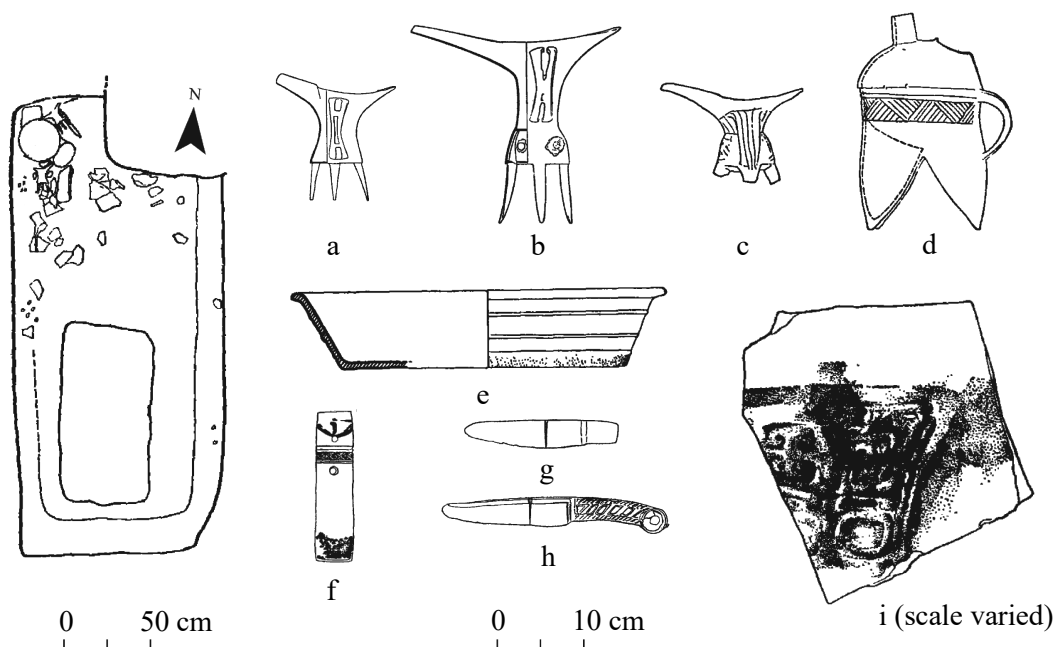


Figure 5.10 Plan of Tomb IIIM2 and its grave goods. a, b: bronze *jue* vessels; c: ceramic *jue* vessel; d: ceramic *he* vessel; e: ceramic basin; f: jade sceptre; g, h: bronze knives; i: lacquerware fragment (after Yang, G. and Liu, Z. 1983).

status, or, in her words, a type of “prestige goods” (I may use the word “high-status object”) at Erlitou.⁵⁶ The two white vessels may have matched each other, as similar cases can also be seen in Phase III Tombs 1980VM3 and 1987VIM44.⁵⁷ Therefore, I may suggest that the purpose of the two white ceramic vessels was probably to fulfil the ritual requirements in a traditional way, while the two bronze *jue* vessels probably reflected a personal taste of either the tomb occupant or those who helped arrange this tomb.

To further investigate the role of the bronze *jue* in an Erlitou tomb setting, we may also refer to a Phase IV tomb, 1984VIM11. Based on its scale and grave goods, this may also have been an elite tomb.⁵⁸ In this case, the individual was buried with two ceramic *he* vessels, a ceramic *jue* vessel and a bronze *jue* vessel. The two *he* vessels were light grey, but the ceramic *jue* was red-orange. We can imagine that the bronze *jue* vessel might originally have been quite close to the red-orange in colour (as discussed in Chapter 4). Therefore, the bronze *jue* probably complemented the ceramic vessels by forming two sets, both having a combination of white *he* and red-orange *jue*.

By reviewing these examples, we can see that the first few bronze *jue* vessels were all buried with those who probably would have had a relatively high social status in the Erlitou society. These bronze *jue* were put in the tomb in the same way as the ceramic ones, indicating that both types of vessel were considered to have similar functions in the afterlife. Then, why did people choose to make the *jue* type in bronze, but not the other types of vessel? My suggestion is that, first, the *jue* and the *he* were definitely the two most common types in a tomb setting. However,

⁵⁶ Liu, L. 2003. See also Liu, L. and Chen, X. 2003: 60–64. I avoid using the word “prestige goods” since, as many scholars have argued, this term may cause confusion. See e.g. Campbell et al. forthcoming; Luley 2016.

⁵⁷ The colours of the Erlitou *jue* and *he* vessels, see Kuji 2010: 1007–1013.

⁵⁸ Yang, G. and Zhang, G. 1986.

most tombs only contained one *jue*, regardless of the social status of the deceased.⁵⁹ Meanwhile, the presence of other unusual or rare objects in the tombs indicates that elite members may have been very keen on trying something different. When the elite members and their relatives realised that the *jue* vessels could be “upgraded” to those made of a brand-new material, those people were more likely than others to try it. Also, the *jue* vessels were the first to be transformed into metal probably because the *jue*, as drinking vessels, were more intimate to people than serving vessels. The exaggerated design of this vessel type, as I previously described, also suggest that, at Erlitou, the *jue* was probably more important than other vessels in the ritualization of wine-drinking.

However, if we consider a funeral as an organised ritual practice, changing the material of ritual vessels was not something insignificant. Why would people accept bronze as a proper material for ritual vessels? And who in the community can decide this? I would argue that the adoption of bronze ritual vessels at Erlitou was probably a ritual change decided at the top level of the society. The high-status individuals may have decided to make a few bronze vessels when they were still alive. For people who organised the burials (such as the family members of the high-status individuals), it seems that they were not following rigid rules of what should be included as grave goods, as well as how and in what number should the grave goods be placed. If we look at the tombs just discussed, there was no clear pattern in terms of the type, colour, and quantity of the grave goods in those grand tombs. This seems to suggest that people were experimenting with new ideas: bronze *jue* vessels were either used to replace ceramic ones, or simply to stand side-by-side with the complete ceramic sets, probably as “belt and braces” —in case the bronze ones do not function in the afterlife banquet, at least people can still use the ceramic ones. The match in colour—if it did exist—also seems to have been a ritual experiment or even a personal

⁵⁹ There may even have been a rule of the number of vessels. This is still unclear based on the current finds.

taste. The close relationship between the elite members and the craftspeople, illustrated by the proximity of the palatial area to the workshops, may also have been a reason for this successful reform.

In terms of the alloy materials of the bronze *jue* vessels, so far, four Erlitou *jue* vessels and one which probably came from Erlitou have been analysed. Among them, three are dated to Phase III and the other two are dated to Phase IV. Interestingly, none of the objects contain more than 5% lead (Table 5.3).⁶⁰ If we compare the *jue* vessels with other non-vessel bronze objects at Erlitou, we can also see clearly that, on average, the lead levels of the *jue* vessels are much lower than those of the non-vessel objects (Figure 5.11). These results, although not based on every single *jue* vessel, are probably not a coincidence. It indicates that the craftspeople may intentionally have chosen or at least preferred unleaded bronze alloys for the making of the *jue* vessels.

Why were the newly developed bronze ritual vessels made of relatively unleaded bronze alloys? As I discussed in Chapter 3, this technological choice was probably driven by multiple factors. From the material perspective, for example, although both tin and lead can be added to copper to produce ritual vessels, there are differences between these two materials. Comparatively speaking, a cast made of unleaded bronze would have better mechanical properties than a leaded copper or leaded bronze one. Colour may also be a reason as unleaded bronze tends to be shinier and more golden (Chapter 4). There may also have been other cultural reasons such as the personal preference by the craftspeople. We may not be able to confirm which reason contributed the most to people's understanding of the metals, but in general, I suggest that the Erlitou people may have considered unleaded bronze a finer material than leaded bronze. Therefore, when they

⁶⁰ A *jue* vessel and a *jue* foot fragment analysed by Zhao Chunyan and colleagues are probably corroded, so it is possible that the objects originally contained more lead.

Table 5.3 Analysed Erlitou bronze *jue* vessels.

Phase	Object ID	Object type	Composition (%)				Method of analysis
			Cu	Sn	Pb	As	
III	1973VIIIIT22(3):6	<i>jue</i> vessel	92.0	7.0	-	-	XRF
	-	<i>jue</i> vessel	78.8	2.2	3.9	-	ICP-AES
	-	<i>jue</i> foot	92.0	2.2	0.3	1.0	ICP-AES
IV	1974IV 采:65	<i>jue</i> vessel	91.9	2.6	2.3	2.3	?
	Shanghai Museum	<i>jue</i> vessel	92.6	6.5	0.9	-	XRF

References: Chen, G. (2008); Ma, J. (2014); Zhao, C. et al. (2009); Zhongguo (1999b: 196).

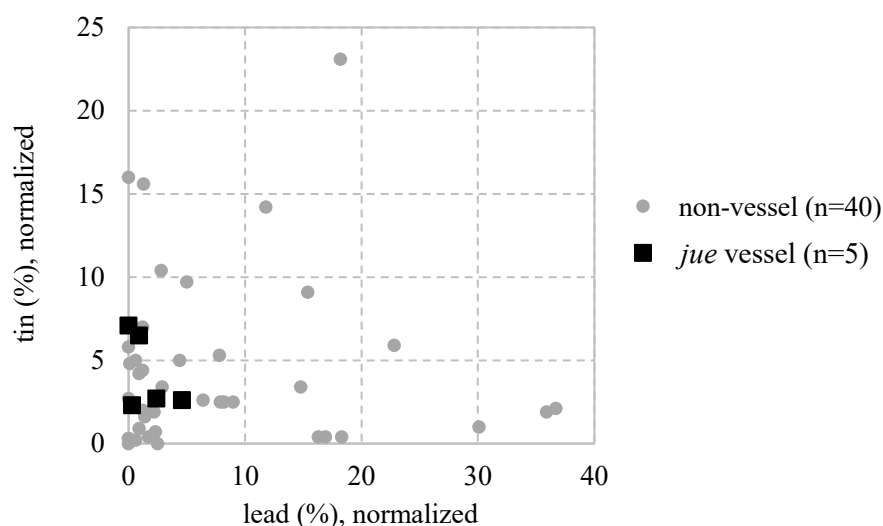


Figure 5.11 Comparison of the chemical compositions of Erlitou *jue* vessels and those of non-vessel metal objects.

decided to make the bronze *jue* vessels, people may have intentionally chosen unleaded bronze to match the high status of the individuals with whom the vessels were going to be buried.⁶¹

As we can see, this is just a suggestion which we may not be able to confirm archaeologically.

However, when people started to make unleaded bronze vessels, we may be able to predict its

⁶¹ Again, since we do not know clearly how the craft production was organized at Erlitou, I cannot suggest whether the decision of using unleaded bronze was made by the commissioner of the objects (such as the elite members) or the craftspeople. I can only assume that the decision was made by the metalworking community, as I previously discussed.

consequences. One direct consequence may have been that the exchange value of tin was pushed even higher. As previously discussed in Chapter 3, to communities in the middle Yellow River Valley, lead was much more accessible than tin, so tin may have been more precious than lead (Figure 3.2).⁶² The decision to make unleaded bronze means that the craftspeople needed to choose only pure copper and tin (or pre-alloyed copper tin) as their raw materials.⁶³ This may have made tin even more precious.⁶⁴ In other words, we may say that making an unleaded bronze was probably more costly than making an unleaded one. Although I use the word “cost”, I do not want to suggest that it was a case of costs based on a monetary economy.⁶⁵ However, for the metallurgical community who probably controlled the metal resources in the Erlitou society, it is probably safe to assume that the amount of tin under people’s control was much small than the amount of lead. This is why I suggest that using a certain amount of tin would be more costly than using a certain amount of lead.

⁶² Although it is very hard to prove this hypothesis archaeologically, the idea of considering tin more precious (with a higher exchange value) than lead is known in many later texts. For example (which is probably not the earliest text regarding this issue), a tenth century Chinese text, titled *Taiping huanyu jiin* 太平寰宇記 (*Universal Geography of the Taiping Era*), mentions that “the excellent tin (*xi* 錫) is named lead (*qian* 鉛); Lead (*qian*) is white tin (*xi*).” The Chinese characters *xi* and *qian* in the text probably had opposite meanings than those we now understand (which means that *xi* in the text refers to lead and *qian* refers to tin), as this often happened in historical Chinese texts: Yue, S. 2007: 3023 (English translation by the author). Pliny’s *Naturalis Historia* also shows that, in ancient Rome, tin was about ten times more expensive than lead: Pliny 1938: 243. In modern commodity markets, tin is also more expensive than lead in general. See e.g. the prices of tin and lead in the London Metal Exchange: www.lme.com.

⁶³ Since most analysed Phases I–III non-vessel objects are not lead-free, we can assume that recycled metal alloys cannot really have been used for casting unleaded bronze vessels.

⁶⁴ I think the presence of high tin levels in some everyday metal products cannot be used to prove that tin was not considered precious, as many everyday objects may have been made by recycling high-tin bronzes.

⁶⁵ Scholar still have no consensus view on the political economics of most second millennium BC societies in Central China, including Erlitou, Zhengzhou, and Anyang (Yinxu). See the discussion in Campbell 2021; Campbell et al. forthcoming; Liu, L. and Chen, X. 2001; Underhill and Fang, H. 2004. Based on the discussion, I think that the production of ritual bronzes may have been under a redistributive model, as the raw materials centrally controlled by the elite members, and the products—the ritual vessels—distributed among the elite members. Therefore, there may have been no concepts such as “buying” or “selling” a bronze vessel.

Based on this hypothesis, I may further argue what I call socio-economic reasons behind the technological choice of unleaded bronze vessels. For various reasons, people may have considered unleaded bronze a finer material and thus wished to use it for ritual vessels. This was probably due to the better mechanical properties of unleaded bronze over leaded bronze, but the higher exchange value of tin over lead may also have been a reason behind this concept. Meanwhile, the demands of the lead-free vessels may also have widened the economic gap between tin and lead by making tin even more precious. However, this new idea of making and using unleaded bronze vessels, if it was really established, did not last very long. In the next section, we will see that leaded bronze vessels emerged when Erlitou ushered in a new era.

From Unleaded to Leaded

After Phase III, certain changes happened to the material culture of Erlitou. In terms of bronze vessels, the *jue*, as the only vessel type in Phase III, continued to be used and became slightly taller and slenderer. Meanwhile, some new types of bronze vessel appeared in the later contexts, such as the *he* and the *jia* 𩚑, as well as a type of tripod cooking vessel, the *ding* 鼎.⁶⁶

From the perspective of the materials, one remarkable change is the chemical compositions of post-Phase III vessels. So far, five analysed vessels were made of at least two very distinct types of alloy (Table 5.4). Two *jia* vessels and a *jue* vessel were all made of bronze with no or low (below 5%) lead, which is similar to the material of the Phase III *jue* vessels. By contrast, the other two vessels, a *he* and a *jia*, both contain very high (over 20%) lead contents, making them two of the most leaded objects at Erlitou. For such high lead levels, they cannot have been introduced unintentionally. Two possible explanations are, first, lead ingots were deliberately

⁶⁶ References of these vessel types, see Wu, W. 2009; Li, C. 2006; Du, J. 1992b; Peng, Y. 2018. See also Uchida 2013. In addition, there may also be bronze *gu* vessels at Erlitou as one was reported by Zheng, G. 1991. The original object is lost in a tomb robbery.

Table 5.4 Analysed late phase Erlitou bronze vessels.

Object ID	Object type	Height (cm)	Composition (%)				Method of analysis
			Cu	Sn	Pb	As	
1986IIM1:1	<i>he</i>	24.5	62.8	13.9	22.3	-	ICP-AES
1975V 采 M:66	<i>jia</i>	22.5	89.0	7.1	-	-	ICP-AES
1984VIM9:1	<i>jia</i>	30.5	90.0	5.0	4.6	0.2	ICP-AES
1987VM1:2	<i>jia</i>	26.8	64.0	6.6	26.7	0.0	ICP-AES
1974IV 采:65	<i>jue</i>	16.0	91.9	2.6	2.3	-	?

References: Chen, G. (2008); Jin, Z. (2000).

used during the alloying processes, and second, those vessels were made of recycled high-leaded bronze alloys.⁶⁷ In either case, the use of high-leaded alloys shows an obvious shift from the previous tradition of only using unleaded alloys for making bronze ritual vessels. So, what are the possible reasons behind this change?

For these two high-leaded vessels, unfortunately, we only have very limited information on their archaeological background. Neither of them was found in official archaeological excavations. The *he* vessel is published only in a few catalogues. Since no other bronze *he* like this one has ever been found, the relative date of this vessel is unclear (although some scholars attribute it to Erlitou Phase IV).⁶⁸ The information of the *jia* vessel (Figure 5.12, a) is a little clearer. It was discovered by the locals at Erlitou in 1987 and was later confiscated by the police. According to people's recollection, the vessel was originally placed in a tomb with at least two other bronze vessels, a *ding* and a *gu*, and some jade objects. Among these objects, only the *jia* and the *ding* vessels survived.⁶⁹ The *jia* vessels, either in ceramic or in bronze, were very rare at Erlitou. There

⁶⁷ This is possible since several Phase IV metal objects have over 30% lead: Zhongguo 1999b: 399.

⁶⁸ Zhongguo 1993: 120; Higuchi 1993: 16; Zhongguo and Shanxisheng 1996: 19. The *he* vessel is also described in Xu, H. and Zhao, H. 2010; Taketsugu 2014.

⁶⁹ Zheng, G. 1991.

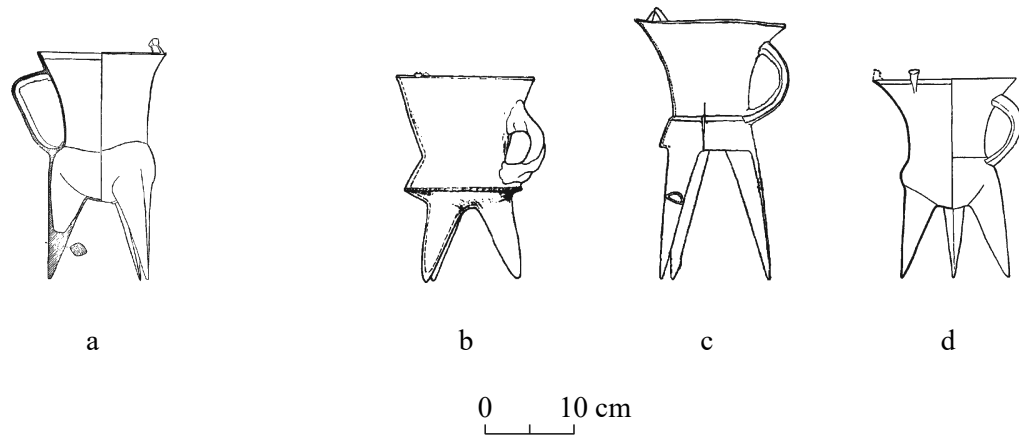


Figure 5.12 Comparison of the *jia* vessels. a: round-bottomed bronze *jia* from Erlitou 1987VM1 (after Zheng, G. 1991: 1138); b: ceramic *jia* vessel from Erlitou Phase III (after of Zhongguo 1999: 211); c: flat-bottomed bronze *jia* from Erlitou 1984VIM9 (after Yang, G. and Zhang, G. 1986: 320); d: bronze *jia* from Wangchenggang (after Henansheng and Zhongguo 1992: 154).

is only one well-preserved ceramic *jia* vessel, from a Phase III context.⁷⁰ This vessel (Figure 5.12, b) has a slightly rounded bottom, with a clear transitional edge marking the upper part. In addition, there is a bronze *jia* vessel from Tomb 1984VIM9, a Phase IV tomb with many high-status grave goods. That *jia* vessel (Figure 5.12, c), a moderate-leaded (4.6%) one, has a flat bottom, as well as a clear edge. If we further look at other vessels at Erlitou, such as the *jue* vessels, we can see that flat-bottomed vessels are the majority. The 1987VM2 *jia* vessel, however, has a very different round bottom. The closest object to this *jia* type is a bronze *jia* vessel found at Wangchenggang (Figure 5.12, d), a site within 100 km of Erlitou.⁷¹ The Wangchenggang *jia* vessel has been found in a cultural context which is considered contemporaneous with Erlitou Phase V, or around 1600–1500 BC. Therefore, scholars like Miyamoto and Xu Hong believe that the Erlitou round-bottomed *jia* vessel should also be dated to this period.⁷²

⁷⁰ Zhongguo 1999b: 210.

⁷¹ Henansheng and Zhongguo 1992: 154.

⁷² Miyamoto 2006; 2019; Xu, H. and Zhao, H. 2010.

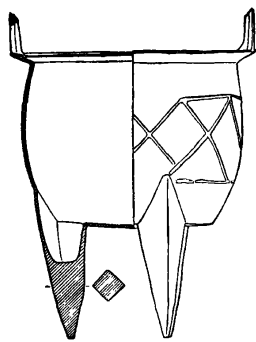


Figure 5.13 Bronze *ding* Vessel from the tomb 1987VM1. Left: drawing (after Zheng, G. 1991: 1138); right: photo (after Zhongguo 1996b: Pl. 1).

The *ding* vessel (Figure 5.13) found in Tomb 1987VM1 is also an unusual object. This vessel is not analysed, so we do not know whether it was made of leaded bronze or not. The *ding* is a type of tripod vessel which is generally considered to be for cooking by heating from below.⁷³ Although the *ding* vessels were relatively common in ceramics at Erlitou, the 1987VM1 *ding* vessel is the only bronze *ding* vessel found at the site. One detail, noticed by Miyamoto, is that both the *jia* and the *ding* vessels from Tomb 1987VM1 were cast with a new technique. By carefully observing the moulding flash remains on the bodies of the vessels, Miyamoto suggested that all the Erlitou *jue* vessels, as well as the previously mentioned flat-bottomed *jia* from Erlitou Tomb 1984VIM9, were cast with two outer mould sections. This two-outer-mould casting technology was also used on some small bells at Erlitou.⁷⁴ By contrast, both the *jia* and the *ding* vessels from Tomb 1987VM1 were cast with three outer mould sections, obviously a more complex technique.⁷⁵ Also, this *ding* vessel was not cast very successfully. In the inner side, a

⁷³ The Neolithic *ding* vessels in East Asia, see Pei, W. 1987b; Han, J. 2015.

⁷⁴ Cai, J. 2014. See also footnote 39.

⁷⁵ Miyamoto 2006; 2019. See also Liu, Y. et al. 2015b.

patch indicates that, during the original casting, the molten alloy did not fill the mould completely.⁷⁶ This also demonstrates that casting a *ding* shape vessel was not an easy task.

By reviewing these objects, we can almost confirm that the heavy-leaded bronze vessels first appeared at Erlitou during Phases IV–V. What we also know is that, for the whole Erlitou society, this was a transitional period in which the site declined significantly.⁷⁷ In the last years of Phase IV, some most important features in the palatial area, including the walls and some large buildings (according to their foundations), were abandoned, as they were cut by new features (such as pits). Meanwhile, some new buildings were established in the palatial area, but they too were soon abandoned. Many scholars believe that these changes in the palatial area signify political unrest at the centre of society. When most of the palatial area was abandoned, the turquoise and bronze workshops continued to operate, even with some new constructions in them. However, these workshops were also abandoned by the end of Phase IV. In the following Phase V, only a few small houses and tombs were constructed. Those activities were limited to an area of merely 30 hectares, about one tenth of the previous size of Erlitou.⁷⁸

During Phase IV, some new types of ceramic vessel also appeared at Erlitou. Scholars believe that there were two sources of these new elements in the material culture. One is in the Taihang Mountains; the other is in the lower Yellow River Valley.⁷⁹ Although the introduction of new material culture does not always mean the invasion by outsiders, we cannot rule out this possibility. Also, during this time, some new regional powers emerged. The largest of these was established at a site in Zhengzhou, often known as the “Zhengzhou Shang City”, about 80 km

⁷⁶ Gao, J. 2014.

⁷⁷ For a detailed discussion of the changes of the archaeological features, see Xu, H. et al. 2004; Zhao, H. 2016.

⁷⁸ Xu, H. et al. 2004.

⁷⁹ New elements in the material culture: Fang, H. 1987; discussion: Jin, S. 2004; Zhao, H. 2016; Chen, G. 2019. See also Zhongguo 2014b: v. 3, 1655–1663.

from Erlitou. Zhengzhou had already been an important settlement site during Erlitou Phase IV. Around 1500 BC, Zhengzhou rapidly developed into the largest site, with an area of about 1,500 hectares.⁸⁰ The emergence of the Zhengzhou Shang City must have had an impact on Erlitou, which used to be the centre of the region. We will revisit Zhengzhou in the next section. Another potential competitor which was much closer to Erlitou than Zhengzhou was a site known as the “Yanshi Shang City”, which is merely 6 km from Erlitou. The site was occupied from 1600 to 1360 BC, with its heyday from 1500 to 1400 BC.⁸¹ This was roughly the same period of Erlitou Phase V, as when then site declined. From the perspective of material culture, the same types of ceramic vessel (often called the “Erligang type”) used at Erlitou during Phase V were also used at Yanshi and Zhengzhou. Putting the evidence together, the emergence of large settlement sites at Yanshi and Zhengzhou and the appearance of Erligang type objects at Erlitou probably point to the same reason, that is, a new regional power emerged which challenged Erlitou’s authority, causing its decline and in due course the final abandonment of Erlitou.

Considering this background, what were the possible reasons behind the adoption of leaded bronze vessels? One suggestion may be the change in the procurement of raw materials. For example, a sudden shortage of copper and tin supplies could have led people to use more lead. I think this is not likely to have been the case, because it cannot explain why high-lead alloys were only used for a few types of vessel but not the others. Also, the tin levels of most of the objects are still quite high, so it seems that the use of lead was not due to the lack of tin.

Another suggestion is that a new group of craftspeople moved into Erlitou, bringing new alloy practices. If so, we may expect to see high-leaded bronze used at other sites prior to Erlitou. However, during the time when the Erlitou workshop was operating, there was no large bronze

⁸⁰ Hou, W. 2018; Li, B. 2017; Sun, Z. 2018; Yuan, G. 2003.

⁸¹ Zhongguo 2013; dating: Zhongguo 2013: v. 2, 727–730.

workshop in any nearby site.⁸² Therefore, it is not likely that the new technology was introduced by the migration of craftspeople.

There is another possible explanation: the use of leaded bronze was a choice made by the same local metalworking community who used to make unleaded bronze vessels. Then, why did they choose to use this new material? There may be a technological reason as people wanted to cast something bigger and more complicated than the *jue*. But, for those two objects with as much as 20% lead, the excessive lead may actually have made the casting more difficult (the *ding* vessel may be one of such cases). More likely, following the decline of the Erlitou society, the craftspeople and the consumers lowered their standard for vessel casting. Instead of accepting only the perfect products (which should probably be cast with unleaded bronze), people started to tolerate vessels with some casting defects. In this way, lead was no longer excluded from vessel casting.

Therefore, I think the shift from unleaded bronze vessels to leaded ones is probably a decision made by the Erlitou metalworking community due to the socio-economic reasons. On the one hand, people needed to continue making high-status ritual objects—the bronze vessels. On the other hand, the whole community was also facing increasing pressure from Zhengzhou and Yanshi. In this situation, adding lead may have provided a technological solution for the metalworking community to adapt to the social changes. In other words, the use of leaded bronze at Erlitou was probably a technological choice in the form of a local adaptation driven by the external stimuli.

⁸² The bronze workshops in Zhengzhou and Yanshi were both established around 1450 BC, right before the abandonment of the Erlitou bronze workshop. See Henansheng 2001: v. 1, 308; Zhongguo 2013: v. 2, 278.

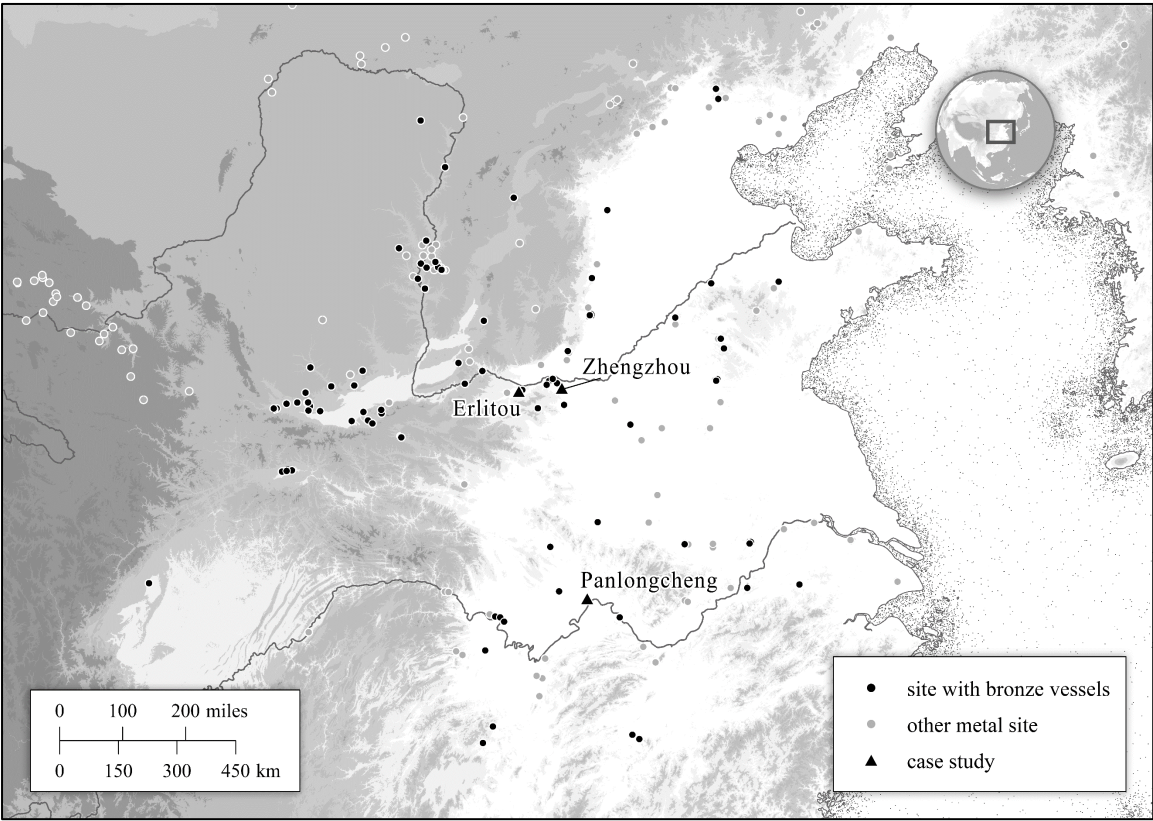


Figure 5.14 Sites yielding bronze vessels between 1600 and 1200 BC, with the location of Erlitou, Zhengzhou, and Panlongcheng.

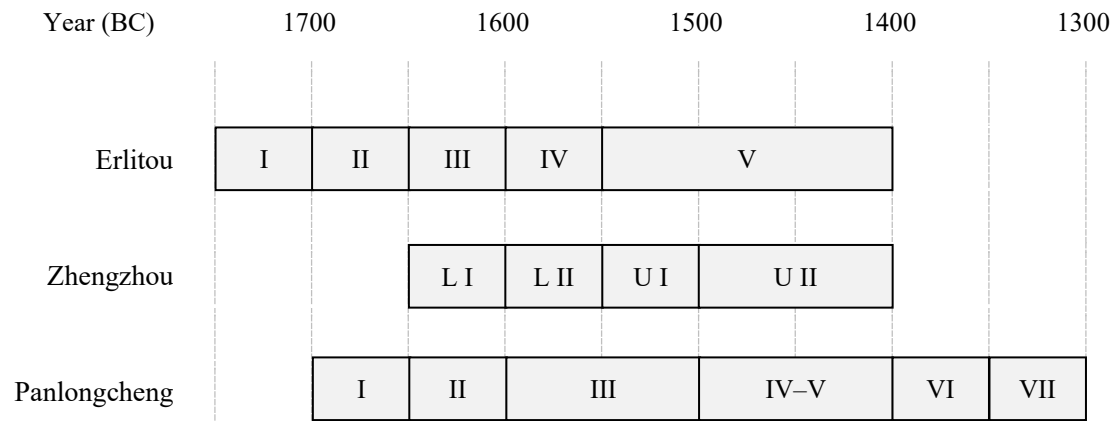


Figure 5.15 Chronological framework of Erlitou, Zhengzhou, and Panlongcheng (chronology: Hubeisheng 2001: v. 1, 441–446; Xia Shang Zhou 2000: 63–65; Zhongguo 2014b: v. 3, 1215–1238).

The Legacy of Erlitou: Zhengzhou and Panlongcheng

After Erlitou declined around 1550 BC, we do not know the destiny of the Erlitou craftspeople. Did they all disappear together with the site, or were they recruited by new rulers and moved to other sites? What we know is that bronze ritual vessels continued to be made in the middle Yellow River Valley and this tradition even expanded to new territories such as the Yangtze Valleys. Meanwhile, the use of leaded bronze for vessels was also carried on. By the time of that people settled at Anyang, or Yinxu (c. 1250–1046 BC), three hundred years after Erlitou, about half of its bronze objects contain more than 5% lead contents.⁸³ The technological choice initiated at Erlitou, as well as the tradition of making bronze ritual vessels, seems to have been passed on to other communities in early China (Figure 5.14). Here, I will choose two of them, Zhengzhou and Panlongcheng, to discuss the possible legacy of Erlitou's high-leaded bronzes (Figure 5.15).

Zhengzhou

Zhengzhou, or the “Zhengzhou Shang City” (Figure 5.16), is about 80 km east of Erlitou. The earliest excavations were conducted in the early 1950s at Erligang, later confirmed as a south-east outlier of the central walled area. But the name “Erligang” has been carried on as the term of the archaeological culture attributed to a group of sites with closely related material culture, as we mentioned in the previous section.⁸⁴

⁸³ There are many published compositional studies on Yinxu bronzes: Li, M. 1982; Ji, L. 1997; Uchida and Iizuka 2015; Liu, Y. et al. 2007; Tian, J. et al. 2010; Zhao, C. 2004; Zhao, C. et al. 2008; a recent summary, see Liu, R. 2016: 278–330.

⁸⁴ For Erligang as an archaeological culture, see e.g. Liu, L. and Chen, X. 2012: 278–290. We will revisit the “Erligang bronzes” in Chapter 8.

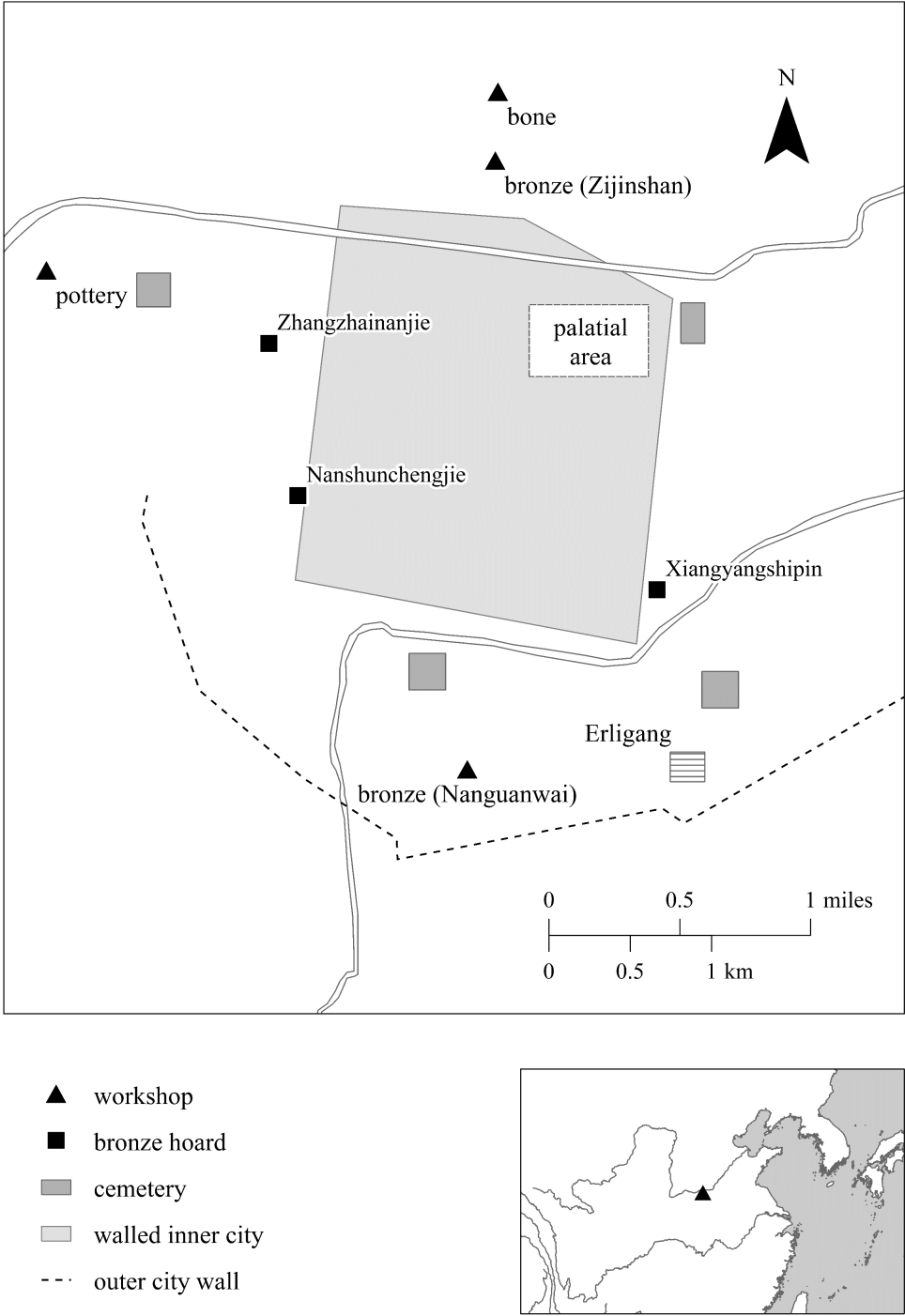


Figure 5.16 Plan of the Zhengzhou Shang City site and the distribution of archaeological features (modified from Henansheng 2001: v. 1, 2).

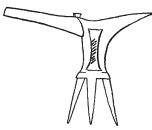
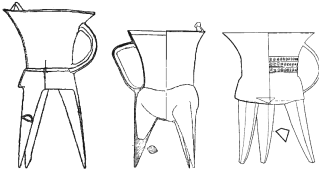
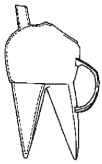
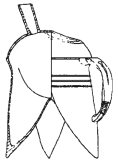
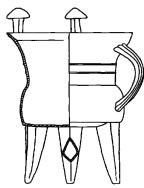
	<i>jue</i>	<i>jia</i>	<i>he</i>
Erlitou			
Zhengzhou (ELG Lower I)			
Zhengzhou (ELG Lower II)			

Figure 5.17 Comparison of bronze vessels from Erlitou Phase IV and Zhengzhou Lower Erligang Phases (Erlitou: after Yang, G. and Zhang, G.1986: 320; Zhongguo 1999: 343; 2003: 105; Erligang Lower I: after Zeng, X. et al. 2003: 10; Lower II: after Henansheng 2001: v. 2, 675).

After the decline of Erlitou, Zhengzhou became the most important site in the middle Yellow River regarding the use and the production of bronze ritual vessels. The earliest metal objects, including a few small tools, have been found in the contexts belonging to the “Lower Erligang Phases” (1600–1550/1500 BC).⁸⁵ So far, only a few bronze vessels, in the types of the *he*, the *li*, the *ding*, and the *jue*, which may be attributed to this phase.⁸⁶ Some of these types were certainly derived from the Erlitou predecessors (Figure 5.17). A bronze workshop at a site called Nanguanwai, about one kilometre south of the palatial area can also be dated to the Lower Erligang phases. During the Upper Erligang period (1450–1300 BC), a second bronze workshop, Zijinshan, was established near the northern wall of the palatial area, mainly for the production of small objects such as knives and arrowheads, while Nanguanwai probably focused on

⁸⁵ Dating: Zhongguo 2014b: v. 3, 1223–1224.

⁸⁶ Zeng, X. et al. 2003. The chronology of Zhengzhou is not fully agreed among researchers. I use the chronology by Wang Wei: Wang, W. 2013.

producing ritual vessels.⁸⁷ Like Erlitou, evidence of smelting has not been found in Zhengzhou, suggesting that the metal resources may have come in the form of ingots. The Zhongtiao Mountains may still have been one of the main metal suppliers, as many mining sites continued to operate during the Erligang time.⁸⁸ Another potential source of metals, especially tin, was the Yangtze Valleys in the south, which will be discussed later.

In Zhengzhou, most bronze vessels were discovered in two types of context: tomb and hoard. In the Zhengzhou tombs, bronze wine vessels such as the *jue*, the *jia* and the *he* were the major types during the Lower Erligang period, probably as a continuation of the Erlitou tradition. In the Upper Erligang period, other vessels like the *ding* and the *gu* also became common, while the bronze *he* disappeared.⁸⁹ In addition to the bronzes from the tombs, three bronze hoards have been discovered, named after their nearby streets or landmarks, Zhangzhainanjie (shortened as “ZZ”), Nanshunchengjie (“NS”) and Xiangyangshipin (“XY”), all located near the inner city walls.⁹⁰ Twenty-four bronze vessels have been retrieved. According to the stratigraphy and object typology, the hoards were interred between 1400 and 1250 BC, while the bronze vessels were produced between 1450 to 1250 BC.⁹¹ The nature of the hoards is still debated, but the bronzes from the hoards include some of the largest bronzes discovered at the site, suggesting that the bronzes were either owned by some special individuals, such as the rulers of the community, or made for some special uses, such as important public ritual ceremonies. In particular, among the vessels were four large rectangular *ding* vessels, two from XY and two

⁸⁷ Henansheng 2001: v. 2, 1030.

⁸⁸ A new walled settlement, Yuanqu, emerged as the new regional centre in the Zhongtiao Mountains during Lower Erligang Phase II. This was probably part of Zhengzhou’s efforts to ensure the metal supply: Zhongguo et al. 1996; Zhongguo et al. 2014.

⁸⁹ Henansheng 2001: v. 1, 563; 583–586; v. 2, 850–852; Zeng, X. 2003.

⁹⁰ Henansheng 1975; Yang, Y. and Yu, X. 1983; Henansheng and Zhengzhoushi 1998. See also Henansheng and Zhengzhoushi 1999; discussion: An, J. 1989; 1997; Chen, X. 1986; Yang, Y. 1983; Zhang, G. 2018.

⁹¹ Henansheng and Zhengzhoushi 1999: 99–102.

from ZZ. Even the smallest of them are 81 cm high, with four sides of 53–55 cm, and weights of more than 50 kg. Compared with other previous and contemporaneous bronze vessels, the sheer sizes of these four rectangular *ding* vessels must have been astonishing to anyone who saw them. Since these four vessels were unearthed from hoards, we are not sure when and how people would have used these vessels. However, we can assume that those giant ritual vessels may have been displayed to a large audience. Zhang Guoshuo pointed out that the hoards were very neatly organised and sprinkled with cinnabar pigment. He suggested that the bronze vessels were probably put into the hoards after some public ritual activities.⁹²

Among all these bronze vessels, about forty objects have been analysed using methods such as ICP-OES, SEM-EDS,⁹³ and wet chemical analysis. All these methods usually provide much more reliable results than XRF. The analyses show that many bronzes were made of high-leaded bronze alloys, and the high lead contents were not reserved for certain vessel types.⁹⁴ One problem is that, apart from nine bronzes from the hoards, the other thirty-two analysed bronzes were published without archaeological backgrounds. One attempt was made by Tian Jianhua to divide the vessels into either Lower or Upper Erligang phases by typology (hoarded bronzes were all Upper Erligang ones).⁹⁵ Based on her chronology, the alloy compositions of the nine Lower Erligang bronzes are relatively uniform, as they all have 80–85% copper, 8–12% tin, and 5–10% lead (Figure 5.18, especially b). Interestingly, the deviation of copper levels is smaller than the deviations of tin and lead levels, suggesting that the craftspeople may have been considering tin and lead as interchangeable in order to keep the overall level of copper stable. When we move to the Upper Erligang objects, the median levels of the three alloying elements

⁹² Zhang, G. 2018. An example of large-scale ritual feasting during this period, see Reinhart 2015.

⁹³ ICP-OES stands for “inductively coupled plasma optical emission spectroscopy”.

⁹⁴ Tian, J. 2013; Tian, J. et al. 2013.

⁹⁵ Tian, J. 2013: 52–56.

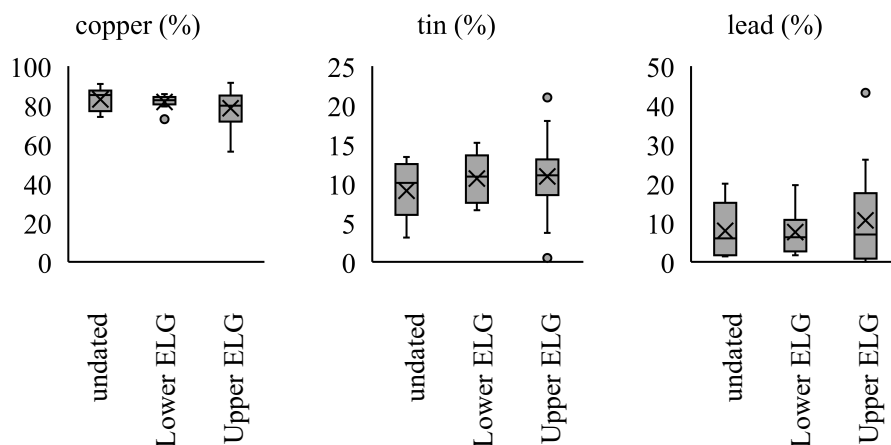
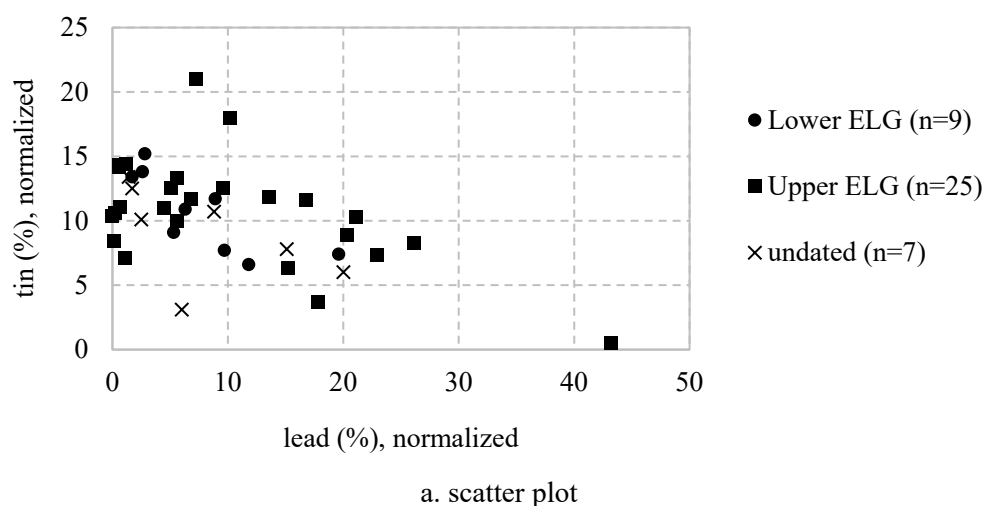


Figure 5.18 Distribution of copper, tin, and lead in the analysed Zhengzhou bronze vessels (data: Tian, J. 2013; Tian, J. et al. 2013).

do not change a lot. However, we can see on the charts that the deviations of copper and lead levels as a pair are quite large. Statistically, this may not indicate a significant difference between Lower and Upper Erligang alloying levels due to the much larger size of the Upper Erligang sample (25 vs. 9). But it is also possible that, for some of those analysed Upper Erligang vessels, the craftspeople used alloys with more lead and less copper, probably as a way to lower the costs of the raw materials.

For a particular example, a *jue* vessel (ID 1568), Tian analysed both the body of the vessel and a metal “spacer” in the body. A spacer is a small piece of metal which is pre-installed between the inner (core) and the outer moulds before the casting in order to maintain the thickness of the body wall. When a cast is undertaken, spacers are usually left in the body of the vessel.⁹⁶ A technical issue is that spacers should not melt during the casting. In other words, the material of the spacers should have a higher melting point than the casting material.⁹⁷ For this Zhengzhou *jue* vessel, the spacer contains much lower tin and lead (3.8% tin, 8.2% lead) than the body (6.3% tin, 15.1% lead), suggesting that the spacer was indeed made of an alloy with higher melting point (see also Chapter 4).⁹⁸ This shows that the craftspeople probably understood the role of tin and lead in lowering the melting temperatures of the bronze alloys as they used the alloys appropriately.

The nine vessels from the hoards did not have similar uniform chemical compositions, as some of them were clearly much more leaded than the others (Table 5.5). In particular, if we consider all the rectangular *ding* vessels. There are in total five analysed *ding* vessels from all three hoards. Four of them, three from NS and one from ZZ (e.g. Figure 5.19, left), were made of bronze with around 15–25% lead, more leaded than the Upper Erligang vessels on average.⁹⁹ By contrast, a *ding* from the XY Hoard (Figure 5.19, right) is very different in its material. This *ding*, along with the other two vessels from the same hoard, are almost unleaded (with higher copper levels).

⁹⁶ Spacers are close to the “chaplets” used in modern-day casting but for a different purpose. A spacer is to keep a cavity which is filled by metal during casting, while a chaplet is to keep a cavity which is not filled by metal. So, after casting, spacers are normally left in the object, while chaplets need to be taken out of the object: Barnard 1975; Liu, Y. et al. 2015a; Su, R. 2015.

⁹⁷ This was confirmed by Pope and Gettens when they analysed the Chinese bronze vessels in the Freer Collection: Gettens 1967: 99.

⁹⁸ Tian, J. 2013: 80.

⁹⁹ Sun, S. 1999. Some of these vessels are heavily corroded, so there may be a potential problem with their original compositions.

Table 5.5 Analysed bronze vessels from the hoards (Upper Erligang phases), Zhengzhou.

Loc	Vessel					Composition (%)			Method of analysis
	ID	type	height (cm)	weight (kg)	thickness* (cm)	Cu	Sn	Pb	
NS	H1 上:2**	sq. <i>ding</i>	72.5	26.7	?	69.5	8.7	19.9	SEM-EDS
	H1 上:3**	sq. <i>ding</i>	64.0	21.4	?	70.9	17.8	10.1	SEM-EDS
	H1 上:4	sq. <i>ding</i>	59.0	20.3	?	64.3	8.1	25.6	SEM-EDS
	H1 上:5***	<i>jia</i>	40.4	?	?	53.3	0.5	40.9	SEM-EDS
	H1 上:9	<i>gui</i>	24.4	?	?	79.9	13.1	5.5	SEM-EDS
XY	H1:2	sq. <i>ding</i>	81.0	75.0	0.7	87.7	8.0	0.1	wet
	H1:4	<i>zun</i>	30.5	7.1	0.5	91.3	7.1	1.1	wet
	H1:7***	<i>pan</i>	12.7	7.5	0.2	86.4	10.9	0.7	wet
ZZ	DLH1:2	sq. <i>ding</i>	87.0	64.2	0.6	75.1	3.5	17.0	wet

* the thickness of the body of the object

** corroded

*** fragment

References: artefacts: Sun, S. (1999); chemical compositions: Yang, Y. and Yu, X. (1983); Sun, S. (1999); Tian, J. (2013).

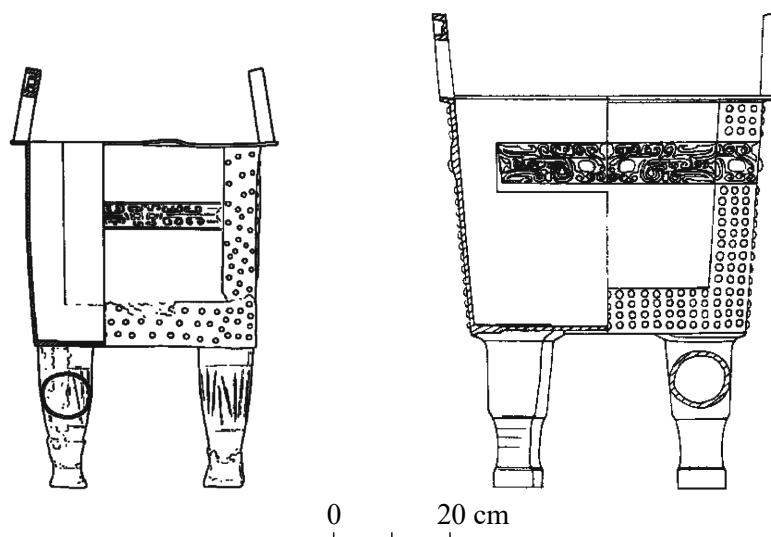


Figure 5.19 Two rectangular *ding* vessels, Zhengzhou. Left: NSH1 上:2; right XYH1:2 (after Henansheng and Zhengzhoushi 1999: 13; 87).

Why did the craftspeople make similar objects of two different alloy materials?¹⁰⁰ The castability of the alloys was certainly not the issue since the bronze alloys used for all these *ding* vessels, regardless of whether they had a high or low lead content, are fairly castable. Alternatively, I think weight may be a reason. Three *ding* vessels from the NS Hoard are on average about 65 cm high and 23 kg in weight. Comparatively, the XY Hoard H1:2 *ding* vessels is only 25% taller, but more than three times heavier. What is even more surprising is that the heavier *ding* from the XY Hoard is indeed the one with less lead (lead is denser than copper, Chapter 4). Furthermore, the walls of the heavy XY vessel are very thin, only about 0.7 cm. It seems that the craftspeople were doing something really challenging—an extremely heavy vessel with thin walls and almost no lead. It is worth noting that the *pan* vessel from the same hoard was also made of an unleaded bronze alloy, which is very similar in composition to the one used for the *ding* vessel. Compared with other *pan* vessels of the same size, this *pan* is also extraordinarily heavy.¹⁰¹

In summary, what we see are heavy vessels with thin walls, made of unleaded bronze alloys. To make a vessel with all these criteria is possible, but not easy. This must have required craftspeople to devote extra effort. So, why did the craftspeople create such a challenge for themselves? Especially, why did they avoid using an alloy with higher lead levels that would have made the task easier (at least in terms of weight)? I think the logic behind this technological choice may have been similar to what we have suggested in the Erlitou case. For the Erlitou

¹⁰⁰ Here I assume that using either material was a technological choice to the same metalworking community. Nevertheless, as the vessels could be more than a hundred years apart according to the dating, I cannot really rule out the possibility that using different alloys reflects a changing technological tradition due to other reasons, rather than a technological choice.

¹⁰¹ A Panlongcheng Phase V *pan* vessel (PLZM1:6) is almost the same height (12 cm) as the Zhengzhou one. The diameter of the former is 28 cm; the diameter of the latter is 49 cm. As an estimation, the volume of the latter is about 3 to 4 times bigger than the volume of the former. Nevertheless, the Zhengzhou *pan* (even as it is not intact) weighs almost 7 times heavier than the Panlongcheng one. Interestingly, the Panlongcheng *pan* vessel was also made of unleaded bronze (with 13% tin). It is very hard to understand the extreme heaviness of the two Zhengzhou bronzes. This is probably due to some unseen structure or the microstructure of the metal materials.

craftspeople, lead was probably added in order to lower the costs of the vessels. By contrast, in the Zhengzhou case, the craftspeople may have done the opposite. As they were probably aware of that lead can be a cheaper substitute for copper and tin, those craftspeople may have chosen unleaded bronze to deliberately increase the costs of the vessels. This was probably to fit, as previously discussed, either the special users or the special uses of these bronzes.

Panlongcheng

By the time of Zhengzhou, bronze vessel production had developed not just in the middle Yellow River Valley, but also in the middle and lower Yangtze Valley. In the latter region, a site that can be compared with Zhengzhou in terms of metal production is Panlongcheng (Figure 5.20). Panlongcheng lies in an area mainly shaped by rivers and lakes. This is also an area important for its access to abundant metal resources. The site was first established as a settlement site around 1700 BC, paralleling Erlitou Phase II. The major occupation ceased around 1300 BC. These four centuries are generally divided into seven cultural phases by the excavators. These phases paralleled some phases at Erlitou and Zhengzhou as we just discussed (Figure 5.15). Many scholars believe that Panlongcheng and the northern powers were not simply neighbours. During its Phases IV–V, Panlongcheng grew from a small settlement site into a large regional centre of about 300 hectares and with a walled “palatial area” of about 7.5 hectares. One interpretation of this rapid development is that Zhengzhou, during its heyday, relied on Panlongcheng to control the metal resources in the middle Yangtze Valley. In this way, metal resources as well as finished products can have been conveyed from South China to the middle Yellow River Valley.¹⁰²

¹⁰² Dou, H. 2017; Liu, L. and Chen, X. 2002; Shi, J. 2016; Sun, Z. 2019; Xu, S. 2003; Zhang, C. 2006; a metallurgical perspective, see also Liu, R. et al. 2017; 2019. The discussion of the lower Yangtze Valley will be in Chapter 8.

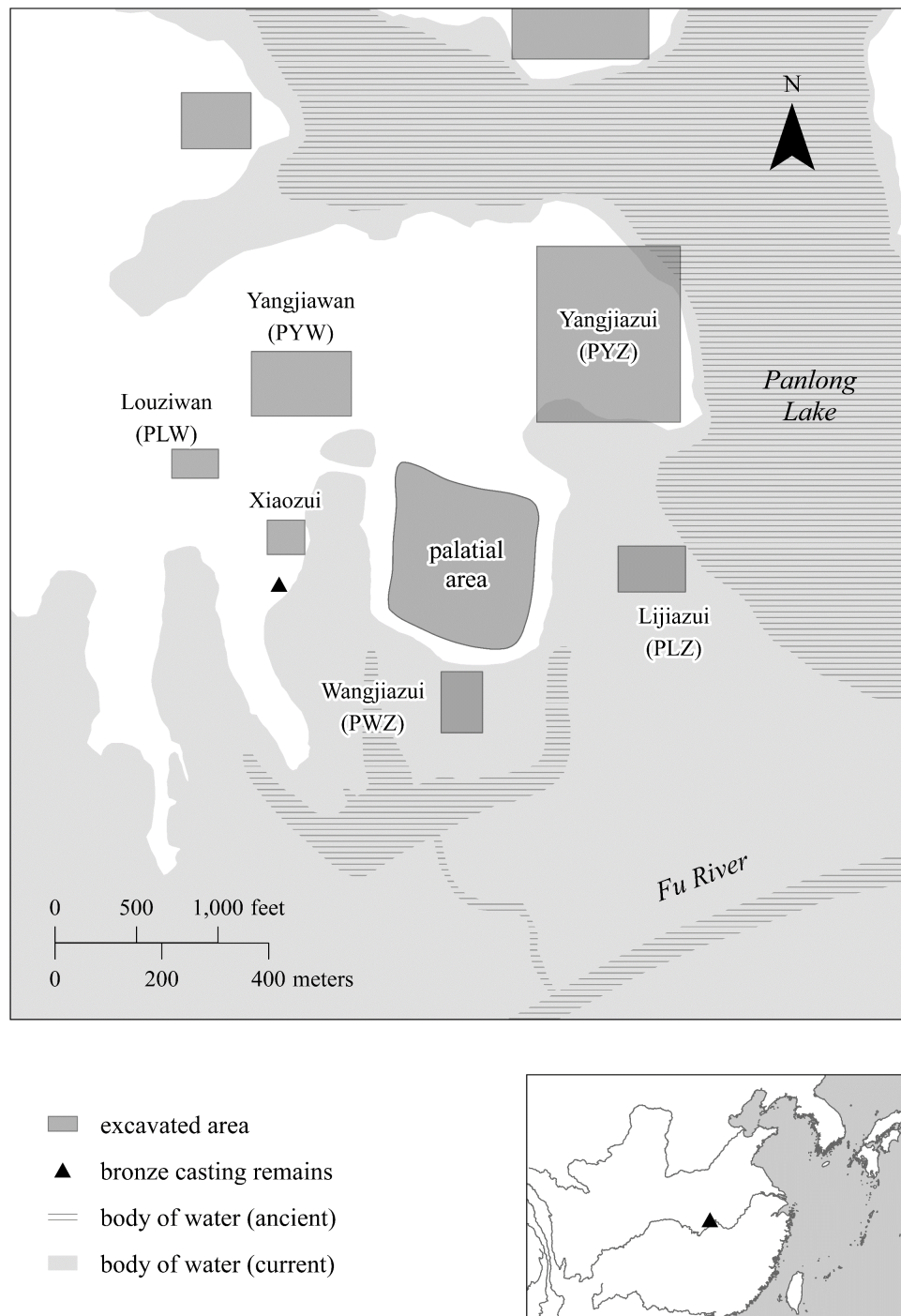


Figure 5.20 Plan of the major excavated areas of Panlongcheng and the distribution of archaeological features. The line pattern shows the approximate shape of the water during the Panlongcheng time, as the water level was much lower than that is now (modified from Zhang, C. 2018; Zou, Q. 2018).

Table 5.6 Analysed bronze vessels from Panlongcheng.

Site	Tomb			Vessel					Composition (%)		
	ID	phase	group	ID	type	ht. (cm)	wt. (g)	section	Cu	Sn	Pb
PLW	M3	5	3	3	<i>jia</i>	27.2	?	handle	65.3	12.0	21.2
	M6	4	3	3*	<i>jue</i>	?	?	?	59.4	19.5	16.4
PLZ	M1	5	1	1	<i>ding</i>	45.0	9.9	?	63.0	10.2	25.5
				6	<i>pan</i>	12.0	1.1	?	84.3	13.1	0.3
				8	<i>zun</i>	24.2	?	foot	87.7	6.8	2.4
									86.4	7.7	2.9
				12	<i>jia</i>	25.4	?	?	71.6	3.9	24.5
				18*	<i>jue</i>	?	?	rim	69.0	14.8	8.2
								spout	66.3	11.9	14.9
								body	69.1	14.0	13.0
								foot	57.3	10.0	31.1
	M2	4	1	19	<i>jia</i>	25.6	1.1	?	81.8	8.4	6.8
				46*	<i>ding</i>	?	?	foot	62.8	11.2	23.9
								body	62.1	10.4	25.8
				55	<i>ding</i>	35.6	?	?	79.9	13.1	5.5

* fragment

Bronze vessels first appeared in Panlongcheng Phase III, roughly overlapping Erlitou Phase IV and Zhengzhou Lower Erligang Phase I. These earliest bronzes were found in a tomb, PYWM6 at Yangjiawan (PYW), an outlying excavated area of Panlongcheng. The tomb occupant was accompanied with seven vessels, three in bronze and four in ceramic, as well as a jade *ge* blade, showing a similar bronze-using burial practice as at Erlitou and Zhengzhou.¹⁰³ As in the case of Erlitou, the number and the type of bronze vessel in the Panlongcheng tombs may also be used to suggest the social status of the deceased.¹⁰⁴ For all the tombs with bronze vessels, some scholars suggest that they can be divided into three groups. Group 1 includes the grandest tombs

¹⁰³ Hubeisheng 2001: v. 1, 220.¹⁰⁴ Wang, W. 2013.

Table 5.6 (*continued*)

Site	Tomb			Vessel					Composition (%)		
	ID	phase	group	ID	type	ht. (cm)	wt. (g)	section	Cu	Sn	Pb
PWZ	M1	6	1	2	<i>zun</i>	30.8	2.6	shoulder	81.3	4.8	11.1
									77.1	4.3	15.8
				5	<i>gu</i>	?	?	?	57.9	13.1	26.5
PYW	M2	5	3	1	<i>jia</i>	26.8	0.2	?	71.2	16.7	9.5
	M3	6	2	7	<i>jia</i> *	?	?	?	64.7	13.0	19.9
	M4	6	2	1	<i>zun</i>	25.4	1.3	foot	65.5	12.6	20.5
								shoulder	66.9	13.4	15.8
								?	65.6	14.3	18.1
								rim	77.7	12.9	9.4
	M1 1	7	1	16	<i>ding</i>	?	?	part 1	80.0	5.9	11.2
									80.5	5.5	11.0
								part 2	82.6	6.0	8.4
									82.6	5.8	8.2
								?	63.8	13.6	21.0
								rim	66.9	15.8	14.8
				25*	<i>zun</i>	?	?	shoulder	64.6	14.7	18.0
								body	59.2	15.5	21.3

Method of analysis: SEM-EDS; references: Hao, X. and Sun, S. (2001); He, T. (2001).

at Panlongcheng. Each tomb has at least twelve bronze vessels—four sets of *jue-jia-gu*. These tombs are also larger (3.5–12 m²), and with more other high-status objects. A Group 2 tomb usually has six (two *jue-jia-gu*) or four (two *jue-jia*) vessels. These tombs are around 2–4 m². A Group 3 tomb only has three vessels (*jue*, *jia*, and *gu*) or even just one *jue* vessel, with a size around 0.9–2.8 m². The remaining tombs are those without bronze vessels.¹⁰⁵ As I previously mentioned, the burial patterns may not necessarily reflect the social status of the buried

¹⁰⁵ Hubeisheng 2001: v. 1, 499–501; Jiang, G. 2005; Zhang, C. 2018.

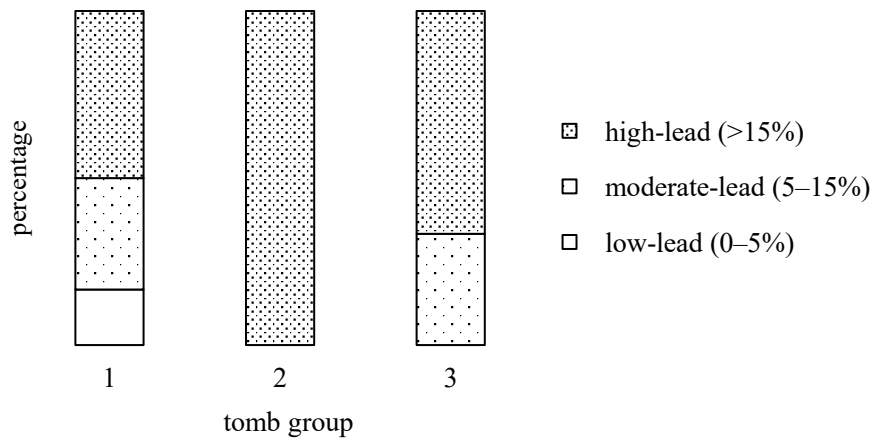


Figure 5.21 Lead levels by tomb group, Panlongcheng (data: Table 5.6).

individuals. However, this is the best working hypothesis based on our current understanding of these early Chinese communities.

With this suggested grouping, there seems to be a correlation between the lead levels and the groups of the tombs (Table 5.6).¹⁰⁶ While tombs of all groups had moderate- and high-leaded bronzes, only the grandest tombs in Group 1 had low-leaded ones (Figure 5.21). Due to our sample size and the inevitable subjectivity of the tomb grouping, it is very hard to confirm whether this is merely a statistical bias or a real correlation. But if this correlation did exist, how can we explain it? One possible explanation is that, for most Panlongcheng tombs, to have the right quantity of the vessels was more important than to have those with the highest quality. Therefore, even the Group 1 tombs did not exclusively use low-leaded bronzes. However, individuals with a high social status were nonetheless more likely to afford or to receive at least a few low-leaded bronzes. That is why we can only see those bronzes in Group 1 tombs.

From an owner or a user's perspective, low-leaded and high-leaded bronzes may also have been distinguishable. Here, I choose six bronzes—three high-leaded and three low-leaded to make a

¹⁰⁶ For the analyses, mostly destructive, fragmentary objects were intentionally chosen so as to minimise the impact of the objects. However, a problem following this approach is that we do not know the chemical composition of most complete and typologically important objects.

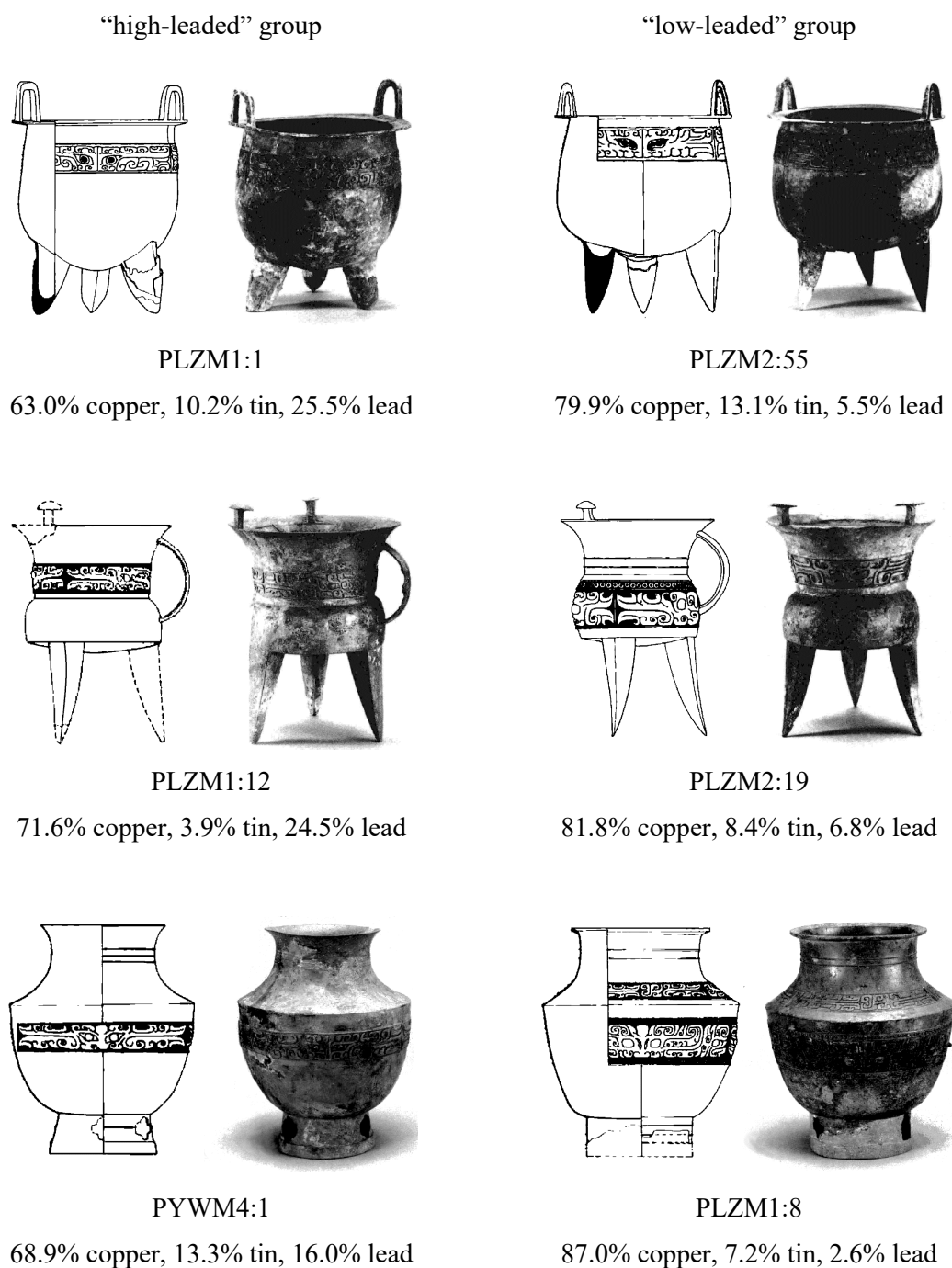


Figure 5.22 Comparison of high-leaded and low-leaded bronze vessels (modified from Hubeisheng 2001: v. 1, 167; 171; 195; 197; 200; 256; v. 2, Pl. 47, 48; 58; 59; 76).

comparison. Five of them were from tombs PLZM1 and PLZM2, both considered to be of Group 1 and with close dates (PLZM1: Phase IV; PLZM2: Phase V). The first pair of the comparison is the high-leaded M1 *ding* vessel and the low-leaded M2 *ding*. The second pair is the high-leaded M1 *jia* and the low-leaded M2 *jia*. We may also compare the *zun* vessel from M1 and the

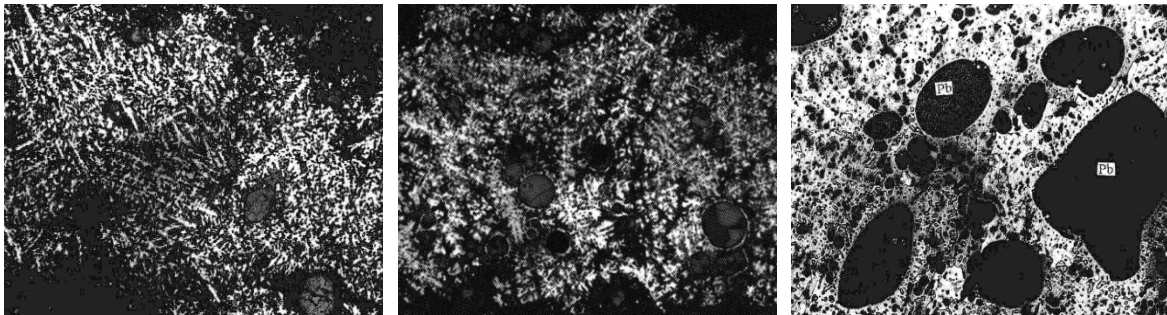


Figure 5.23 The microstructures of three sections of the Panlongcheng PLZM1:18 *jue* vessel. a: rim; b: body; c: foot (after Hubeisheng 2001: v. 2, Pl. 150; Sun et al. 2011: 105).

zun from Tomb PYWM4 (Phase VI) (Figure 5.22). These pairs are chosen so that the vessels under comparison are close in style and size, but different in casting material. When we compare these vessels, the first impression is that the low-leaded ones are preserved better than the high-leaded ones. Especially, the rims and the feet of the low-leaded ding and *jue* vessels are almost intact, while those parts of the high-leaded ones are often broken. The poor condition of the high-leaded bronzes may be due to the mechanical properties. As discussed in Chapter 4, high lead levels deteriorate the strength and the hardness of the copper alloys. Besides this simple observation, the analyses of the Panlongcheng bronzes also suggest that high lead contents caused casting problems. One example is the *jue* vessel from Tomb M1 of Lijiazui (PLZ). Hao Xin and Sun Shuyun analysed the object and found that the body of the *jue* vessel contains 13% lead, while its foot has more than 30% lead.¹⁰⁷ The microscopic examination by Sun and colleagues also suggested this issue (Figure 5.23). This disproportionate distribution of lead was probably caused by the sinking and segregation of lead during casting. In use, the lead-rich lower part of the object would be very likely to break or to detach from the body. Therefore, I suggest that high-leaded bronzes were not considered as good as low-leaded ones as the differences are really noticeable to a user. The use of high-leaded bronze vessels in some Erlitou, Zhengzhou, and Panlongcheng tombs also suggests that some vessels, especially those with very high lead

¹⁰⁷ Hao, X. and Sun, S. 2001.

contents (such as >20%), may have been dedicated to funerary purposes. In these contexts, the problems associated with high lead levels, such as the durability of the objects, may have been less obvious, while other concerns, such as cost-saving, became more important.

In summary, the cases of Zhengzhou and Panlongcheng suggest that lead played a double role in the casting of bronze vessels at the time. A bronze alloy with some lead may be less costly than an unleaded bronze alloy, while still having a good castability. However, if too much lead is added, the potential for casting defects also increases. This may also increase the total cost of the production as the object may need to be repaired or even recast. For craftspeople and the consumers (who are often individuals with a relatively high social status), the level of lead probably suggests a balance between how much they can have afforded to make a vessel, and how good they expected the vessel to be. For those few people who did not need to worry a lot about cost, unleaded bronze was certainly the best choice. But in most other cases, adding some lead may have been a more sensible choice. This socio-economic approach behind the adoption of leaded bronze was probably started by the Erlitou metalworking community. However, after communities such as Zhengzhou and Panlongcheng also adopted this method, the use of leaded bronze vessels became a new material culture, helping shape the Bronze Age of East Asia in the next millennium.

Golden Rings, Silvery Weapons

Bronze and Lead at Dadianzi

About eight hundred kilometres east of Erlitou, the Yellow River flows into the Pacific Ocean, which is here named the Yellow Sea. The Yellow Sea is between the continent of China and the Korean Peninsula. Today, the land forms two major bays, the Bohai Bay and the Korea Bay, divided by the Liaodong Peninsula. In this chapter, I will mainly focus on the Bohai Bay, or, especially, the northern part of the “Bohai Rim”, as some of the earliest metal-using communities in this region emerged in the second millennium BC (Figure 6.1), roughly contemporaneous with Erlitou. One of the communities was Dadianzi.

In the Dadianzi cemetery, people were buried with various grave goods, including metal objects. Most of them were small penannular rings made of bronze (one made of gold), with a few bronze and lead objects which were probably used as (or to decorate) symbolic weapons, such as mace heads and shaft caps. From our modern scientific perspective, some objects from Dadianzi were made of what we may call leaded bronze, as the lead levels are often between 1 and 5%. However, by examining the metal production remains in the northern Bohai Rim, we may suggest that, unlike the craftspeople in Central China who, in our previous case study, deliberately produced

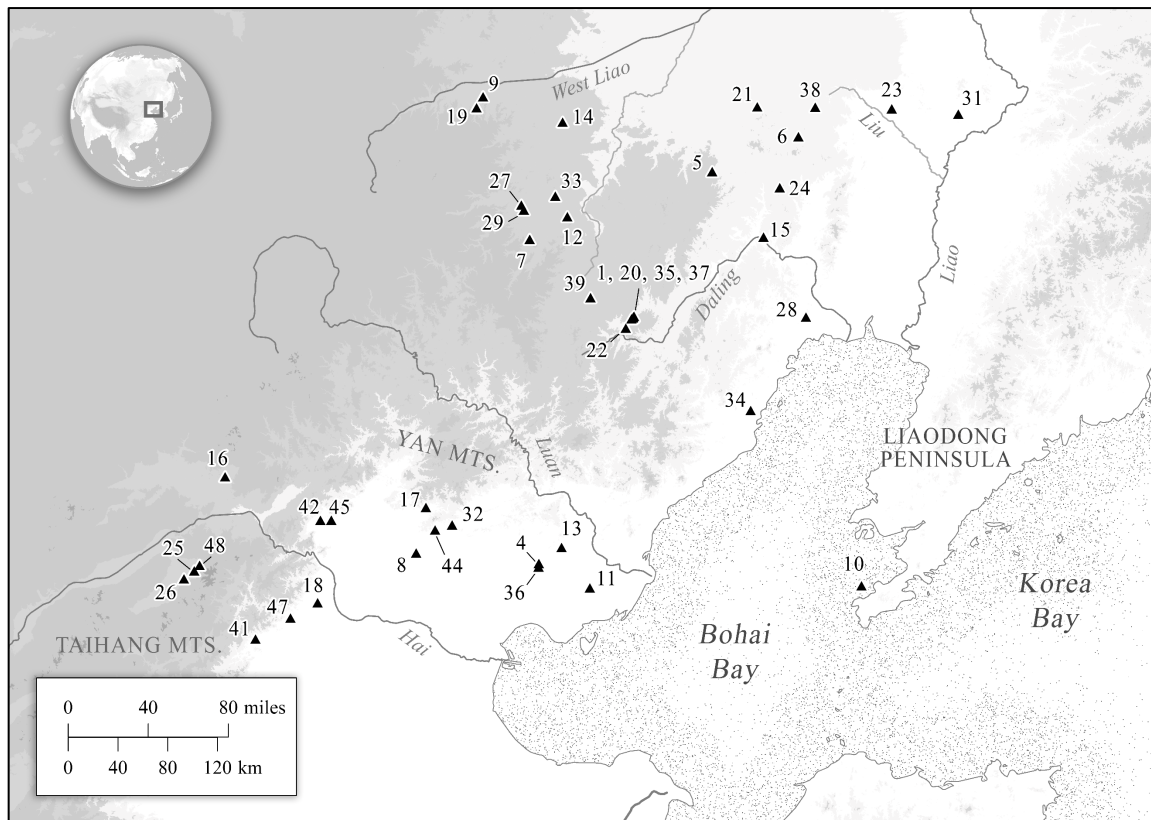


Figure 6.1 Metal-bearing sites in the northern and western Bohai Rim, c. 2000–1100 BC. 1: Bagaidi; 2: Baoshenmiao; 3: Caoyanzhuang; 4: Dacheangshan; 5: Dadianzi; 6: Daihai; 7: Dashanqian; 8: Datuotou; 9: Dayingzi; 10: Dazuizi; 11: Dongzhuangdian; 12: Erdaojingzi; 13: Guye; 14: Jianshanzi; 15: Kangjiatun; 16: Lidarenzhuang; 17: Liujiahe; 18: Liulidian; 19: Longtoushan; 20: Miaotaidi; 21: Nanpaoziya; 22: Niuheliang; 23: Ping'anbao; 24: Pingdingshan; 25: Qianbao; 26: Sanguan; 27: Sanzuodian; 28: Shuishouyingzi; 29: Sifendi; 30: Taixi; 31: Wanliu; 32: Weifang; 33: Xiajiadian; 34: Xianlingsi; 35: Xiaobeishan; 36: Xiaoguanzhuang; 37: Xiaoheishan; 38: Xiaonailingao; 39: Xiaoyushulinzi; 40: Xiaqiyan; 41: Xiayuegezhuang; 42: Xueshan; 43: Yinjiacheng; 44: Zhangjiayuan; 45: Zhangying; 46: Zhaoyao; 47: Zhenjiangying; 48: Zhuangke.

leaded bronze alloys, the leaded bronze used in the northern Bohai Rim was not an intentional technological choice. Rather, as I will show by the comparison of the objects across the regions, there was a “steppe-Inner Asian tradition” of making metal objects, such as the rings and the mace heads, using certain metals, including gold, silver, and bronze without high lead contents. When this tradition was adopted by different communities, people may have tried to use local metal resources available to them to produce such objects. In the case of the northern Bohai Rim,

since most local metal deposits are polymetallic ores with certain levels of lead, lead was inevitably introduced into the bronze objects when such metal resources were used.

Besides this external stimulation, I will also consider the internal factors which facilitated the adoption of metal objects in the Dadianzi community. Based on the analysis of the burial patterns, I argue that the possession of grave goods reflects that the use of metal objects, as a steppe tradition, may have been considered incompatible with the other tradition of using the Erlitou-style ceramic vessels and lacquerwares, both indicating cultural connections with the south, as people owning one type of object did not own the other type of object. The burial patterns as well as the cultural connection with the steppes also suggest that three types of metal—bronze (not high-leaded), gold, and lead—were probably used to represent two metallic colours: gold (by bronze and gold) and silver (or metallic grey, by lead).

Unintentionally Leaded Bronze: Dadianzi and Its Metal Objects

Dadianzi and Its Surroundings

The Dadianzi site lies between the Daling River and the Laoha River, a tributary of the West Liao River. The site comprises a residential area and a cemetery (Figure 6.2). The residential area is not well preserved. However, from the remaining part of it, which is about 6 hectares (60,000 m²), we can still know that Dadianzi was one of the largest sites in the northern Bohai Rim in its time. The residential area was surrounded by moats and rammed-earth walls, these features were also common in the contemporaneous sites in this area.

To reconstruct the regional pattern surrounding Dadianzi is difficult due to the absence of a clear chronology of the sites. Traditionally, archaeologists attribute Dadianzi and many sites in the West Liao River and Daling River Valleys to the Lower Xiajiadian culture, named after its type

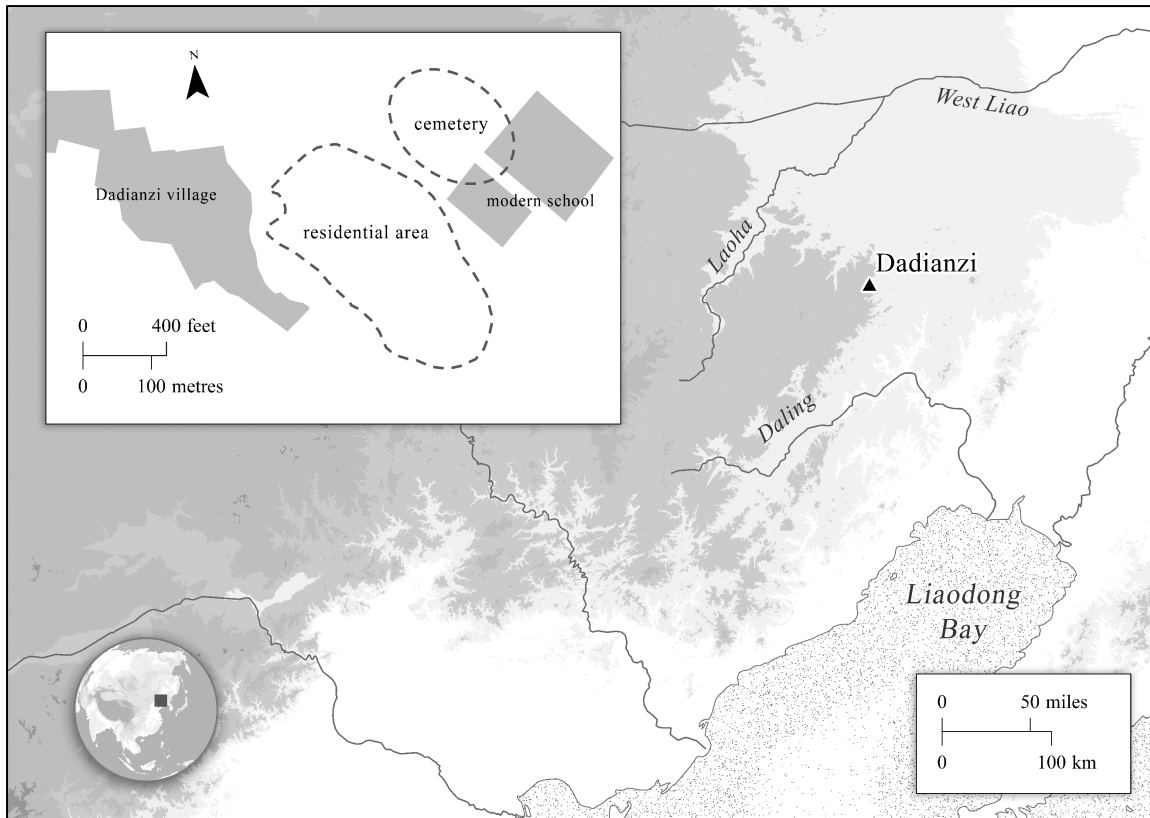


Figure 6.2 The location of Dadianzi and the plan of the site (modified from Zhongguo 1996c: 2).

site near today's Chifeng, Inner Mongolia.¹ According to our discussion in Chapter 2, to group sites based on archaeological culture, especially when the culture is narrowly defined by a few characteristics of the archaeological materials, such as ceramic typology, can be a questionable approach. In the 2000s, archaeological surveys in the West Liao River region, especially the one conducted by the Chifeng International Collaborative Project, provided a more in-depth view of how the local communities were organised. The settlement pattern revealed by the surveys show that the northern Bohai Rim was occupied by hundreds of fortified sites, either walled with stone or rammed earth, or protected by moats. In a small area near the modern city of Chifeng, the density of the fortified settlements was as high as one site per two km² (Figure 6.3).² Radiocarbon

¹ Liu, L. and Chen, X. 2012: 302–312; Wang, L. 2013a.

² Chifeng 2003: 33–34.

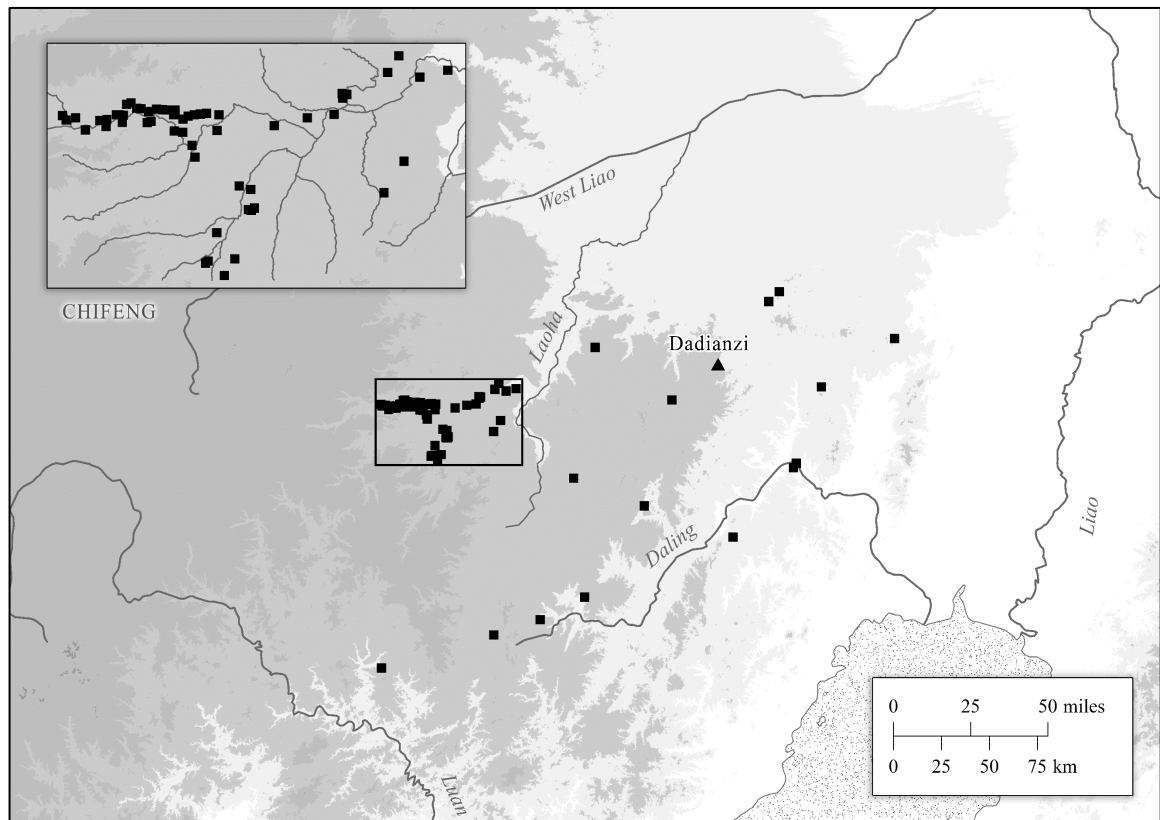


Figure 6.3 Major fortified sites in the northern Bohai Rim, c. 2000–1400 BC (modified from Xu, H. 2017: v. 1, 155).

dates suggest that most of the fortified settlements were used around 2000–1400 BC.³ Regarding the nature of these fortified sites, many scholars believe that they were not defending against a common enemy, but against one another.⁴ Local ecological issues may have been one of the causes of the political tension. Paleoclimate data shows that the West Liao Valley was relatively warm and humid during the first half of the second millennium BC. This trend was interrupted around 1500 BC, and the whole area became drier and colder with decreasing forest cover.⁵ In all, the geopolitics of the northern Bohai Rim during Dadianzi's time was probably very different from the middle Yellow River Valley, where Erlitou and Zhengzhou were located. As Robert

³ Chifeng 2011: 21.

⁴ Wang, L. 2013b; Xia, B. 2011.

⁵ Kong, Z. et al. 1991.

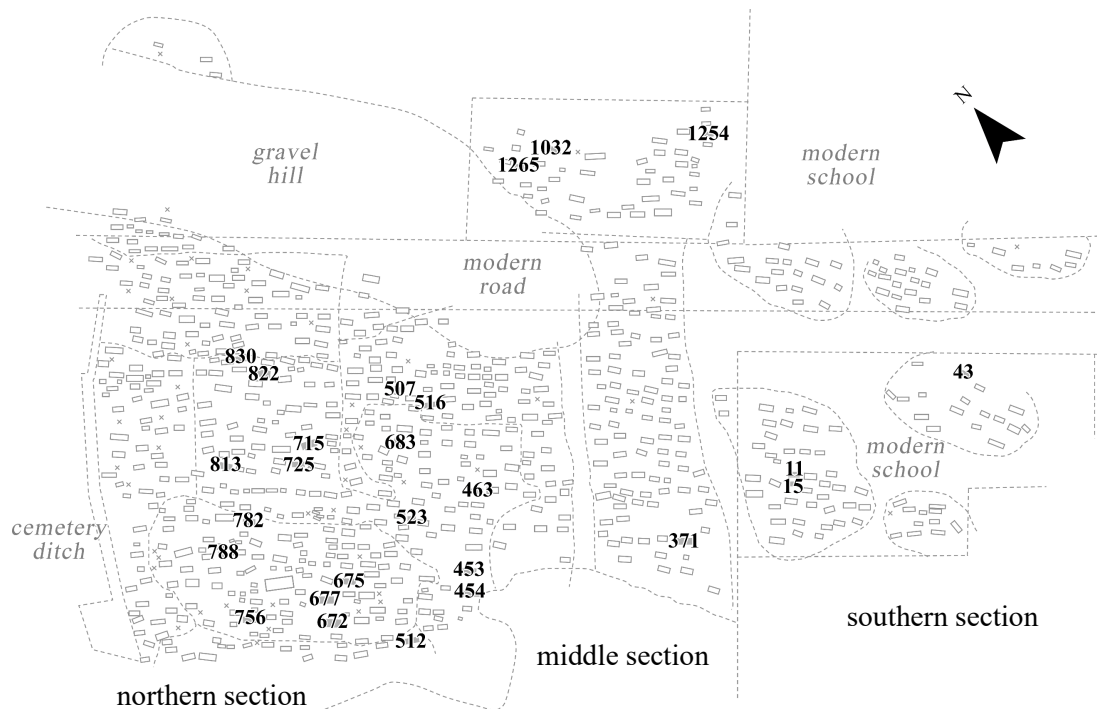


Figure 6.4 Plan of the Dadianzi cemetery. The numbers show the location of tombs mentioned in the text (modified from Zhongguo 1996c: 40–41).

Drennan and Dai Xiangming suggested, Dadianzi was in a region with low political integration, while the area of Erlitou and Zhengzhou had a high political integration on a regional scale.⁶ As I will argue later, this low level of political integration may also have affected how metals were used, produced, and distributed in the northern Bohai Rim.

What makes Dadianzi really famous is its cemetery. In an area of about 1 hectare (10,000 m²), the excavators recovered more than eight hundred tombs (Figure 6.4). Although most of the tombs were only a few metres from one another, only two intrusions with a later tomb breaking an earlier one (archaeological term: “cuts”) have been identified. This means that the whole area was well organised. Also, two corridors—without any tombs in them—divided the cemetery into three sections. Based on this division and the typological studies on the grave goods (which will

⁶ Drennan and Dai 2010.

be further discussed later in this chapter), the excavators suggested that the cemetery may have been used by several groups of people who were organised as families or clans, each buried in a certain area of the cemetery. These people together formed the Dadianzi community.⁷ Two radiocarbon dates, obtained from the wood remains in two tombs, are in the range of 1735–1463 BC.⁸

Metal Objects

More than fifty metal objects have been found in the Dadianzi burials. The most common objects are rings. More precisely speaking, they are penannular rings since the circles are not fully complete (Figure 6.5, a and b). These rings usually have one or both sides slightly enlarged as a flat end. Some penannular rings found at other northern Bohai Rim sites also have enlarged ends which were made into a shape like the bell of a trumpet (Figure 6.5, c). At Dadianzi, twenty-nine tomb occupants, predominantly buried in the northern section, owned such rings as either earrings or finger rings. One example is Tomb M453, which was located near the south-eastern corner of the northern section. The plan of the burial is not published in the excavation report. According to the description, the individual was identified as a female, aged 25 to 30, buried in a wooden coffin. Two sets of earrings were found on both sides of her head. The left set was composed of two bronze rings and six tubular turquoise beads; the right set was composed of another two bronze rings and eighteen turquoise beads. Besides, the individual also wore a necklace made of beads in three materials: jade, carnelian, and a type of white stone. On her right hand, there were also three bronze rings. Such an elaborate use of bronze and other materials as personal ornaments must have been very impressive to anyone who saw it. In another example, Tomb M677, the occupant, also a female, even had eleven rings on her ten

⁷ Report: Zhongguo 1996c.

⁸ Zhongguo 1991: 56.

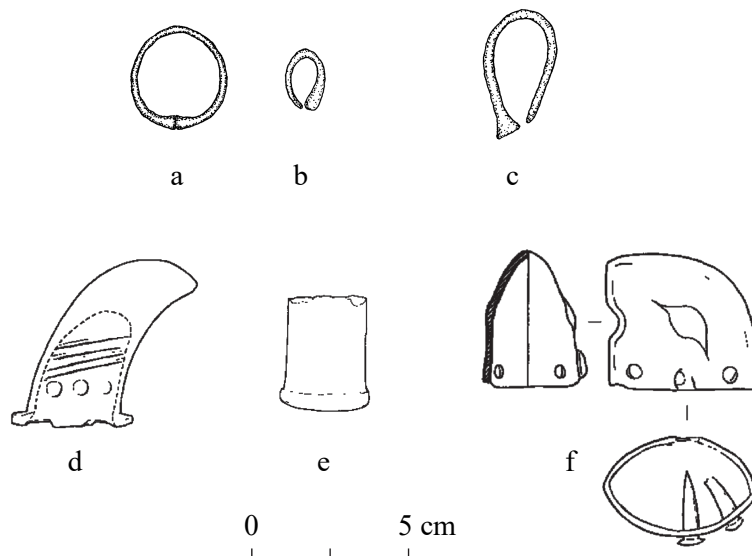


Figure 6.5 Metal objects from Dadianzi. a: ring; b: earring; c: trumpet-shaped earring (for comparison), Pingdingshan Phase I; d: mace head, Dadianzi; e and f: shaft caps (b is gold; all others are bronze) (Dadianzi: after Zhongguo 1996c: 190; Pingdingshan: after Zhong, Y. et al. 1992b).

fingers. Most tomb occupants with finger rings are identified as females, but earrings accompanied both male and female occupants.⁹ Tomb M822 is one of the tombs whose occupant is identified as a male. He was buried with two bronze earrings and stone and shell beads. Another tomb, M516, also had an occupant identified as a male. He had a gold earring in the same style as the bronze ones.¹⁰

From a technical perspective, there are two ways to make such rings: casting and forging (hammering). Between these two options, rings made by forging tend to have better mechanical properties (stronger and harder). Casting, however, has its own benefit in mass-producing objects with a relatively low technical threshold, mainly because moulds are used.¹¹ Among the

⁹ However, I should point out that the identification of sex at this site is based on the osteological measurements (such as pelvis), so the results may not always be reliable. See e.g. Buonasera et al. 2020.

¹⁰ Zhongguo 1996c: 188–191.

¹¹ Moulds do not need to be made by the casters. Nowadays, people can easily find silicone moulds from DIY shops and use them to cast resin jewellery. Like in today's case, this division of labour separating mould-making and casting may also have been meaningful to small-scale metal production in the past.

Table 6.1 Analysed copper-based rings from the Dadianzi cemetery.

ID	Type	Test method	Composition (%)			Technique of manufacturing
			Cu	Sn	Pb	
M11:1	earring	ICP-AES	73.3	6.5	0.9	forged
		SEM-EDS	91.1	7.5	-	
M453:1-1	earring	SEM-EDS	89.4	8.4	2.2	?
M453:1-2	earring	SEM-EDS	84.5	12.6	2.9	?
M453:2	earring	SEM-EDS	81.8	15.1	3.1	forged
M453:9-1	ring	SEM-EDS	77.0	22.4	-	?
M453:9-2	ring	SEM-EDS	71.3	23.2	4.8	?
M453:9-3	ring	SEM-EDS	72.1	24.5	2.4	?
M454:1	ring	SEM-EDS	80.3	18.2	1.4	cast
M454:3	ring	SEM-EDS	80.2	18.2	1.3	?
M454:8-1	ring	SEM-EDS	80.6	18.7	-	cast
M454:8-2	ring	SEM-EDS	80.8	18.6	0.6	cast
M454:9	ring	SEM-EDS	77.1	22.1	-	?
M463:7	earring	SEM-EDS	84.0	13.9	2.2	forged
M507:1	earring	SEM-EDS	83.7	14.7	1.5	forged
M507:3	earring	SEM-EDS	79.0	19.5	-	?
M523:3-1	earring	SEM-EDS	96.9	2.2	-	?
M523:3-2	earring	SEM-EDS	92.4	4.4	2.7	forged
		SEM-EDS	91.7	4.1	2.7	

References: Li, Y. et al. (2002; 2003); Wang, Y. (2018).

analysed Dadianzi rings, most earrings are forged, while most finger rings are cast. In terms of the chemical compositions (Table 6.1), Li Yanxiang and colleagues suggested that the chemical compositions of the rings are not always consistent with their techniques of manufacturing. Ideally, as we have discussed in Chapter 4, copper alloys with low lead contents are more suitable for forging, while alloys with high lead contents are more suitable for casting. However, if we compare the alloy compositions of all earrings (supposing they are all forged) with those of all finger rings (supposing they are all cast), the lead levels of the two types of object are almost indistinguishable (Figure 6.6). This suggests that, as Li argued, the craftspeople who made these rings did not make a distinction between the metals they used for one type of ring

Table 6.1 (*continued*)

ID	Type	Test method	Composition (%)			Technique of manufacturing
			Cu	Sn	Pb	
M672:14	earring	SEM-EDS	85.3	14.4	-	forged
M675:2-1	earring	SEM-EDS	88.0	10.4	-	?
M675:2-2	earring	SEM-EDS	82.8	13.4	2.3	?
M725:1-1	earring	SEM-EDS	84.4	13.9	1.7	forged
M725:1-2	earring	SEM-EDS	88.8	9.2	1.6	?
M756:5-1	ring	SEM-EDS	88.1	10.4	1.5	cast
M756:5-2	ring	SEM-EDS	89.5	8.9	1.6	?
M756:5-3	ring	SEM-EDS	87.3	10.6	1.7	?
M782:9	earring	SEM-EDS	77.4	18.4	-	forged
		ICP-AES	85.2	10.9	0.9	
		SEM-EDS	90.6	8.3	1.1	
M813:3	earring	SEM-EDS	86.9	8.7	4.4	forged
M822:7-1	earring	SEM-EDS	92.7	5.7	1.6	?
M822:7-2	earring	SEM-EDS	90.0	7.6	1.8	?
M830:2-1	ring	SEM-EDS	92.0	3.8	1.8	?
M830:2-2	ring	SEM-EDS	87.1	11.4	1.4	?
M830:2-3	ring	SEM-EDS	89.8	8.3	1.9	?
M1032:5	earring	ICP-AES	81.6	7.0	0.9	forged
		SEM-EDS	91.6	6.5	1.9	
M1254:1	earring	SEM-EDS	88.0	4.8	3.6	forged
		ICP-AES	82.5	2.3	2.0	
		SEM-EDS	97.3	2.4	-	

and the metals they used for the other type of ring.¹² Another thing pointed by Li and colleagues is that, in some cases, rings from the same tomb have very close chemical compositions (e.g. M453, M756). This suggests that several rings owned by one tomb occupant may have been produced together, probably as they were specially made for the funerary use. Following this

¹² Li, Y. et al. 2003.

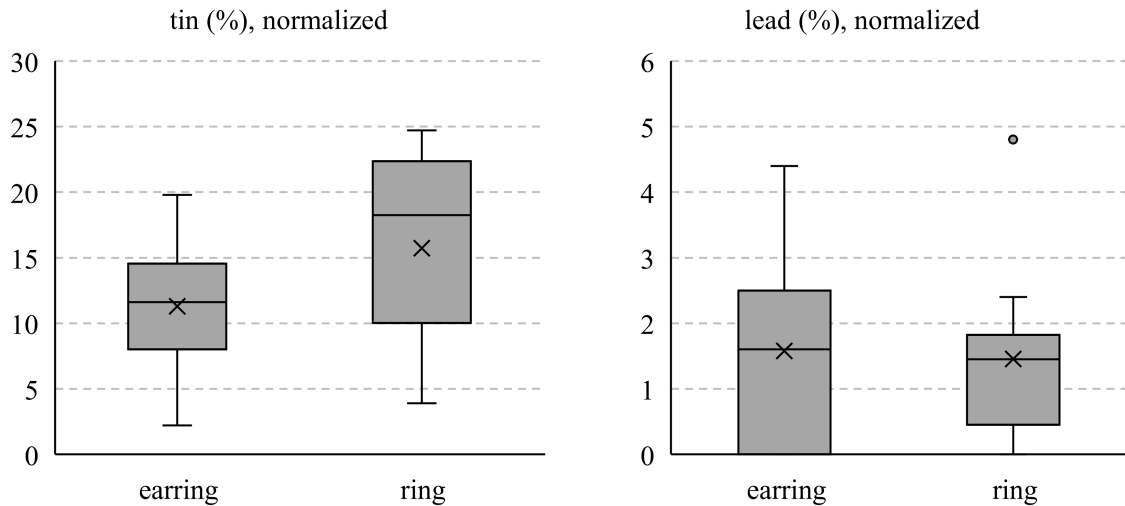


Figure 6.6 Comparison of alloying levels between earrings and rings from Dadianzi (data: Table 6.1).

suggestion, I argue that earrings were chosen to be forged probably because earrings were more noticeable—closer to the face—in a tomb setting. To combine all these implications, we may conclude that most of these rings were made with easily accessible raw materials, and by relatively simple techniques (compared with, for example, casting bronze vessels). Nevertheless, considering that most people buried in the Dadianzi cemetery did not have many belongings, these rings may still have been quite valuable to the deceased.

Besides the rings, some other metal objects have also been found (Table 6.2), including two mace heads, one made of bronze and the other made of lead (with about 5% tin),¹³ from Tombs M43 and M371.¹⁴ Both tombs were relatively rich concerning the grave goods. The tomb occupant of M43, with the bronze mace head, was identified as a male, aged 60–65. He was

¹³ Zhao, K. 1996.

¹⁴ There are two particular types of object placed in many Dadianzi tombs, stone axes (including two metal mace heads) and stone or ceramic spindle whorls. There are around 100 axes and 100 spindle whorls in total, but each tomb occupant only owns one of these objects, either an axe or a spindle whorl (with only one exception, Tomb M398, who owns both). Most scholars believe that these two types of object are indicators of gender, as most human remains in axe tombs are identified as male, while those in spindle whorl tombs are female. Since this gender issue is not directly related to my discussion of the metal objects, I will not elaborate it in this chapter.

buried with five ceramic vessels (including two painted ones) and turquoise and cowrie bead ornaments. There were also pig remains, probably as sacrifice, found in the tomb. Tomb M371 was even grander. The individual, also identified as a male, aged 40–45, was buried with not only the lead mace head, but also large numbers of personal ornaments, ceramic vessels (seven, all painted), and at least four pigs and a dog.¹⁵ As David Anthony suggested, polished stone maces and the sacrifice of animals had become part of the funerary tradition for old chiefs on the Eurasian Steppe since around 5000 BC.¹⁶ In the Dadianzi cemetery, these two tombs with mace heads were separated in two sections—M43 in the southern section and M371 in the southern part of the middle section (Figure 6.4). If we follow the excavator's suggestion that these sections or clusters may reflect some sort of social structure, such as families or clan groups,¹⁷ it is likely that these two individuals buried with metal mace heads were also the leads of their groups. In the next section, I will continue to discuss this possible cultural connection between the northern Bohai Rim and the steppes. In addition, there were also three bronze shaft caps for axes, two from Tomb M715 and one from Tomb M683. Both tomb occupants were identified as males. They were also buried with relatively rich grave goods. Both tombs were in the northern section of the cemetery.¹⁸ In M715, the shaft caps were originally attached to a wooden shaft, together with a stone axe. A bronze cap, with eye-shaped relief decorations on both sides, was installed on the top of the shaft by two nails. The bottom of the shaft was finished by the other bronze cap (Figure 6.7). A rare discovery is a cowrie shell made of lead with about

¹⁵ Zhongguo 1996c: 143–155; 339–409.

¹⁶ Anthony 2007: 160; example: 180.

¹⁷ Zhongguo 1996c: 214–221.

¹⁸ One interesting phenomenon is that not only the two individuals with mace heads did not own metal rings, but they were also buried in two sections where most individuals around them did not own metal rings either. For the two individuals with shaft caps, they were buried in a section where many people around them did have metal rings, but these two individuals did not have metal rings either. The reason behind this phenomenon is not clear. I will discuss some implications of the burial patterns in the final section.

Table 6.2 Analysed copper-based mace head and shaft caps from Dadianzi.

ID	Type	Test method	Composition (%)			Reference
			Cu	Sn	Pb	
M43:12	mace head	SEM-EDS	81.9	17.9	-	Li, Y. et al. (2002; 2003)
M683:7	shaft cap	SEM-EDS	75.9	18.1	6.0	
	- needle	SEM-EDS	88.1	9.5	2.3	
		SEM-EDS	84.4	11.9	3.7	
M715:13	shaft cap	SEM-EDS	76.5	23.0	-	
M715:15	shaft cap	SEM-EDS	79.4	16.8	3.8	

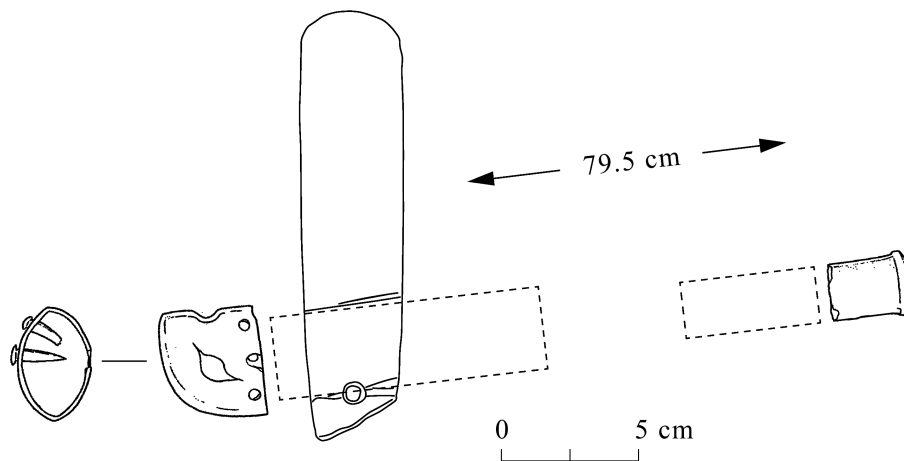


Figure 6.7 Reconstruction of the wooden-shafted stone axe with two bronze caps, Tomb M715 (modified from Zhongguo 1996c: 160; 190). The wooden shaft is not preserved. Its length is estimated by the excavators based on the relative position of the stone and metal objects.

10% tin in Tomb M512.¹⁹ This may be an imitation of the natural cowrie shells, which were placed in more than forty tombs.²⁰

Based on this brief review of the metal objects from Dadianzi, we can make some direct observations. In general, the use of metals may not have been a very restricted practice. Although

¹⁹ Zhao, K. 1996.

²⁰ Zhongguo 1996c: 183–187.

the mace heads and shaft caps were quite rare and may have belonged to the leaders only, the metal penannular rings, on the other hand, were quite common and may have been produced relatively easily. The cultural implications of the objects as well as the relationship between the metal use and the social structure and identities will be further discussed in the later sections. In terms of the metal materials, three types of metal—bronze, gold, and lead—were used to make the objects. In particular, many bronze objects contain low to medium levels of lead. If we use the concept from modern material science, we may call these alloys leaded bronze. However, these alloys are definitely not the same as the leaded bronze used in Central China, as some of the latter alloys contain more than 20% lead. Was the use of leaded bronze a deliberate choice by the craftspeople who produced the Dadianzi metal objects? If not, how was the lead introduced into the bronze alloys? To answer these questions, we need to examine the evidence of early metal production in the northern Bohai Rim.

Local Metal Resources and Metal Production

Since only the cemetery of Dadianzi has been excavated, we do not have information about how (or whether) metal objects were produced at this site. To understand the metal production and the use of the bronze alloys, we need to look at some other sites in this area.

Evidence of metal production has been found at several sites in the northern Bohai Rim (Table 6.3; Figure 6.8). These remains can be divided into two types. Smelting remains, such as slags and the fragments of the refractory materials (e.g. crucibles), have been found at a few sites in the upper Daling River Valley, including Bagaidi, Miaotaidi, Xiaobeishan, and Xiaoheishan. These remains are dated by radiocarbon dating to 1890–1450 BC. Close to these sites is Niuheliang, a famous Neolithic site but with Bronze Age remains as well. Refractory fragments and slags (thought to be left by copper smelting), have also been found at Niuheliang. The refractory fragments were dated by thermoluminescence to 1550–1050 BC. Although this result seems to suggest that Niuheliang is later than other sites, the relative dating based on the ceramics

Table 6.3 Metallurgical remains found in the northern Bohai Rim.

Site	Absolute date (BC)	metal ore	refractory (crucible etc.)	smelting slag	casting mould (ceramic)	casting mould (stone)
Bagaidi	1890–1450		•	•		
Baoshenmiao	n/a					•
Dayingzi	1511–801	•	•	•		
Guye	n/a					•
Jianshanzi	n/a	•	•	•		
Kangjiatun	1700–1550					•
Miaotaidi	n/a		•	•		
Ping'anbao	1743–790					•
Sifendi	n/a				•	
Xiaobeishan	n/a		•	•		
Xiaofushan*	n/a		•			
Xiaoheishan	1750–1620		•	•		
Zhuanzishan*	1550–1050		•			

* sub-sites of Niuheliang.

References: Li (2019); Wang, L. et al. (2016).

found with the refractory fragments suggests that the smelting activities at Niuheliang may be as early as those at the other sides. Researchers also analysed the samples and concluded that, at all these sites, the remains were left by smelting relatively pure copper.²¹

After 1500 BC, the core area for metal smelting moved to the West Liao River Valley, probably following the more abundant metal resources in this area.²² Based on the radiocarbon dates,

²¹ Daling River Valley: Wang, L. et al. 2016; Xi, G. and Li, Y. 2019; Niuheliang: Li, Y. et al. 1999; 2004.

²² Copper deposits are also available near the southern ridge of the Nulu'erhu Mountains, where the previous smelting sites clustered: Wang, L. et al. 2016.

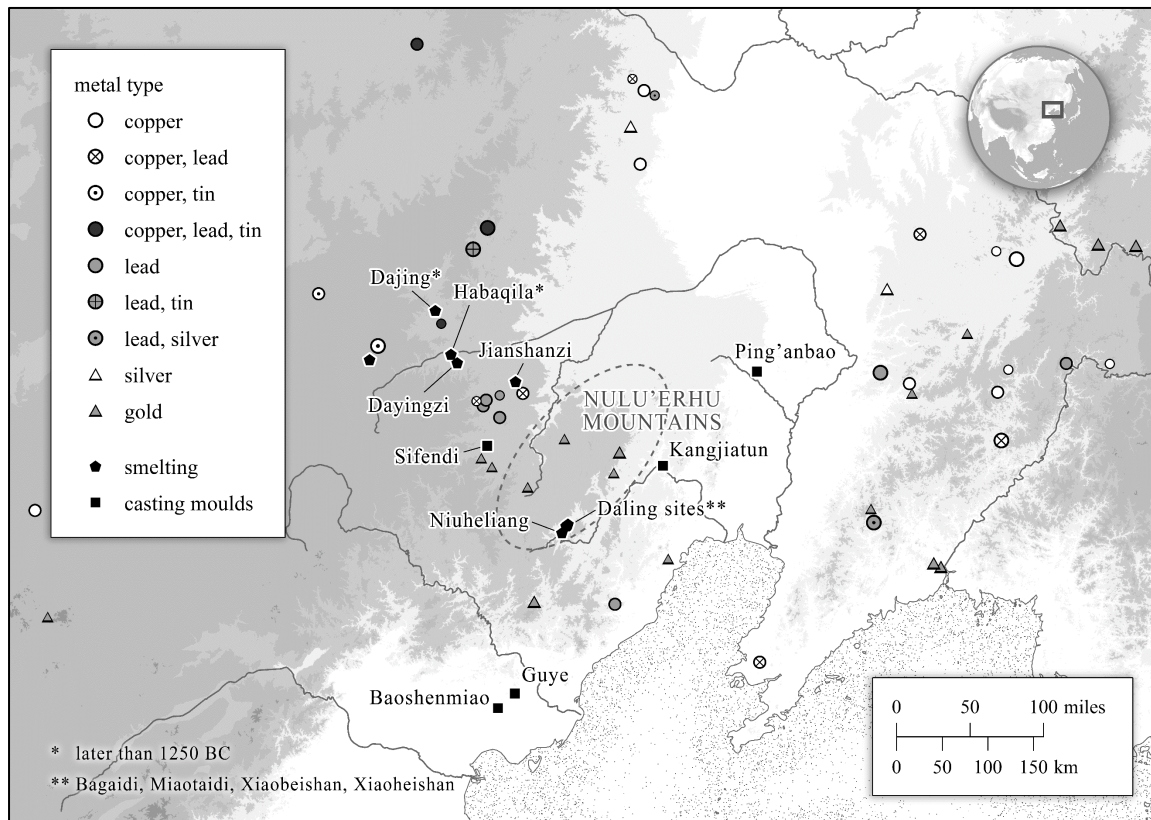


Figure 6.8 Metal resources and major metallurgical finds in the northern Bohai Rim (mines: Zhongguo 1996a).

mining and smelting activities may have started around 1500–1400 BC.²³ One particular feature of the mines in this area is that the ores usually contain more than one type of metal, such as copper with significant amounts of tin, lead, arsenic, silver, and zinc.²⁴ To understand how these polymetallic ores were used in early metallurgy, Li Yanxiang and colleagues analysed some smelting remains from Habaqila, a local site but from a later period (c. 1250–1000 BC). As the results show, copper prills in the slags usually contain arsenic, tin, iron, and silver. Lead, however, was only identified in two of the six analysed slag samples.²⁵ Li and colleagues also

²³ Li, Y. et al. 2019. The exploitation of the Dajing mine, one of the best-known ancient mines in this area, may have started around 1250 BC: *Zhongguo* 1991: 54–55.

²⁴ Feng, J. et al. 1994; Li, Y. and Han, R. 1990; 2002; Li, Y. et al. 2011; 2019; Zhang, C. 2004; Zhao, L. et al. 2002.

noted that most of the ore samples that they collected from the archaeological contexts are lead-free, while most ores collected from the modern mining sites contain lead. This means that people during the second millennium BC may have learned to select ores with relatively low lead contents for copper smelting, a practice which we will see again in the Hexi Corridor (Chapter 7).²⁶ In addition, the analysed slag samples from the local Dajing mine, although dated to the first millennium BC, suggest that bronze (copper-tin) may have been directly produced by smelting polymetallic ores.²⁷ Based on these findings, we may assume that two types of metal were probably produced at those northern Bohai Rim smelting sites. One is relatively pure copper (which may also contain small amounts of other metal elements). The other is pre-alloyed bronze.

For other types of metal which were also found at Dadianzi, such as gold and lead, there is no direct evidence to suggest whether or not they were also produced locally. Lead ores, such as galena, were available in the region, especially between the Western Liao and the Laoha Rivers. Therefore, relatively pure lead, used for the lead objects, may also have been produced locally.²⁸ Discovery of gold, on the other hand, is really a matter of serendipity. Gold deposits have been found at several modern local mining sites. So far, there is no provenance study on the early gold objects in this area, so we do not know whether the raw materials came from local mines or from some interregional exchange.

²⁶ Li, Y. et al. 2011.

²⁷ Some prills in the slags are copper with as high as 30% tin contents: Li, Y. et al. 2002; 2001.

²⁸ Zhang, C. 2004; Zhang, G. 1993; Zhang, Q. 1994; Zhang, Q. et al. 2002. See also Wang, Y. et al. 2020.

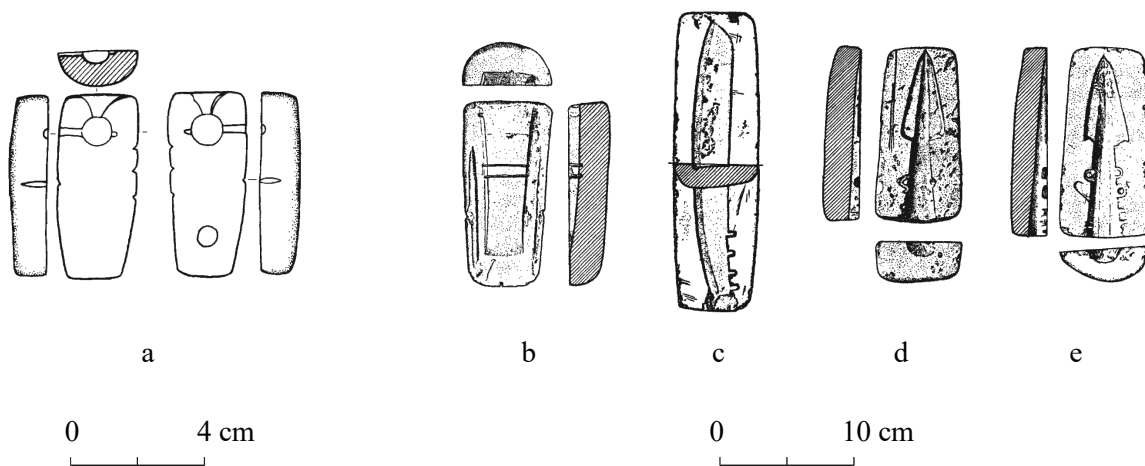


Figure 6.9 Examples of stone moulds from the northern Bohai Rim. a: bead mould (two sections), Kangjiatun (after Xin, Y. and Li W. 2001: 39); b: axe mould, Baoshenmiao; c: knife mould, Baoshenmiao; d, e: two spear head moulds, Baoshenmiao (after An, Z. 1954: 83–84).

In addition to evidence of mining and smelting, fragments of moulds were found at several settlement sites. This suggests that the production of small metal objects may have been done in the local communities. This is very different from the ways in which ritual vessels in Central China were produced, as discussed in the last chapter. In the case of the vessel production as Erlitou and Zhengzhou, most metal resources were transported to a few sites with large metal production capability and cast into ritual vessels. At these sites, there were usually workshops with specific layouts and facilities for metal production. Those workshops were also labour-intensive since multiple people needed to work together to cast bronze vessels. By contrast, no big casting workshop has been found at any Bohai Rim site. The moulds found here are usually very simple, with two sections to form a pair (Figure 6.9). Making such moulds certainly required skills to some degree. But when the moulds were ready, any people with some simple training and a proper firing facility (even campfire) can have cast those small objects. Therefore, it was not necessary to have a centralised manufacturing location with many professionals working together. Instead, a small group of craftspeople, such as a household, could have obtained the raw materials and even the moulds, cast the objects, and given the products to people in their community. These finished products could have gone from hand to hand, and sometimes ended up as scrap metals for a new production cycle. In this sense, the metal

production in the northern Bohai Rim probably shows a non-centralised, more egalitarian model, compared with the centralised, elite-controlled production model at Erlitou and Zhengzhou. This also echoes the pattern of the settlement sites in this region (Figure 6.3), as multiple, independent communities coexisted in this area.

In summary, by referring to the metallurgical remains in the northern Bohai Rim, it seems that the “leaded bronze” Dadianzi objects were not intentionally made of leaded bronze. On the contrary, craftspeople may have chosen to smelt copper and copper-tin ores without high lead contents in order to produce copper and bronze. However, since many polymetallic deposits in this area contain lead, unavoidably, low to medium levels of lead were still introduced during the smelting and were left in the objects. In addition, since lead objects were also used in this area, some lead objects may have been recycled and the lead was mixed with other copper alloys. This may also explain the lead contents in the bronze objects.

But why did people choose to make these metal objects? Why did they use bronze, especially bronze without high lead levels? In the next section, I will compare the use of certain metal objects and certain metals across several East Asian and Central Asian regions to argue that this particular way of using and producing metal objects was indeed a local adoption of the steppe-Inner Asian traditions.

The Objects and the Metals: The External Stimulation

In terms of the origin of the northern Bohai Rim metallurgical tradition, the most likely source is the steppes. As discussed in Chapter 2, the Eurasian Steppe extends all the way from Central Europe to the Khingan Mountains. From the Yenisei River the area is known as the Eastern Steppe, this is the part of the steppes which Dadianzi directly encountered (Figure 6.10). In the area west of Xinjiang, the steppes meet Central Asia. This is also the location of the Inner Asian Mountain Corridor (IAMC), as proposed by Michael Frachetti (Chapter 2). In this section, I will

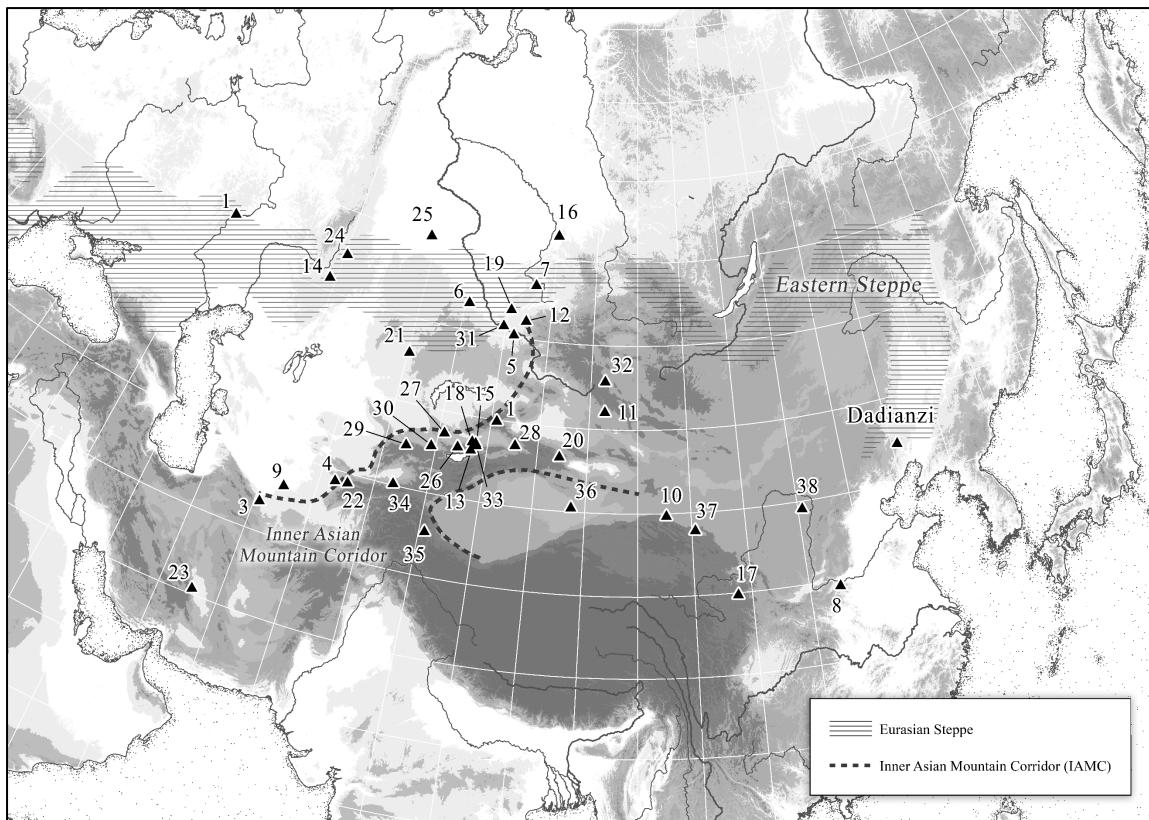


Figure 6.10 Dadianzi, the Eastern Steppe, the IAMC, and the sites mentioned in this section. 1: Adunqiaolu; 2: Alakul; 3: Altyn-depe; 4: Dzhamb; 5: Dzhartas; 6: Ekibastuz; 7: Elunino; 8: Erlitou; 9: Gonur; 10: Huoshaogou; 11: Iagshiin Khödöö 1; 12: Kalyvanskoe 1; 13: Kul'saj; 14: Kupukhta; 15: Kyzyl-Bulak; 16: Malyj Mys; 17: Mogou; 18: Oy-Dzhaylyau; 19: Rublevo VIII; 20: Sa'ensayi; 21: Sangru; 22: Sarazm; 23: Shahdad; 24: Sintashta; 25: Sokolovka; 26: Suukbulak; 27: Tamgaly; 28: Tangbalesayi; 29: Tash-Tyube; 30: Tegermen-say; 31: Tyumen; 32: Ulaan Khudag 2; 33: Uzunbulak; 34: Vuadil; 35: Xiabandi; 36: Xiaohe; 37: Xichengyi; 38: Zhukaigou.

investigate this possible cultural contact across this part of Eurasia following three cultural traits.²⁹ The first is the penannular rings and the metal materials these rings were made of. The second is the mace heads. The third is the use of gold and lead. Nevertheless, it is worth noting that, as mentioned in Chapter 2, cultural contact should not merely be viewed as the dispersal of cultural traits. The logic behind cultural contact, as to what people adopted and how they adopted

²⁹ Scholars have traced the development of many cultural traits and artefacts which first emerged on the steppes and were later adopted by communities in the Bohai Rim. Some of the examples include jade artefacts: Komissarov 1998; Tang, C. 2004; Tang, C. and Deng, X. 2017; Teng, S. 2019; ceramic vessels: Feng, E. 2003; wheat (possibly): Dong, G. 2018.

it, is very complicated.³⁰ For this large geographic region with limited studies, the general conclusions are very likely to be partial. I hope that these conclusions can help us understand the use of metals by the Dadianzi people. Meanwhile, for areas and sites which are covered in this section, we can rely on more comprehensive studies by other scholars to understand the early metallurgy in those cases. Some references of the sites mentioned here are listed in Appendix 1.

Penannular Rings and Their Materials

I choose the penannular rings as the first cultural trait to discuss the steppe-Inner Asian origin of the northern Bohai Rim metallurgical tradition. Since these rings were relatively common in the second millennium BC in a large area from North China to Central Asia, it is possible for us to compare the objects as well as their materials in order to understand how the ideas of using and making these rings spread across the regions. As previously discussed, these rings have been found at many sites in the northern Bohai Rim (Figure 6.11).³¹ If we look at these rings in detail, we can divide them into two subgroups. One is a penannular ring with the one end extended into a trumpet shape, while the other end is sharp as a needle (Figure 6.11, a–k). Rings of this type were usually used as earrings. People probably wore such earrings by either ear piercing or simply by “clipping on”. The other type is a ring with two flat and blunt ends. The two ends are usually attached so as to make a complete circle (Figure 6.11, l and m). Like the examples from Dadianzi, most of these double-flat-end rings were used as finger rings. These two types of rings may have belonged to the same tradition. The trumpet-shaped ends were probably a finer version of the flat ends and are particularly used for the earrings.

³⁰ Cultural contact, see Chapter 2 footnote 19.

³¹ Penannular rings have also been found in the western Bohai Rim, see e.g. Chen, K. et al. 2017b.

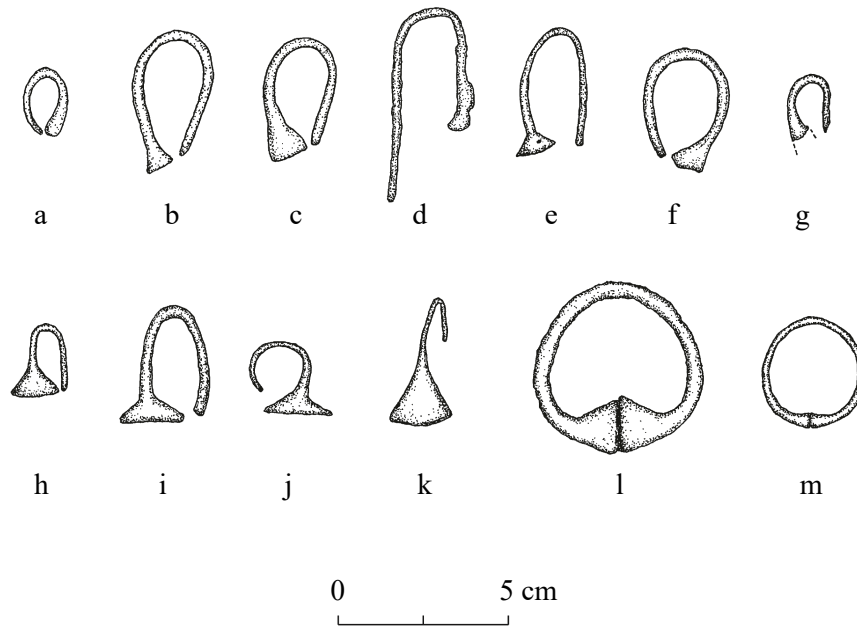


Figure 6.11 Penannular rings from the northern Bohai Rim. Subtype A: a: earring (gold), Dadianzi (after Zhongguo 1996c: 190); b: earring, Pingdingshan (after Zhu Y. et al. 1992a: 403); c: earring, Sanguan; d: earring, Qianbao (c and d after Chen, K. et al. 2017b: 85); e: earring, Weifang (after Li, J. and Liang, B. 1983: 885); f: earring, Xiayuegezhuang (after Liu, H. 2013: 15); g: earring, Liulidian (after Zhao, X. and Tian, J. 1976: 60); h: earring, Xiaoguanzhuang (after An, Z. 1954: Pl. 3); i: earring, Zhangjiayuan (after Liu, H. 2013: 15); j: earring, Liujiaye (after Yuan, J. and Zhang, X. 1977: 6); k: earring, Ping'anbao (after Zhu, Y. et al. 1992b: 452); subtype B: l: ring, Erdaojingzi (after Cao, J. et al. 2010: 25); m: ring, Dadianzi (after Zhongguo 1996c: 190).

Once we leave the northern Bohai Rim, the first area in the west where penannular rings can be found is the Ordos Plateau (or the so-called “Northern Zone”). Here, bronze rings, earrings, and bracelets of this type have been found in the cemetery of Zhukaigou (Figure 6.12, a–e). Based on the ceramic typology, these tombs with the rings are dated to Phase III–V of the site, or around 1800–1300 BC. There are also two outstanding stray finds, which are U-shaped rings, with one sharp end and one flat end (Figure 6.12, f and g).³² By comparing them with objects from the Mongolian Plateau, we know that these two objects were probably used as hairpins.³³ Hairpins

³² Neimenggu and E’erduosi 2000: 123.

³³ Amartuvshin 2016. See also Rawson et al. 2020.

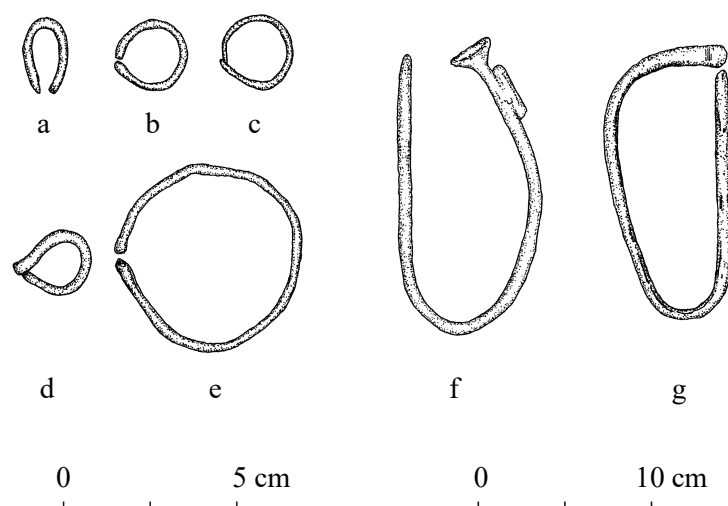


Figure 6.12 Bronze rings from Zhukaigou, c. 1800–1300 BC. a: earring; b–d: rings; e: bracelet; f, g: U-shaped hairpins (after Neimenggu and E’erduosi 2000: 122; 274; 276).

in this shape were used in the second half of the second millennium BC. They may be a version related to, or derived from, the penannular rings.

Like those at Dadianzi, all the earrings at Zhukaigou are forged, while an analysed finger ring, and a large ring which is probably a bracelet, are cast (Table 6.4). The chemical compositions of the Zhukaigou rings also echo what we have seen at Dadianzi—copper alloys with high levels of tin and low levels of lead (only one ring has an over 10% lead content) (Figure 6.13). These results show that the Zhukaigou rings and the northern Bohai Rim rings are not just typologically similar, but technologically close as well. Craftspeople who made these objects probably shared the same technical mind of how such rings should be properly made. However, if we compare all the metal objects from Zhukaigou with those from the northern Bohai Rim, there is still a remarkable difference. In the northern Bohai Rim, as we previously mentioned, most metal objects were made of bronze alloys with no more than 5% lead contents. This was also the only type of copper-based alloy used in the area. By contrast, at Zhukaigou, although most rings were also made of low- or moderate-leaded bronze alloys, there are also a few high (around 20–40%) leaded bronze ritual vessels and arrowheads. There is no evidence suggesting the local production of the bronze vessels. More likely, people in the Northern Zone obtained these high-

Table 6.4 Analysed bronze rings from Zhukaigou.

Object ID	Object type	Phase	Composition (%)			Shaping
			Cu	Sn	Pb	
M2012:2	earring	V	84.5	11.0	0.7	forging
M4007:2	bracelet	III	98.9	-	-	casting
M4035:1	bracelet	III	Cu			?
M4060:6	ring	IV	98.4	-	0.9	casting
M6011:4	ring	IV	Cu			?
T124(2):1	earring	V	75.0	8.5	12.7	forging
stray find	earring	III–IV	84.2	12.5	2.2	forging
stray find	earring	III–IV	81.3	17.0	-	forging
stray find	earring	III–IV	89.8	8.3	1.5	forging
stray find	earring	III–IV	90.4	8.6	-	forging
stray find	earring	III–IV	89.3	8.9	1.4	forging

Method of analysis: SEM-EDS, metallographic analysis; references: Liu, X. and Han, R. (1996; 2000).

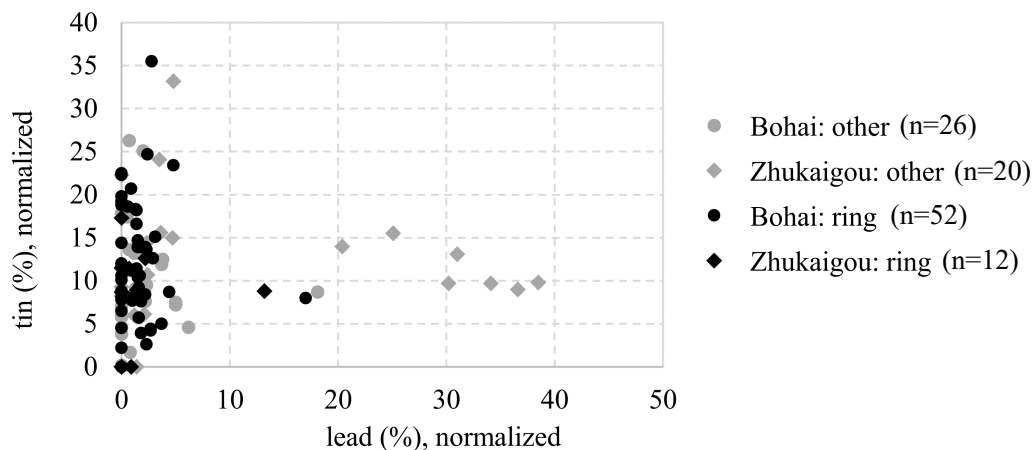


Figure 6.13 Distribution of tin and lead in the analysed metal objects from the two regions.

leaded bronze vessels from Central China. The existence of high-leaded bronze arrowheads suggests that unwanted ritual vessels may have been recycled and the alloys were reused for making other objects.³⁴ However, if this hypothesis is correct, the fact that high-leaded bronze

³⁴ At Zhukaigou, most tested metal objects belong to two time periods, either Phases III–IV (1800–1500 BC) or Phase V (1450–1300 BC). All high-leaded objects, as well as the ritual vessels, are from Phase V.

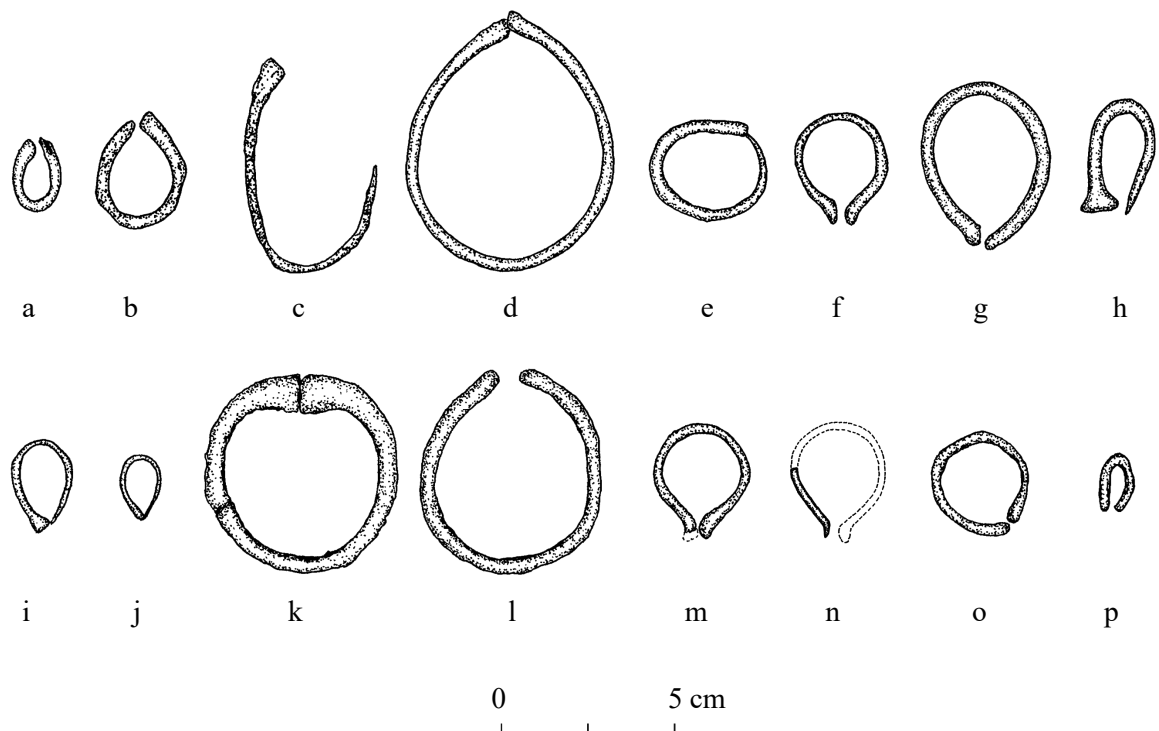


Figure 6.14 Metal rings from the Hexi Corridor. Donghuishan: a: gold earring; b, c: bronze earrings; d: bronze bracelet (after Gansusheng and Jilin 1998: 93); Gamatai: e: bronze bracelet (after Qinghaisheng and Beijing 2016: 181); Ganguya: f–h: bronze earrings (after Gansusheng and Beijing 2016: 189); Huoshaogou: i, j: gold earrings (after Bunker 1998: 607); Mogou: k: bronze bracelet (after Mao, R. et al. 2009: 21); Xingzhuangping: l: bronze bracelet (after Jia, J. 1996: 51); Yingwoshu: m: gold earring; m: bronze earring (after Gansusheng and Beijing 2011: 359; 363); Tianshanbeilu: o: bronze earring (after Qian, W. et al. 2001: 80); Nanwan: p: bronze earring (after He, X. 1987: 6).

alloys were not used to make rings suggests that, in both the cases of Zhukaigou and the Northern Bohai Rim, the craftspeople were probably aware of the material they were choosing. They did not just use low-leaded bronze alloys unconsciously. Instead, they may have chosen to use bronze alloys without high lead content to make the rings as well as most of the other metal products. In addition, as I have argued, this technological choice may have been reflected in the smelting process by avoiding copper and tin ores with high lead contents.

Thus, I think the high-leaded arrowheads and earring were probably made of recycled high-leaded bronze alloys which were originally used for ritual vessels.

When we move further west from the Northern Zone, we meet those penannular rings again in today's Gansu, Qinghai, and eastern Xinjiang, or around the Hexi Corridor. Most rings found here do not have clear dates, but the earliest of them can be safely dated to the first half of the second millennium BC.³⁵ The detail of some objects may not be fully recognisable from the pictures, but some of them show very clear trumpet-shaped ends or flat ends (Figure 6.14). The chemical compositions of the Hexi Corridor rings show that, among around sixty tested samples which are dated approximately to the second millennium BC, unleaded bronze is the most common material, as around 40% of the total tested objects were made of this material. Meanwhile, pure copper objects also account for about a quarter of the tested objects. Lead and arsenic, on the other hand, are identified in some objects, but their levels are usually lower than 5% (Figure 6.15).

Beyond the modern boundary of China, penannular rings have also been found at many sites in Central Asia and on the steppes.³⁶ In particular, if we follow the trumpet-shaped earrings—as the most distinguishing type of ring—the best-known area for such rings is the Zhetysu region (including part of western Xinjiang), extending roughly along the IAMC (Table 6.5; Figure 6.16).³⁷ The chronology of these trumpet-shaped rings is not very clear. Usually, scholars attribute the contexts in which the rings were found to the Andronovo culture. In the Zhetysu region, the earliest radiocarbon dates of the Andronovo culture (also known as the “Federovo type”) is about 1800 BC, while the latest are about 1400 BC. Therefore, the Central Asian

³⁵ Among these rings, those from Huoshaogou and Ganguya are clear examples of earring with one sharp end and one flat or trumpet-shaped end. Huoshaogou is dated by radiocarbon dates to 1950–1700 BC, while Ganguya is dated to 1800–1700 BC. See Gansusheng and Beijing2016: 296–299.

³⁶ Bunker 1998; Kuzmina 2007a: 264–265; 2007b; Lin, Y. 2002; Shao, H. 2014.

³⁷ A more detailed distribution of these rings, see Avanesova 1991: 51; Pl. 44.

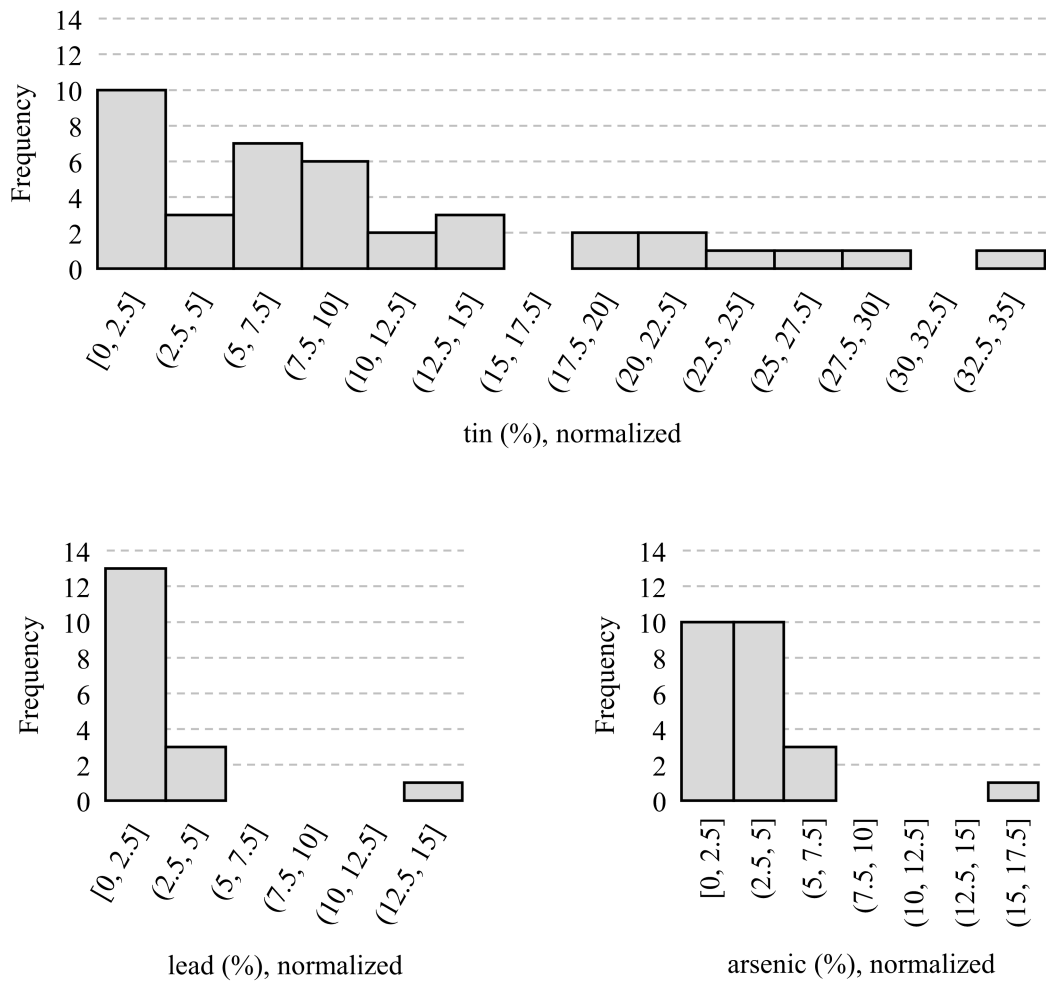


Figure 6.15 Distributions of tin, lead, and arsenic in the analysed Hexi Corridor rings, c. 2000–1000 BC (data: Chen, K. et al. 2018b; Gansusheng and Beijing 2011: 452–454; 2016: 333–352; Gansusheng and Jilin 1998: 191–195; Qinghaisheng and Beijing 2016: 187–192; Mei 2000: 39–40; Sun, S. and Han, R. 1997; Sun, S. et al. 2003; Xu, J. 2009: 33–49; Qian, W. 2006: 129–142; Yang, Z. et al. 2018).

earrings are chronologically comparable to those found in North China. The sites in Xinjiang where such trumpet-shaped earrings have been found, sometimes also attributed to the

Table 6.5 Trumpet-shaped earrings from western Xinjiang and Central Asia.

Site	Material	Reference
Adunqiaolu	bronze	Cong, D. et al. (2017)
Dzham	bronze	Kuzmina (2007a: 698)
Dzhartas	bronze	Kuzmina (2007a: 645)
Kul'saj	bronze	Goryachev and Mar'jashev (1998)
Kupukhta	bronze	Kuzmina (2007a: 645)
Kyzyl-Bulak	bronze	Bendezu-Sarmiento (2004)
Malyj Mys	bronze	Komarova (1952); Gimbutas (1965: 101)
Oy-Dzhaylyau	bronze	Goryachev (2004)
Rublevo VIII	bronze	Kiryushin et al. (2006)
Sangru	bronze	Kuzmina (2007a: 645)
Sokolovka	bronze	Zdanovich (1988: 170)
Tangbalesayi	bronze	Ruan, Q. et al. (2012)
Tamgaly	bronze	Goryachev (2004)
Tash-Tyube	bronze	Kuzmina (2007a: 667)
Tegermen-say	bronze	P'Yankova (1994)
Uzunbulak	bronze	Goryachev and Mar'jashev (1998)
Vuadil	bronze	Kuzmina (2007a: 667)
Xiabandi	bronze, silver	Xinjiang (2012: 24); Zhang, H. (2017: 5)

Andronovo culture, are probably later, as some of the sites are dated to as late as about 1000 BC.³⁸

In terms of alloy types of the Central Asian rings, we may refer to a study on the “Alakul type” metal objects by Y. V. Tigeyeva. The Alakul culture is defined as a subtype of the Andronovo culture, which was mainly in the Volga-Ural region and slightly earlier than the Federovo type. Tigeyeva analysed a group of around 200 Alakul metal objects, including 16 rings. Only one ring contains more than 2% lead, while all other rings have less than 1% lead. Meanwhile, the tin

³⁸ Molodin et al. 2012; Shao, H. and Zhang, W. 2019.

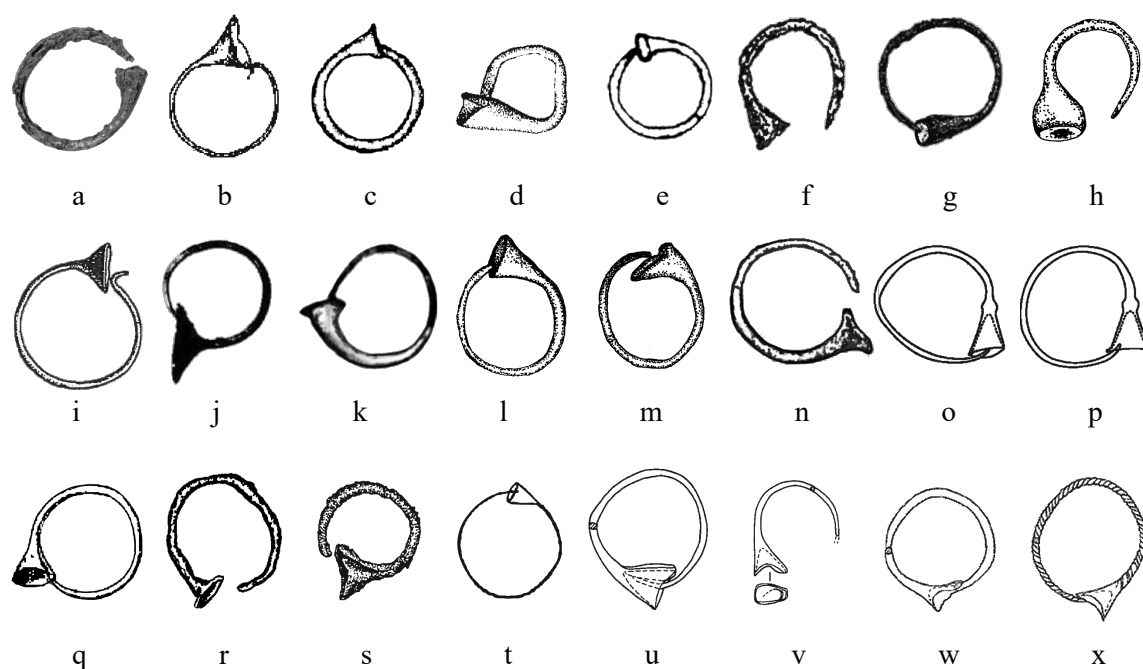


Figure 6.16 Trumpet-shaped earrings from western Xinjiang and Central Asia. a: Andunqiaolu; b: Dzham; c: Dzhartas; d: Kul'saj; e: Kupukhta; f, g: Kyzyl-Bulak; h: Malyj Mys; i: Oy-Dzhaylyau; j: Rublevo VIII; k: Sangru; l, m: Sokolovka; n: Tamgaly; o, p: Tangbalesayi; q: Tash-Tube; r: Tegermen-say; s: Uzunbulak; t: Vuadil; u–x: Xiabandi. w and x were made of silver; others were made of bronze (references see Table 6.5).

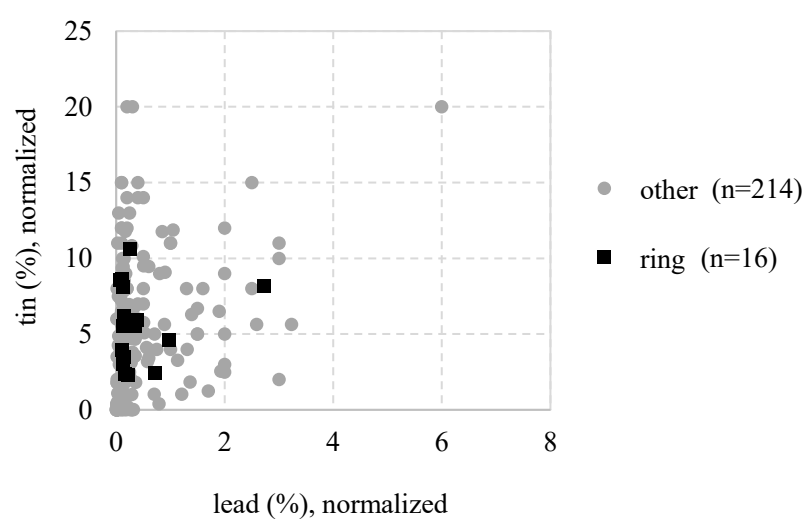


Figure 6.17 Distribution of tin and lead in the analysed Alakul culture rings from the Middle Low Tobol Basin (data: Tigeyeva 2013).

contents vary from 2 to 10%, with an average around 5.6% (Figure 6.17).³⁹ Compared with other types of Alakul objects, the tin and levels in rings are almost the same as those in other objects. Again, we see low-leaded bronze as the major type of bronze alloys.

Therefore, from the northern Bohai Rim to the Volga-Ural region, these steppe and Inner Asian communities all used metal objects mainly made of bronze without high lead contents. As I previously argued, small amounts of lead may have been introduced as the impurities in copper or copper-tin ores. Meanwhile, although the craftspeople normally did not use high leaded bronze alloys to make the rings, there were indeed a few rings with quite high lead contents (such as the one from Zhukaigou). As I previously suggested, this high leaded bronze alloy may have come from recycling leaded bronze ritual vessels, rather than intentionally adding lead to bronze alloys. The existence of this leaded bronze ring, as well as a few other rings with relatively high lead contents, suggests that the craftspeople may have not been strictly avoiding lead in their ring production. An opposite case may be the stricter aversion of lead by the craftspeople in the Hexi Corridor, as I will discuss in Chapter 7. In the case of the northern Bohai Rim, the making of penannular rings was certainly a local adoption of this steppe-Inner Asian ring tradition. People may have received the concepts and techniques of making such metal rings through their cultural exchange with the steppe neighbours, or through the direct immigration of the steppe people.⁴⁰ Driven by this external stimulation, the Bohai Rim craftspeople started to exploit local metal resources, while following roughly the same manufacturing techniques. By observing the rings made by these craftspeople, we can still trace the steppe-Inner Asian tradition in both the trumpet-shaped design and the choice of low-leaded bronze alloys.

³⁹ Tigeyeva 2013. The chemical compositions of Andronovo metal objects were also reported by other scholars. However, most early reports do not include the detailed information of the objects, such as their types, see e.g. Avanesova 1991; Chernykh 1970.

⁴⁰ See Chapter 2, distribution vs. circulation.

Mace Heads

Besides the penannular rings, the mace heads found in the northern Bohai Rim may also reflect a steppe-Inner Asian tradition. In general, the type of artefact called a mace head is a socketed clump made of stone, metal, or other materials. Such an object can be attached to a shaft as a blunt weapon, or, as David Anthony has pointed out, as a symbolic object used by certain people in the community.⁴¹ As I mentioned in the last section, stone and metal mace heads were very common in Eurasia during the Neolithic and Chalcolithic periods.⁴² At Gonur in Turkmenistan, for example, various stone and bronze mace heads have been found. According to the excavators, these objects only belonged to male tombs. In one of these tombs, no. 555, the occupant, 30–35 years old, was buried with a bronze mace head, as well as other grave goods such as four metal vessel (three silver and one bronze), two seals (one silver and one gypsum), and a bronze cosmetic flacon. Another example is tomb no. 500, in which there was a lead mace head, a lead ring, and two gold bands with beads. These two tombs are dated to around 2400–1600 BC.⁴³ At Shahdad, a site in south-eastern Iran, there is also a lead mace head discovered, dating to about 2500–1800 BC.⁴⁴ Metal mace heads were also found at sites associated with the Andronovo culture, such as Alakul.⁴⁵ Mace heads made of various types of stone materials were even more common. Examples of these objects have been found at Gonur,⁴⁶ as well as at Sintashta, dated

⁴¹ Anthony 2007: 160; Li, S. 2021.

⁴² Early examples of metal mace heads in West Asia, see Erez et al. 2016; Sebbane 2014; Shalev et al. 1992; Tadmor et al. 1995; Yahalom-Mack et al. 2015.

⁴³ Two tombs: Sarianidi 2007: 80–81; 108; 218; 220.

⁴⁴ Ḥakīmī 1997: 291; dating: Thornton and Lamberg-Karlovsky 2004.

⁴⁵ Salnikov 1952.

⁴⁶ Sarianidi 2007: 108–109.

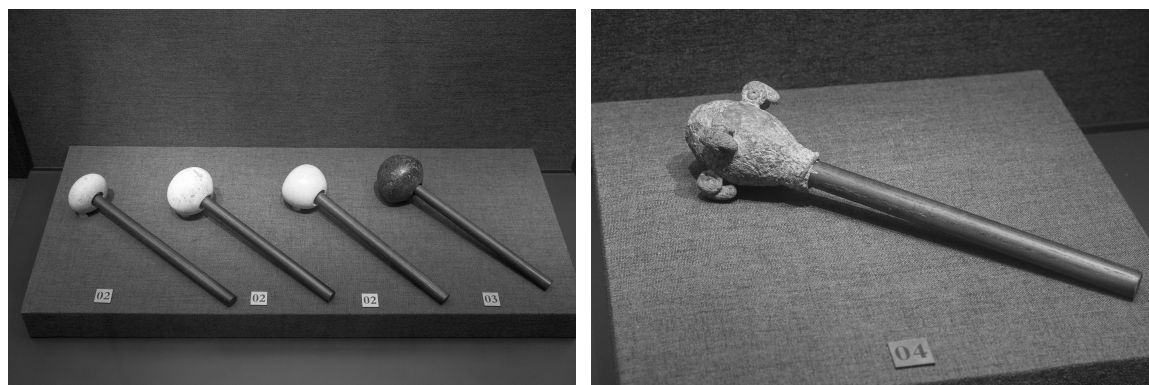


Figure 6.18 Stone and bronze mace heads from Huoshaogou, Gansu (photos taken in the Gansu Provincial Museum).

to around 2100–1800 BC.⁴⁷ Stone mace heads were also found at Andronovo sites such as Sopka-2 and Kenes.⁴⁸

In North China, mace heads similar to those steppe-Inner Asian ones have been found at several sites in the Hexi Corridor.⁴⁹ For example, about a dozen stone mace heads as well as a bronze one have been found at Huoshaogou, dated to around 1900–1700 BC, but the details of this site have not been fully published (Figure 6.18).⁵⁰ At Xichengyi, the excavators also found a stone mould for casting bronze mace heads (see Chapter 7, Figure 7.4).⁵¹ This suggests that people living in the Hexi Corridor may already have started producing bronze mace heads locally. In eastern Xinjiang, stone and metal mace heads dating to the second millennium BC have also been found at several sites, such as Xiaohe (stone) and Sa'ensayi (bronze).⁵²

⁴⁷ Gening et al. 1992: 139; 148; 232; 320; 336; dating: Anthony 2007: 374–376.

⁴⁸ Molodin 2012: v. 3, 153; Zdanovich 1988: 75.

⁴⁹ Li Shuicheng published a book and several papers discussing the mace heads in North China and its typological connections with those in Central Asia and West Asia: Li, S. 2012; 2017; 2018b; 2020; 2021.

⁵⁰ Li, S. 2020; see also Wen, C. Wen 2018: 328; dating: Zhongguo 1991: 272.

⁵¹ Chen, G. et al. 2014.

⁵² Xinjiang 2013: 56.

Table 6.6 Lead objects from the steppes and Central Asia, c. 2800–1600 BC.

Site	Object	Reference
Altyn-depe	lumps or ingot fragments	Salvatori et al. (2002)
Ekibastuz	a piece of lead-copper alloy	Merts (2017: 76)
Elunino	two earrings	Degtyareva et al. (2010); Grushin (2009a)
Gonur	rings, discs, a vessel, mace heads	Kraus (2016); Sarianidi (2007: 81)
Iagshiin Khödöö 1	rings and an earring	Kovalev and Erdenebaatar (2009, 2014)
Kalyvanskoe 1	an earring	Zhang, L. et al. (2017)
Sarazm	an ingot weighing 10 kg	Kuzmina (2007a: 212)
Shahdad	a mace head	Ḥakīmī (1997: 291)
Suukbulak	plates up to 5 kg	Kuzmina (2007a: 92)
Tash-Tyube	beads	Kuzmina (2007a: 90)
Tyumen	a ring	Merts (2017: 76)
Ulaan Khudag 2	a ring and an earring	Tishkin et al. (2015)

Lead, Gold, and Silver

The third cultural trait through which we can discuss the origin of the northern Bohai Rim metallurgical tradition is the use of particular types of metal. In the previous section, I have argued that the use of low-leaded bronze was probably a technological tradition from the steppe. In this section, I will further suggest that the Dadianzi lead and gold objects may also reflect a steppe-Inner Asian tradition.

Small lead objects have been discovered at several steppe and Central Asian sites (Table 6.6). Since most contexts in which the objects were found have not been dated by absolute dating methods, we can only suggest the dates of these objects by the archaeological cultures related to

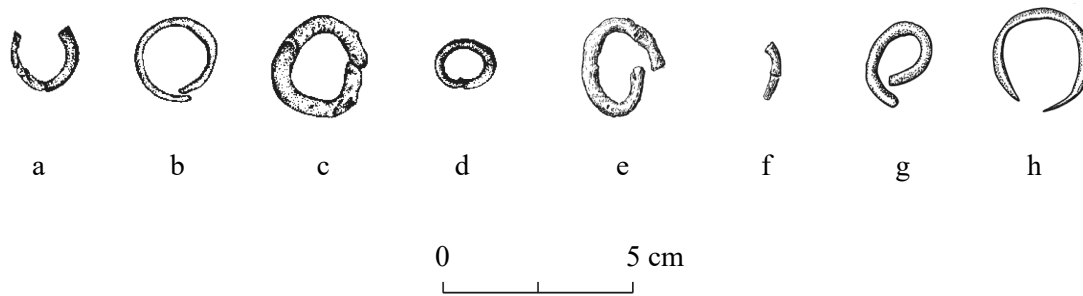


Figure 6.19 Metal rings from the Khovd Province, Mongolia. Lead (a–c) and bronze (d) rings from Iagshiin Khödöö 1 (after Kovalev and Erdenebaatar 2009: 157); lead rings (e, f) from Ulaan Khudag 2 (after Tishkin et al. 2015: 38); lead (g) and bronze (h) earrings from Kalyvanskoe 1 (after Zhang, L. et al. 2017: 19).

their contexts.⁵³ In this way, most of these lead objects are roughly dated to the period from 2800 to 1600 BC. For example, lead objects have been found in the Altai region. At Iagshiin Khödöö 1, a site in today's Khovd Province of Mongolia, three lead rings have been found in a burial together with a bronze one. Like some Bohai Rim rings, those rings at Iagshiin Khödöö 1 are not closed. They were made by bending metal wires into circles (Figure 6.19, a–d). Two radiocarbon dates obtained from the bone samples suggest that the date of the tomb is about 2600–1850 BC.⁵⁴ At another site, Ulaan Khudag 2, two lead earrings (Figure 6.19, e and f) have been found from a stone slab tomb which is dated by radiocarbon dates to 2650–1600 BC.⁵⁵ Such lead rings were also seen at the nearby but further north-west sites which are associated with the Elunin culture in the Ob and Irtysh River valleys, such as Ekibastuz, Elunino, Kalyvanskoe 1, and Tyumen.⁵⁶ At Kalyvanskoe 1, dating to 2500–1700 BC, a lead and a bronze rings (Figure 6.19, g and h) were found. Together with the objects, there are also metallurgical

⁵³ See Chapter 2 for the discussion of archaeological culture and relative dating.

⁵⁴ Kovalev and Erdenebaatar 2009; 2014.

⁵⁵ Tishkin et al. 2015.

⁵⁶ See references in Table 6.6.

remains, including copper ores and slags. The latter are thought to have been left by smelting copper ores and polymetallic ores containing mainly copper, tin, and bronze (copper-tin).⁵⁷

If we further trace this tradition of making and using lead objects, we may then arrive in Central Asia. Various lead objects were found at sites such as Gonur. One special discovery is a bar of lead, considered to be an ingot, from Sarazm in today's Tajikistan. Sarazm is located in an area with rich deposits of polymetallic ores. Evidence relevant to smelting activities has been found throughout the settlement period of the site, which is from 3500 to 2000 BC.⁵⁸ The context in which the lead bar has been found belongs to Sarazm III–IV, dating to 2850–2000 BC.⁵⁹ There is no evidence suggesting any particular use of lead at Sarazm, while most analysed copper-based objects from the site also turn out to be made of relative pure copper.⁶⁰ Therefore, such a lead bar was probably produced for export purposes. Lead (galena) smelting remains were also identified at Altyn-depe, a site lying on the northern foothills of the Kopet Dag Mountains.⁶¹ In the Zhetysu region, there is also evidence for smelting lead as well as silver from lead during the late third to the early second millennium BC, as stone tools associated with the Andronovo culture were discovered at several silver-lead mines. But why did people extract lead? Based on the case of Altyn-depe, there may have been a system of interrelated manufacturing activities, from the use of galena and litharge as colour pigments to the extraction of silver.⁶² Lead was certainly one of the products (or by-products). It was then used to make those small objects mentioned above. Some scholars also believe that lead was intentionally added to copper alloys to make leaded bronze. For example, in his *Ancient metallurgy in the USSR*, Chernykh noted

⁵⁷ Zhang, L. et al. 2017. See also Grushin 2009b.

⁵⁸ Kuzmina 2007a: 211–212; Anthony 2007: 419–421.

⁵⁹ Isakov 1994.

⁶⁰ Isakov et al. 1987.

⁶¹ Salvatori et al. 2002.

⁶² Ibid.

that, without providing further references, “(in Margiana) copper-lead alloys, in which the concentration of lead can reach 8–10%, are very common”. Moreover, Chernykh mentions that in one particular type of object, the “cosmetic bottles”, the concentration of lead is much higher than in other objects. Chernykh considers this as evidence for deliberate alloying leaded bronzes.⁶³ The analysis of Altyn-depe copper-based objects also shows that some objects contain high lead contents, such as a stamp seal with 52% copper, 41% lead and 7% arsenic.⁶⁴ Therefore, there may have been three types of lead-related metal materials used for making objects. The first was relatively pure lead; the second was copper with a low level of lead as a result of utilising polymetallic ores or adding lead ores as fluxes; the third was copper/bronze intentionally alloyed with lead. As a reminder, when we look at Dadianzi, only the first two types of metal material seem to have been used, but not the intentionally alloyed leaded copper/bronze.

Meanwhile, two precious metals which were commonly used in Central Asia, gold and silver, were rare in early East Asia. As Jessica Rawson showed, gold was not widely accepted by communities in the modern territory of China until the late first millennium BC.⁶⁵ The area with the most gold objects which can be dated to around the second millennium BC is the Hexi Corridor (Figure 6.20), especially at Huoshaogou, as gold rings in various forms have been found. Typologically, the earrings and nose rings are also in the penannular ring style with two flat ends. Among the objects found at Huoshaogou, there is also a silver nose ring. This is probably one of the only three second millennium BC silver objects discovered in China. The other two silver items are a pair of trumpet-shaped earrings found at Xiabandi in western Xinjiang, dating to 1500–1100 BC.⁶⁶ The distribution of gold and silver objects in Xinjiang and the Hexi Corridor

⁶³ Chernykh 1992.

⁶⁴ Salvatori et al. 2002: 96.

⁶⁵ Rawson 2018. The question of the absence of gold in early China is first raised by Bunker and is also noted by Sherratt: Bunker 1993; Sherratt 2006.

⁶⁶ Xinjiang 2012: 13. See also Wu, Y. 2012.

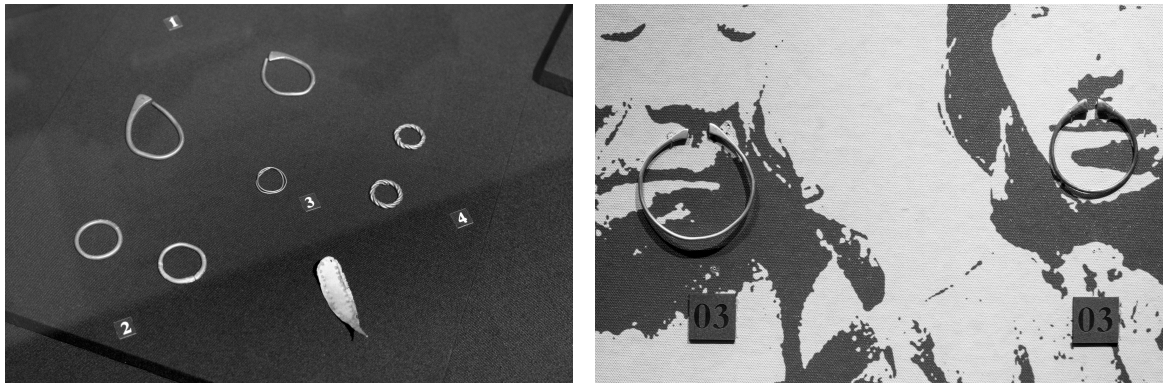


Figure 6.20 Gold and silver rings from Gansu and eastern Xinjiang. Left: 1: two earrings, Huoshaogou; 2: two earrings, Tianshanbeilu; 3: earring, Mogou (photo taken in the “Gold in early China” exhibition in the Jinsha Museum, Chengdu); right: gold (left) and silver (right) nose rings from Huoshaogou (photo taken in the Gansu Museum).

probably reflects the important route of the Inner Asia Mountain Corridor (IAMC), connecting East Asia to Central Asia (Chapter 2).

A Matter of Choice

Interestingly, it seems that the adoption of gold and silver just stopped somewhere at the end of the Hexi Corridor. This distinction between people living in Central China and their western neighbours, according to Jessica Rawson’s suggestion, was probably due to the long-standing (back to the Neolithic) aesthetic tradition of appreciating other materials such as jade by the eastern inhabitants. Under this circumstance, these people often consider metallic materials such as gold and silver “exotic”.⁶⁷ Besides the absence of gold and silver, both the penannular rings and the mace heads were also almost absent in Central China during the first three quarters of the second millennium BC.⁶⁸ Penannular rings were never found there, while the only potential

⁶⁷ Rawson 2018.

⁶⁸ The last quarter of the second millennium BC is a different case, since objects such as rings and maces were much more widely used in Central China, see e.g. Li, S. 2020.

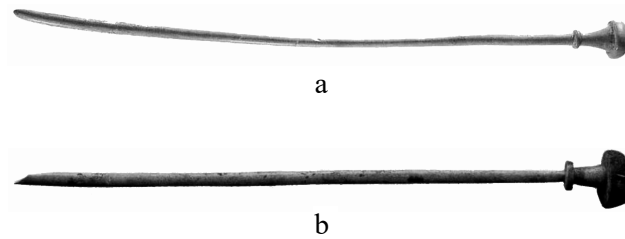


Figure 6.21 Two staffs from Erlitou. a: ivory, found near the casting workshop; b: bone (replica, original object not well preserved), 82IXM10:8 (after Li, S. 2020: 87).

examples of maces are two staffs, one made of ivory (47 cm long) and the other made of bone (only the head preserved), found at Erlitou (Figure 6.21, a).⁶⁹

The absence of these cultural traits in Central China confirms that the traditions of using those objects in the northern Bohai Rim cannot have come from central China. These traditions must have come from the steppes.⁷⁰ More importantly, the acceptance of these cultural traits by people in the northern Bohai Rim and the rejection of the same cultural traits by people in Central China suggests that people did not simply adopt everything they received. Instead, people made their choices based on their own cultural contexts and their own understanding of the objects. In the case of Dadianzi, people who adopted the use of gold, bronze, and lead as well as penannular rings and mace heads must have had known that these objects had a steppe connection. Thus, the decision to use such objects and materials was probably a way to display such a steppe connection. In the case of Central China, however, we do not know whether people rejected these metals and metal objects due to their implied connection with the steppes—which people tried to avoid in this case—or merely due to the exoticness. Nevertheless, it is clear that the

⁶⁹ Li, S. 2020.

⁷⁰ I point this out since, as I will discuss in the next section, the “Erlitou style” vessels and the lacquerwares from Dadianzi suggest possible connection with Central China. People may suggest that the traditions of using certain metal objects and metals may also have come via the same connection. Since these cultural traits were absent in Central China, I think this suggestion is not possible. In the next section, I will also argue that the use of metal objects seems to have been a practice incompatible with the use of southern style vessels and lacquerwares.

decision was also made due to some internal factors. This reminds us of what we discussed in Chapter 2, as both the external stimulation and the internal adoption, adaptation, and innovation contributed to the cultural contact.

Inside the Dadianzi Society: Social Structure, Identities, Adaptation

According to the previous discussion, I have suggested that the ideas of making certain types of metal object—rings and mace heads—with certain types of metal—bronze, gold, and lead—probably came from the steppes as some of the steppe-Inner Asian metal-using traditions. Meanwhile, I have also suggested that, for people at Dadianzi to accept particular metal-related ideas in the particular ways, the choices depended not only on external stimulation, but also on internal factors in a community. In this section, I will rely on the analyses of the burial patterns to further argue that the use of metal objects at Dadianzi reflects a certain steppe-related cultural identity. With this way of metal use, I will also suggest that people may have perceived different metals based on their colours.

The Burial Patterns and the Metal Objects

The burial patterns of Dadianzi have been studied by many scholars to understand the social structure of the community.⁷¹ These studies have shown that some tombs were clearly larger and had more grave goods than others. Tomb M672, for instance, is near the western end of the northern section. Like most burials, it was a rectangular shaft tomb, 3 metres long, 1.1 metres wide, and 4.6 metres deep from its bottom (Figure 6.22, left). That makes it one of the biggest tombs (15.3 m³ by volume) at the site. On one side of the burial chamber there was an L-shaped

⁷¹ Flad 2001; Shelach-Lavi 2001.

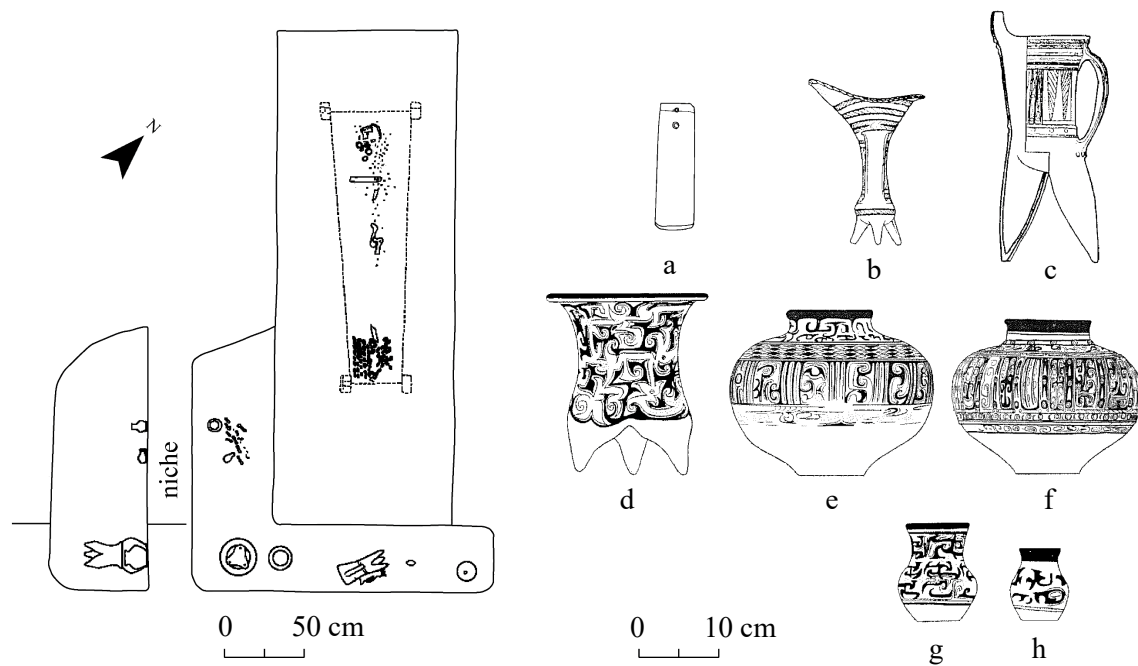


Figure 6.22 Plan of Tomb M672 and some of its grave goods: a: jade axe; b: ceramic *jue*; c: ceramic *gui*; d: painted ceramic *li*; e–h: painted ceramic (after Zhongguo 1996c: 50; 159; 200).

niche, providing additional space to hold ceramic and lacquer vessels, seashells, and a pig's hoof. There were seven ceramic vessels in this niche (Figure 6.22, right, b–h), while the average number of vessels per tomb was only 1.6. Lacquer vessels were even rarer. Among all the tombs, only thirty-eight had lacquer vessels, and this tomb had at least two, one of which is decorated with turquoise inlays. A further look at the ceramic vessels shows that five of them are painted with colours (Figure 6.22, d–h). About two hundred tombs had such painted wares, while the others did not. Among the ceramic vessels in the tomb, there were also a *jue* (Figure 6.22, c) and a *gui* (d) vessels lying in the southern part of the niche. These two vessel types, together with the *he* vessel found in other tombs, were not common at Dadianzi, as they were only found in fourteen tombs. These vessels relate directly with the ceramic vessels found, at a similar time, in the middle Yellow River Valley, especially at Erlitou (Chapter 5). This suggests some cultural contact between Central China and the northern Bohai Rim, which remains puzzling and have not been explained satisfactorily. In the middle of the burial chamber of M672 was a wooden coffin. The tomb occupant was about thirty-five years old, sex unidentified, with two bronze

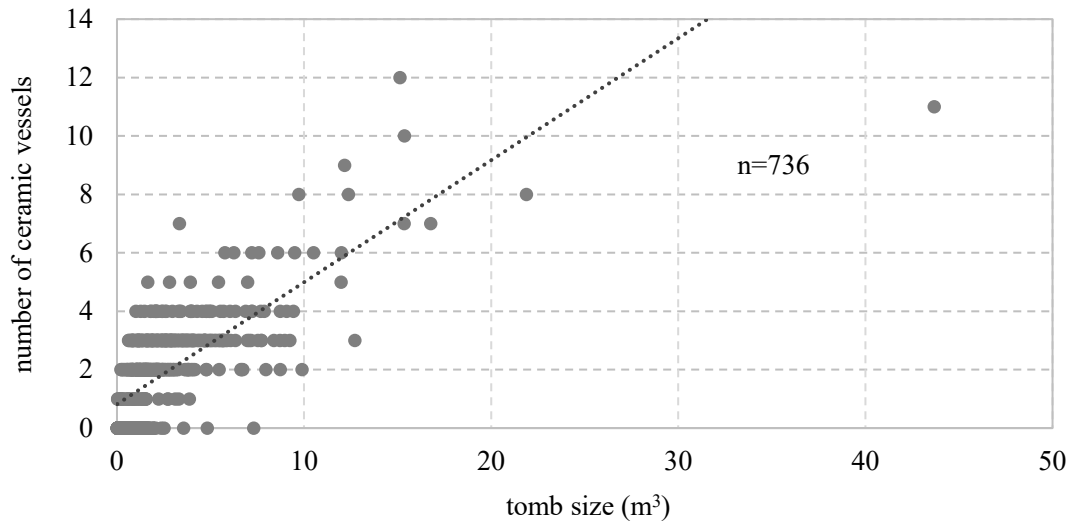


Figure 6.23 The relationship between tomb size and number of ceramic vessels.

earrings and a turquoise bead near the head. A jade axe (Figure 6.22, a) was placed near of the individual's chest. Some bone arrowheads were put near the feet. There were also many turquoise and seashell beads around the body, probably as the original decoration on the clothes. In the rammed earth covering the coffin, there were also the remains of a pig and a dog, another feature only seen in a small number of tombs.

To further examine the differences among the burial patterns, I choose a few criteria and put them into a statistical model.⁷² The first two criteria I have chosen are tomb size and number of ceramic vessels, since these numbers/values are available with most tombs. These two criteria seem to be correlated, as larger tombs tended to have more ceramic vessels (Figure 6.23).

⁷² This study is possible since all Dadianzi burials were excavated in the same period of time and well published in the report. The large number of the burials and the fact that most of them are well preserved also facilitate the statistics. The raw data used in this section is from the report: Zhongguo 1996c: 338–409.

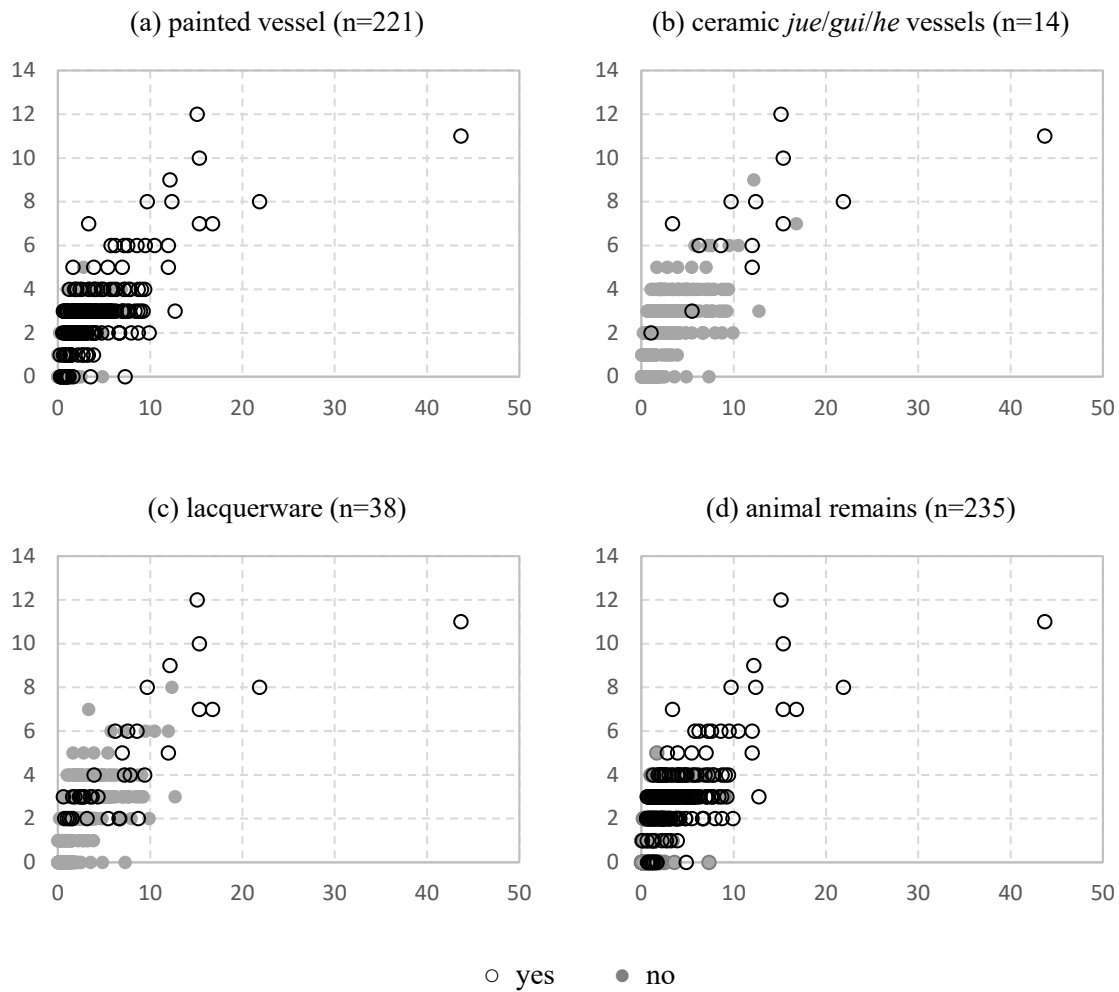


Figure 6.24 Four types of grave goods and their relationship with tomb size and number of ceramic vessels: (a) painted vessels; (b) ceramic *jue/gui/he* vessels, (c) lacquerware; (d) animal remains.

Table 6.7 The coexistence of metal objects and the four types of grave goods

(a) painted vessel (n=221)	number	%	(b) animal remains (n=235)	number	%
animal remains	141	64	painted vessel	141	60
lacquerware	27	12	lacquerware	34	15
<i>gui/jue/he</i>	14	6	<i>gui/jue/he</i>	14	6

(c) lacquerware (n=38)	number	%	(d) <i>gui/jue/he</i> (n=14)	number	%
animal remains	34	90	animal remains	14	100
painted vessel	27	71	painted vessel	14	100
<i>gui/jue/he</i>	10	26	lacquerware	10	72

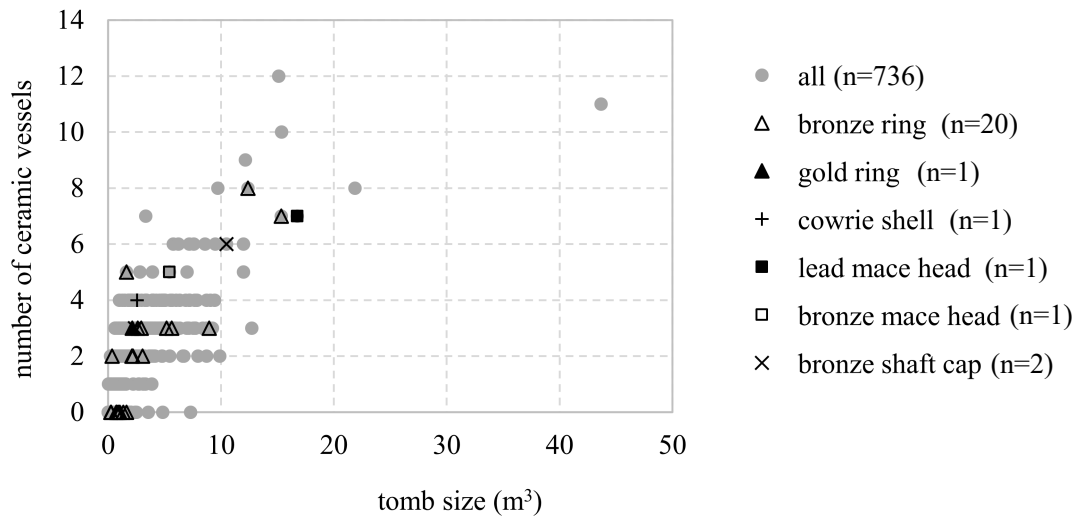
Therefore, I suggest that these two criteria can be used together to indicate the wealth and the social power of the buried individuals.⁷³

We may further consider the presence of four types of grave goods previously mentioned: painted vessels, the “Erlitou-style” ceramic *jue*, *gui*, and *he* vessels, lacquerwares, and animal remains.⁷⁴ As Figure 6.24 shows, on the one hand, all four types of grave goods were more likely to be seen in larger and vessel-rich tombs than in smaller and vessel-poorer tombs. This may also help confirm that tombs with larger size and more ceramic vessels are indeed more elaborate than the others. On the other hand, each type of object seems to have a different level of correlation with the suggested richness of the tombs. This can be clearly shown by the coexistence of the four types of grave goods (Table 6.7). Among them, the Erlitou-style *gui/jue/he* vessels are probably the strongest indications of wealth, as all tombs with those vessels also had painted vessels and animal remains, while 10 out of 14 (71%) *gui/jue/he* tombs had lacquerwares. The presence of lacquerwares is also a relatively strong indicator, as most lacquerware-holding tombs also had animal remains and painted vessels. By contrast, animal remains and painted vessels are more likely to have been in moderate tombs.

In terms of the metal objects, however, they were not all buried in the large and vessel-rich tombs (Figure 6.25). Metal rings, in particular, also appeared in some small-sized tombs with few vessels. This echoes our previous observation that those rings were not restrictively owned by a small group of people. The tombs with the weapon-related metal objects, the mace heads and the shaft caps, tend to be relatively larger and vessel-rich, but they were not the grandest tombs as well. In addition, the metal objects and the lacquerwares or the Erlitou-style vessels (Table

⁷³ At Dadianzi, most tombs are single burials, there are only about ten tombs with more than one occupant, usually a female or a male adult with a child. For these tombs, I assume that most grave goods belong to the adult occupants. Therefore, I do not treat them separately from other tombs.

⁷⁴ These are not the only four types of object which may indicate the differences between the tombs. However, I choose them since they are relatively common, well published, and easy to be quantified.



Grave Goods and Two Cultural Identities

According to the above statistics, the burial patterns of the Dadianzi cemetery reflect two characteristics of the community. First, people in this communities certainly had different level of wealth which can have been displayed in the burials. More precisely, Rowan Flad suggested that there were two types of value reflected in the Dadianzi tombs. The objects which are directly attached to the tomb occupants, such as the metal rings, reflect what he calls the “deceased grave values”. That is to say, these values were directly related to the identities of the individuals, such as wealth. On the other hand, objects put in the niches and rammed earth reflect what Flad calls “ceremony grave values”. These objects, such as the ceramic vessels and animal remains, are more related to how the community valued the individuals.⁷⁵

The second characteristic reflected by the burial pattern is something different from wealth. As I previously suggested, people buried with some types of object were usually not buried with some other types of object. To reflect these two characteristics, I will define them as two types of identities. The first is what we may call “social identities”, such as wealth and social power. In the previous case of Erlitou, I have argued how the social identities help form the social status of an individual. In the case of Dadianzi, the social identities of an individual are reflected by the grandness of the tomb, such as its size and the number of grave goods, or the two values suggested by Flad. The other type of identity is what we may call “cultural identities”, this term is often used to refer to a way for a group of people to express their distinct culture, or the distinct way by which people are culturally connected to each other, such as, in many contemporary cases, gender, ethnicity, religion, or the membership of an online community.⁷⁶ In the Dadianzi

⁷⁵ Flad 2001.

⁷⁶ The theories of social and cultural identities have a long and complex history in archaeology. Reviews of identity in archaeology, see e.g. Díaz-Andreu García 2005. Material reflections of cultural identity, see the discussion in Fowler 2010.



Figure 6.26 Distribution of different types of grave goods in the Dadianzi cemetery.

cemetery, the incompatibility of metal objects and lacquerwares/Erlitou-style vessels may suggest that these two types of object were associated with two incompatible cultural identities. As we previously discussed, the use of penannular rings and mace heads were certainly steppe traditions. People at Dadianzi must have also acknowledged this origin of these traditions. The use of lacquerwares and “Erlitou-style” vessels, however, suggest a connection with the south, as both types of object were widely used in Central China.⁷⁷ The coexistence of two mutually exclusive cultural identities in the Dadianzi community is also reflected in the spatial distribution of the tombs with these grave goods. As Figure 6.26 shows, tombs with the same type of object tended to cluster in one section of the cemetery. For example, several tombs with lacquerwares were all in the north-eastern corner of the cemetery, while most tombs with rings were all in the

⁷⁷ Du, J. 1995; Gao, W. 1986; Yang, Y. 2018.

south-western part. This suggests that how the burials were clustered in the Dadianzi burials, as have been pointed out by the excavators, must have been related to the cultural identities.

In terms of the reasons behind the incompatible practices of owning metals and owning “southern” vessels, these two practices may reflect two cultural groups coexisting in the Dadianzi community. One group of people, the metal-users, probably held the metal weapons and wore the metal rings in order to display their connections with the steppe, while the other group of people, the “southern vessel” owners (and people who arranged their burials), probably tried to do the opposite—they may have carefully avoided displaying any metal objects in order not to be associated with the “steppe identity”.

Besides the wishes to show identities by placing different objects in tombs, Jessica Rawson reminded me that the use of two types of object may also reflect two sources of acquisition of display goods.⁷⁸ In the case of Erlitou, we assume that the bronzes were probably given by the rulers based on the social status of the receivers. For those people at Dadianzi, did they also receive the objects from their leaders? Or were they able to acquire the objects from other sources? The current archaeological evidence may not be able to answer these questions directly, but we may refer to a later model proposed by William Honeychurch as what he called the “patron-client relations”. In such relations, leaders gave gifts in order to obtain others’ loyalty or service in exchange. Therefore, what reflected by the richness of a burial may not be the high social status of the buried individual, but the closeness between the individual and the leader.⁷⁹ Although what Honeychurch describes happened in a much later time period (the second half of the first millennium BC), the “patron-client” system provides us with an alternative explanation of the possession of two different types of grave goods—as these objects may reflect two

⁷⁸ Jessica Rawson, personal communication.

⁷⁹ Honeychurch 2014; 2015: 249–252.

different types of relation with the leaders. In the Dadianzi cemetery, as we previously assumed, those individuals with the metal weapons may have been the leaders, but we still cannot confirm this based on the current materials.

In all, by analysing the burial patterns, we can confirm again that the use of metals in the Dadianzi community was due to its cultural contact with the steppe, as these objects were integrated into the expression of a certain “steppe identity”, which may have been considered incompatible with the “southern identity”, held by the other group of people who were buried with lacquerwares or Erlitou-style ceramic vessels.

All That Glitters Is Not Gold

Based on our previous discussion, it is quite clear that the tradition of using and making metal objects in the norther Bohai Rim was a steppe tradition adopted by the local communities. Meanwhile, we should also admit that the communities did not passively accept what came externally. As the previous interregional comparisons show, there were also regional characteristics, such as the absence of certain metals in a particular region. In particular, in Central Asia, we can see that gold, silver, bronze (with or without high lead), and lead were all used to make small objects. Lead and high-leaded bronze were missing in Xinjiang and the Hexi Corridor until late second millennium BC (Chapter 7), while gold, silver, and unleaded bronze were used. In northern Bohai Rim, gold, lead, and not high-leaded bronze were found, while the other two were missing (Table 6.9). Why did people in one region use a certain metal while those in another region did not? Why did people at Dadianzi use bronze, gold, and lead, but not silver, copper, or leaded bronze? In my view, these questions may be related to how people perceived these metals.

A detail suggested by the burial pattern may help us find some answers. From a modern perspective, we may assume that gold is more valuable than bronze, while bronze is more valuable than lead. The Dadianzi burial patterns (Figure 6.25), however, suggests a different

Table 6.9 Metal materials used in three regions.

Metal	Central Asia	Xinjiang/Hexi Corridor	Northern Bohai Rim
gold	Y	Y	Y
silver	Y	Y	N
lead	Y	N	Y
copper	Y	Y	N
bronze			
<i>0–1% lead</i>	Y	Y	Y
<i>1–10% lead</i>	Y	N	Y
<i>>10% lead</i>	Y	N	N

hierarchy of the metals. The only gold ring was found in a tomb which is 2.2 m³, with three ceramics, while the average size of the tombs with bronze rings is 3.5 m³, and these tombs have on average two ceramics. This means that the value of the gold ring was probably not that different from the value of a bronze one. Meanwhile, if we compare two tombs with mace heads, the tomb with the lead mace head, Tomb M371, was probably more elaborate, since the tomb is not only bigger (16.8 m³ vs. 5.4 m³), but was also supplied with more ceramic vessels (7 vs. 5), more personal ornaments, and more buried animals. Hence, lead was perhaps more valuable than bronze.

Of course, these suggestions are prone to be biased due to the small sample size. However, provided that such a value hierarchy did exist, it may reveal that, as I argue, the use of those three particular types of metal by the Dadianzi people may have been due to the colours of the metals. As previously discussed in Chapter 4, gold, silver, and copper represent three major metallic colours which were adopted by many early communities, including those we just mentioned in this section. Gold has a natural “golden” colour, but this colour can also be imitated by mixing certain amount of copper and tin, which creates bronze. As some scholars argue, early

bronze objects may have been favoured because of their gold-like hue.⁸⁰ The colour of silver, meanwhile, can be imitated by metals such as tin, lead, and their alloys. Although pure tin and lead were not commonly used to make objects since they oxidize easily, examples of early communities using such objects did exist.⁸¹ In addition, copper alloyed with high levels of tin or arsenic contents can also achieve greyish colours.⁸² The reddish colour of pure metal copper is a unique colour, and it is not likely to be imitated by other metals.

In the northern Bohai Rim, three major types of metal used here—gold, lead, and not high-leaded bronze—probably represented two types of colour. Both gold and bronze were used for their golden colour, while lead was perhaps used for its greyish, silver-like colour.⁸³ This may explain why the individual buried with the gold earring at Dadianzi does not appear to have had a higher social status than those buried with bronze earrings (unless gold marked an identity which is not identified by us). This can also explain why both copper and lead were used as materials for mace heads. What these two metals stood for were not two types of metal from our modern chemistry perspective, but two metallic colours. The only missing colour at Dadianzi, if compared with the other regions, was the reddish colour of pure copper.⁸⁴ Nevertheless, personal

⁸⁰ Radivojević et al. 2013; 2018.

⁸¹ E.g. Gillis 1999.

⁸² Mödler et al. 2017; Radivojević et al. 2018.

⁸³ One question remains unclear is whether the production of lead in the northern Bohai Rim was associated with the desire of silver. Lead ores from several modern mines in the area are indeed argentiferous: e.g. Baiyinnuo and Haobu mines, Inner Mongolia: Zhongguo 1996a: v. Inner Mongolia, 130; 134. However, since no early silver object or evidence for silver smelting or cupellation has been found in this area, we can only assume that lead is the only type of metal which was smelted and used to make silvery objects.

⁸⁴ Pure copper objects were rarely used. The only exceptions are a copper earring found at Erdaojingzi, a site chronologically and spatially close to Dadianzi, and a copper chisel found at Zhangying in the Hai River Valley, dated roughly to the later period of the Dadianzi cemetery. Erdaojingzi: Cao, J. et al. 2010; Wang, Y. et al. 2013; Zhangying: Beijingshi and Beijingshi 2007: 98; Cui, J. et al. 2008.

ornaments such as rings made of pure copper were not as common as golden (gold or bronze) and silvery ones in other two regions either.

Therefore, although we do see quite a few leaded bronze objects used at Dadianzi cemetery, leaded bronze as a particular material may not have been recognised or deliberately created by people. Meanwhile, lead itself was appreciated probably due to its silver-like colour. If we compare Dadianzi with the previously mentioned cases of Erlitou and Tepe Hissar, at Erlitou and Hissar, leaded bronze was associated with casting objects either with large size, or with high complexity, such as bronze vessels (Erlitou) and figurines (Hissar). The castability of leaded bronze and the relatively low cost of lead against tin may have encouraged the use of this material. When bronze alloys were used to make rings and earrings at Dadianzi, on the other hand, those benefits of lead may not have been well reflected, while other properties of metals, such as colour, may have become more noticeable.

East Wind, West Wind

Unleaded and Leaded Bronzes in the Hexi Corridor

After the previous two case studies, covering Central and North-east China, I shall move to North-west China, to the Hexi Corridor (Figure 7.1). The Hexi Corridor is the name given to a strip of narrow land between the northern slopes of the Qilian Mountains (the north-eastern border of the Tibetan Plateau) and the deserts extending into Mongolia, or roughly today's Gansu and the eastern part of Xinjiang Provinces. As the name suggests, the Hexi Corridor is a natural route through which people can move relatively easily from Central Asia into East Asia. New types of material culture and technology from the west were often first introduced into this region, before being adopted by people in the Yellow River Valleys.¹ For early metallurgy, the Hexi Corridor is a region with abundant metal resources, including copper, tin, and lead. Some of the earliest metal objects and metallurgical remains on the modern territory of China have also been found in this region. Therefore, the Hexi Corridor is an important area of study for us to understand the development of metallurgy in North China, especially how different mechanisms,

¹ Stevens et al. 2016.

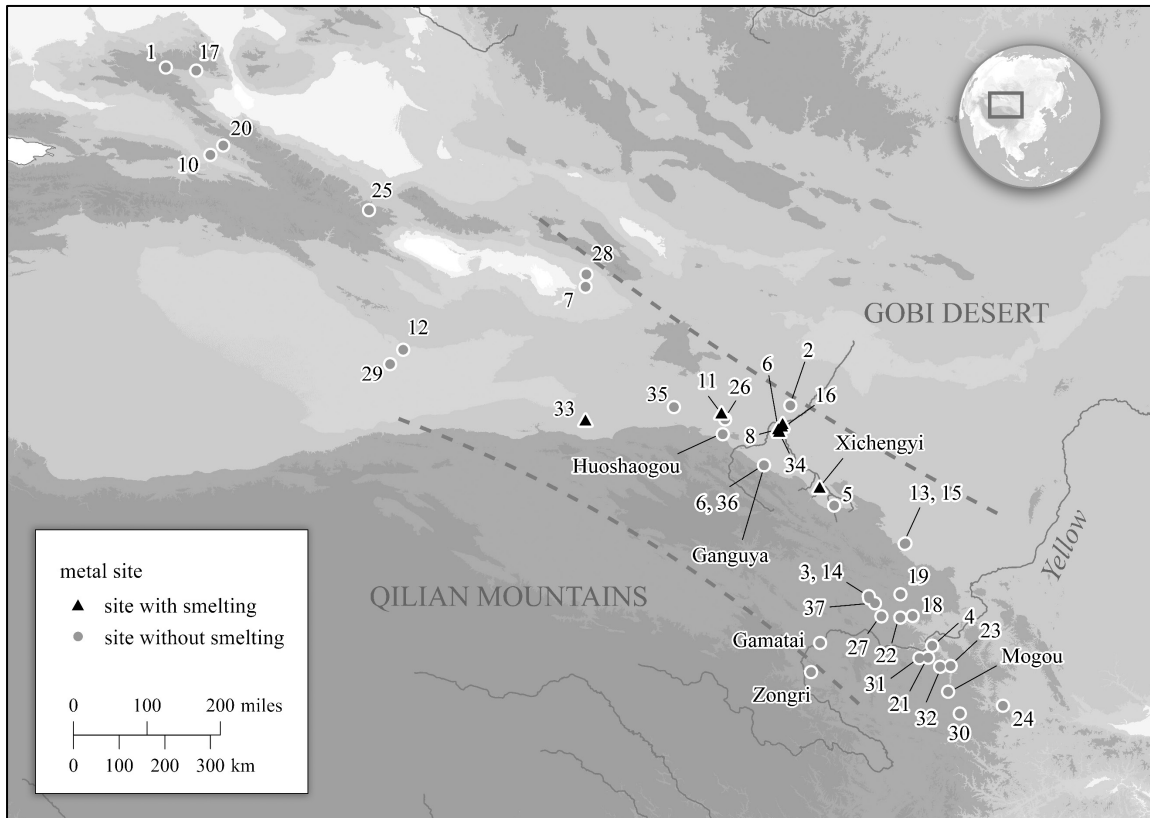


Figure 7.1 Metal-bearing sites in the Hexi Corridor and eastern Xinjiang, c. 2100–1500 BC (Linjia: 2900–2700 BC). Major sites are labelled with names; other sites are labelled with numbers. 1: Adunqiaolu; 2: Baishantang; 3: Changning; 4: Dahezhuang; 5: Donghuishan; 6: Erdaoliang; 7: Fuzhisuanchang; 8: Ganggangwa; 9: Gaomuxudi; 10: Gongliu; 11: Gudongtan; 12: Gumugou; 13: Haizangsi; 14: Huangjiazhai; 15: Huangniangniangtai; 16: Huoshiliang; 17: Husta; 18: Jiangjiaping; 19: Jinchankou; 20: Jirentai goukou; 21: Linjia; 22: Liuwan; 23: Qijiaping; 24: Qinweijia; 25: Sa'ensayi; 26: Shaguoliang; 27: Shenna; 28: Tianshanbeilu; 29: Xiaohe; 30: Xinglin; 31: Xinzhuangping; 32: Xiping; 33: Xitugou; 34: Yigedigou; 35: Yingwoshu; 36: Zhaobitan; 37: Zongzhai.

such as external stimulation and local adoption, adaptation, and innovation interacted and contributed together to this process.

In terms of the external stimulation, the metal use and metal production in the Hexi Corridor were constantly shaped by external stimuli from both west and east. The attitude towards leaded bronze is perhaps a good reflection of the local responses under such external stimulation (see also Chapter 2). In the early stage (before 1600 BC), people in the Hexi Corridor learned metal production from their western neighbours. Most metal objects at this stage, especially the

everyday tools (knives, awls, etc.), were made by the techniques of forging (hammering when the metals are hot) or cold working (hammering when the metals are cold). As I have discussed in Chapter 4, these techniques can make objects with relatively high strength and hardness—properties suitable for tools. However, leaded bronze is normally not suitable to be hammered, since the alloys may break into pieces.² In the Hexi Corridor, as I will suggest, the favour of forging and hammering may have led to an aversion to lead at the beginning. In the second half of the second millennium BC, nevertheless, leaded bronze objects became commonly used in the region. Two examples, Mogou and Xujianian, show how the lead aversion gradually faded as people in the Hexi Corridor were increasingly bound with the east. In this way, the changing materials reflect changing cultural patterns of the metal-using communities.

A Lead-Free Beginning

Xichengyi and the Ejin River Valley

The earliest metal objects found in the Hexi Corridor is a knife from Linjia in today's Gansu Province. According to the radiocarbon dates of the context, this knife is probably as old as 2900–2700 BC.³ It is single-edged, with a slightly curved shape. Similar knives have also been found at various sites on the steppes, as well as in the Altai-Sayan region.⁴ However, since the dates of the knives are all very close, it is still unclear whether the Linjia knife is a local invention or an imitation of a steppe one.⁵ The Linjia knife has been analysed and found to be made of

² See also Chapter 4 footnote 95.

³ Guo, D. and Meng, L. 1984. It is widely known among archaeologists that this date may be questionable, but the evidence for and against this date has not been well presented yet.

⁴ Chernykh 1992: 188; 196; 272.

⁵ Chen, G. 2017a.

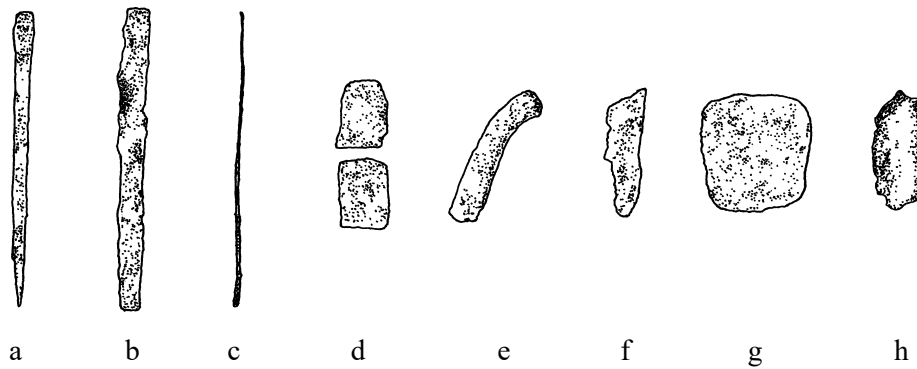


Figure 7.2 Metal objects from Xichengyi (scale varied). a, b: awls; c: wire; d, e: rings; f: tube; g: *pao* boss; h: knife (modified from Chen, G. 2017b: 40; Chen, G. et al. 2015a: 106).

bronze with 6–10% tin, cast in a two-part mould.⁶ In the same context, the excavators also found some highly-corroded metal fragments which are probably the product of smelting polymetallic ores (copper with iron).⁷ We do not know whether the metal fragments were smelted locally, or were transported to Linjia as a raw material for metal production. However, it seems that people here had started some metallurgical activities. The bronze knife may have been a result of these activities.

Increasing evidence of metal use and metal production appeared around 2100 BC. So far, the best-known site dating to this time is Xichengyi. As previously mentioned, Xichengyi's location in the middle of the Hexi Corridor suggests that the ideas and technologies may have come from the Mongolian Plateau through the Ejin River to this site (Chapter 2). At Xichengyi, metal objects (Figure 7.2) and metallurgical remains have been found in three sequential cultural phases which are dated to 2135–1890 BC, 1880–1620 BC, and 1745–1530 BC.⁸ Copper ores as well as fragments of refractory ceramic were left at the site. According to the copper ores left at

⁶ By Raman spectroscopy: Sun, S. and Han, R. 1997.

⁷ Guo, D. and Meng, L. 1984.

⁸ Report: Chen, G. et al. 2015b; metal objects: Chen, G. et al. 2015a; metallurgical remains: Li, Y. et al. 2015a; dating: Zhang, X. et al. 2015.

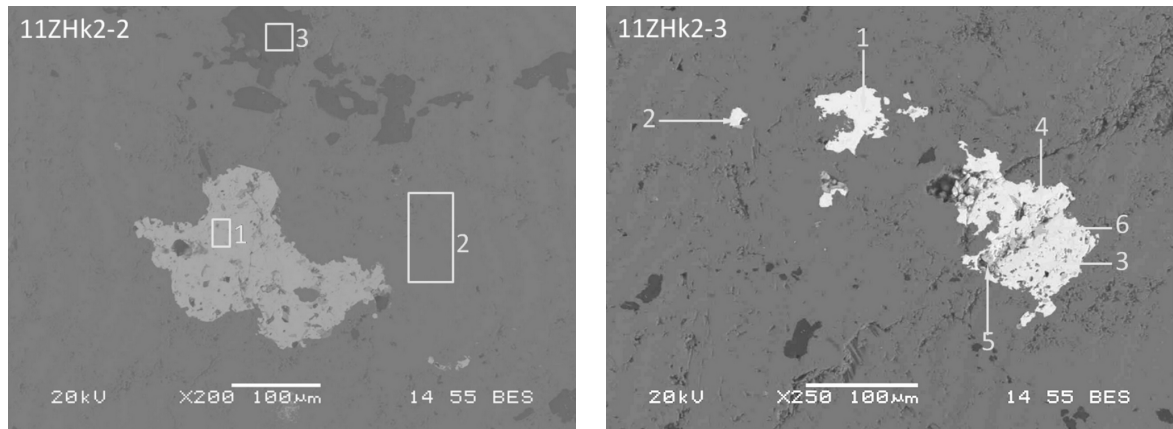


Figure 7.3 The microstructures of two lead-bearing polymetallic ore samples from Xichengyi. Left: 1: PbCO_3 ; right: 1 and 4: $\text{Pb}_5(\text{AsO}_4)_3\text{Cl}$; 2, 3, 5, 6: PbCO_3 (after Li, Y. et al. 2015a: 123).

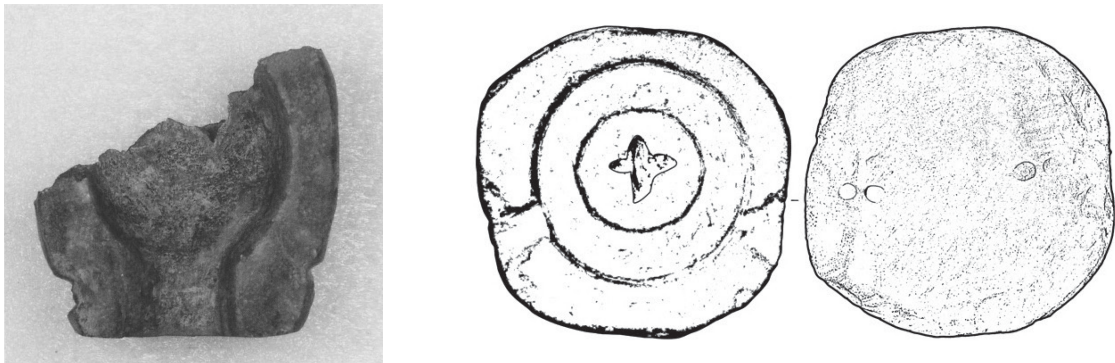


Figure 7.4 Stone mould pieces for casting a mace head (left) and a mirror (right) (after Chen, G. et al. 2014: 16; 2017b: 40).

the site, the excavators suggested that two types of copper ore were used. One is copper oxide ore. The other type is polymetallic ore, containing mainly copper but also arsenic, lead, and tin (Figure 7.3).⁹ Dozens of finished objects, including awls, knives, rings, and other personal ornaments, have also been found at the site. Most metal objects were discovered in various residential contexts. The only exception is a fragmented circle-shaped metal object (M2:13), probably a ring or a bracelet, found in Tomb M2, together with nine ceramic vessels, a stone

⁹ Although tin ore has not been found at Xichengyi, tin is identified in some refractory fragments as well as in some finished products.

knife, some green stones, and animal remains. The bones of the individual are not well preserved, so we do not have much information about this tomb occupant.¹⁰ Since only a few tombs have been excavated at Xichengyi, it is still too early to confirm how the metal objects meant to people's daily lives and afterlife. However, according to the current finds, it seems that metal objects were not considered by the local population to be of very high values (otherwise they would not have been disposed everywhere). At Xichengyi, the excavators also found evidence pointing to the production of more extraordinary objects: stone moulds for casting a mace head and a mirror (Figure 7.4). The finished products of these kinds have been found at some nearby sites, such as Huoshaogou (mace heads) and Gamatai (mirror).¹¹ These two types of metal object are visually remarkable and required considerable effort to achieve. According to these finds, we may suggest that Xichengyi was probably a regional production centre of metal objects. Metal ores were transported to the site and were processed here, while the finished products were partly consumed by the Xichengyi people, and partly sent to other sites in this region.

The model of metal production at Xichengyi was also different from that at Erlitou and in the northern Bohai Rim. In the cases of Erlitou and the northern Bohai Rim, smelting activities were usually operated at the mining sites, rather than in the residential areas. The separation of smelting and final-product manufacturing is understandable. Logistics may have been the primary reason. Smelting activities were usually conducted at locations adjacent to either the mines or the sources of fuel (e.g. forests for charcoal).¹² Meanwhile, craftspeople benefit from living in a large community to have more job opportunities or, in the Erlitou's case, to directly engage with the elite members. In addition, environmental concerns may also have been reasons to place smelting far away from densely populated residential areas. Although people in the past

¹⁰ Chen, G. et al. 2015b.

¹¹ Zhang, X. et al. 2021; Qinghaisheng and Beijing 2016: 130.

¹² A historical era example of transporting metal ores to a coal mine for smelting: Mo, L. et al. 2018.

may not have been fully aware of the impact of smelting activities on environment and on public health as we are nowadays, but the thick smoke and the pungent odour from furnaces would certainly have been unwelcome. In Xichengyi's case, the site was probably a specialised metal production site, operated and resided in by the metalworkers. The relationship between Xichengyi craftspeople and their consumers—probably those living in the nearby sites—is still unclear, since not many sites in this area have been thoroughly excavated. Most residential sites near Xichengyi were not very large, certainly not as large as Erlitou.¹³ Considering the ecosystem in the middle Hexi Corridor which, even nowadays, is not very suitable for sedentary agriculture, I suggest that many consumers of the Xichengyi metal products were people moving around in the Hexi Corridor, or even in a larger area (such as travellers coming from Inner Asia). Because of this lack of a strong connection with a nearby consumer community, the Xichengyi craftspeople were certainly more autonomous than the Erlitou metalworkers in respect to what they produced, and how they produced them.¹⁴

Apart from Xichengyi, there are also a few other sites in the region with remains of smelting activities (Figure 7.1). It is unclear whether they were only engaging in smelting, or whether they were producing finished metal products as well. However, like Xichengyi, most of these sites are also located in the middle Ejin River Valley. So why was this area developed as a major metal production centre?

The main reason was probably because that the middle Ejin River Valley had good access to raw materials, especially metal ores. According to the geological surveys, there are several copper mines in the Qilian Mountains, close to the upper Ejin River Valley. Since the river flows north-

¹³ Guojia 2011. See also Gansusheng and Beijing 2011.

¹⁴ One large community which may have been a potential destination of some Xichengyi metal products is Tianshanbeilu: Mei, J. 2000: 63; Qian, W. et al. 2001; Liu, C. et al. 2020. However, since the materials of this site and its chronology have not been fully published. The relationship between Xinchengyi and Tianshanbeilu is still not clear.

northeast into the desert, ores from these mines may have been transported via the waterway to Xichengyi with relatively low costs. In addition, copper and other metal resources were also available on both sides of the middle Ejin River Valley (such as in the Heli Mountains and the Beishan Mountains). Polymetallic ores, in particular, have been found at a few mines in these areas, such as Huitongshan (copper, silver, and tin) and Mingxishan (tin and arsenic) in the Beishan Mountains region, and Baishantang (copper, lead, and silver) in the middle Ejin River Valley (Figure 7.5).¹⁵ These mines may have been the sources of the polymetallic ores found at Xichengyi. Fuel is also an important raw material for metal production. At the time of Xichengyi, charcoal may have been one of the major types of fuel for smelting. Nowadays, most parts of the Hexi Corridor are not heavily wooded, but the vegetation coverage during the early second millennium BC may have been much better. As an analysis of 656 charcoal samples from Xichengyi shows that, more than half of the samples belong to *Tamarix chinensis* (a species of tamarisk), whose trunk can be used for burning as well as for house building.¹⁶ Besides, using cattle and sheep dung as fuel was also possible, since both animals were raised in the Hexi Corridor from as early as the third millennium BC.¹⁷

In addition, early metallurgy may have been established in the middle Ejin River Valley as a result of the advantageous resources in this area. The valley is a crossroad for people moving west-east along the Hexi Corridor and for those moving north-south along the Ejin River. Therefore, it was probably easy to attract passers-by or to transport goods to potential consumers from this location. One potential region which may have relied on the products from the middle Ejin River Valley is the land between the upper Yellow River Valley and the upper Wei River Valley, in the southern part of the Gansu Province and the eastern part of the Qinghai Province.

¹⁵ Zhongguo 1996a: v. Gansu, 24; 27; 58.

¹⁶ Wang, S. et al. 2014. Another analysis of charcoal samples from two nearby sites, Huoshiliang and Ganggangwa, draws a similar conclusion: Sun, N. et al. 2010.

¹⁷ Flad et al. 2007; 2009.



Figure 7.5 Middle Ejin Metal Production Zone and the neighbouring mining sites (mines: Zhongguo 1996a. See also Li, Y. et al. 2015a).

Metal objects have been found at various sites in this region (Figure 7.1). The earliest of them can be dated to about 2000–1700 BC. However, evidence for local metal production has not yet been found. As Chen Guoke suggested, it is possible that the metal objects discovered in this area were produced in the middle Ejin River Valley.¹⁸

These metallurgical activities in the middle Ejin River Valley gradually came to an end around 1500 BC. The rise and fall of the metal production are well reflected in the changes the copper concentration in soil samples, as this index peaked in the first half of the second millennium BC.¹⁹ One possible reason for the decline of the metal production in this area is environmental

¹⁸ Chen, G. 2017b.

¹⁹ Yang, Y. et al. 2017; Zhang, S. et al. 2017.

degradation. Ecologically, the middle Hexi Corridor was and still is relatively fragile. As this area is in the frontal zone of the East Asian Summer Monsoon, any change of the monsoonal flow may cause abrupt temperature and humidity changes in the Hexi Corridor.²⁰ Meanwhile, intensive agricultural activities and over-irrigation may also have led to the loss of soil fertility and salinization.²¹ Smelting activities may at the same time have contributed to this environmental degradation. A study done on the site Huoshiliang (Figure 7.1, site 16) shows that, during the period when smelting activities were active, c. 2000–1860 BC, the amount of rubidium (an element which is relatively immobile in soil, and therefore commonly used to trace the movement of soil) in the nearby lake increased significantly. This may indicate increasing soil erosion as minerals, like rubidium, were washed away from the soil and carried into the lake. Although we cannot confirm whether the erosion was directly linked with metallurgical activities or other activities such as agriculture, or merely with the general trend of climate deterioration, it is possible that smelting-led deforestation for fuel partly caused such soil erosion.²² Probably as a result of the environmental change and the abandonment of the metallurgical activities, the number of settlements in the middle part of the Hexi Corridor also shrank remarkably in the second half of the second millennium BC.²³ In this next period, the metal production centre may have shifted south-east to the more habitable upper Wei River Valley, as we will discuss later.

Metals without Lead

One intriguing characteristic of the metal objects found in the early Hexi Corridor is the absence of lead in the copper alloys. Around thirty finished metal products from Xichengyi have been analysed. About half of them were made of almost pure copper, while the rest contain 1–10%

²⁰ Chen, F. et al. 2008; Chen, J. et al. 2016; Chen, J. et al. 2018.

²¹ Zhou, X. et al. 2012.

²² Li, X. et al. 2011.

²³ An, C. 2005; Li, F. 1993.

Table 7.1 Analysed metal objects from Xichengyi.

Phase	Object ID	Object type	Shaping*	Composition (%)			
				Cu	Sn	Pb	As
II	T0101(5)a:6a	ring	casting, forging (c)	100	-	-	-
	T0101(5)a:6b	ring	forging (h, c)	97.1	1.0	-	-
	T0101H19(1):4	awl	forging (h)	96.8	3.2	-	-
	T0201(6)c:1	awl	casting, forging (c)	100	-	-	-
	T0201H63:2	awl	forging (h, c)	100	-	-	-
	T0202(6):6	awl	casting	99.7	-	-	-
	T0301(6)c:17	boss	?	59.5	-	-	-
	T0301(8)c:1	awl	forging (h, c)	98.8	-	-	1.2
	T0301H34(1):1	tube ornament	casting	77.8	-	-	-
	T0302(6)a:4	awl	forging (h, c)	100	-	-	-
	T0302(6)c:5	awl	forging (h)	100	-	-	-
	T0302(7)a:12	awl	casting	100	-	-	-
	T0302(8)a:5	awl	forging (h, c)	98.4	-	1.6	-
	T0302(8)b:1	awl	casting	96.6	-	-	3.4
	T0302G5(2):1	awl	forging (h, c)	99.0	-	-	1.0
	T0302H8(5):1	awl	casting	98.1	1.9	-	-
	T0302H15(3):1	ring	forging (h, c)	97.2	-	0.5	2.3
	T0403(4)b:2	awl	forging (h, c)	100	-	-	-
	T0403H10:6	awl	forging (h)	100	-	-	-
	T0404H1(3):t1	tube ornament	casting	100	-	-	-

* h: hot forging; c: cold forging.

arsenic or tin (Table 7.1). These two alloy types echo the two types of ores found at Xichengyi—relatively pure copper oxide ores and polymetallic ores. In addition, Li Yanxiang and colleagues also identified two types of slag at the site. Most slags were left by smelting copper oxide ores, while the inclusions of rest are mainly copper alloyed with arsenic and antimony.²⁴ Therefore, we may conclude that the pure copper used at Xichengyi was produced from the copper ores which normally do not have significant amount of other metal elements, while the copper-arsenic

²⁴ Li, Y. et al. 2015.

Table 7.1 (*continued*)

Phase	Object ID	Object type	Shaping	Composition (%)			
				Cu	Sn	Pb	As
III	T0101(4)c:9	ring	casting	95.3	-	-	4.7
	T0101(4)d:t1	boss	casting	77.8	9.4	-	-
	T0201(4)b:13	boss	forging (h, c)	95.7	-	-	4.3
	T0201(4)b:20	awl	casting	95.5	-	-	4.5
	T0202(1):4	awl	forging (h)	97.7	-	-	-
	T0301(1):4	knife	forging (h)	100	-	-	-
	T0301(3)b:2	awl	casting	91.8	-	-	-
	T0301F1L1:1	awl	forging (h)	94.9	-	-	5.1
	T0301M2:13	ring	forging (h, c)	92.8	-	-	7.2
	T0302F1(3)a:1	awl	casting	100	-	-	-
	T0302F2Q:1	awl	forging (h, c)	99.0	-	-	-
	cj:1	boss	?	80.0	-	-	4.4

Method of analysis: SEM-EDS, metallographic analysis; reference: Chen et al. (2015a).

and copper-tin alloys were probably produced by co-smelting copper and polymetallic ores.²⁵

The almost random arsenic and tin levels in the analysed objects seem to suggest this “uncontrolled but not unintentional” (Thornton’s words, see Chapter 3) way of making alloys.

Moreover, if we divide the analysed objects into two general groups: tools (awls and knives) and personal ornaments (rings, bosses, etc.), it seems that copper alloys were not only used for tools, but also (and mostly) for personal ornaments. Seven out of the total eleven analysed ornaments were made of either arsenical copper or bronze, while, for twenty-one analysed tools, only eight were made of either arsenical copper or bronze (1% threshold). This pattern reminds us of the studies on early metallurgy in other parts of Eurasia. In many of these studies, the researchers suggest that arsenical copper and bronze were used for the special, yellow-to-grey colours of the

²⁵ It is possible that tin was smelted separately and then added to copper to make the alloys, but this is not likely in the case of arsenic due to its volatility. See also Chapter 5, footnote 44.

materials.²⁶ Lead, nevertheless, is almost missing among the analysed objects. This is surprising since, like arsenic and tin, many polymetallic ores found at Xichengyi also contain lead (Figure 7.3). If those ores were used during the smelting, lead should have been common in the finished products as well. Therefore, we can only assume that metalworkers knew how to identify ores with high lead contents. Those ores were thus excluded from smelting. In other words, people probably had a clear idea of deliberately avoiding lead in the copper smelting process.²⁷

To test this hypothesis, we may also refer to the metal objects from the Huoshaogou cemetery, dating to 1800–1500 BC.²⁸ More than three hundred tombs have been excavated, in which about two hundred metal objects have been found. In the most recent published study, sixty-seven objects are analysed. Unlike those Xichengyi objects, lead is more common among the Huoshaogou objects. Nevertheless, the lead contents are usually lower than 2%.²⁹ If we consider all analysed metal objects in the Hexi Corridor, dated to around or earlier than 1700 BC, we find that those objects were predominantly made of pure copper (56%), followed by tin bronze (24%), and arsenical copper (11%). If we use 2% as a threshold, only 6% of the objects were made of leaded copper or leaded bronze (Figure 7.6).³⁰ Based on these chemical results, I argue that lead may have been a metal element which early craftspeople in the Hexi Corridor tried to avoid when making the objects. This attitude toward lead was quite different compared that we see in the middle Yellow River Valley and the northern Bohai Rim. At Erlitou, many metal objects contain moderate to high levels of lead. Lead was even intentionally alloyed with copper in the case of

²⁶ E.g. Meliksetian et al. 2009.

²⁷ As what we have seen in the case of the northern Bohai Rim (Chapter 6), people there may have made the same choice.

²⁸ This is the latest dating result based on bone samples from a tomb: Zhang, X. et al. 2021. The site was previously dated (with four charcoal samples) to 1950–1700 BC: Gansusheng and Beijing 2016: 296.

²⁹ Chen, K. et al. 2018b.

³⁰ Sites and data see Appendix 2 and the supplementary materials. A recent review of the studies on early metallurgy in the Hexi Corridor, see Dong, X. and Li, X. 2021.

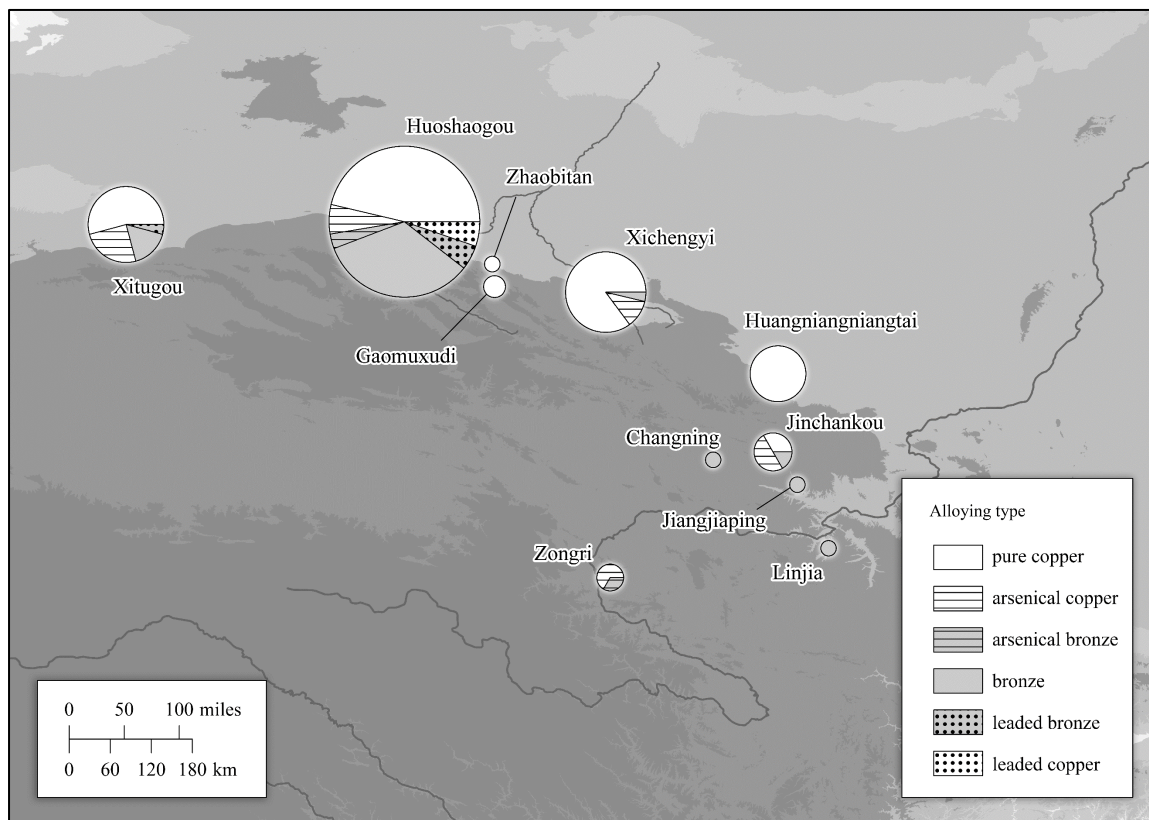


Figure 7.6 Metal objects by alloy type, before 1700 BC. The sample size of each site is indicated by the size of its pie.

later Erlitou bronze vessels. In the northern Bohai Rim, although people may have chosen ores without high lead contents to produce copper-based objects, most objects still have low to moderate levels of lead. In the Hexi Corridor, however, people appear to have been more lead-averse. Lead was not intentionally smelted or used, while polymetallic ores with high lead contents were avoided. What caused this lead-aversion? I think the most obvious reason is that the craftspeople (probably as well as some potential consumers) knew very well the problems with the copper-lead alloys. This can also be suggested by the analytical results of the Xichengyi objects. Many objects have been cold worked (hammered) after shaping. Cold working is supposed to improve the strength and hardness of the metals. Adopting such a method means that the metalworkers or the metal-users were conscious of the mechanical properties of the

alloys, and really tried to make their tools stronger.³¹ This also means that those people may have been aware of that the additional lead would weaken these properties, and make their attempts to hammer the objects undoable (Chapter 4). Therefore, the lead aversion may have been developed due to these concerns. Considering what we discussed in Chapter 6, that there was a steppe-Inner Asian tradition of using bronze without high lead contents, the aversion towards lead in bronze alloys was probably not developed independently in the Hexi Corridor, but had its origin on the steppes. Considering that the Ejina River Valley was almost not settled by any people before the second millennium BC,³² it is very likely that people who were conducting metallurgy at Xichengyi were direct immigrants from the steppe who brought their metallurgical knowledge and know-how and started the lead-free metal production at this new location.

“Leadening” the Hexi Corridor: The Case of Mogou

Around 1600 BC, a remarkable change took place in the Hexi Corridor regarding the use of metals, as leaded bronze finally emerged. To be more specific, we can divide the area in and around the Hexi Corridor into three subregions (Figure 7.7), the first subregion is the eastern part of the Qinghai Province, especially the Gonghe Basin near today’s Xining. The earliest metal objects appeared at Zongri (2000–1700 BC), Jinchankou (2000–1750 BC), and Gamatai (1700–1500 BC).³³ The finds of metal materials which can be dated to the second half of the second millennium BC are very limited, and none of these objects have been analysed. To

³¹ If we compare the metal assemblage of Xichengyi with that of Dadianzi, we can see that most Xichengyi metal objects were tools, while Dadianzi had much more personal ornaments. This may also be a reason for the Xichengyi metalworkers to care more about the mechanical properties of the metals.

³² Guojia 2011: v. 1, 68–72.

³³ Zongri: Xu, J. et al. 2010; Gamatai: Qinghaisheng and Beijing 2016: 187–192; Jinchankou: Wang, Q. 2013. See also Qiao, H. 2018.

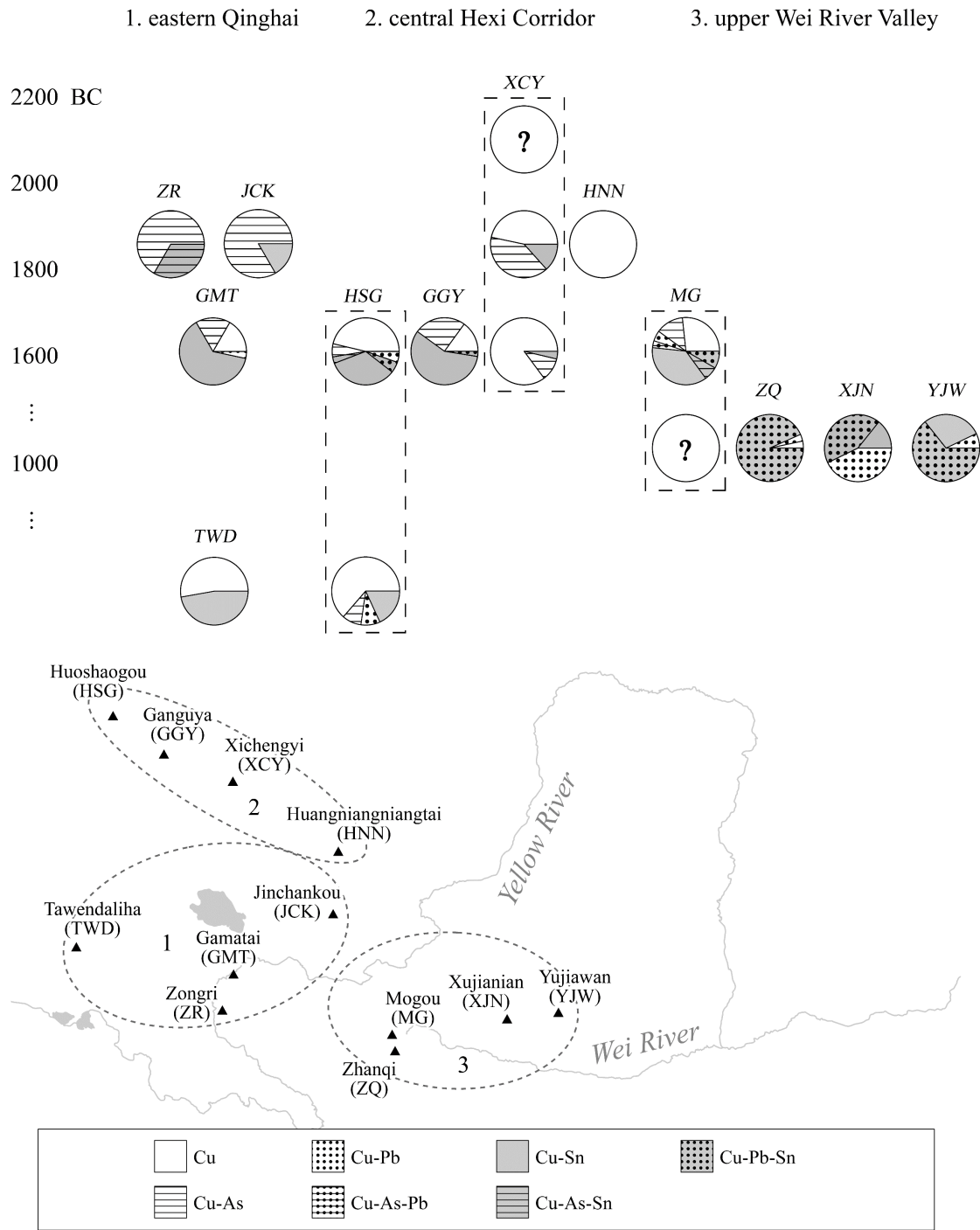


Figure 7.7 Comparison of the alloy types of the metal objects from the three subregions.

understand the change of metal materials over time, we may also refer to Tawendaliha as a site dated to the first millennium BC.³⁴ The alloy compositions of metal objects from this site show that the most used alloy type in this subregion was arsenical copper/bronze (Cu-As or Cu-As-Sn) in the early stage and bronze (Cu-Sn) in the late stage. The second subregion is the central Hexi Corridor which we have mentioned above. Xichengyi demonstrates the early stage of the metal-use in this area. Like in the first subregion, metal objects dating to the second half of the second millennium BC in this zone were also very rare. Only objects from the late phase of Huoshaogou (700–400 BC) have been analysed.³⁵ For these central Hexi Corridor sites, early objects were mainly made of pure copper or arsenical copper, while bronze became common around 1600 BC. In both eastern Qinghai and the central Hexi Corridor, leaded copper or leaded bronze objects were very rare. This is very different from the situation in the third subregion, which is located between the Yellow River and the upper Wei River Valley. Metal objects appeared relatively late in this area, only around 1600 BC. However, from this beginning, many metal objects contained high levels of lead. In the second half of the second millennium BC; leaded bronze even became the major type of alloy used in this subregion.

Mogou, which has been fairly well researched, is a good example for the emergence of leaded bronze. The archaeological contexts at Mogou can be divided into two phases. The first phase is dated to 1700–14/1300 BC, while the second is dated to 14/1300–900 BC.³⁶ Metal objects have been found in both phases. Typologically, the Mogou objects are not very different from those in the other two subregions. This suggests that people at Mogou may have learned metal production from their western neighbours. So far, only objects from the first phase have been analysed. According to Xu Jianwei's analysis of about forty objects, many of them were made

³⁴ Xi, G. and Li, Y. 2020.

³⁵ Chen, K. 2018a.

³⁶ Chen, J. et al. 2012; Liu, X. et al. 2014.

Table 7.2 Analysed metal objects from Mogou.

Object ID	Object type	Method of analysis	Composition (%)*					
			Cu	Sn	Pb	As	Ag	Fe
M41:E4	boss	XRF	41.1	4.4	53.0	-	0.4	-
M60:1	ring	XRF	98.2	-	-	-	-	-
M72:B2	earring	XRF	97.9	-	-	Y	-	-
M76:B5	knife	XRF	99.0	-	-	Y	0.3	-
M90:12	knife	XRF	98.6	-	-	Y	-	0.1
M90:13	other	XRF	98.0	-	-	Y	0.4	0.1
M101:10	earring	XRF	95.9	-	2.6	-	-	-
M101:11	boss	XRF	97.8	1.1	0.6	0.5	0.3	-
M101:12	other	XRF	94.2	3.5	-	2.4	-	-
M101:9	personal ornament	XRF	93.4	5.7	0.1	-	0.1	-
		SEM-EDS	98.7	1.3	-	-	-	-
M113 下层:1	knife	XRF	97.4	-	0.8	-	0.1	0.5
M118 顶部:6	personal ornament	XRF	90.3	8.5	0.1	Y	0.2	0.3
M132:X	boss	XRF	98.2	-	-	1.8	-	-
M133:5	personal ornament	XRF	96.4	-	-	Y	-	-
M142:7	personal ornament	XRF	98.4	-	-	1.6	-	-
M143:4	ring	XRF	98.5	-	1.0	0.5	-	-
M152:9	knife	XRF	98.3	-	Y	Y	-	-
		SEM-EDS	100	-	Y	Y	-	-
M184:5	boss	XRF	53.7	1.1	44.6	-	0.4	-
M186:6	earring	XRF	89.1	6.4	4.0	-	-	-
M203:1	boss	XRF	89.7	9.1	0.2	-	0.2	-
M203:2	boss	XRF	27.2	4.6	66.7	-	0.5	-
M203:3	boss	XRF	50.5	5.3	42.9	-	0.5	-
M208:12	knife	XRF	98.5	-	-	Y	-	-
M208:14	boss	XRF	95.8	-	3.3	Y	0.26	-
M216:10	personal ornament	XRF	98.5	-	-	1.6	-	-
M227:4	armband	XRF	97.6	-	-	2.4	-	-
M232:13	boss	XRF	92.4	6.3	-	-	-	0.5
M252:5	earring	XRF	76.8	20.3	-	2.9	-	-
M259:B1(1)	earring	XRF	84.5	14.4	0.6	-	-	-
M259:B1(2)	earring	XRF	93.1	5.6	0.9	-	-	-
M267:B4	bracelet	XRF	97.9	-	0.5	-	-	-
M272:5(1)	boss	XRF	37.4	34.7	26.0	-	0.8	-
M272:5(2)	boss	XRF	82.9	10.9	1.1	-	-	4.1

Table 7.2 (continued)

Object ID	Object type	Method of analysis	Composition (%)					
			Cu	Sn	Pb	As	Ag	Fe
M291:7	ring	XRF	92.4	1.9	3.8	-	-	-
M295:C18	personal ornament	XRF	98.2	-	-	1.8	-	-
M295:C18-3	personal ornament	XRF	97.1	-	1.4	-	-	-
M295:C21	knife	XRF	97.4	-	1.2	1.4	-	-
M298:6	tube ornament	XRF	54.0	12.0	32.9	-	-	-
		SEM-EDS	94.2	5.8	Y	-	-	-
M303:B18	personal ornament	XRF	90.2	8.7	0.8	-	-	-
M309:1	boss	XRF	88.5	10.7	0.4	-	-	-
M309:2	boss	XRF	92.5	5.7	-	-	-	-
M329:B8	knife	XRF	98.2	-	-	1.8	-	-
M341:10	earring	XRF	47.9	24.9	24.9	2.4	0.5	-
M341:6	earring	XRF	96.7	-	1.8	-	-	-
M343:9	personal ornament	XRF	95.4	-	-	4.6	-	-
M350:B3	personal ornament	XRF	52.7	7.6	38.4	-	0.7	-
xCQ001**	tube ornament	SEM-EDS	73.6	26.4	-	-	-	-
xCQ002**	boss	SEM-EDS	51.7	-	12.2	36.1	-	-
xCQ003**	earring	SEM-EDS	88.9	11.1	-	-	-	-
xCQ004**	personal ornament	SEM-EDS	89.1	10.9	-	-	-	-
xCQ005**	tube ornament	SEM-EDS	73.5	26.5	-	-	-	-
xCQ006**	tube ornament	SEM-EDS	88.6	11.4	-	-	-	-
xCQ007**	personal ornament	SEM-EDS	85.6	12.6	-	1.8	-	-
xCQ008**	personal ornament	SEM-EDS	92.7	5.0	-	2.4	-	-
xCQ009**	personal ornament	SEM-EDS	84.3	15.7	-	-	-	-
xCQ010**	boss	SEM-EDS	84.5	15.5	-	-	-	-
xCQ011**	personal ornament	SEM-EDS	77.8	22.2	-	-	-	-
xCQ012**	boss	SEM-EDS	71.9	10.8	17.3	-	-	-
xCQ013**	personal ornament	SEM-EDS	85.8	14.2	-	-	-	-
xCQ014**	armband	SEM-EDS	79.0	21.0	-	-	-	-
xCQ018**	tube ornament	SEM-EDS	86.8	13.3	-	-	-	-

* Y: elements which are identified but not quantitatively measured

** objects without original archaeological ID

Reference: Xu, J. (2009: 34–48).

of copper with tin, lead, arsenic, silver, and sometimes iron (Table 7.2).³⁷ This suggests that polymetallic ores may have been used to produce the materials. However, unlike the objects from Xichengyi, some Mogou objects have very high levels of lead. If we look at the analysed objects from Mogou more carefully, most objects either have very low lead contents, or very high lead contents. There are not many objects that have moderate levels of lead (e.g. 2–10%). This suggests that, for most objects, the craftspeople still used the traditional bronze alloys with low lead levels. When making some other types of object, people sometimes turned to high-leaded alloys. One particular type of object which often contain high lead levels is what we may call a boss ornament (or *pao* 泡 in Chinese), like to a small button (Figure 7.8). A *pao* boss is usually a round disc, slightly convex on one side. For example, in Mogou Tomb M886, three bosses have been found near the waist of a male occupant. There are hollow protrusions on the back of the bosses, so we guess that threads can go through holes in these protrusions in order to attach the bosses, like the modern-day shank buttons.³⁸ Normally, for making such an object, we can imagine that the main concern is the strength of the material, while other factors, especially colour and cost, may also be considered. Thus, any copper-based alloy, either leaded or unleaded, would be a perfectly acceptable material for the *pao* bosses. If we compare the *pao* bosses from Mogou with those from the other Hexi Corridor sites, the lead levels in the *pao* bosses from the other sites, as we previously discussed, are very low. However, the lead levels in the Mogou *pao* bosses are significantly higher (Figure 7.9). Why did not the Mogou people avoid lead like their neighbours? My suggestion is that, in the central Hexi Corridor, the original lead-aversion, as we previously discussed, may have been derived from some technological reasons. This experience may have led to the rejection of lead. Such a general lead-aversion,

³⁷ Xu, J. 2009. A more recent study on Mogou metal objects also confirmed most conclusions in Xu's thesis: Wang, L. 2019: 61–141.

³⁸ Qian, Y. et al. 2014. There are also flat (sew-through) buttons, see, for example. Gamatai: Qinghaisheng and Beijing 2016: 131–132.



Figure 7.8 Examples of small *pao* bosses from Mogou (after Li, B. 2018: v. 20, 29).

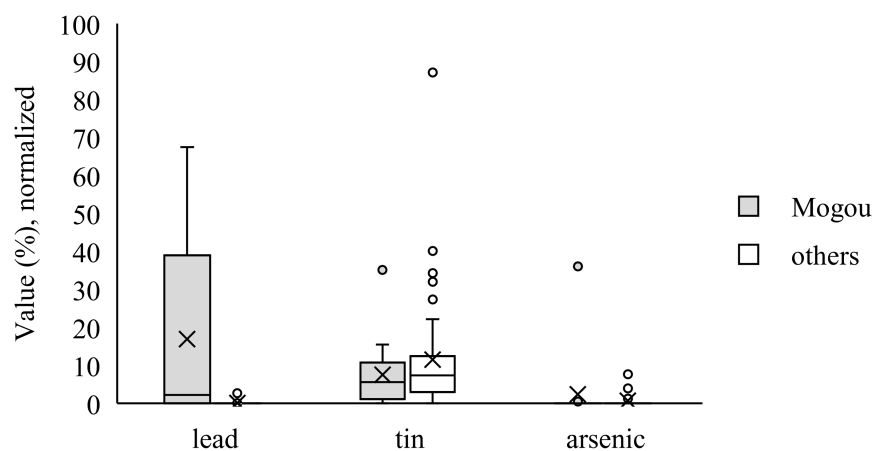


Figure 7.9 Comparison of alloying levels of the bosses from Mogou and those from other Hexi Corridor and East Xinjiang sites, c. 2000–1400 BC (data: Mogou: Table 7.2; other sites: see Appendix 2).

however, does not really make sense. Lead exists in many ores in this area. The rejection of lead means that these lead resources were not taken advantage of. At Mogou, people may have figured out that alloys with lead are not really useless, especially for making objects such as the *pao*. Therefore, to exclude lead and lead-bearing ores seemed to be uneconomical. Such an economic concerns may have been the reason behind the acceptance of lead.

Meanwhile, another external stimulus may also have pushed the “leadening” of the Hexi Corridor. This time, the stimulus may have come from the other direction—east. Throughout the fourth to the second millennium BC, the upper Wei River Valley had been continually densely

inhabited, due to its ideal climate and landscape for agriculture.³⁹ However, when metal objects first appeared in the middle Ejin River Valley around 2000 BC, this new material culture was initially not adopted by communities in the upper Wei River Valley. Only around 1600–1500 BC did metal objects first appear in this area. When we look to the east, bronze, especially leaded bronze, became widely used in Central China around the same time (Chapter 5). Typologically speaking, the bronze objects from Mogou are very close to those from the central Hexi Corridor and Xinjiang, so we do not need to question the connection between Mogou and its north-western neighbours. Nevertheless, from the material perspective, the high-leaded bronze used in many Mogou objects do remind us of the bronzes in the east. So, is it possible that the idea of using high-leaded bronze, or even the material itself, actually came from the east? If we look at the archaeological finds between the upper Wei River Valley and the middle Yellow River Valley, only a few sites with metal finds have been reported. Two of them are Donglongshan and Laoniupo, both near the modern city of Xi'an, in the area known as the Guanzhong Basin. The Guanzhong Basin and the upper Wei River Valley are connected by a convenient route following the Wei River (Figure 7.10). Metal objects with the earliest dates at Donglongshan are all fragmented pieces (one is probably a decorative plaque) and slags. These objects have been found in the contexts with ceramics which are typologically close to those from Erlitou Phase III–IV. Therefore, the excavators suggested that the contexts are dated relatively to 1650–1500 BC.⁴⁰ At Laoniupo, the earliest metal objects, including an awl, two arrowheads, and two slags, are dated—also by ceramic typology—to the Upper Erligang period, or 1450–1300 BC.⁴¹ Cultural contact between the Guanzhong Basin and the middle Yellow River Valley is clearly shown by the shared characteristics in the ceramic vessels.⁴² Therefore, I think the possible

³⁹ Guojia 2011: v. 1, 68–73.

⁴⁰ Shaanxisheng and Shangluoshi 2011: 185–186; 280.

⁴¹ Liu, S. 2002: 91; 330.

⁴² Hu, P. 2018; Jing, Z. 2004.



Figure 7.10 Locations of the Ejin River Valley (represented by Huoshaogou), the upper Wei River Valley (Mogou), the Guanzhong Basin (Donglongshan, Laoniupo), and the middle Yellow River Valley (Erlitou, Zhengzhou).

scenario is that, when Central China was heavily involved in the production of high-leaded bronzes, some objects arrived in the nearby areas for various reasons (distribution, circulation). The objects were then recycled, and the high-leaded bronze materials were reused to produce other objects. In the case of the Upper Wei River Valley, people may also have received some leaded bronze materials from Central China indirectly, such as through the Guanzhong Basin. These metals were then used to make the *pao* bosses. Since the metal objects at Donglongshan

and Laoniupo have not yet been analysed,⁴³ we cannot really test this hypothesis. In future, the provenance studies on the Mogou metal resources may help answer this question.⁴⁴

In conclusion, leaded bronze started to appear at sites in the upper Wei River Valley around the middle of the second millennium BC. This new material culture practice cannot be fully explained by the previous Hexi metal production tradition as most early sites in the Hexi Corridor all tried to avoid lead in their metal products. Therefore, the acceptance of leaded bronze may be a result of two factors. Internally, people may have chosen to give up their lead aversion as they wished to utilise as much metal resources as possible. Externally, metal resources from the east, mostly leaded, may have become available to the craftspeople in the upper Wei River Valley. In the next section, we will move on to the second half of the second millennium BC, as this was the time when leaded bronze became the most used metal material in the upper Wei River Valley. By reviewing metal objects from some new sites, we will discuss how the interregional cultural contact continued shaping the metallurgical practices in this area.

Keeping Up with the East? The High-Leaded Weapons

In the case of the Mogou leaded bronze objects, I have suggested that the adoption of leaded bronze may be a result of the external stimulation from the east. To further investigate this cultural influence, in this section, I may slightly extend my time period beyond 1250 BC to

⁴³ Smelting slags and ores from Laoniupo and a nearby site, Huaizhenfang, have been analysed: Chen et al. 2017; Zhangsun, Y. et al. 2019; 2020b. These analyses do not find obvious presence of lead in the smelting remains. This means that the local workshops may not have been producing leaded bronze objects, but we do not know whether there were imported leaded bronze objects used in this area.

⁴⁴ In her dissertation, Wang Lu published lead isotopic data of some Mogou metal objects. It shows that the metals may have come from different sources. Especially, some of the objects contain high radiogenic lead: Wang, L. 2019: 193–199. The provenance of the East Asian high radiogenic lead is still a hotly debated topic, see e.g. Chen, K. 2015; Jin, Z. 2008: 48–56; Liu, R. et al. 2018; Liu, S. et al. 2018; Ying, Q. et al. 2020; Zhangsun, Y. 2021. Due to the complexity of this problem, I will not elaborate it in this thesis.

include some later metal-using communities. We will start with Xujianian, a site with a residential area (not preserved) and a cemetery. It is located in the upper Wei River Valley, not far away from Mogou. The cemetery has been excavated, in which around a hundred tombs, together with two horse-and-chariot-pits, have been found. Based on the ceramic and bronze typology, scholars date the site to around 1150–1050/900 BC.⁴⁵

Dozens of metal objects have been found in the tombs, including weapons (blades, spearheads, arrowheads, etc.), tools (knives), and miscellaneous ornamental objects (armbands, bosses, beads, earrings, etc.). The metal objects from Xujianian can be clearly divided into two groups. One group of objects are those which were originally known and used in the Hexi Corridor, such as curved knives, earrings, armbands, and the *pao* bosses. Besides these objects, there are also a group of objects which had never been seen in this area. For example, a type of weapon which is often called *ge* 戈 in Chinese, were found at Xujianian.⁴⁶ A *ge* is a dagger-like blade which can be attached to a shaft as a pole weapon. The earliest bronze *ge* blades may have been derived from early stone tools. At Erlitou and Panlongcheng, bronze and jade *ge* blades, certainly as symbolic objects rather than real weapons, were placed in tombs, probably as high-status objects.⁴⁷ In the second half of the second millennium BC, the *ge* blade as a weapon became widely adopted in both North and South China. One possible reason is the start of the new, chariot-based way of warfare, especially in North China, which really unleashed the potential for this weapon. Probably as a result, burying *ge* blades in tombs also became more prevalent, at least among people who had a relatively high social status.

⁴⁵ Zhongguo 2006: 160. See also Meng, Q. 2016: 34–43; Song, J. 2001: 12.

⁴⁶ Besides Xujianian, the *ge* blades have also been found at some nearby sites such as Jiuzhan, Lanqiao, and Zhanqi: Wang, Z. and Shui, T. 1997; Zhao, H. and Liu, C. 1987; Han, C. 2012.

⁴⁷ Jing, Z. 2009; Song, X. 2012; Zhang, C. 2018. Examples of jade and bronze *ge* blades from Erlitou, see Chapter 5, Figure 5.10. The discussion of high-status objects in burials, see Chapter 5, footnote 15.

Table 7.3 Analysed *ge* blades and other weapons from Xujianian.

Object ID	Type	Composition (%)					
		Cu	Sn	Pb	As	Ag	Sb
M9:3	<i>ge</i> blade	69.0	4.5	27.7	0.5	0.1	0.1
M70:7	<i>ge</i> blade	63.3	0.4	36.1	1.2	0.1	0.1
M16:20	knife	88.6	1.6	6.1	0.3	0.2	-
M70:3	spear head	91.5	2.9	6.2	0.1	0.1	-
M70:4	arrowhead	82.8	14.4	-	-	-	-

Reference: Zhao, C. (2006).

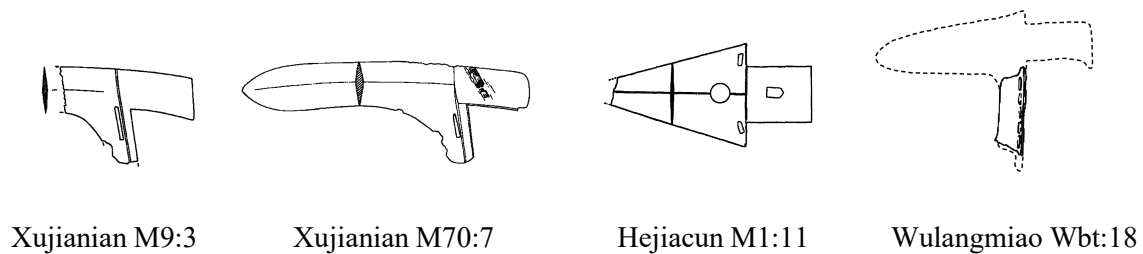


Figure 7.11 Examples of analysed high-leaded *ge* blades from the Wei River Valley and the Hanzhong Basin (after Zhongguo 2006: 92; Dai, Y. 1976: 35; Zhao, C. 2006: 56).

At Xujianian, the best example of a burial with the *ge* blades is Tomb M70. The main occupant is identified to be a woman, aged 35–40. She was buried with various metal weapons, including a *ge* blade (Figure 7.11), a spear, and arrowheads. The typology of these bronze weapons suggests that the tomb is probably dated to 1050–900 BC, or the late phase of the site. A large number of ceramic vessels were also placed in her tomb. Next to her tomb was a pit (M104) with the remains of two horses and a chariot. With all the information, we may suggest that the tomb occupant was probably buried as a chariot warrior who was commemorated with, or was supposed to continue fighting in her afterlife with, the weapons.

The chemical composition of the *ge* blade, however, does not really fit for this supposed fighting purpose. From a technological perspective, we may expect that a weapon should be made of bronze with moderate tin contents and low lead contents in order to be strong enough. However,

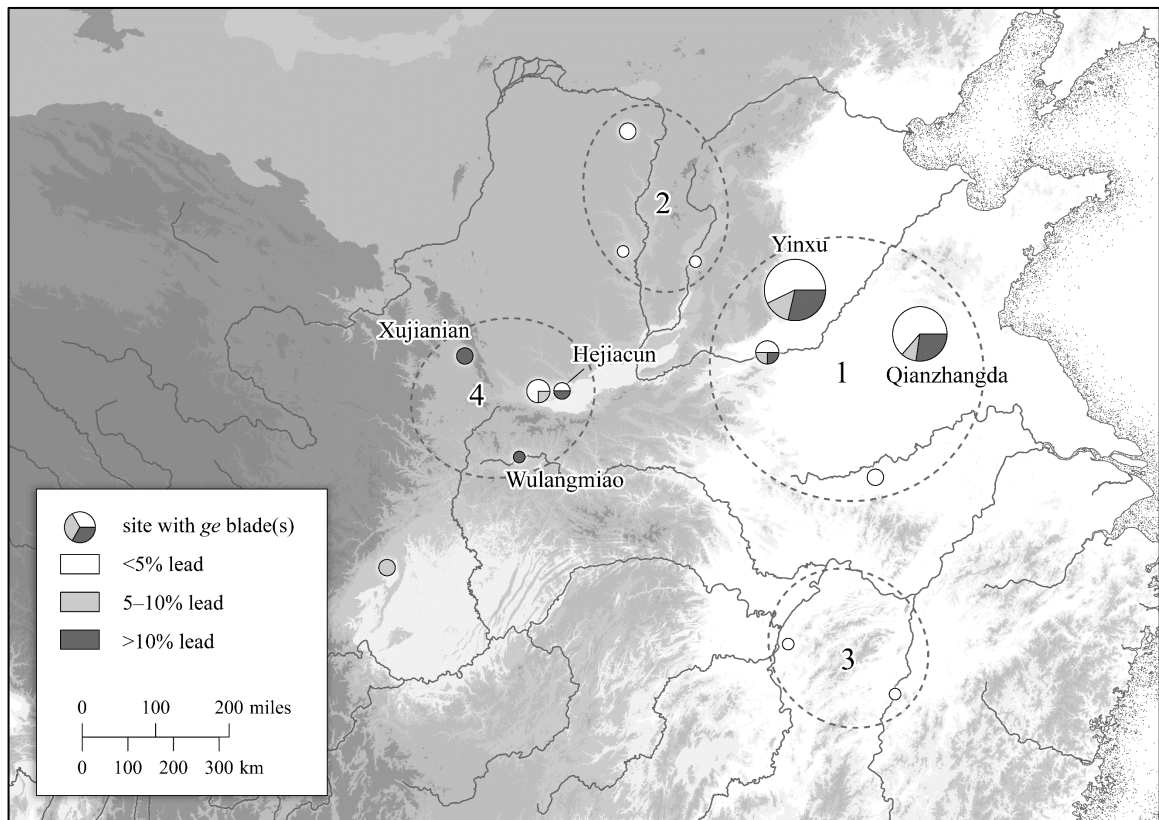


Figure 7.12 Sites with analysed *ge* blades, 1200–1000 BC. The pies show the percentages of lowly-, moderate-, and high-leaded samples, while the size of the pies show the relative size of the samples. The sites are grouped into four regions: 1: the middle Yellow River and the Huai River Valleys; 2: the East Loop; 3: middle Yangtze Valley; 4: Wei River Valley and Hanzhong. Sites mentioned in the text are marked on the map.

the M70 *ge* blade was made of copper with a fairly high level of lead, while tin is low. Another analysed *ge* blade from a different tomb also has a similar alloy composition (Table 7.3). Blades with such compositions are certainly not ideal to be really used as weapons. I suggest that those *ge* blades were probably made particularly as symbolic items instead of for practical fighting.

Examples of such high-leaded *ge* blades did not just appear in the upper Wei River Valley. In the Guanzhong Basin, three *ge* blades have been found in Tomb M1 at Hejiacun, near Baoji.⁴⁸ Among them, one has been analysed and the result shows that it was made of high-leaded (15.7%)

⁴⁸ Dai, Y. 1976.

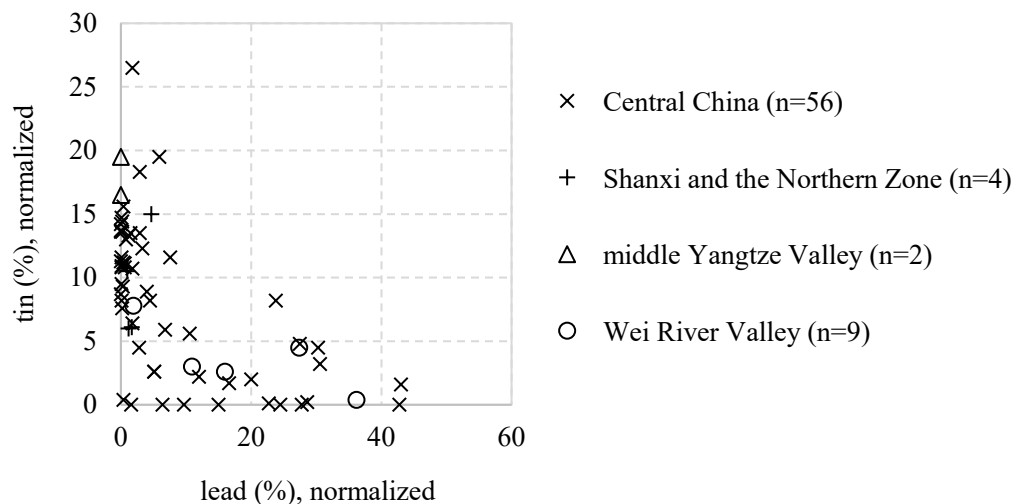


Figure 7.13 Distribution of tin and lead in the analysed *ge* blades, c. 1200–1000 BC (data: Appendix 2).

bronze.⁴⁹ Another example is a fragmented *ge* blade found at Wulangmiao in the Hanzhong Basin, south of Baoji and the Wei River. This *ge* was also made of bronze with a fairly high lead content (10.5%) (Figure 7.12).

However, not all *ge* blades were made of high leaded bronze. There are also many “properly” made of alloys with relatively high tin and low lead contents. If we put all the analysed *ge* blades which are dated close to 1200–1000 BC together, we can see at least two patterns of the distribution of tin and lead (Figure 7.13). First, most *ge* blades are low-leaded, or with below 5% lead. These objects contribute nearly 60% of the total samples. However, there are also high-leaded (>10%) objects. Especially, those with over 30% lead account for 17% of the samples. At that time, many metal producing centres, such as Yinxu, the centre of the Shang state, were already standardizing their alloy compositions. Therefore, I suggest that, for the *ge* blades from Yinxu, both the low levels and the high levels of lead were the results of intentional technological

⁴⁹ Yang, J. et al. 2003a.

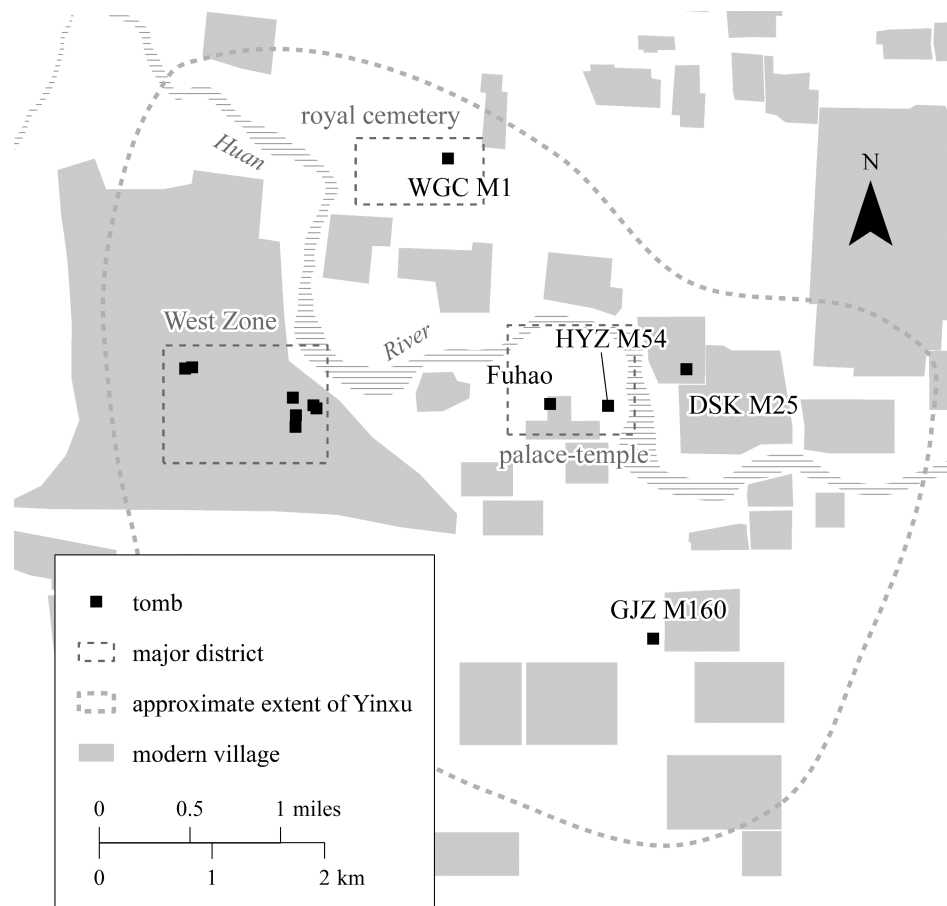


Figure 7.14 Plan of Yinxu, with tombs mentioned in the text (modified from Gu, F. 1989: 591; Guo, B. 1951: 2; Yang, B. and Yang, X. 1979: 28; Zhongguo 1980: 2; 1998: 1; 2007: 2).

choices, rather than coincidences.⁵⁰ Second, if we roughly divide the sites into four regions, most of the high-leaded *ge* blades appeared either in Central China, or in the Wei River Valley and the Hanzhong Basin in the west, while none of the *ge* blades from the “East Loop” (the eastern part of the Ordos Plateau) or from the south were high-leaded.

Why was leaded bronze used to make some of the *ge* blades? Why did most of these objects appear only in the two regions? To answer these questions, we may look at the *ge* blades from Yinxu first. The site of Yinxu is north-west of the modern city of Anyang, Henan Province. The

⁵⁰ See also Liu, R. 2016: 278–330; Liu, R. et al. 2020.

main archaeological features spread on both side of the Huan River (Figure 7.14). There are three major districts which are related to our discussion. The first is an area on the northern bank of the Huan River, close to the northern border of Yinxu's extent. Twelve large tombs, which some of the largest tombs in Yinxu, and hundreds of small burials were located in this so called "royal cemetery" area.⁵¹ On the southern bank of the river there is an area around 70 hectares, with 53 rammed earth foundations discovered. This is often interpreted as the "palace-temple" area. There are also several large tombs located in and around this area.⁵² Other tombs, usually not as grand as those in the previous two districts, have been found in many other areas in Yinxu. One of them is the "West Zone". In this district, more than a thousand tombs, organised in several clusters, were located.⁵³

The *ge* blades have been found in many Yinxu tombs. Among them, examples from twelve tombs have been analysed. Based on the working hypothesis we used in the last two chapters that burial patterns reflect the social status of the buried individuals, we can divide these twelve tombs into three tiers. In the first tier is Wuguancun (WGC) M1 from the Xibeigang royal cemetery district. It is a relatively small tomb in that district but still one of the biggest in Yinxu, with two ramps on both the northern and the southern sides of the tomb. Based on its scale and grave goods, scholars believe that the tomb occupant was a member of the Shang royal family. Seven *ge* blades have been found in the tomb (Figure 7.15, a, b).⁵⁴

In the tier slightly lower than this tomb are Xiaotun M5, Huayuanzhuang (HYZ) M54, and Guojiazhuang (GJZ) M1. The first two tombs are located in the so-called palatial-sacrificial district on the south bank of the river. Xiaotun M5 is one of the most famous tombs in Yinxu,

⁵¹ Yang, X. 1981.

⁵² Chen, Z. 1987; Yue, H. et al. 2006.

⁵³ Han, Y. 1997; Yang, B. and Yang, X. 1979.

⁵⁴ Report: Guo, B. 1951; Zhongguo 1979; discussion: Cao, D. 1988.

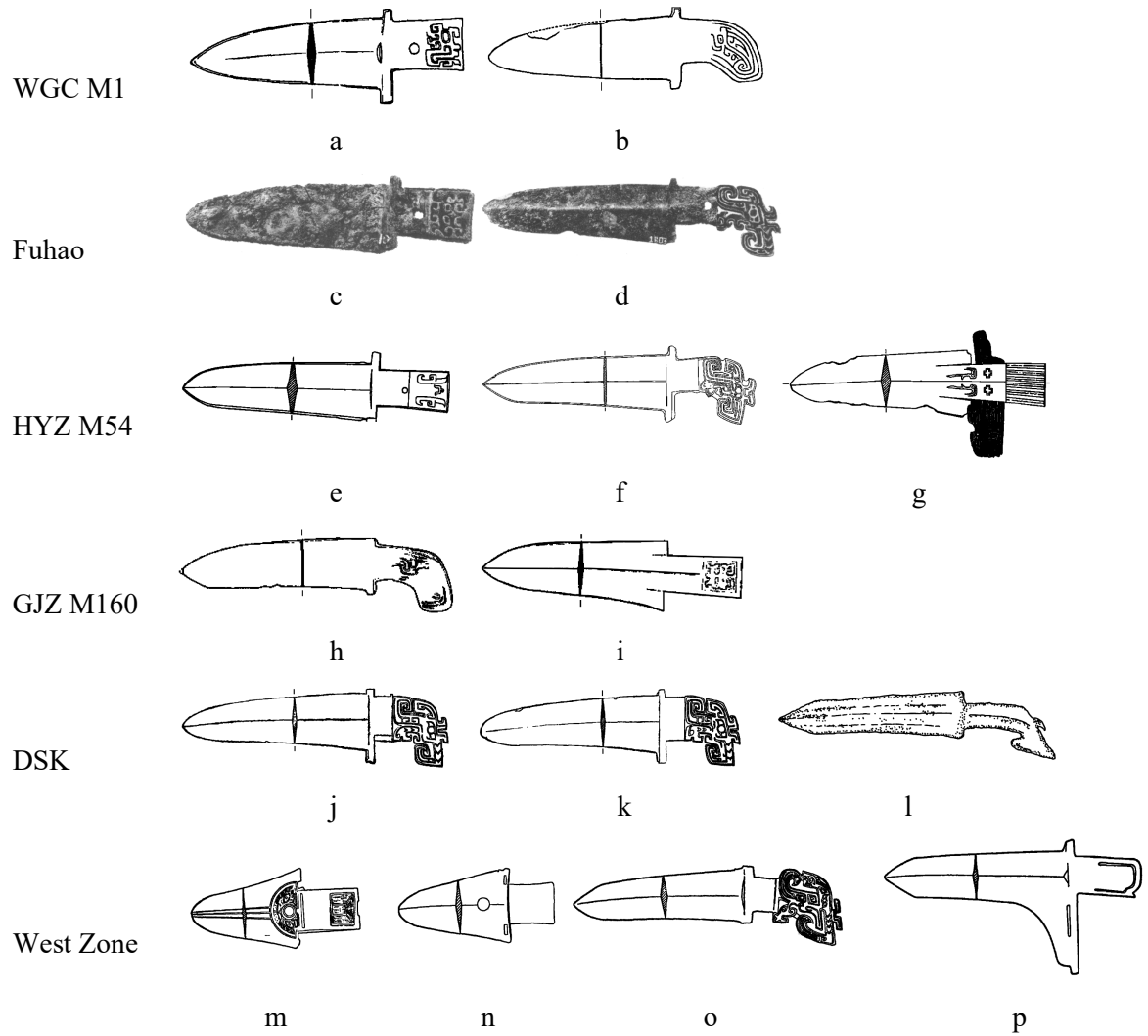


Figure 7.15 Examples of Yinxu *ge* blades. WGC M1: a: 11; b: 14; Fuhao's tomb: c: 5; d: 1603; HYZ M54: e: 126; f: 82; g: 246; GJZ M160: h: 9; i: 307; DSK: j: M25:1; k: M25:3; l: M136:2 (lead); West Zone: m: M279:1; n: M355:8; o: M613:3; p: M1052:5 (references see reports cited in the text).

since it belongs to Lady Fuhao, one of the principal consorts of King Wuding.⁵⁵ Fuhao is said to have been a military leader, or even a general of chariots. She was buried with more than 300 weapons, including 93 *ge* blades (Figure 7.15, c, d).⁵⁶ HYZ M54 is close to, and slightly smaller than, Fuhao's tomb. The occupant, probably named Yachang as mentioned in a few bronze inscriptions, was also buried with a large number of weapons, including 73 *ge* blades (Figure

⁵⁵ The bronze *ding* vessel in the Introduction belongs to her. See Chapter 1, Figure 1.1.

⁵⁶ Zhongguo 1980: 105–109.

7.15, e–g). Besides, he also had several injuries on his body, one of which was fatal and probably caused his death. On these accounts, the occupant may also have been an important military leader who was rewarded with this grand burial for his military achievement and sacrifice.⁵⁷ GJZ M160 is south of the palace-temple district. Although the tomb is smaller than the previous three, it also has a large assemblage of grave goods, including an amazing number of 119 *ge* blades (Figure 7.15, h, i). The tomb occupant, according to the inscriptions, is probably Yazhi. The character “*ya* 亚” suggests that both Yachang and Yazhi may have been military generals.⁵⁸ Thus, we can assume that they may have had comparable social status. In all tombs, as well as in WGC M1, there were bodies of death attendants placed on the secondary ledges of the tombs. Some of these people were also equipped with weapons as if they were bodyguards in the afterlife. In GJZ M160, several *ge* blades found on the secondary ledge (Figure 7.15, h) probably belonged to these guards.

In the third tier are tombs which are smaller, with fewer grave goods. One of them is Dasikong M25. The occupant has three bronze vessels, as well as six *ge* blades. These blades are nicely decorated with motifs (Figure 7.15, j, k), like those from HYZ M54.⁵⁹ A few other tombs found in the West Zone can also be included in this tier. The *ge* blades have also been found in some of these tombs, but only a few in each tomb. Some objects carry motifs, while others are plain (Figure 7.15, m–p). Individuals buried in these third-tier tombs were relatively wealthy or even with an above average social status.⁶⁰ Interestingly, ritual vessels and weapons made of pure

⁵⁷ Report: Zhongguo 2007a: 68–231; discussion: He, Y. 2012; 2013; Rawson et al. 2020.

⁵⁸ Zhongguo 1998: 70–126.

⁵⁹ Gu, F. 1989.

⁶⁰ Report: Yang, B. and Yang, X. 1979; discussion: Han, J. 1997.

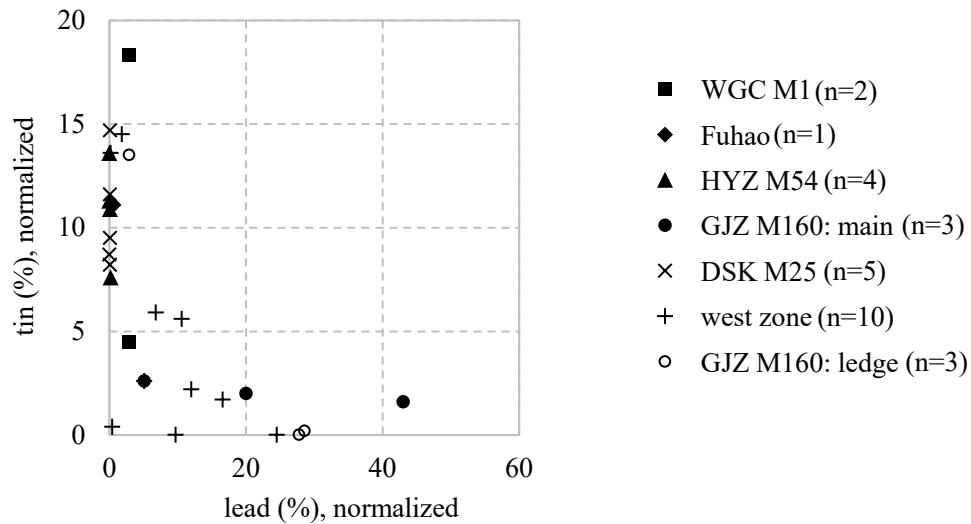


Figure 7.16 Distribution of tin and lead in the analysed Yinxu *ge* blades (data: Liu, Y. et al. 2007; Zhao 2004).

lead have also been found in some tombs. They are usually in the same types as the bronze ones (Figure 7.15, l).⁶¹ Scholars suggest that the lead objects were cheap replicas of the bronze ones.⁶²

Regarding the chemical compositions of the *ge* blades, around twenty-eight of them have been analysed.⁶³ The results show that all the *ge* blades from WGC M1, Fuhao's, and HYZ M54 were made of bronze with no or low lead contents. High-leaded samples are mostly from GJZ M160 and the tombs from the West Zone (Figure 7.16). Also, there seems to be no correlation between a particular sub-type of the *ge* blade and the alloy compositions. For example, WGC M1:14 and GJZ M160:9 (Figure 7.15, b and h) may look very similar, but the former has 2.8% lead, while the latter has 28.6%.

Therefore, we can suggest the following conclusions: those low-leaded *ge* blades may have been considered to have relatively high values since these objects, although often used as ritual objects, are also good weapons. For the deceased who had the highest social status, those who organised

⁶¹ Ma, D. et al. 1955; Yang, B. and Yang, X. 1979.

⁶² Li, M. 1984.

⁶³ Method of analysis: Atomic absorption spectroscopy (AAS); reference: Zhao, C. 2004.

these tombs usually put in only low-leaded weapons in. By contrast, the high-leaded *ge* blades, like the pure lead ones, were probably used as cheap replicas of the low-leaded ones. Since these high-leaded blades are not suitable for real fighting, it is not likely that those objects would have been owned by the tomb occupants during their lifetime. Rather, those *ge* blades may have been made for the particular burial purpose. In the case of GJZ M160, the presence of high-leaded *ge* blades has two possible explanations. First, two high-leaded *ge* blades were found on the secondary ledge where the attendants were placed. As previously mentioned, these individuals may have been buried in the tomb to protect their masters. In this way, the weapons were probably not really owned and used by the attendants when they were alive. Second, some *ge* blades found with the main occupant, Yazhi, were also made of high-leaded bronze. However, we can imagine that, for an individual buried with hundreds of weapons, it is clear that what the people who arranged this burial really wanted to do is to reflect (or even to uplift) the social status of this individual. Therefore, the quantity of the weapons was probably more important than their quality.⁶⁴

In conclusion, the reason behind the choices between low- and high-leaded *ge* blades in Yinxu may have been, like the reason behind the choices of leaded bronze ritual vessels in Chapter 5, socio-economic. To test this theory, we may also look at the *ge* blades from Qianzhangda, an eastern cemetery site chronologically and culturally close to Yinxu. At Qianzhangda, burying weapons, especially the *ge* blades, was also a very common practice at least among people with a certain level of social status.⁶⁵ Twenty-one of the *ge* blades from twelve tombs have been analysed. Among them, only five objects contain more than 20% lead, while the others all have

⁶⁴ We do not really know who the supposed audience of these burials were. The weapons may have been presented in the funerals so as to show the social status of the deceased. More likely, the weapons may have been placed in the burial so the deceased and the guards can defend themselves from any threat.

⁶⁵ Zhang, M. 2016: 201–208; Wang, W. 2018. It is worth noting that we know very little about the commoners' burials at both sites, as most published tombs belonged to people with a certain level of wealth and social status.

below 6% lead. These five high-leaded *ge* blades were from two tombs: M11 and M201. M201 was disturbed with only part of the grave goods left, so we do not have much information about this tomb. M11 was intact. It was a median-sized tomb, but the main occupant was buried with an exceptionally large number of grave goods, including 31 *ge* blades, while three out of the four analysed *ge* blades are high-leaded.⁶⁶ Those blades may also have been placed in the tomb to increase the overall quantity of the grave goods.

Outside the Shang sphere, there was no uniform funerary practice in using these objects. Among around a hundred excavated tombs at Xujianian, only six had the *ge* blades. The high-leaded *ge* blades from Xujianian and the other sites are very similar to those from Yinxu (we may therefore call them “Shang-style” *ge* blades). Since no provenance studies on the western *ge* blades have been undertaken,⁶⁷ we do not know whether the objects were made locally in the Wei River Valleys or were originally made in Central China and were transported there. But in either case, we certainly cannot assume that those *ge* blades placed in the Xujianian tombs were also related to the expression of wealth or social status. A detailed observation of the burial contexts may give us some information about the use of such objects. In Tomb M70, for example, the *ge* blade was buried together with a spearhead and two arrowheads. This may not be a random choice. If we look at Yinxu, this *ge*-spear-arrowhead combination recurred in many tombs.⁶⁸ In Tomb M9, the tip of the *ge* blades were intentionally broken before the object was placed in the tomb. Most scholars believe that this was a tradition that originated in the Guanzhong Basin around the second half of the second millennium BC, while some other scholars also point out that there

⁶⁶ I even suspect that, since the chemical analyses are often destructive, if there is a large group of similar objects (such as hundreds of *ge* blades) from the same tomb, the researchers may be inclined to choose samples from those which are less well-preserved. With this approach, high-leaded bronze objects are more likely to be selected as samples for analyses.

⁶⁷ No lead isotopic study has been done on the Wei River bronze weapons.

⁶⁸ Zhang, M. 2016: 208.

were a significant number of such tombs in Zhengzhou and Yinxu.⁶⁹ In Tomb M70, a piece of jade was put in the mouth of the occupant. Such a practice is not seen in other tombs of this area. However, we know that there are a few examples in Yinxu, such as Xiaotun M20 and Dasikong M233, M289.⁷⁰ Put these pieces of evidence together, I would suggest that some people at Xujianian may have intentionally chosen (or their family members may have helped them choose) to be buried in a way like those Shang people in the east. The placement of the *ge* blades may have been part of this burial practice.

But why would these people have chosen to be buried in the Shang way? I think one possible reason is that some Xujianian individuals may have played a special role in the community by negotiating their relationships with both the Shang people and the local population. These people may have originally come from the Shang sphere, such as through intermarriage. We may not be able to confirm this by the current archaeological materials. However, as previously mentioned, the high-leaded bronze *ge* blades were not likely to be used as real weapons. For these Xujianian people and their families, if they wanted to place the *ge* blades in the tombs, they would have either asked the local craftspeople to make these ritual weapons following the Shang style, or obtained these objects directly from the Shang. If it was the second scenario, there must have been continued communication between those Xujianian individuals and the Shang people regarding what burial weapons they can get, and how many they can get. Meanwhile, this continued contact with the Shang must also have an impact on the positions of the individuals in their own community. Based on the burial patterns, we may even suspect that those individuals may have been valued in the Xujianian community due to their abilities to negotiate with the Shang.

⁶⁹ Jing, Z. 2006; Yao, E. 2018; Zhang, M. 2005; 2016: 236–255.

⁷⁰ Shi, Z. 1952: 454; Ma, D. 1955: 55.

In summary, the cases we have discussed indicate that there were three waves of interregional exchange in the Hexi Corridor regarding the early development of metallurgy. In the first wave, metal production was introduced into the middle part of the Hexi Corridor, probably from the steppes via the Ejin River Valley. Based on the analyses of the metal products and the metallurgical remains, the communities may have been people directly coming from the steppe, as they focused on making the steppe-style objects and using unleaded copper alloys. Around 1600/1500 BC, the middle Ejin River Valley became less populated. In the south, large metal-using communities, such as Mogou, emerged in the upper Wei River Valley. These new communities continued to use the previous types of metal objects, indicating that they were partly influenced by the north. Nevertheless, the adoption of new materials such as leaded bronze suggests both a local change (as to abandon the previous lead aversion), and a possible external stimulus (in the arrival of leaded bronze resources). Finally, in the last centuries of the second millennium BC, new types of metal object appeared in the upper Wei River Valley, symbolising a new wave of influence from the east. The most typical objects appeared in this wave was the high-leaded ritual weapons which were commonly used in Central China. The Hexi Corridor, as a region connecting but also constantly influenced by both the west and the east, demonstrates vividly that technological choices, such as whether or not to use leaded bronze, are not merely technological problems, but cultural problems as well. When culture changed, people's ideas of what materials to be used also changed. Thus, leaded bronze, the material once considered unfavourable in one cultural context, was later adopted in another cultural context.

A Divided Land

Leaded Bronze in the Lower Yangtze Valley

The region in this last case study is the lower Yangtze Valley in East China. Today, the Yangtze Delta is one of the most densely populated areas in East Asia, with one tenth of China's population living here and contributing one fifth of the country's GDP.¹ Nevertheless, during the second millennium BC, large population and metropolises were certainly not the features of the lower Yangtze Valley. Instead, this area was occupied by relatively small communities who lived on lands divided by the rivers, the lakes, and the coastal floods. Meanwhile, beneath the feet of these early settlers, there were hidden treasures waiting for them: metals. The metal deposits in the lower Yangtze Valley are so rich that, even today, this is still one of the major metal-mining areas in China. It was in such a condition that people started to engage with metals.

The early metallurgical practices in this region can be divided into two models. Some communities chose to participate in large-scale production of ritual bronzes, just like those we have seen at Erlitou, Zhengzhou, and Panlongcheng in Chapter 5. Other communities, however, only possessed and produced a few small metal tools, probably for everyday use. In this chapter,

¹ Population: 2020 Chinese Census; GDP: 2020 annual GDP. Source: National Bureau of Statistics, China: www.stats.gov.cn.

I argue that the communities following the second model may have recycled metal objects or scrap metals produced by their neighbours following the first model. As a result, high-leaded bronze alloys were reused to make everyday tools. Since, compared with other materials, such as stone and bone, leaded bronze usually does not have better mechanical properties, the metal recyclers may have concluded that metals in general were not particularly useful and thus did not use metal objects widely in their daily lives.

Sitting on the Mines

Similar to the middle Yangtze Valley, which has been briefly mentioned in Chapter 5, the lower Yangtze Valley is also famous for its abundant mining resources (Figure 8.1). Today, Anhui Province alone has about 4.1 million tons of copper, or about 5.7% of China's total copper reserves. Most of the copper deposits are concentrated in the city of Tongling, whose name literally means "Copper Hill". Tongguanshan, the main copper mine in Tongling, provides one sixth of the total blister copper (partly purified copper) in China annually.² A 1993 archaeological survey in Tongling found several early mining sites which can be dated to the late second to the early first millennia BC.³ The recent discovery of Shigudun, a major metal production site which we will discuss later, further pushed the history of large-scale metal production in this area back to the middle second millennium BC.⁴

These metal deposits would have certainly attracted the attention of people who longed for the resources. The same desire may have pushed people to establish settlements in the middle Yangtze Valley, such as Panlongcheng (Chapter 5). In the lower Yangtze Valley, however, we

² Zhongguo 1996a: v. Anhui, 79.

³ Wang, J. and Yang, L. 1993.

⁴ Anhuisheng 2020.

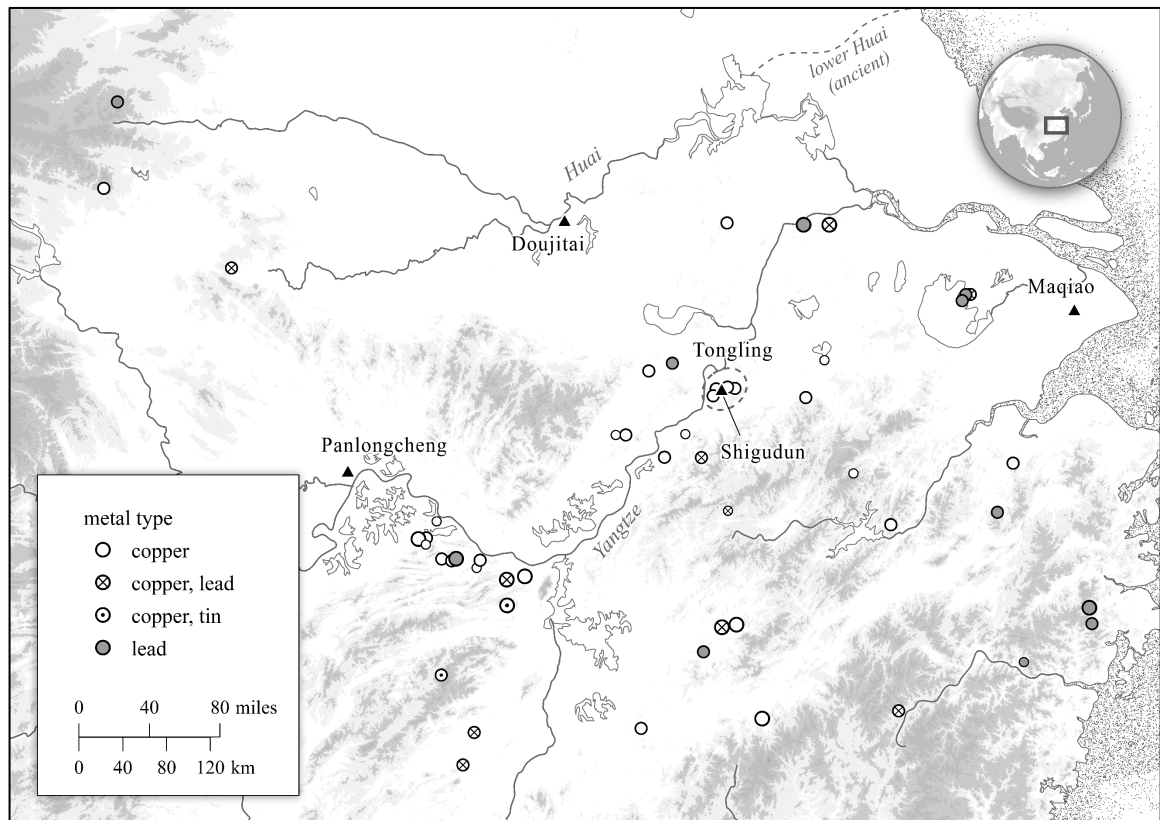


Figure 8.1 Metal deposits in the lower Yangtze Valley and major second millennium BC sites (data: Zhongguo 1996a).

know little about the early metalworking communities in the second millennium BC. During this millennium, the most significant regional phenomenon was probably the dramatic decrease in the number of settlements. As calculated by Gao Menghe, by the end of the third millennium BC, there were around 110 sites in this area. This number declined to 52 by 1500 BC, and to 46 by 1000 BC. As a comparison, during the Liangzhu period (3300–2300 BC), there were 517 sites in the same area.⁵ There are several possible reasons for this decrease in the number of settlement sites. Some scholars suggest that the once densely populated Yangtze Delta may have encountered a series of water problems from the rise of the sea-level to the expansion of the lakes.⁶ These issues forced people to abandon the large settlement centres, such as Liangzhu.

⁵ Gao, M. 2005: 63–101. See also Xiao, Y. et al. 2018; Zhang, C. 2003: 224–232.

⁶ Chen et al. 2005; Stanley et al. 1999; Wang, Z. et al. 2018; Zhao, D. 2016.

Throughout the second millennium BC, the area was occupied by less crowded communities, and each community was relatively small.⁷ The land adjacent to the eastern coast was not totally abandoned. People who remained there probably learned how to live with water. The new settlements relied not on building rammed-earth foundations and dams, but on natural beach ridges shaped by marine regression.⁸ The best example is Maqiao in today's Shanghai. The site is now about 50 km from the coast. The excavation and the reconstruction of the paleoenvironment show that the site was located on a beach ridge which was formed around 3500 BC. To the east, about 1 km from Maqiao, there was another beach ridge. In the third millennium BC, most human activities at the site were restricted to the west of the western beach ridge, while in the second millennium BC, people gradually moved to the piece of land between the two ridges, in an area around 15 km². Meanwhile, the proportion of agriculture and animal husbandry in the subsistence economy decreased, replaced by the increasing hunting-gathering activities.⁹ For people to settle in such a location, they may also have depended on maritime exchange with other coastal communities. Some ceramics from Maqiao shared characteristics with those from Shandong, suggesting possible exchanges between these two regions.¹⁰ But whether the cultural communication was via along-the-coast seafaring or by coast-inland-coast routes cannot be confirmed based on the current, still limited archaeological materials. In areas further inland, the material culture was more influenced by the north. An example showing this is Doujitai, on the bank of the Huai River.¹¹ Based on the ceramic typology, the site is relatively dated to 1900–1500 BC. Upon closer analyses, scholars found that the Doujitai ceramics

⁷ Guojia 2014.

⁸ Gao, M. and Pan, B. 2019; Tan, Q. 1973.

⁹ Shanghaishi 2002: 341–344; Song, J. and Hong, X. 1999.

¹⁰ Shanghaishi 2002: 375–377.

¹¹ The Huai River is the major river in this area. Historically, the Huai River used to enter the sea at somewhere near today's Yancheng, Jiangsu. See: Elvin 2004: 135–136; Zhu, G. et al. 2005. This ancient lower Huai River is marked on the maps, see Figures 8.1; 8.2.

absorbed cultural traits from almost all nearby regions, especially the middle Yellow River Valley and Shandong.¹²

The land being unsuitable for large and populous settlements, as well as the intensive cultural contact with both the coast and the inland river valleys, probably encouraged communities in the lower Yangtze Valley to exploit local metal resources. During these attempts, different external stimuli and technological choices also led people towards two different relations with metals. The problem of whether or not to use leaded bronze may have been part of this division.

Identical Metals, Two Metallurgies: The River Valleys vs. the Coast

For a long time, the only metal production centre in the Yangtze Valleys we knew of was Panlongcheng. Metal production there started during the Erligang period, or around the middle of the second millennium BC. Archaeological findings show that the same types of bronze ritual vessel as those from the middle Yellow River Valley were produced at Panlongcheng and were used by people in burial rituals. Beyond Panlongcheng, evidence of metal use and metal production was sporadic, especially in the lower Yangtze Valley, but this understanding started to be changed, especially in the first decade of the twenty-first century, when a few new metal production sites were discovered on the plain between the Yellow River and the Huai River (Figure 8.2). These discoveries make it possible to reconsider the circumstances of early metal use and metal production in the lower Yangtze Valley, as well as the cultural exchange between the north and the south.

¹² Wang, X. 1994: 54–57; Zhang, X. 2016.

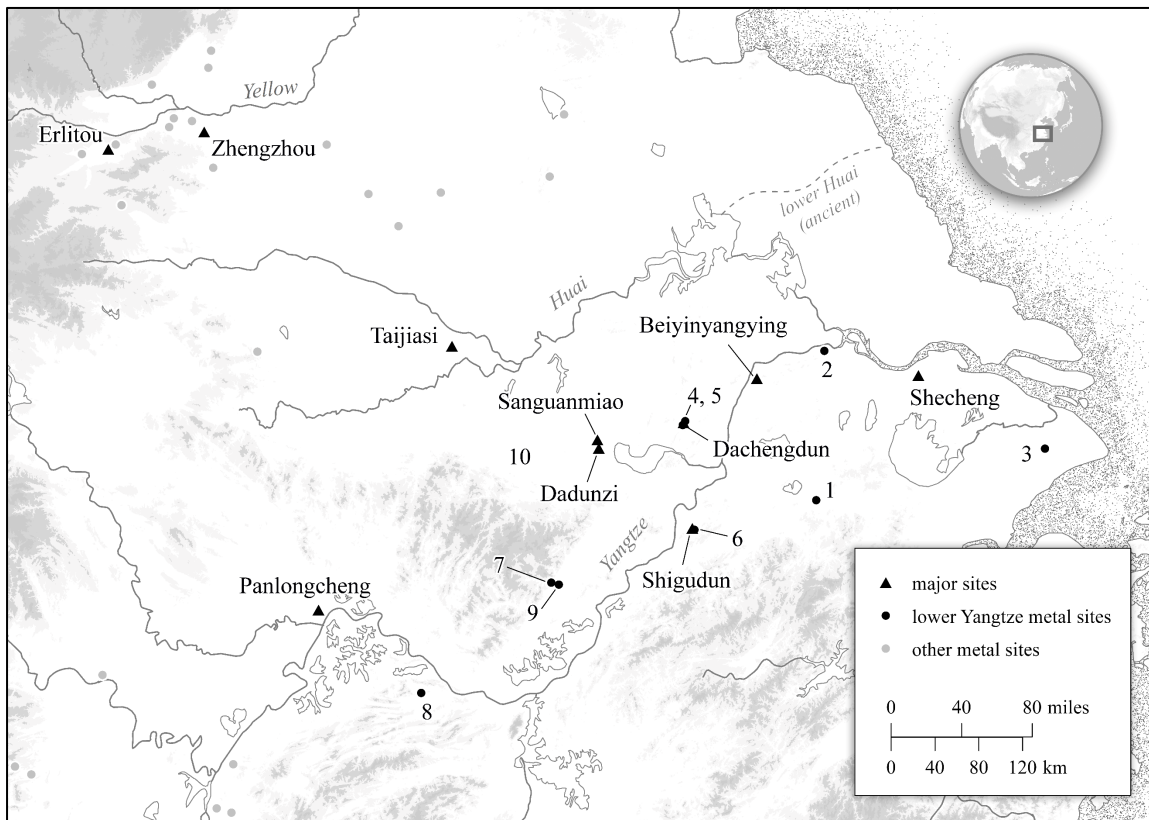


Figure 8.2 Metal sites in the Huai River and the lower Yangtze Valley, 1700–1300 BC. Sites mentioned in the text are marked on the map. Others: 1: Langxi; 2: Majishan; 3: Maqiao; 4: Sunjiagang; 5: Sunqi; 6: Tongdun; 7: Xuejiagang; 8: Yinshan; 9: Zhangfashan; 10: Zhongdesi.

The Valley Model

So far, the earliest evidence of metal use and metal production in the lower Yangtze Valley is dated to around 1600–1500 BC. At Dadunzi in today's Hefei, Anhui Province, three metal objects were found at the site in the 1970s, including two *jia* vessels and a bell (Figure 8.3, a–c).¹³ The archaeological context of these objects is unknown. Nevertheless, we can still make a few suggestions by comparing them with similar objects from Erlitou. At the latter, the bronze *jia* vessels are dated to the transitional period from Erlitou to Erligang, while the bells were mainly found in the Phases II–IV contexts (Chapter 5). Most scholars suggest that the Dadunzi

¹³ Chen, L. 2014.

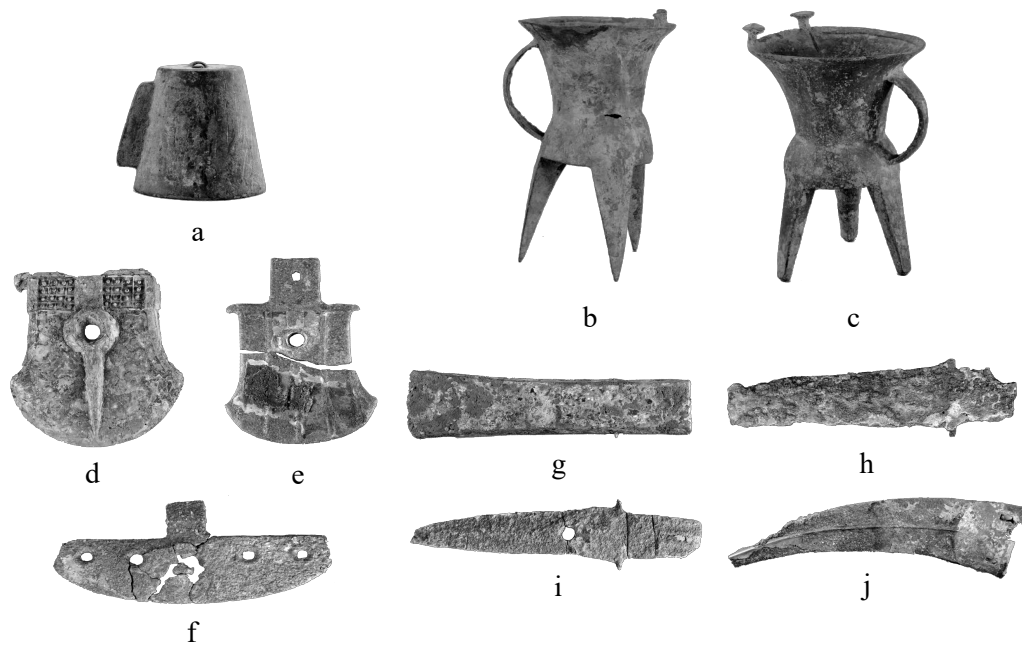


Figure 8.3 Metal objects from the lower Yangtze Valley, 1600–1400 BC. Dadunzi: a: bell; b, c: *jia* vessels (after Chen, L. 2014: 2; 4); Sanguanmiao: d–g: axes; h, i: *ge* blades; j: horn-shaped object (after Fang, L. 2020: 6–7).

bell is typologically closer to the Erlitou Phase IV bells, and thus date the Dadunzi bronzes to the period from Erlitou IV to Lower Erligang, or around 1600–1450 BC.¹⁴ Not far away from Dadunzi, dozens of metal weapons have been found at Sanguanmiao (Figure 8.3, d–i). These weapons, probably mainly for ritual uses as well, are also dated to the same period based on their typology.¹⁵ Since the excavation at this site has not been fully published, we will definitely have more information in future. However, in the case of Erlitou, bells, ritual vessels, and weapons were only placed in the tombs of high-status individuals. Thus, the presence of such objects in the lower Yangtze Valley is itself a remarkable phenomenon. Either some local rulers were ordering ritual bronzes and were wishing to be buried in the same way as those elite members in

¹⁴ Cheng, L. 2014; Du, J. 2007; Li, C. 2006.

¹⁵ Qing, R. 2018; Fang, L. 2020.

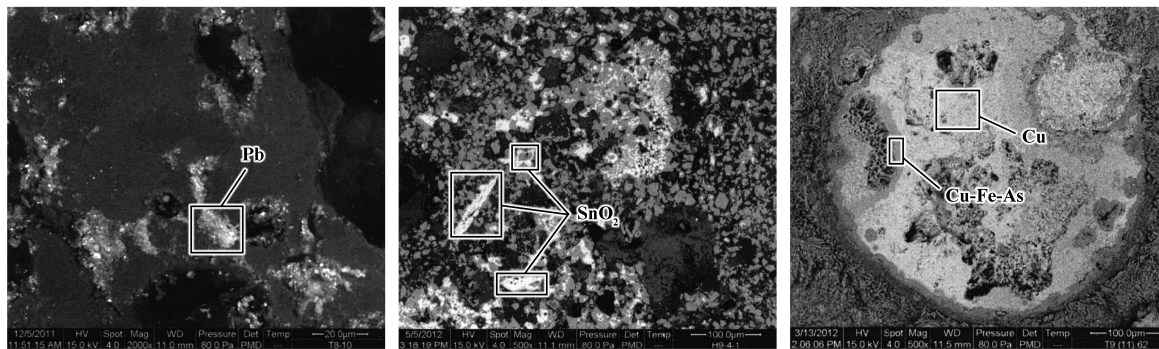


Figure 8.4 SEM images of the refractory fragments from Shigudun. Left: T8(10):1; middle: H9:4; right: T9(11):62 (after Wang, K. et al. 2013: 96).

the middle Yellow River Valley, or people who were buried with these bronzes came directly from the north, probably as a way to control the local population.

Metal production remains are also said to have been found at Dadunzi, but again they are not well-published.¹⁶ A better-known contemporaneous metal production site is Shigudun, located in one of the major copper mining areas in the lower Yangtze Valley. Archaeological materials found at the site suggest that the period of occupation spanned from the first half of the second millennium BC to the first half of the first millennium BC. Metal objects and metal production remains have been found in almost all cultural layers. Three refractory fragments and a sample of crucible slag in the contexts of the early stage of the site, dating to 1700–1600 BC, were collected for further analysis.¹⁷ By observing the microstructure of the samples, researchers identified at least three types of metal material which were melted, and thus may have been involved in the metal production at the site: lead, copper-tin-lead, and copper-arsenic (Figure 8.4).¹⁸

¹⁶ Zhang, A. and Lu, Q. 2010.

¹⁷ Report: Anhuisheng 2020; Shuo, Z. et al. 2013. See also Wang, K. et al. 2013; dating: Anhuisheng 2020: v. 1, 649–651.

¹⁸ Wang, K. et al. 2013; Yu, Y. et al. 2015.

Over the next few centuries, another site, Taijiashi, emerged and became an important metal manufacturer in this region. In the excavated part of this site, there were houses in two rows, surrounded by moats on three sides and river on the other side. In the northern row, the houses were built on a platform. At the eastern end of this row was a house which may have been used as a bronze workshop (Figure 8.5). It was about 50 m². In the eastern part of this house, there was a round area covered with white pigments (calcium carbonate) and small bronze granules, probably left by metalworking activities. Interestingly, this workshop layout is very similar to those found in Zhengzhou. This suggests that the Yangtze metal production sites were not only producing objects similar to those in the north, the metal producing technologies may also have come directly from the north.¹⁹ In the southern part of the excavated area, thousands of ceramic mould fragments have been found in several pits. Some of these moulds show clearly that they can be used to cast bronze vessels such as the *ding*, the *gu*, and the *jue*.²⁰ On many fragments, the decorative patterns were finely made, indicating that the ritual vessels produced here were probably of high quality. Finished bronze products have not been found at Taijiashi. However, on the other side of the river, a few tombs with bronze ritual vessels and weapons have been found, but the detailed information has not yet been published. In addition, a few bronze vessels were found near Taijiashi in the 1950s. These vessels may also have been produced at this site.²¹ Currently, no absolute date of Taijiashi has been published. By comparing the objects with those from Zhengzhou, the excavators suggest that the main contexts of Taijiashi can be dated to around 1450–1300 BC.

In the Yangtze Delta, some communities may also have been participating in metal production during the early second millennium BC. The evidence comes from Shecheng, near Lake Tai.

¹⁹ Henansheng 2001: v. 1, 307–383. See also Chang, H. 2018.

²⁰ He, X. and Gong, X. 2018.

²¹ Ge, J. 1959.

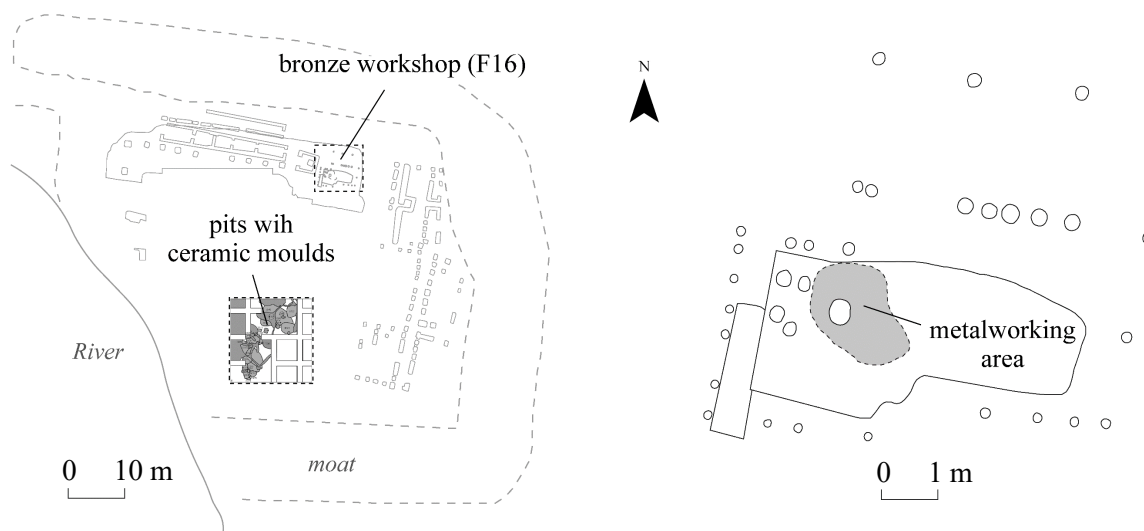


Figure 8.5 Plan of Taijiashi, the bronze workshop (F16), and the area where the pits with ceramic moulds have been found. Right: detailed view of the bronze workshop (modified from He, X. and Gong, X. 2018).

The site was fortified with walls and moats. The inner area is about 30 ha. This is the only known walled site in the lower Yangtze Valley of its time. About 200 metres from the eastern wall, there was a small site called Huashan. Massive refractory and bronze fragments have been found at the site, suggesting that this may have been the location of a bronze workshop. As dated by the ceramics, Shecheng was probably occupied from around 1500 to 1000 BC. Only very preliminary reports of this site have been published.²²

Archaeological materials from these sites, although still quite limited and only partly published, demonstrate clearly that there were multiple metal production centres in the lower Yangtze Valley. From the layout of the workshop, the types of the ritual vessels, as well as the preliminary information of the alloying, we can see that the analogy between the metallurgical practices in the lower Yangtze Valley and those in the middle Yellow River Valley is clear. This suggests that, like Panlongcheng, these lower Yangtze communities may also have been participating in what we may call a “middle Yellow River and middle Yangtze Valleys model” of metal

²² Cai, W. et al. 2001; Diao, W. and Wu, H. 2004; Lu, J. et al. 2001.

production, or, in short, a “valley model”. The difference is that, in the cases of Erlitou, Zhengzhou, and Panlongcheng, many burials with bronze vessels and weapons have been found, suggesting that a large number of the metal objects produced at the sites were also consumed locally. In the lower Yangtze Valley, by contrast, there were not such large settlements or cemeteries. Considering the large scale of metal production in this region and the small number of tombs containing ritual bronzes, we may suspect that the lower Yangtze communities were not producing ritual bronzes for themselves, but mainly for export. However, as new sites are being discovered every year, it is still too soon to confirm (or reject) this hypothesis.

Overall, we can see that the “valley model” metal production was gradually established at a few sites in the lower Yangtze Valley under a strong influence from the north. As a result, the craftspeople at these sites seem to have focused on producing high-end bronze objects such as ritual vessels and symbolic weapons. Nevertheless, at the same time, another type of metal production also emerged in roughly the same region. Unlike the “valley model” which was relatively large-scale and ritual-bronze-oriented, the second model, what we may call the “coastal model”, was small-scale and mainly focused on producing everyday objects. The percentage of such objects in the total material assemblages was low, suggesting that those metal objects may not have been considered important. By comparing these two parallel models of metal production, I will also propose a hypothesis that the use of recycled leaded bronze alloys may have hampered the broader acceptance of metals in some communities.

The Coastal Model

Centuries before the emergence of the Erlitou-Erligang style metal objects and the associated “valley model” of metal production, communities in the lower Yangtze Valley may already have started to use this new material. At Dachengdun, on the north-western side of the Yangtze, a fragment of a knife has been found in a context which belongs to the second phase of the site (Figure 8.6, a). Phase II is not dated, but the succeeding one, Phase III, is dated (relatively and

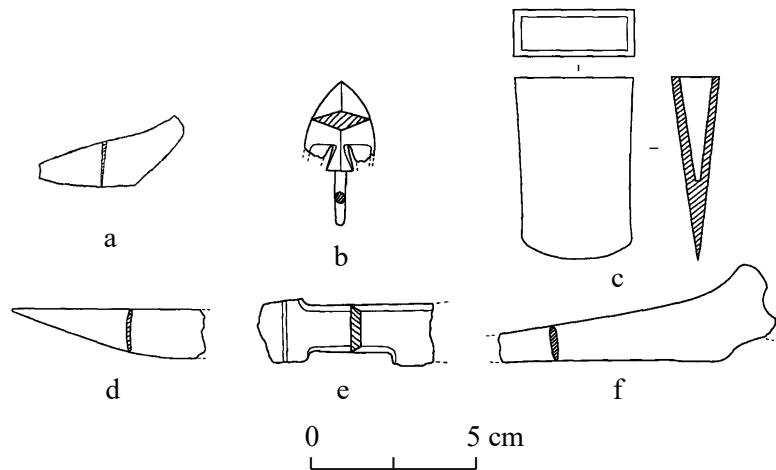


Figure 8.6 Metal objects from: Dachengdun: a: knife (after Zhang, J. 1989a: 107); Maqiao: b: arrowhead; c: axe; d–f: knives (after Shanghaishi 2002: 289).

absolutely) to 1700–1500 BC. Therefore, the date of the knife is probably prior to 1700 BC.²³ Beside this object, it is said that a crucible, slags, and charcoals have also been found at the site, suggesting the existence of local metal production. However, since the materials have not yet been published, we do not know the exact dates or other details.²⁴ Around the same time, the practice of metal use have reached even further east, to the coastal site Maqiao. Seven metal objects, including an arrowhead, an axe, and several knives, have been found in the contexts which are dated to 1700–1400 BC (Figure 8.6, b–f).²⁵ These metal objects demonstrate that, besides the northern style bells, vessels, and weapons, some forms of everyday bronzes may also have been made, used, and exchanged in the lower Yangtze Valley.

Beiyinyangying is the best-known example to demonstrate how these everyday metal objects were produced and used. The site is divided by the excavators into three phases, in which most

²³ Object: Zhang, J. 1989a; dating: Zhang, J. 1989b.

²⁴ Zhang, A. and Lu, Q. 2010.

²⁵ Shanghai 2002.

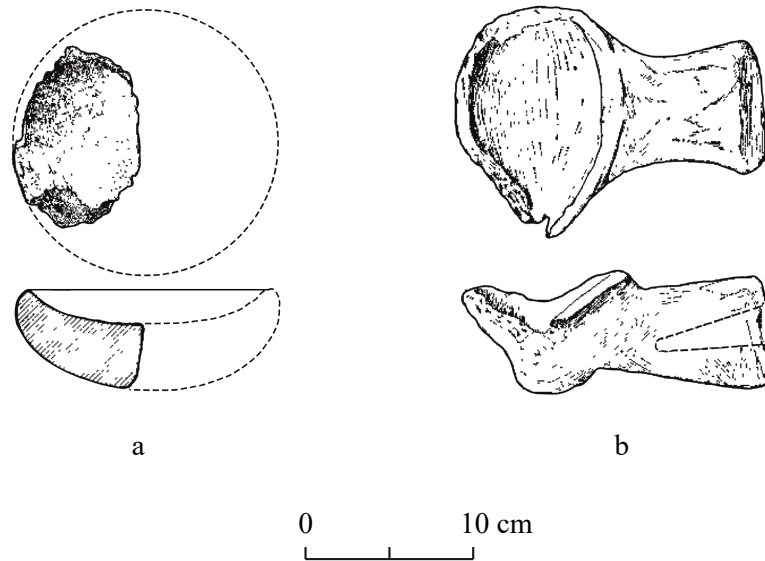


Figure 8.7 Metalworking tools from Beiyinyangying. a: crucible; b: ladle (after Nanjing 1993: 143).

archaeological materials belong to the first Neolithic phase, dating to 4000–3300 BC.²⁶ Phase II is dated to 1872–1543 BC, about the same time as when some nearby sites were involved in the “valley model” metal production.²⁷ Between Phases I and II there was a gap about a millennium. At Beiyinyangying, the Phase II bronze objects include thirty-three arrowheads, three drills, a knife, and a fragment. Besides these objects, the excavators have also found some tools which were used in metal production. One of them is a fragment of a ceramic vessel (Figure 8.7, a). The inner surface is covered with a layer of copper, so the object may have been originally used as a crucible to melt metal. There are also finds of two ceramic ladles (Figure 8.7, b), probably for pouring molten metal into a mould. The crucible, if reconstructed, seems to be very shallow and much smaller than the crucibles found in Zhengzhou.²⁸ For this reason, we may suggest that

²⁶ There is no absolute date for the first phase, the time period is suggested by the ceramic typology: *Zhongguo*: 2010: 487.

²⁷ Report: Nanjing 1993; dating: *Zhongguo* 1991: 102.

²⁸ E.g. *Henansheng* 2001: v. 1, 339; 350.

metal objects produced at Beiyinyangying were probably small objects, such as those found at the same site, instead of large objects such as ritual vessels.

Therefore, the model of the metal production at Beiyinyangying was certainly different from the “valley model”, which we have discussed in the last section. For Dadunzi, Taijiashi, and Shigudun, metallurgical activities were normally conducted in particular spaces, such as workshops. The scale of the manufacturing at each site, indicated by the quantity of the remains (such as moulds), was quite significant. At Beiyinyangying, however, the scale of the metallurgical activities was relatively small, while the production was probably organised on an individual or household level. The objects produced by the two types of site were also very different. When the “valley model” sites focused on producing export-oriented, complicated ritual bronzes, the metal products from Beiyinyangying were small everyday tools, which were supposed to be used and distributed locally.

Also, as the small, everyday metal objects appeared in the lower Yangtze Valley earlier than the establishment of the “valley model” metal production, the craftspeople at Dachengdun, Maqiao, and Beiyinyangying may have learned metallurgy from somewhere else, rather than from their “valley model” metalworking neighbours. Based on the object typology and the location, I suggest that the practices of using and producing those everyday metal objects may have originated in the Huanghuai Plain (the land between the Yellow River and the Huai River) and the Shandong Peninsula. Metal objects appeared in this area around 2000 BC and have been used since then (Chapter 2, Figure 2.10). In particular, some metal objects were found in the contexts together with a type of ceramic vessel. These vessels, from the perspective of archaeological culture, are often defined as the Yueshi culture (Figure 8.8).²⁹ By absolute and

²⁹ Xu, J. 2006; 2007. The use of archaeological culture and its potential problems have been discussed in Chapter 2.

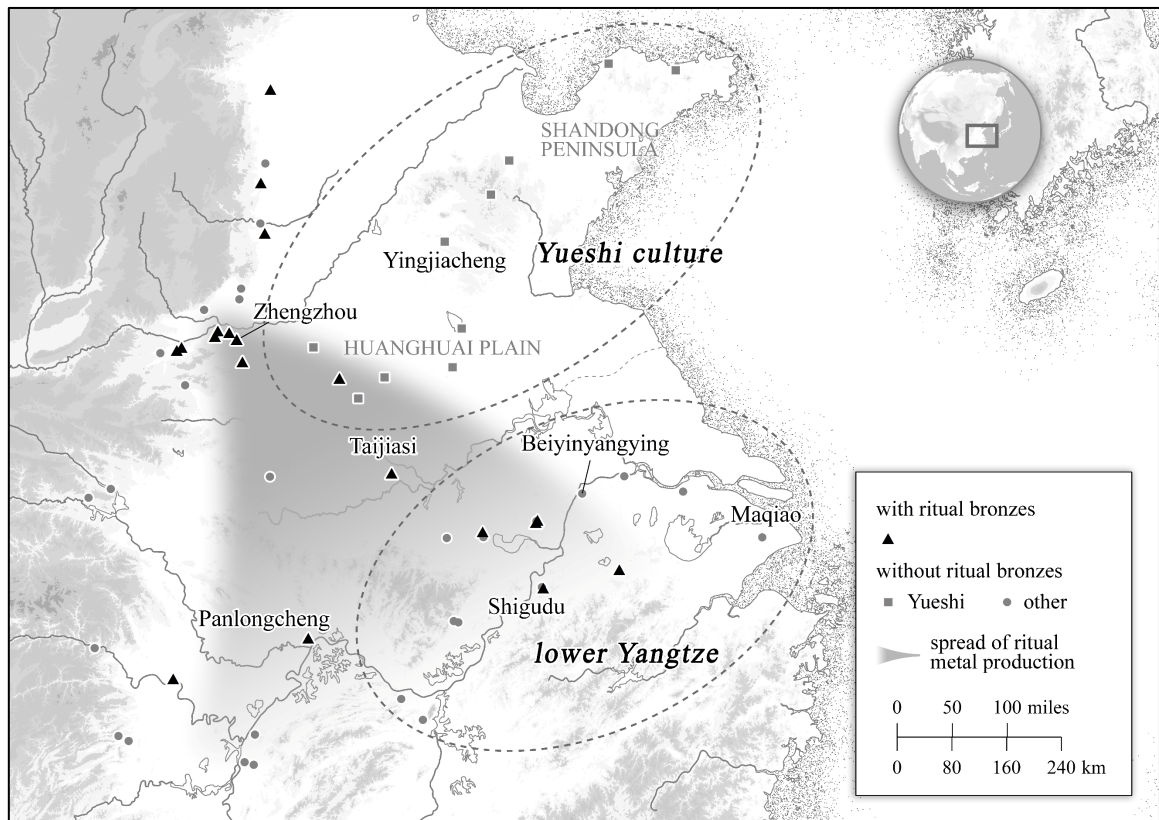


Figure 8.8 The metal-bearing sites in the lower Yangtze Valley and in the Yueshi culture, together with the spread of the “valley model” metal production.

relative dating, Yueshi ceramics were mainly used around 1800–1450 BC.³⁰ Most metal objects associated with the Yueshi ceramics are also small tools such as knives and arrowheads, while bronze ritual vessels and weapons were very rare. So far, evidence of metal production has not been found at any Yueshi site. If those Yueshi metal objects were produced locally, the scale of such metalworking activities may also have been quite small. Therefore, the small metal objects from the Yueshi culture sites and those from the lower Yangtze Valley sites may have reflected the same metal production tradition. We may call it the “coastal model”, since these sites were closer to the coast than those following the “valley model”.

³⁰ Fang, H. 1998.

Leaded Bronze as a Not Very Useful Material?

If we look at those lower Yangtze communities with everyday metal objects. The quantity of the metal objects at each site is usually very small. Beiyinyangying has the largest so far discovered metal assemblage: thirty-eight objects, but even at this site, most tools were still made of traditional materials such as stone, bone, and horn. It seems that metals were not essential in the daily lives of the people. So why did those communities not use metals more widely when the resources were abundant?

The chemical compositions of the objects may help answer the question. Most early metal objects from the lower Yangtze Valley have not been analysed, with only one exception. At Beiyinyangying, five metal samples, including an arrowhead, a knife and three unidentified metal fragments, were analysed, with semi-quantitative results published.³¹ The results show that the alloy compositions of these samples are highly heterogeneous (Table 8.1). Since we do not know the chemical compositions of other lower Yangtze objects, we may use the published results of analysed metal objects from Yingjiacheng for reference. Yingjiacheng is a site in the Huanghuai Plain. Metal objects and Yueshi type ceramics have been found in contexts which are dated to 1900–1500 BC.³² Like the metal objects from Beiyinyangying, the chemical compositions of the Yingjiacheng samples are also quite random. However, a few tools, such as a knife and an awl, contain high lead contents (Table 8.2). If we compare these objects with what we see in our previous case studies, such as Erlitou (Chapter 5), Dadianzi (Chapter 6), and Mogou (Chapter 7), such high lead contents do not seem to have been caused by simply smelting polymetallic ores. Also, since high lead levels would certainly compromise the strength and the

³¹ A problem is that metal objects found at Beiyinyangying belong to two phases: Phase II and Phase III. For those analysed objects, their archaeological contexts are not published, so some objects may belong to Phase III, or 1300–1000 BC.

³² Shandong 1990.

Table 8.1 Analysed metal objects from Beiyinyangying.

Object ID	Object type	Composition (%)	
		>1	0.1–1
10:3970	arrowhead	Cu, Fe, Bi	Sn
10:4033	knife	Cu, Sn	-
10:3908	fragment	Cu, Si	Fe
10:3981	fragment	Cu, Sn, Pb	Bi
10:3515	fragment	Cu, As, Pb, Sn	Bi

Reference: Nanjing (1993: 146).

Table 8.2 Analysed metal objects from Yinjiacheng.

Object ID	Object type	Composition (%)			
		Cu	Sn	Pb	Ag
H5:4	knife	45.0	40.0	4.0	2.0
H479:1	fragment	73.0	3.0	8.0	0.5
T198(7):5	knife	66.8	1.0	32.7	-
T211(7)D:16	fragment	99.1	0.9	-	-
T216(7):27	bracelet	91.0	3.0	2.0	0.1
T221(7):21	knife	95.8	4.2	-	-
T222(7):45	knife	48.0	39.0	5.0	1.0
T258(7):7	awl	71.1	15.1	13.8	-
T268(7):4	fragment	64.0	7.0	25.0	0.5

Methods of analysis: ABS and SEM; reference: Sun (1990).

hardness of the copper alloys (Chapter 4), it is also not very likely that the people who made the tools intentionally added lead into the bronze.

Two possible scenarios may help explain the random alloy compositions and the high lead levels of the metal objects. First, the “valley model” ritual bronze producers may have left many unwanted objects and scrap metals with high lead contents. These metal resources may have been remelted and reused by people in the neighbouring areas attempting to make small metal

objects for everyday use. In this way, the high lead contents were “inherited” by the new objects, as lead went on in new “karmic cycles” (Chapter 3). The other possible scenario is that lead came from “low quality” metal ingots produced by the smelting communities. This can be suggested by the recently discovered Yinshan mining and smelting complex (with dozens of small sites) near Panlongcheng (Figure 8.2, site 8). According to Li Yanxiang and colleagues, sites in the complex are dated (by the ceramic typology) to the late second to the early first millennium BC, so metal ingots produced here were probably offered to communities in the middle Yangtze Valley and even those in the north, such as Anyang. The slags left at the sites suggest that some lead ingots may have contained high levels of copper and arsenic.³³ These lead ingots could have been further refined to remove copper and arsenic, leading to relatively pure lead ingots like what have been found at Anyang.³⁴ Meanwhile, some of these unrefined ingots may have been deserted due to their low quality (low purity), and may have been obtained by the “valley model” craftspeople who then reused the metals—probably mixing them with other metals—to make everyday objects.

No matter which is the real reason behind the emergence of these high-leaded bronze tools, one thing is certain: those high-leaded tools may have been useful to some extent, but they would not be mechanically superior to tools made of traditional materials. This may help explain why only a few metal tools were used at Beiyinyangying and Yinjiacheng. Although people at these sites may have learned some metallurgical technologies (such as casting) from their neighbours, unlike those at Xichengyi, the Beiyinyangying craftspeople probably did not figure out how to intentionally make unleaded bronze objects (either by co-smelting unleaded copper and tin ores, or by mixing unleaded copper and tin ingots). In other words, the potential for metal as a new material had not yet been fully revealed to the users of the metal objects produced by the “costal

³³ Li, Y. et al. 2021.

³⁴ Tang, J. et al. 2018.

model”. As a result, there was no incentive for people to replace their everyday tools with those made of this new material.

In all, we can divide the development of the metal production in the lower Yangtze Valley into several stages. In the late third millennium BC, some communities in the middle and the lower Yellow River Valleys may already have had access to, or even succeeded in, making a few small metal objects (see also Chapter 2, Figure 2.10). During the first half of the second millennium BC, the emergence of the new metal-using communities such as Erlitou in the middle Yellow River Valley pushed some new technologies and secondary metal resources (such as scrap metals) to the eastern coast. On the Huanghuai Plain and the Shandong Peninsular, local communities continued to produce small metal objects (as those attributed to the Yueshi culture) , while also started to partly rely on the secondary metal resource from the west. Cultural contact with the northern Bohai Rim may also have provided important external stimulation. At Yingjiacheng, a metal bracelet found in a Yueshi culture context has two flat ends—very similar to the rings we discussed in Chapter 6. The object may have directly come from the north, or have been a local imitation of those in the north.³⁵ During the time of the Yueshi culture, some metal objects and metalworking knowledge may have travelled further south, to the lower Yangtze Valley (e.g. Maqiao).

Around 1500 BC, Erligang type metal production started to expand, turning some sites in the middle and the lower Yangtze Valley into regional production centres for bronze ritual vessels and symbolic weapons. The logic behind this expansion is not fully understood, but the abundant metal resources in the Yangtze Valleys must have been one of the driving forces. Some people at these newly established metal producing sites may also have adopted the tradition of using

³⁵ As previously mentioned in Chapter 6, no penannular ring or bracelet has been found in the middle Yellow River Valley, so it is unlikely for the Yinjiacheng bracelet (or the idea of making such a bracelet) to have come from that direction.

those ritual bronzes, such as putting the vessels and weapons in their own tombs. At the same time, communities on the Huanghuai Plain and the Shandong Peninsula were not involved in this movement. This is probably because of the lack of metal resources in this region.³⁶ In the lower Yangtze Valley, there were also some communities (such as Beiyinyangying) who did not join their neighbours in producing ritual bronzes. All those people who were left out of the business may have continued to use and to produce only a few types of small metal object. Exchanges between the “valley model” and the “coastal model” communities certainly existed. As some scholars point out, the knives and the arrowheads found at Beiyinyangying look almost identical with those found in the middle Yellow River Region.³⁷ So, it is possible that some of the Beiyinyangying metal objects were not made locally but by a “valley model” site. However, to participate in the “valley model” metal production, communities must reorganise themselves in the way to fit into the “mass production”. That is to say, there should be people (probably special craftspeople) working at special locations (workshops) for special parts of the metal production process (smelting, mould making, casting, etc.). All these elements did not exist in the communities who only participated in the “coastal model” of metal production. For those who has chosen not to follow the “valley model”, there may have been environmental issues discouraging mass craft production at the location. Maqiao, as previously discussed, is an example of such a community who literally survived in the cracks—between two beach ridges 1 km from each other. If we look at Beiyinyangying, the site is only a few kilometres from the Yangtze, with an elevation of only fifteen metres.³⁸ During its second phase, most archaeological features at Beiyinyangying are quite simple, such as small houses, fireplaces, and kilns for making pottery. Only three tombs have been found. Since part of the site has been demolished by modern construction, we do not know whether the original site had more features. But

³⁶ Zhongguo 1996a: v. Shandong, 2.

³⁷ Zhongguo 2003: 471.

³⁸ Nanjing 1993: 4.

according to what is left, Beiyinyangying during its second phase seems to have been a relatively small village. The environmental problem, especially water, may have encouraged people at sites like Maqiao and Beiyinyangying to choose a more mobile lifestyle with less “heavy industry”, such as large-scale metal production. This is perhaps why ritual bronzes were only produced in the inland river valleys instead of near the coast.

Therefore, the abundant metal deposits in the lower Yangtze Valley only changed the lives of a few people who were participating in the “valley model” of production. For everyone else, metals were just an optional but not necessary material. One possible reason for the limited use of bronze was the presence of high lead contents in most metals available in this area, such as the scrap metals left by the ritual vessel manufacturers. Therefore, the “coastal model” craftspeople were not fully aware of the potential for the metals, such as to make stronger tools. In their eyes, metals were probably a kind of material of some use, but not very useful. In other words, as I argue, it was indeed the easy access to leaded bronze resources which discouraged the further adoption of metal tools in the area.

PART THREE

Conclusions and Discussion

Why Was Leaded Bronze Used?

In the previous two parts of the thesis, I have discussed the geographic, technological, and the scientific backgrounds of leaded bronze, as well as four early Chinese cases of people using (or not using) leaded bronze. The discussion and case studies show that people in early China developed not only one, but several scenarios of cultural practices engaging this special metal material. Meanwhile, despite the fact that not everyone using leaded bronze had the same understanding of this material and its physical and mechanical properties, most people in these case studies were more or less aware of their choices of whether to include lead or not in making their metal objects. For this final chapter, I will first review how the land of East Asia helped form the later leaded-bronze-using culture. In addition, I will show that at least three distinctive scenarios of using leaded bronze were adopted by the communities that I presented in the case studies. In the next section, I will discuss some possible general reasons for the use of leaded bronze, and what this engagement with the material can tell us about the cultures and societies of these early communities.

Geographic Conditions and Technological Choices

The particular geology and geography of East Asia provide at least two fundamental conditions for the development of leaded bronze in early China: two distinctive yet adjacent geographic spheres, and a wide distribution of lead deposits in both spheres. As discussed in Chapter 2, most

plains and river valleys in the east and the south of East Asia are separated from the western and the northern highlands—with mountains and high plateaux running from north-eastern to south-western China—by elevation, leading to two very different landforms and ecosystems (Figure 2.1).¹ One particular result of the difference between these two distinctive ecosystems is the much higher population density on the lowlands than that on the highlands.² During the time period of those early metal-using communities, we may assume that central China was also more densely populated than the regions around it. This difference in population density may also have affected what type of metal production would have been conducted by the communities, and how metal products would have been used in the communities, as I will revisit this point in the last section.

When the knowledge of metallurgy came from the steppes and Inner Asia, communities on the northern and western highlands were the first to adopt this new technology, as well as some traits of the steppe-Inner Asian material culture, such as new types of weapon, tool, and personal ornament. In Chapter 2, I discussed several mechanisms of cultural contact and interregional exchanges (Figure 2.3). For the East Asian highlands, as people from the steppes and Inner Asia could easily move to regions such as the Hexi Corridor and the northern Bohai Rim, circulation, as travelling people bringing new ideas and objects around, must have played a vital role, although other mechanisms, such as local innovation and distribution, also contributed to the

¹ The highland areas surrounding central China are sometimes called the “crescent-shaped belt” or the “Arc”. This is first proposed by Tong Enzheng as a term in archaeology: Tong, E. 1987; see also Lyu H. and Zha, X. 2014. Later, Jessica Rawson developed this idea, describing the Arc as a transitional area between the Central Plains and the Eurasian Steppe/Inner Asia: Rawson 2017a. From the modern agricultural perspective, the Arc also overlaps the transitional area (the “ecotone”) between China’s farming and animal husbandry economies: Chen, Q. et al. 2007.

² A demographic idea, the “Heihe–Tengchong Line”, was first proposed by Hu Huanyong in the 1930s. This imaginary line divides China into two parts with roughly the same size. However, about 95% of China’s population live in the eastern half, which consists mostly of the plains and the river valleys, while only about 5% of the population live on the western half, which consists mostly of the highlands: Hu, H. 1935.

development of metallurgy. The two river valleys and the eastern plains, on the other hand, are not directly connected with the steppes or Inner Asia. The cultural contact between them must go through the highlands. In this way, communities in central China used metals very differently from people on the steppes or those on the highlands. One particular outcome was the making of bronze ritual vessels, which depended in part on an adaptation of the new technology and material, and partly on the local innovation, which grew out of the previous tradition of feasting and ancestral cult with ritual vessels.³

The other condition for the occurrence of the leaded-bronze-using communities, as discussed in Chapter 3, is the wide distribution of lead deposits (Figure 3.2). More importantly, it is not just the existence of lead ores, but the coexistence of lead ores and other metal ores, especially the polymetallic ores of the “silvery metals”—especially tin, lead, and arsenic—that allowed for or even stimulated the use of lead. For people who learned metalworking from the steppes or Central Asia, those “silvery metal” ores may have looked quite similar to tin and arsenic ores which people often encountered in other part of Eurasia. Thus, in the early stage, metalworkers may have tried to co-smelt copper ores with those “silvery metal” ores in order to make intentional but uncontrolled copper alloys (see Chapter 3, p. 115; see also Table 3.1). Meanwhile, it is also possible that people smelted “silvery metal” ores alone, creating some sort of lead-arsenic-tin alloys. In these cases, lead was introduced into the final products (unless the craftspeople deliberately avoided lead-bearing ores). In all four regions represented by the case studies, these “silvery metal” ores were more or less used in the metal production (see Tables 9.1; 9.2).

³ The Neolithic background of the ritual vessels, see e.g. Underhill 2002: 67–87; Zhang, C. 2015: 311.

Table 9.1 Technological choices reflected in some of the studied cases.

Process	Option	Erlitou (early)	Erlitou (late)	Dadianzi	Xichengyi	Mogou	Beiyinyangying
procurement of raw materials	copper ore				•		
	“silvery metal” ore				•		
	copper ingot	•	•	•		•	•
	lead (or copper-lead) ingot	• (?)	•	•		• (?)	
	tin (or copper-tin) ingot	• (?)	•				
	“silvery” (or copper-silvery metals) ingots			•		•	•
	recycled metals	•	•	•	•	•	•
smelting	copper ores -> copper				•		
	“silvery metal” ores -> “silvery metal” alloys				•*		
	copper + “silvery metal” ores -> copper alloys				•		
alloying & shaping	pure copper	•	•		•	•	
	pure lead			•			
	copper alloys (with “silvery metals”)	•		•	•*	•**	•
	copper-tin alloys		•				
	copper-lead-tin alloys		•				

* without lead

** with additional lead

Table 9.2 Types of metal material known to metalworking people in the communities.

Community	Types of metal material
Erlitou	early: copper, “silvery metal”, and their alloys late: copper, tin, lead, and their alloys
Dadianzi	copper, “silvery metal”, lead, and their alloys
Xichengyi	copper, unleaded “silvery metal”, and their alloys, lead (to avoid)
Mogou	copper, “silvery metal”, lead, and their alloys
Beiyinyangyin	copper-based (probably from both smelting polymetallic ores and recycling)

Because of these two geographic conditions, people in early China accumulated knowledge about copper and lead through both their own experience and their contact with the northern and western neighbours. However, this does not mean that different communities all shared the same metallurgical knowledge of leaded bronze. Nor did these people adopt (or reject) leaded bronze for the same reasons. As discussed in Chapter 3, in this thesis, I use technological choices to refer to the diversity in the technological practices shaping the material culture. For people using leaded bronze, their practices also reflect different sets of technological choices (Tables 9.1). In this section, I will discuss three typical scenarios summarized from the case studies. The discussion is to show that a superficially similar outcome, such as the use of leaded bronze, can reflect very diverse technological choices, while the general driving forces behind the cultural practices of using leaded bronze will then follow in the next section.

The first technological scenario was to create leaded bronze by mixing copper, tin, and lead and to use the material for ritual vessels. This can be seen in the case study of Erlitou (Chapter 5). In the first two phases of Erlitou, this method of making leaded bronze may not have been properly developed, as copper alloyed with tin, lead, or arsenic were used almost indiscriminately (see the discussion on pp. 169–171).⁴ In the late phases of Erlitou, however, as well as in Zhengzhou and Panlongcheng, people seemed to be using copper, tin, lead, and their alloys in a more organised way. In particular, we started to see that, although leaded bronze and unleaded bronze were both used for making ritual vessels, unleaded bronze vessels were often associated with high-status individuals. This shows that people were consciously choosing whether to add lead into the bronze alloys nor not (see e.g. Figures 5.21). Meanwhile, recycled metals may also have been used in Erlitou, Zhengzhou, and Panlongcheng. If people were practicing sorted recycling—recycling unleaded and leaded bronze separately—they may have been able to use the recycled unleaded bronze for new objects that needed to be made of unleaded bronze, such

⁴ See also Xu, H. and Liu, Y. 2020.

as high-quality vessels. Otherwise, people may only have been able to use the recycled metals for objects which did not require certain chemical compositions, such as arrowheads.⁵ This, however, needs to be clarified by future research.

The second technological scenario was to use lead and leaded bronze for personal ornaments but not for tools or weapons. Also, leaded bronze used in this scenario was usually not created by intentionally mixing lead with copper and tin, but by other “uncontrolled alloying” methods discussed in Chapter 3, such as co-smelting or smelting polymetallic ores (see Table 3.1). One example is the metal objects found at Dadianzi (Chapter 6), as the random (uncontrolled) levels of lead are identified in the ornamental objects, such as rings and earrings (Table 6.1). The gold-like colour of leaded bronze may have been one of the reasons why people used these objects. The same material, however, was rarely used for objects which required certain mechanical strength and hardness, such as everyday tools.⁶ In the Hexi Corridor sites, we also see that the early metal-using communities intentionally avoided lead in their metal objects, especially the weapons and the tools (Chapter 7, Table 7.1; Figure 7.6). I would argue that the use of leaded bronze for personal ornaments and the avoidance of leaded bronze for tools and weapons probably reflect the same set of metallurgical knowledge, as part of the “Steppe-Inner Asian tradition” (see the discussion on pp. 227–247; 263–275; see also Table 6.6). When people in the northern Bohai Rim and those in the Hexi Corridor introduced metallurgy from their steppe and Inner Asian neighbours, they also learned the knowledge of lead, including some properties of

⁵ Ten Erlitou Phases III–IV copper-based arrowheads have been analysed. The lead levels vary from 0 to 37%: Zhongguo 1999: 399; 2014b: v. 3, 1516. Because of the random and sometimes surprisingly high lead levels, I suspect that the alloys were not particularly prepared for the arrowheads, but from recycling other metal objects.

⁶ A few tools (knives, awls, etc.) from the northern and western Bohai Rim, dating to the first half of the second millennium BC, have been analysed. Most of them do not contain high lead levels: Chen, K. et al. 2017b; Wang, Y. et al. 2018. However, since the sample size is small, more studies are needed to confirm whether people, like those in the Hexi Corridor, intentionally avoided using high-leaded bronze for making such objects.

this metal. With such knowledge, some people chose to make small lead ornaments (mace head and cowrie-shell-shaped ornament at Dadianzi, pp. 219–221), while others chose to avoid lead-bearing ores (Xichengyi, p. 273). Meanwhile, no one in these cases chose to make high-leaded bronze as those in central China did, as there seemed to be no particular use for such a material. In terms of recycling, whether recycled metals were used in these two regions has not been fully studied. In the case of the “lead-averse” metalworkers in the Hexi Corridor (p. 274–275), what we can suggest is that, as long as lead was excluded from the alloys in the smelting process, the unleaded alloys can keep their relatively good mechanical properties, no matter how many times they were shaped into different objects.⁷ Again, with the metaphor in Chapter 3, we can say that the exclusion of lead ensured the “karmic cycle” (p. 110) of unleaded bronze.

For people who used leaded bronze, but did not have an intention to use this particular type of alloy, I put them together as the third technological scenario. People in these cases either recycled leaded bronze from the leaded bronze users (such as the communities in central China), or directly obtained some leaded bronze objects from the latter. Mogou (Chapter 7) and Beiyinyangying (Chapter 8) can probably represent the first situation, as leaded bronze may have become available at these sites as a new source of material through the cultural contact with central China (pp. 281–284; 314–316). Xujianian (Chapter 7) probably belongs to the second situation, as the leaded bronze symbolic weapons, the *ge* blades, may have been produced in central China and were given to people in the Wei River Valley (pp. 284–297). In all these cases, people usually just wanted a some metal materials in general, but not leaded bronze in particular. Strictly speaking, we may not call the use of leaded bronze in these cases a technological choice. Nevertheless, these unintentional uses of leaded bronze still contributed to the wide spread of this material. In some cases (such as the costal sites in Chapter 8), the presence of lead in the

⁷ A physical way to strengthen/harden an unleaded copper alloy is forging. Traces of forging are seen on many Xichengyi objects. See Chapter 7, Table 7.1.

bronze alloys may have discouraged people from adopting more metal objects at all (pp. 316–317).

The technological choices described in these three scenarios are of course simplified from the often more complicated real cases. By looking at these scenarios, I suggest that multiple technological practices, rather than a single one, were behind the seemingly uniform phenomenon of the spread of leaded bronze in early China (e.g. Chapter 1, Figure 1.3). However, despite the differences among the technological scenarios, the leaded-bronze-using communities in early China were not all separated from one another. They were connected by the exchanges of metallurgical knowledge, resources, and people. It is also these exchanges which partly contributed to the widespread adoption of leaded bronze. In the next section, I will use the geographic and the technological features I just discussed to suggest some general reasons for people to engage with leaded bronze in early China.

The Use of Leaded Bronze: Possible Reasons and Driving Forces

In this section, I will try to move from the specific discussion of technological choices to some general views. I would argue that the increasing use of leaded bronze in early China was mainly driven by two reasons: the adoption of leaded bronze ritual vessels in central China and the exploitation of metal resources from central China by people in the neighbouring areas. These two phenomena may already have emerged in the first three quarters of the second millennium BC. On the one hand, as the case studies show, leaded bronze was first used for ritual vessels at Erlitou. This tradition was later followed by Zhengzhou, Panlongcheng and many other communities in central China (Chapter 5). On the other hand, the “leadening” of bronzes in the Hexi Corridor (Chapter 7) and the limited uses of leaded bronze in the lower Yangtze Valley (Chapter 8) may both indicate reusing metal resources from central China. Here, I would suggest that these two reasons for using leaded bronze also continued to the later first millennium BC.

A few examples later than 1250 BC will be included in this discussion to provide a more complete picture regarding the continuing development of the use of leaded bronze.

Central China: Leaded Bronze as Ritual Vessels

The first general driving force behind the adoption of leaded bronze was to make ritual vessels, especially, to make the vessels with the more affordable and more accessible metal—lead, rather than with purely copper and tin. This happened mainly in central China. As I have argued, economic concerns may have been the primary reason for this choice, as tin was more valuable than lead due to the rarity of tin deposit in central China (Chapter 3, Figure 3.2). Meanwhile, there are also three features of ritual vessels which enabled the use of leaded bronze for this purpose.

First, making ritual vessels requires certain properties of the metals which are very different from the properties required for making other metal objects, such as weapons or ornaments. If we look at the earliest metal objects that appeared in East Asia, they were all small tools, weapons, and personal ornaments (Chapter 2, pp. 62–68). For these objects, people may have preferred metals with good mechanical properties and visual attractiveness. The making of ritual vessels, on the other hand, required different attributes of metals. While visual attractiveness remained to be desired, the properties related to castability—such as melting points, fluidity, and segregation—became more important than, for example, strength and hardness.⁸ The discussion of the metal properties in Chapter 4 shows that leaded bronze was a material with relatively good (although not as good as unleaded bronze) castability (pp. 127–135) and visual characteristics (pp. 138–

⁸ The same properties of leaded bronze may also have contributed to the use of leaded bronze in other cases, such as the sculptures and bronze trees from Sanxingdui: Cui, J. and Wu, X. 2013; Ma, J. et al. 2012.

143). On account of these properties, it is understandable that leaded bronze became a suitable material for ritual vessels.

Meanwhile, the hierarchical use of ritual vessels also encouraged the use of leaded bronze. In the ritual practices of the bronze vessels, the quantity and quality of the vessels were often associated with the wealth and power of the owners. This means that, in practice, people demanded not only the vessels in large numbers, but also the way to provide people from different social backgrounds with different vessels. Various clues discussed in Chapter 5 indicate that, for some communities in central China, unleaded bronze vessels were often associated with individuals who were wealthier and more powerful than others in the communities, while adding lead was probably to make the ritual vessels more affordable, and thus more accessible to some other people in the societies.⁹ When the tradition of using ritual bronze vessels was adopted by more communities in early China, the idea of making leaded bronze vessels as part of the hierarchical system were also spread around. The best site to demonstrate this use of leaded bronze is Yinxu, as tombs with more ritual vessels—an indication of the wealth and power of the individuals—usually had a lower proportion of high-leaded vessels as well.¹⁰ The five Yinxu tombs shown here all belong to Phase II of the site, or around 1250–1200 BC (Table 9.3).¹¹ As we can see from the data, the correlation between the social hierarchy of the individuals and the use of leaded bronze was both strong and uniform.¹²

⁹ For the ritual vessels and symbolic weapons, it is also possible that some people may have preferred the colour of the leaded bronze vessels. However, since most ritual bronzes belonging to the high-status individuals were not leaded, I think cost-saving, instead of colour, may have been the main reason for using leaded bronze. For the additional discussion of the economic concerns, see Chapter 5 footnote 65.

¹⁰ See Chapter 1, footnote 85.

¹¹ Here I choose five tombs which were both undisturbed and with analysed ritual vessels as my examples.

¹² Besides the more standardised use of leaded and unleaded bronze for different vessels, the type and the quantity of ritual vessels, both ceramic and bronze ones, also became more standardised during the Yinxu period, see Li, H. and O’Sullivan 2020.

Table 9.3 The relationship between the number of buried vessels from the burials and the lead levels of the vessels, Yinxu Phase II.

Tomb*	Number of ritual vessels			Average lead level (%)	Reference
	total	analysed	>5% lead		
Fuhao (M5)	210	44	5	1.6	Zhongguo (1980); Li, M. (1982)
HYZ M54	40	18	1	1.6	Zhongguo (2007a)
83ASM663	9	8	3	3.9	Xu, G. (1988); Zhao, C. (2004)
86ASNM29	5	5	4	8.0	Gu, F. (1989); Zhao, C. (2004)
86ASNM25	3	3	3	8.4	Gu, F. (1989); Zhao, C. (2004)

* Yinxu plan see Chapter 7, Figure 7.14. The last three tombs are near the Dasikong Village.

The third feature of ritual vessels which contributes to the widespread of leaded bronze was the wide distribution and redistribution of the vessels. Based on the current archaeological evidence, only a small number of second millennium BC sites may have been producing bronze vessels, and most of these sites were in the middle Yellow River or the middle to lower Yangtze Valleys. The reason is probably that making such vessels was not an easy task, which required not only highly skilled craftspeople, but also other criteria, such as the additional people and organisations who provided the raw materials, supervised the operation, and managed the labour. Meanwhile, the products—the ritual vessels—were not just consumed by those living in or near the production sites, as the vessels were actually found in a much broader geographic area.¹³ This suggests that many bronze vessels must have been transported from the production sites to other regions. The cross-regional distribution of ritual vessels may already have started in the middle of the second millennium BC, as people in central China used these vessels to strengthen their relations with the south (see the examples of Panlongcheng in Chapter 5 and the “valley model” metal producers in Chapter 8). Later, people in other areas may also have been able to obtain bronze vessels from the regimes in central China, either as gifts or by looting.

¹³ For example, some bronze vessels have been found in the Daling River Valleys, dating to around 1000 BC: Beidong 1974; Liangningsheng and Chaoyang 1973; Kazuoxian et al. 1977; Wang, et al. 1998.

One example is Shigushan, a site near today's Baoji, Shaanxi. Four tombs, buried around 1050–1000 BC,¹⁴ have been excavated. About ninety ritual vessels, a surprisingly large number, have been retrieved from the tombs.¹⁵ Among these vessels, about 70% of the analysed vessels are high-leaded.¹⁶ If we look at Tomb M3 in particular, among fourteen analysed vessels (out of twenty-nine) from Tomb M3, half of them contain less than 5% lead, with an average of 2.1%. Meanwhile, for the five most high-leaded vessels, the average lead level is as high as 26%.¹⁷ The striking point of these vessels is that we can almost identify the distinction between the low-leaded vessels and the high-leaded ones by simply observing the vessels (Figure 9.1). The low-leaded ones all carry cast characters, which are considered to be the names or symbols of the initial owners of the vessels. For many Yinxu tombs, the bronzes in one tomb usually carry one type of the inscribed name (such as “Fuhao”). The M3 vessels, by contrast, carry different inscriptions, suggesting that these vessels initially belonged to other owners, before they were later obtained by (or granted to) the tomb owners.¹⁸ Moreover, these low-leaded bronze vessels all have complicated decorative motifs. Following these motifs and the forms of the vessels, scholars suggest that these vessels were probably produced by one of the production sites in central China, such as Xiaomintun near Anyang.¹⁹ The high-leaded bronzes, on the other hand, are not only less decorated and without inscriptions, but also in different forms. Especially, the basin-shaped *gui* vessels with knobbed patterns (M3:7–9 in Figure 9.1) was a very typical trait

¹⁴ Discussion of the dating: Cao, B. 2016.

¹⁵ Reports: Liu, J. et al. 2013a; 2013b; Wang, Z. et al. 2016.

¹⁶ Shao, A. et al. 2021.

¹⁷ Shao, A. et al. 2021.

¹⁸ Hwang, M. 2012; 2013.

¹⁹ Scholars have noticed that the decorative patterns on some of the Shigushan bronzes match the moulds found at the bronze workshop at Xiaomintun. This suggests that these Shigushan bronzes may have been produced there: Li, Y. and Yue, Z. 2015; Zhang, C. 2019.

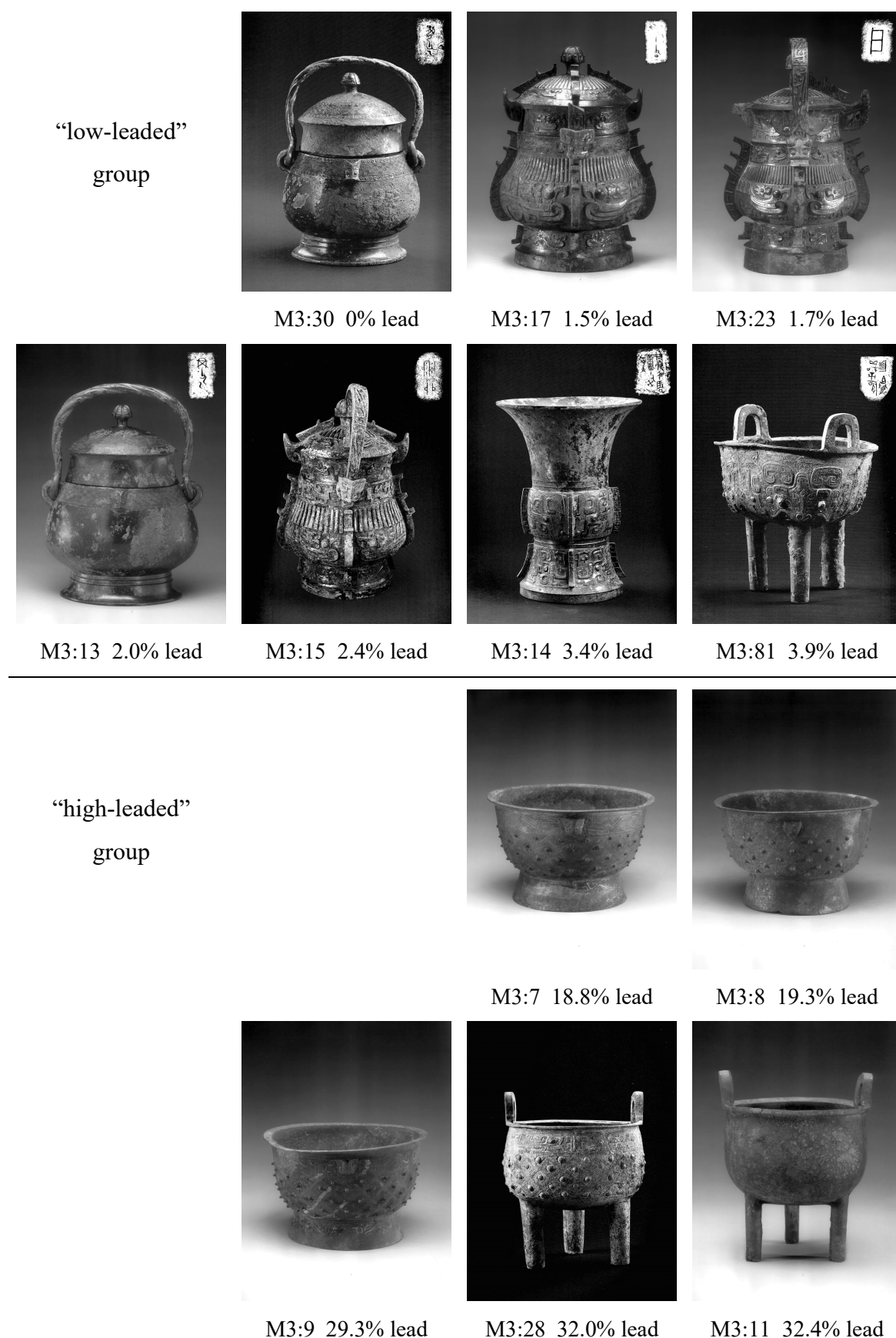


Figure 9.1 Analysed ritual vessels from Tomb M3, Shigushan by lead level (photos: Ch'en, C. 2015; Shanghai 2014; chemical compositions: Shao, A. et al. 2021).

of the local material culture in the Guanzhong Basin area.²⁰ These vessels are usually called “pre-Zhou bronzes” by scholars, and are considered to be either made locally in the Guanzhong Basin, or made in central China but commissioned by the local people.²¹ If we consider the background of the Shigushan burials, around the same time when the individual was buried, the Zhou people, who used to live in the Guanzhong Basin, defeated Shang in the east and became the new ruler of central China. The people at Shigushan were probably Zhou’s allies in its campaign against Shang. When Zhou controlled Anyang and the workshop there, they may have rewarded the Shigushan leaders with some bronze vessels previously belonging to the Shang elite members.²² These high-quality, low-leaded vessels were placed together with the “pre-Zhou bronzes”, which were made of high-leaded bronze, probably as a less valuable material.

In all, I argue that the demands of more and hierarchically distinguishable ritual vessels, as well as the needs to distribute these vessels in and around central China, sometimes as part of the political negotiation, were the main driving forces behind the use of leaded bronze. Lead came into this system since the addition of lead can help create the hierarchy of value within a series of vessels, by providing more vessels with relatively lower costs. Meanwhile, when people around central China adopted the cultural practice and the technology of making and using bronze ritual vessels, those people may also have used leaded bronze to create their own vessels (such as those pre-Zhou bronzes from Shigushan). The wide adoption of these bronze vessels, therefore, laid the foundation of the wide distribution of leaded bronze objects in early China.

²⁰ Similar *gui* vessels have also been found at other sites in this area, see e.g. the discussion in Li, H. 2017. Bagley also considered some bronzes in this form to be pre-Zhou bronzes: Bagley 1987. see also Li, H. 2021. See also Zhang, H. and Jie, H. 2016.

²¹ Cao, B. 2016; Cao, B. and Chen, B. 2019. Besides, Li Longjun suggests that some Shigushan vessels were probably locally produced imitations of Shang vessels, which often have higher quality than the locally produced ones: Li, L. 2018.

²² See also Rawson et al. forthcoming.

Beyond Central China: Other Possible Driving Forces

Next, I will move to some areas around central China, especially those in the north and the west between central China and the steppe, to examine the use of leaded bronze there. As previously discussed, to people in the Hexi Corridor and the Bohai Rim, metals were mainly used for everyday tools or small personal ornaments, in the style of the steppe-Inner Asian tradition. Since these applications usually required metals to have certain mechanical or visual properties, high-leaded bronze was rarely used at the beginning, even though these people certainly had the ability to obtain lead and to produce leaded bronze.²³ This situation, however, began to change in the second half of the second millennium BC, as people in the Hexi Corridor started to produce some high-leaded objects. In the first millennium BC, high-leaded bronze objects also emerged in other northern regions, such as the Bohai Rim and the Northern Zone. Here, I will try to summarize possible reasons behind the emerging uses of leaded bronze objects in these regions.

The fundamental reason for the adoption of leaded bronze may have been the shortage of metal supplies. Like those in central China, people living in the northern regions also craved metals (although for the different uses as I just mentioned). Metal deposits are available in many northern regions. Besides the northern Bohai Rim and the Hexi Corridor as we have examined in Chapters 6 and 7, metal deposits (copper, tin, and lead) are also abundant in today's Mongolia, as copper is still one of its largest exports.²⁴ Nevertheless, compared with people in the northern regions, the regimes in central China still had two advantages regarding the supply of metal resources. The first advantage, as I have mentioned at the beginning of this chapter, was the larger size of the labour force who could participate in mining and smelting activities. The second advantage was the better transportation network between central China and some mining

²³ Bronze with low levels of lead—usually as products of polymetallic ores, were sometimes used for ornamental objects such as rings.

²⁴ A summary of the metal resources of Mongolia: Gerel et al. 2021.

areas, such as the Yangtze River Valleys (especially for tin). In most northern regions, large-scale metallurgical activities were lacking in the second and the first millennia BC.²⁵ As a result, we have reason to believe that there would always have been a shortage of metals in the north.

Because of this constant shortage of supplies, people in the northern regions must have looked for any potential metal resources. This leads to our speculation that metal resources from central China may have been recycled and reused in some northern regions. In the previous chapters, I have discussed the possibility of recycling several times. This refers to the method of obtaining bronze objects (such as vessels) from central China, remelting them, and reusing the metals to make other objects. Alternatively, it was also possible that people outside central China obtained other types of metal material from central China, such as pre-alloyed copper-lead or lead-tin ingots which were originally prepared for making ritual vessels,²⁶ or scrap metals retrieved from objects such as ritual vessels. In the case studies, I have discussed the possibility that some leaded bronze objects, such as the Mogou *pao* bosses (Chapter 7) and the Beiyinyangying small tools (Chapter 8), may have been produced by using the recycled resources from central China. However, since the related provenance studies are still very limited, we cannot really confirm these suggestions. By the end of the second millennium BC, we may have more evidence showing the exploitation of the leaded bronze resources from central China. One example is the new communities emerged in the Bohai Rim region in the first millennium BC. Compared with their Dadianzi predecessors, who only had some moderate-leaded bronze objects—probably due

²⁵ So far, Xichengyi and the surrounding area is the only known area out of central China with a relatively large scale of early metal production during the second millennium BC. However, its scale was still much smaller than those of the contemporaneous metal production centres in central China.

²⁶ Mei Jianjun reminds me that remelting a bronze vessel was actually not an easy task. In many cases, it may have been more sensible for people to import ingots from central China, rather than to obtain vessels, break them into pieces, and remelt the fragments.

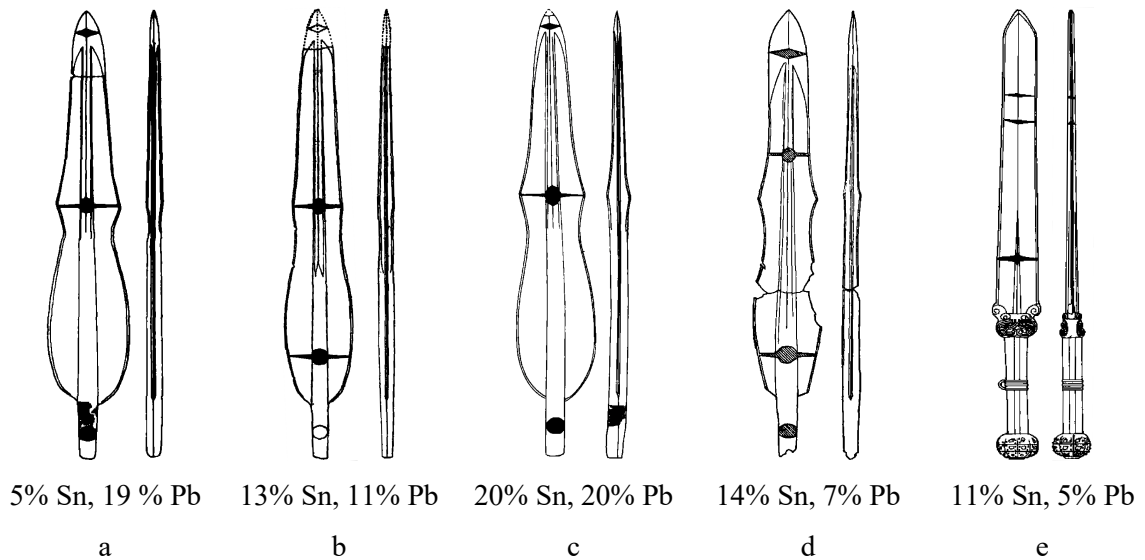


Figure 9.2 Swords from the northern Bohai Rim, c. 1000–500 BC. a: Chaowenguan 228 (after Jin, F. 1988); b: Chaodibo 116 (after Jin, F. 1983); c: Mutougou M1:1 (after He, T. and Jin, F. 2002); d: Zhengjiawazi 6512:1 (after Shenyang and Shengyangshi 1975); e: Jundushan YYM17:2 (after Beijingshi 2010: v. 2, 925).

to the use of polymetallic ores (pp. 222–225)—people in this new era had bronze objects with far more lead. One particular example is the new weaponry, which we may call a sword or a dagger. There is no consensus among scholars on the origin of these swords. Some claim that this type of weapon was developed locally—in the Bohai region, while others suggest that it originated further north, in eastern Siberia. The areas around the Bohai Rim—Korean and North-east China—were the core region for the distribution of these swords.²⁷ Around forty swords, dating to the first half of the first millennium BC, have been analysed. Surprisingly, the result shows that many swords contain lead contents as high as 15–20% (Figure 9.2).²⁸ Some high-leaded bronze swords have also been identified among the analysed samples from the Korean Peninsula.²⁹ Such high lead contents were not possible to be the “impurities” in copper or tin.

²⁷ Lyu, J. 2006; Tong, Z. 2001; Yang, J. 2007

²⁸ He, T. and Jin, F. 2002.

²⁹ Lee, H. 1993.

Also, the diverse compositions suggest that there may not be a single explanation. For example, some swords have high lead levels, but very low tin levels (e.g. Figure 9.2, a), while some others (e.g. Figure 9.2, c) have both high lead and high tin levels. In the former case, the craftsman who produced such a sword may have tried to substitute lead for tin. In the latter case, the high-tin and high-leaded bronze was probably a result of using raw materials (or recycled materials) which were originally prepared for casting ritual vessels. Nevertheless, using high-leaded bronze alloys for swords would certainly have reduced the mechanical properties of the weapons. We may even suspect that the sword producers, who adopted a high-lead-low-tin recipe, were cheating by offering such shoddy products. In fact, people may have been able to recognise that some swords, with lower lead levels, were more valuable than those high-leaded ones. Two swords from Jundushan, a large cemetery site near Beijing, dating to the eighth to the fifth centuries BC, both have 10–15% tin and around 5% lead.³⁰ For practical weapons, this composition seems to be almost ideal.³¹ According to the published drawing of one of the swords (Figure 9.2, e), it is also more decorated than most of the other contemporaneous swords from the same Bohai region. This suggests that, when producing swords with higher values, the craftspeople may have intentionally chosen unleaded or low-leaded bronze as their materials.³² That is to say, although people in this later period used leaded bronze to produce some objects, which had traditionally been made of unleaded bronze, they were not unaware of the potential problems of this material. The way people used leaded bronze for weapons shows how they were

³⁰ He, T. et al. 2002. Site report: Beijingshi 2010.

³¹ This can be seen on the diagrams of Chapter 4, Figure 4.8.

³² Interestingly, Yang Ju's study shows that bronze knives from the same region are usually less leaded than the swords (and also less leaded than the contemporaneous *pao* buttons): Yang, J. 2015: 56–137. I think one possible reason is that these knives were considered more utilitarian, and thus needed to have good mechanical properties. By contrast, swords were more related with the expression of wealth and power, and thus can sometimes sacrifice their mechanical properties for reasons, such as cost or even colour.

able to provide themselves with more metal objects, while carefully balancing the costs and the quality of their bronze products.

Besides the resource shortage and recycling, there may have been a third reason for the use of leaded bronze, which is the arrival of a replacement for bronze—iron. The earliest iron in East Asia appeared around the fourteenth century BC, at Mogou.³³ The iron smelting technology gradually emerged in other areas, especially along the Yellow River Valleys in the first half of the first millennium BC.³⁴ Compared with copper, iron deposits are more abundant, and the material is also more suitable for weapons and tools due to its superior mechanical properties. Although iron weapons and tools were still much smaller in number than bronze ones by the end of the first century BC, the appearance of iron certainly provided people with an alternative and even a better option to make good weapons. Archaeological evidence supporting this suggestion is the discovery of a few “bronze-iron compound weapons”. For these weapons, iron was usually used for the points and the cutting edges, while bronze was used to make the bodies and handles/hilts.³⁵ Such a technological choice shows that the bladesmiths certainly understood that iron is stronger and harder than copper and, thus, more suitable for the blades. In the late first millennium BC, there were also a few iron swords with highly decorated gold or bronze hilts (Figure 9.3). The ways in which the material was used shows clearly that, when iron became available, it was the castability and perhaps also the colour of bronze, not its mechanical strength,

³³ Chen, J. et al. 2012. Since the materials of Mogou have not been fully published, it is not clear whether the use of bronze and the use of iron influenced each other at the site.

³⁴ Early iron objects were made from three type of iron: meteoric iron, bloom (sponge iron, which can be forged into wrought iron), and pig iron (crude iron, which can be decarbonized into wrought iron or steel by “stirring”). Currently, most scholar believe that bloomery iron smelting was introduced from the west into North China during the second half of the second millennium BC (the Mogou object was made from bloomery iron), while pig iron smelting was developed in China around the fifth century BC: Chen, J. 2014a; 2014b; Han, R. and Chen, J. 2013.

³⁵ E.g. Chen, J. et al. 2009; Tang, Y. 1975; Wang, Y. et al. 2019.

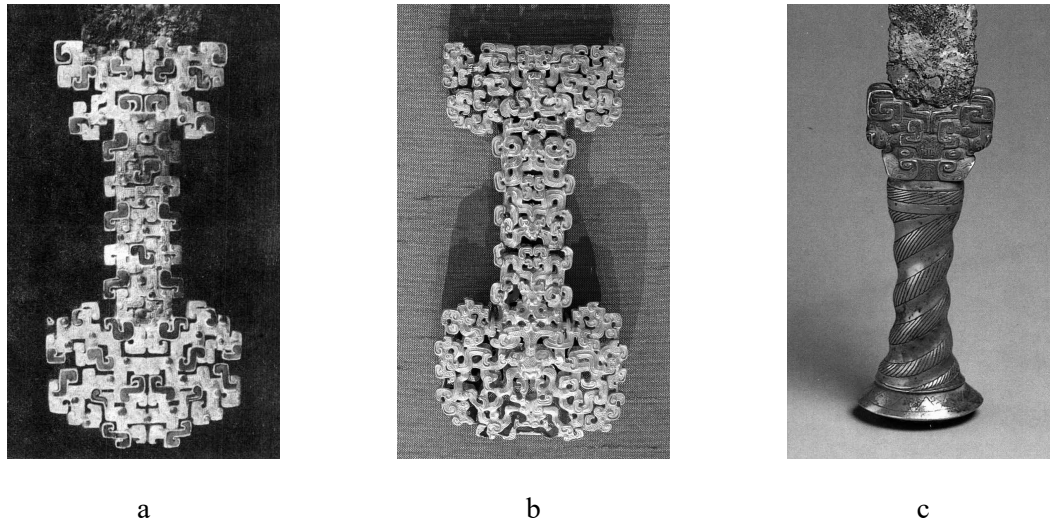


Figure 9.3 Iron swords with decorated gold or bronze hilts. a: gold hilt from Yimencun, Shaanxi (after Tian, R. and Lei, X. 1993); b: gold hilt in the British Museum, provenance unknown (probably from the Hunyuan County, Shanxi, photo taken in the British Museum); c: bronze hilt with a gold surface layer, from Liulige, Henan (after Henan and Taibei 2003: 128).

which people mostly valued. This approach to bronze, as well as the casting technology used in making these sword hilts, were certainly shaped in central China by the production of ritual vessels.³⁶ The bronze hilts in these cases have not been analysed, but we can imagine that both leaded and unleaded bronze would have been capable materials. In other words, after the arrival of iron, bronze may have been increasingly used for decorative purposes. As a result, the mechanical disadvantages associated with leaded bronze may no longer have been a reason for the craftspeople to avoid this material.

In conclusion, the comparison of different technological scenarios of using leaded bronze shows that there is no unilateral model of technology and material culture. Any choice in technology, no matter how simple or how complex it may look to the modern observers, represents multiple, interrelated human-thing engagements. By examining the examples of metal-using communities

³⁶ Iron swords decorated with gold, silver, or bronze have also been found at several steppe and Inner Asian sites. See e.g. Fig. 2 of Rawson 2018. So the original idea of combining two metals for decorative purposes may have come from the west.

in early China, I suggest that, for the wide distribution of leaded bronze objects in early China, the two primary reasons are the use of leaded bronze vessels in central China and the reuse of the leaded bronze metals from central China. For communities which I did not fully cover in this thesis, there may have been other driving forces behind the adoption or the rejection of leaded bronze. Instead of listing all the possible reasons, I choose these particular examples to show that, regardless the diverse technological scenarios, there may still have been some general reasons which affected people's choices as well as their relations with this material. Moreover, the investigation of leaded bronze in the early communities also reminds us that a certain technology or material culture cannot be understood without studies of its culture and social context. The understanding of the material, in return, can also reveal more perspectives of the societies in which we are interested.

Appendix 1

Early Metal-Related Sites in Afro-Eurasia

In this section, I provide a list of some early metal-related sites (either with metal objects or with metallurgical remains). Please see Chapter 2 for more discussion.

For the locations of the sites, I give GPS coordinates in the form of “longitude (E), latitude (N)”. Most of the coordinates are approximate as they are based on either the physical addresses (townships, villages, etc.) or the locations of the site marked on other maps. These GPS locations are used for the sites in various maps in this thesis.

The “metal (start)” column shows the dating results (absolute dates based on radiocarbon dating or relative dates based on archaeology culture) of the earliest metal-bearing contexts at each site. This is to show when the earliest evidence of metal use or metal production appeared at a location. These dates are normally not the dates of the sites themselves. For example, at the Erlitou site, metal objects have been found from contexts attributing to all five phases, I–V, or 1750–1550 BC. Since these Phases are separately dated, I put the time period of the first phase, 1750–1700 BC, in this column. Nevertheless, for any site without a clearly proposed chronology, I use the date of the site as the date of the metals. Since dating is itself a very complicated issue. The dates given here may only reflect the suggestions by some studies (I try to use the most recent dating results), and are likely to be revised in future. All dates, if not especially noted, are BC.

For most Chinese sites, I try to include the original excavation reports or the first-hand reports mentioning the metal remains in the references (or some of the reports due to space limit). However, since the limits of my language ability (Chinese and English only) and the focus of this research, for sites in other regions, I may sometimes provide second-hand references in which the sites and their metal finds are mentioned. Usually, the original reports can be found in these references.

ID	Province	Site	Location	Metal (start)	Reference
1	Anhui	Dachengdun 大城墩	118.00 , 31.80	2000–1700	Zhang, J. (1989a; 1989b)
2	Anhui	Dadunzi 大墩孜	117.15 , 31.71	1600–1500	Anhuisheng (1978); Chen, L. (2014)
3	Anhui	Heying 何郢	118.35 , 32.35	1050–950	Wei, G. (2005)
4	Anhui	Langxi 郎溪	119.13 , 30.98	1400–1200	Song, Y. (1987); Zhang, A. & Lu, Q. (2010)
5	Anhui	Lu'an 六安	116.50 , 31.77	1250–1050	Li, Y. (2008); Li, Y. & Gu, Y. (2000)
6	Anhui	Qianbai 前白	117.08 , 34.00	1600–1000	Ren, Y. & Qiu, S. (2017)
7	Anhui	Sanguanmiao 三官庙	117.15 , 31.78	1600–1500	Fan, L. (2020); Qin, R. (2018)
8	Anhui	Shigudun 师姑墩	117.91 , 30.93	1650–1500	Anhuisheng (2020); Wang, K. et al. (2013)
9	Anhui	Sunjiagang 孙家岗	118.02 , 31.81	1600–1400	Wu, X. (1977)
10	Anhui	Sunqi 孙威	117.99 , 31.78	1600–1400	Yang, D. (1992)
11	Anhui	Taijiasi 台家寺	115.87 , 32.72	1350–1300	He, X. & Gong, X. (2018)
12	Anhui	Tangjiadun 汤家墩	117.55 , 30.91	1260–1040	Gong, X. (2004)
13	Anhui	Tongdun 童墩	117.93 , 30.91	1600–1300	Zhang, A. & Lu, Q. (2010)
14	Anhui	Xiajiadun 夏家墩	118.05 , 30.99	1000–900	Cui, C. et al. (2020)
15	Anhui	Xuejiagang 薛家岗	116.50 , 30.67	1500–1300	Anhuisheng (2004)
16	Anhui	Zhangfashan 彰法山	116.57 , 30.64	1600–1400	Zhang, A. & Lu, Q. (2010)
17	Anhui	Zhengxiaozhuang 郑小庄	116.41 , 32.52	1050–1000	Liu, H. (1985)
18	Anhui	Zhongdesi 众德寺	116.58 , 31.77	1600–1400	Beijing & Anhuisheng (1997)
19	Beijing	Baifu 白浮	116.25 , 40.19	1050–950	Beijingshi (1976)
20	Beijing	Jundushan 军都山	115.90 , 40.51	800–500	Beijingshi (2010b; 2010a); He, T. et al. (2002)
21	Beijing	Liujiahe 刘家河	117.21 , 40.20	1500–1200	Wang Y. (2006); Yuan, J. & Zhang, X. (1977)
22	Beijing	Liulidian 刘李店	116.04 , 39.62	1530–1300	Zhao, X. & Tian, J. (1976)
23	Beijing	Liulihe 琉璃河	116.05 , 39.62	1050–980	Liulihe (1990); Liulihe (1990)
24	Beijing	Xueshan 雪山	116.18 , 40.22	1530–1300	Liu, H. (2013)
25	Beijing	Zhangying 张营	116.28 , 40.21	1650–1550	Beijingshi & Beijingshi (2007)
26	Beijing	Zhenjiangying 镇江营	115.76 , 39.53	1600–1300	Beijingshi (1999)
27	Chongqing	Lijiaba 李家坝	108.67 , 31.10	500–200	Huang, W. et al. (2003); Luo, E. (2001)
28	Chongqing	Shuangyantang 双堰塘	109.79 , 31.28	1000–500	Zheng, R. (2001; 2003)
29	Chongqing	Yuxi 玉溪	107.86 , 30.04	1400–1100	Fang, G. et al. (2003); Jiang, X. et al. (2006)
30	Chongqing	Zhongba 中坝	108.04 , 30.29	800–200	Sun, Z. et al. (2003)
31	Fujian	Dongzhang 东张	119.25 , 25.71	900–770	Xu, Q. (1965)
32	Fujian	Hulinshan 虎林山	117.72 , 24.52	1200–1000	Fujian et al. (2003)
33	Fujian	Xitou 溪头	119.08 , 26.23	1050–770	Lin, G. et al. (1984)
34	Gansu	Baicaopo 百草坡	107.52 , 35.11	1050–1000	Chu, S. (1977)
35	Gansu	Baishantang 白山堂	99.43 , 40.64	1700–1300	Li, Y. (2014)
36	Gansu	Dahezhuang 大何庄	103.37 , 35.90	1700–1500	Huanghe (1960); Zhongguo (1974a)
37	Gansu	Donghuishan 东灰山	100.75 , 38.66	1700–1500	Gansusheng & Jilin (1998)
38	Gansu	Erdaoliang 二道梁	99.26 , 40.26	1800–1500	Li, Y. (2014); Li, Y. et al. (2015a)
39	Gansu	Ganggangwa 缸缸洼	99.15 , 40.15	2000–1700	Li, Y. (2014); Li, Y. et al. (2015a)
40	Gansu	Ganguya 干骨崖	98.85 , 39.38	1700–1500	Gansusheng & Beijing (2016)
41	Gansu	Gaomuxudi 高苜蓿地	98.85 , 39.38	2300–2000	Gansusheng & Beijing (2011)
42	Gansu	Gudongtan 古董滩	97.61 , 40.37	1800–1600	Gansusheng & Beijing (2011)

ID	Province	Site	Location	Metal (start)	Reference
43	Gansu	Haizangsi 海藏寺	102.63 , 37.95	2000–1800	Chen et al. (2019); Liang, X. & Liu M. (1993)
44	Gansu	Hamadun 蛤蟆墩	102.29 , 38.61	900–300	Pu, C. & Pang, Y. (1990)
45	Gansu	Huangniangniangtai 皇娘娘台	102.61 , 37.94	2000–1800	Guo, D. (1960); Wei, H. (1978)
46	Gansu	Huoshagou 火烧沟	97.70 , 39.94	1800–1500	Chen, K. et al. (2018b); Mao, R. et al. (2019); Zhang et al. (2021)
47	Gansu	Huoshiliang 火石梁 (金塔县)	99.24 , 40.21	1800–1500	Li, X. (2011); Li, Y. et al. (2015a)
48	Gansu	Jiangjiaping 蒋家坪	102.86 , 36.49	2300–2000	Sun, S. & Han, R. (1997)
49	Gansu	Jiuzhan 九站	108.18 , 36.04	1530–1220	Wang, Z. & Shui, T. (1997)
50	Gansu	Lanqiao 栏桥	105.23 , 33.76	1200–1000	Zhao, H. & Liu, C. (1987)
51	Gansu	Lianhuatai 莲花台	103.17 , 35.77	1250–1000	Pu, C. & Nan, Y. (1988); Xie, D. (1980b)
52	Gansu	Linjia 林家	103.27 , 35.66	2900–2700	Guo, D. & Meng, L. (1984); Ren, S. (2004)
53	Gansu	Liuhudun 柳湖墩 (沙井)	102.93 , 38.55	900–300	Andersson (1943; 2016)
54	Gansu	Majiyuan 马家塬	106.17 , 35.04	300–200	Gansusheng (2014); Huang, W. et al. (2013)
55	Gansu	Mogou 磨沟	103.78 , 34.98	1700–1500	Mao, R. et al. (2014); Qian, Y. et al. (2014)
56	Gansu	Qijiaping 齐家坪	103.83 , 35.50	1700–1500	Hung, L. et al. (2019)
57	Gansu	Qinweijia 秦魏家	105.12 , 34.70	1700–1500	Huanghe (1960); Xie, D. (1975)
58	Gansu	Sanjiaocheng 三角城	103.32 , 38.99	900–300	Pu, C. & Pang, Y. (1990)
59	Gansu	Shaguoliang 沙锅梁	97.73 , 40.25	1700–1500	Gansusheng & Beijing (2011)
60	Gansu	Shipo 石坡	103.68 , 34.53	1200–1000	Gannan (1994)
61	Gansu	Siwa 寺洼	103.81 , 35.21	1200–1000	Pei, W. (1987a); Xia, N. (1949)
62	Gansu	Xichengyi 西城驿	100.34 , 39.02	2150–1900	Chen, G. et al. (2014; 2015a; 2015b)
63	Gansu	Xinglin 杏林	104.07 , 34.54	1700–1500	Yang, Y. (1985)
64	Gansu	Xinzhuangping 新庄坪	103.06 , 35.64	1700–1500	Jia, J. (1996)
65	Gansu	Xiping 西坪	103.57 , 35.48	1700–1500	Sun, S. & Han, R. (1997)
66	Gansu	Xitugou 西土沟	94.04 , 39.90	1900–1700	Li, Y. et al. (2018)
67	Gansu	Xujianian 徐家碾	106.06 , 35.23	1150–1050	Zhongguo (2006)
68	Gansu	Yigediwo 一个地窝南	99.18 , 40.10	1800–1500	Li, Y. et al. (2015a)
69	Gansu	Yingwoshu 鹰窝树	96.33 , 40.39	1700–1500	Gansusheng & Beijing (2011)
70	Gansu	Yujiawan 于家湾	107.08 , 35.32	1200–1050	Gansusheng (2009); Zhang, Z. & Ma, Q. (2008)
71	Gansu	Zhangjiazui 张家咀	103.16 , 35.79	1000–600	Huanghe (1959); Xie, D. (1980a)
72	Gansu	Zhanqi 占旗	103.84 , 34.71	1200–1000	Han, C. et al. (2012); Wang, L. et al. (2016)
73	Gansu	Zhaobitan 照壁滩	98.85 , 39.38	2300–2000	Gansusheng & Beijing (2011)
74	Guangdong	Beifushan 背夫山	111.30 , 22.87	500–400	Qiu, L. & Mao, Y. (1986)
75	Guangdong	Dingdabushan 顶大埔山	116.87 , 23.85	1500–1000	Qiu, L. & Peng, R. (1984)
76	Guangdong	Matougang 马头岗	112.84 , 23.64	500–400	Mo, Z. et al. (1964)
77	Guangdong	Nanmendong 南门洞	111.50 , 22.51	550–400	Xu, H. (1983)
78	Guangdong	Niaodanshan 鸟旦山	112.81 , 23.29	500–400	He, J. et al. (1975)
79	Guangdong	Shixia 石峡	113.58 , 24.67	800–600	Guangdongsheng et al. (2014)
80	Guangxi	Andengyang 安等秧	108.50 , 23.30	500–200	Chen, Z. (2015)
81	Guangxi	Dushanyandong 独山岩洞	108.39 , 23.42	500–200	Chen, Z. (2015)
82	Guangxi	Fenggenshan 凤根山	110.82 , 22.80	500–200	Qu, Y. (2009)

ID	Province	Site	Location	Metal (start)	Reference
83	Guangxi	Fuzucun 富足村	110.52 , 25.18	500–200	Chen, Z. (2015)
84	Guangxi	Ganzhuyan 敢猪岩	108.50 , 23.30	1250–1050	Jiang, T. & Lan, R. (1984)
85	Guangxi	Gaowubeiji 高屋背岭	111.51 , 24.39	500–200	Chen, Z. (2015)
86	Guangxi	Guogailing 锅盖岭	107.08 , 23.62	500–200	Chen, Z. (2015)
87	Guangxi	Hejiang 贺江边	111.56 , 24.40	500–200	Chen, Z. (2015)
88	Guangxi	Huaguoshan 花果山	111.05 , 23.05	500–200	Chen, Z. (2015)
89	Guangxi	Hutoushan 虎头山	107.05 , 23.62	500–200	Qu, Y. (2009)
90	Guangxi	Longzhong 龙中	111.50 , 24.35	500–200	Chen, Z. (2015)
91	Guangxi	Madongcun 马东村	111.49 , 24.34	700–500	Chen, Z. (2015)
92	Guangxi	Mianlingshan 勉岭山	108.50 , 23.30	1050–950	Liang, J. (1978)
93	Guangxi	Qixingpo 七星坡	110.38 , 25.20	300–200	Qu, Y. (2009)
94	Guangxi	Shuitoucun 水头村	110.59 , 25.33	500–200	Chen, Z. (2015)
95	Guangxi	Weipo 韦坡	109.08 , 23.02	500–200	Chen, Z. (2015)
96	Guangxi	Xianacao 下那曹	109.92 , 24.03	500–200	Chen, Z. (2015)
97	Guangxi	Yangjia 秧家	110.87 , 24.99	600–500	Chen, Z. (2015)
98	Guangxi	Yinshanling 银山岭	110.90 , 24.54	500–200	Chen, Z. (2015)
99	Guangxi	Yuanlongpo 元龙坡	108.50 , 23.30	1050–500	Chen, Z. (2015)
100	Guizhou	Jigongshan 鸡公山	103.83 , 27.21	1300–700	Zhang, H. et al. (2006)
101	Guizhou	Kele 可乐	104.40 , 27.24	500–300	Guizhousheng (2008)
102	Guizhou	Tonggushan 铜鼓山 (普安)	105.04 , 25.53	800–1	Liu, E. (2002); Liu, E. & Xiong, S. (1993)
103	Guizhou	Wayao 瓦窑	105.03 , 27.32	1400–1000	Xi, K. & Zhu, X. (1987)
104	Guizhou	Xikou 溪口	109.47 , 26.98	1210–520	Li, F. (2015)
105	Hebei	Baoshenmiao 雹神庙	118.20 , 39.62	1530–1300	An, Z. (1954)
106	Hebei	Beizhuangzi 北庄子	114.99 , 38.53	1250–1100	Li, H. (1996); Wang, H. (1992)
107	Hebei	Caoyanzhuang 曹演庄	114.48 , 37.06	1600–1200	Tang, Y. (1958)
108	Hebei	Chaodaogou 抄道沟	118.73 , 40.43	1100–900	Varenov (1999); Zheng, S. (1962)
109	Hebei	Dachengshan 大城山	118.21 , 39.65	1530–1300	Chen, H. (1959)
110	Hebei	Datuotou 大坨头	117.05 , 39.88	1530–1300	Tianjinshi (1966)
111	Hebei	Dongzhuangdian 东庄店	118.65 , 39.41	1530–1300	Liu, H. (2013); Wen, Q. (1983)
112	Hebei	Guye (Beisicun) 古冶 (北寺村)	118.45 , 39.74	1530–1300	Liu, H. (2013);
113	Hebei	Houqianyi 后迁义	118.77 , 39.68	1300–1000	Zhang, W. & Zhai, L. (2016)
114	Hebei	Jiancun 渐村	115.72 , 39.49	1250–1200	Li, H. (1996); Wu, D. (1992)
115	Hebei	Lidarenzhuang 李大八庄	115.31 , 40.64	1530–1300	Liu, H. (2013); Tao, Z. (1990)
116	Hebei	Luanxian 滦县	118.59 , 39.76	1100–1000	Meng, Z. & Zhao, L. (1994)
117	Hebei	Qianbao 前堡	114.89 , 39.97	1515–1327	Kong, Z. et al. (1984)
118	Hebei	Sanguan 三关	114.78 , 39.92	1520–1315	Kong, Z. et al. (1984)
119	Hebei	Shizikou 狮子口	114.65 , 40.44	1250–1200	Li, H. (1996); Liu, J. (1988)
120	Hebei	Taixi 台西	114.72 , 38.04	1400–1250	Hebeisheng (1985)
121	Hebei	Xiaoguanzhuang 小官庄	118.20 , 39.62	1530–1300	An, Z. (1954)
122	Hebei	Xiaoshandongzhuang 小山东庄	118.76 , 39.93	1200–900	Zhai, L. & Yin, X. (1997)
123	Hebei	Xiaqiyan 下七垣	114.28 , 36.26	1600–1500	Sun, D. et al. (1979)
124	Hebei	Xiayuegezhuang 下岳各庄	115.40 , 39.41	1530–1300	Bu, G. (1988); Liu, H. (2013)
125	Hebei	Xinchengpu 新城铺	114.68 , 38.26	1250–1100	Li, H. (1996); Liu, Y. & Fan, Z. (1984)
126	Hebei	Yabazhuang 哑叭庄	116.07 , 38.72	1400–1300	Guo, R. et al. (1992); Li, H. (1996)

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127	Hebei	Zhaoyao 赵窑	114.37 , 36.81	1600–1500	Chen, H. & Jiang, D. (1992)
128	Hebei	Zhuangke 庄窠	114.95 , 40.01	1600–1250	Kong, Z. et al. (1984)
129	Henan	Dashigu 大师姑	113.49 , 34.84	1700–1550	Zhengzhoushi (2004)
130	Henan	Dasikong 大司空	114.33 , 36.13	1260–1240	Zhongguo (2014a)
131	Henan	Donggangou 东干沟	112.42 , 34.67	1750–1550	Kaogu (1959)
132	Henan	Dongzhai 董砦	113.61 , 34.77	2500–1900	Jiang, N. et al. (2002)
133	Henan	Erlitou 二里头	112.69 , 34.69	1750–1700	Zhongguo (1999b; 2014b)
134	Henan	Fucheng 府城	113.20 , 35.19	1500–1400	Yuan, G. & Qin, X. (2000)
135	Henan	Gaocunsi 高村寺	113.38 , 34.90	1500–1400	Chen, L. & Ma, D. (1991)
136	Henan	Getengshan 葛滕山	115.67 , 32.19	1250–1050	Liu, K. et al. (1991)
137	Henan	Haojiatai 郝家台	114.03 , 33.59	1750–1700	Henansheng (2012a)
138	Henan	Hougang 后冈	114.32 , 36.12	2500–2000	Ren, S. (2004)
139	Henan	Huanbei 浍北商城	114.33 , 36.13	1350–1300	Meng, X. (1985)
140	Henan	Huayuanzhuang 花园庄东地	114.32 , 36.12	1260–1240	Zhongguo (2007a)
141	Henan	Lidazhao 李大召	113.79 , 35.28	1650–1550	Zhengzhou et al. (2006)
142	Henan	Liujiazhuang 刘家庄	114.32 , 36.10	1250–1200	Anyang (2010); Tang, J. et al. (2018)
143	Henan	Liulige 琉璃阁	113.81 , 35.45	1250–1050	Henan & Taibei (2003)
144	Henan	Luantai 栗台	115.51 , 33.77	2200–1900	Zhang, W. et al. (1989)
145	Henan	Lutaigang 鹿台岗	114.90 , 34.53	2500–1900	Zhengzhou & Kaifengshi (2000)
146	Henan	Meishan 煤山	112.77 , 34.22	1900–1750	Yuan, G. (1991); Zhao, Z. (1982)
147	Henan	Mengzhuang 孟庄	113.84 , 35.42	1700–1550	Henansheng (2003)
148	Henan	Niuzhai 牛砦	113.62 , 34.77	2500–1900	An, J. (1958); Li, J. (1985)
149	Henan	Pingliangtai 平粮台	114.91 , 33.68	2300–2100	Cao, G. (1983); Cao, Y. et al. (2017)
150	Henan	Qingliangshan 清凉山	115.97 , 34.00	1900–1500	Zhang, C. (1997)
151	Henan	Runlou 闰楼	114.43 , 32.76	1200–1050	Li, A. (2018); Liu, Q. (2016)
152	Henan	Sanmenxia 三门峡虢国墓地	111.21 , 34.79	900–800	Henansheng (1999)
153	Henan	Tianhu 天湖	114.50 , 32.20	1250–1150	Ou, T. (1986); Xiao, M. et al. (2016)
154	Henan	Wangchenggang 王城岗	113.13 , 34.38	2130–1835	Henansheng & Zhongguo (1992)
155	Henan	Wangjinglou 望京楼	113.73 , 34.45	1650–1600	Yao, Z. & Wu, Q. (2018); Zhengzhoushi (2016)
156	Henan	Xiaohucun 小胡村	113.47 , 34.93	1250–1100	Jia, L. et al. (2015); Jin, R. et al. (2019)
157	Henan	Xiaoshuangqiao 小双桥	113.57 , 34.86	1450–1400	Henansheng (2012b); Huang et al. (2011)
158	Henan	Xiasi 下寺	111.54 , 32.78	620–571	Henansheng et al. (1991)
159	Henan	Xiawanggang 下王冈	111.44 , 32.93	1650–1600	Henansheng & Changjiang (1989)
160	Henan	Xiaxiangpu 夏饷铺	112.65 , 33.08	800–700	Wang, W. et al. (2019); Zheng, Q. et al. (2019)
161	Henan	Xinmensi 心闷寺	115.25 , 34.07	1500–1400	Zhang, H. (1983)
162	Henan	Xinzhai 新砦	113.54 , 34.44	1900–1800	Beijing & Zhengzhoushi (2008); Liu, Y. (2016)
163	Henan	Xishicun 西史村	113.33 , 34.83	1600–1500	Zhao, Q. & Wang, Y. (1981)
164	Henan	Yangzhuang 杨庄	113.96 , 32.88	1750–1700	Beijing & Zhumadianshi (1998)
165	Henan	Yanshi 偃师商城	112.77 , 34.73	1600–1550	Zhongguo (2013)
166	Henan	Yinxu 殷墟	114.32 , 36.12	1260–1240	Liu, R. (2016); Zhao, C. (2004)
167	Henan	Zhanglei 张雷	113.73 , 35.50	1600–1400	Li, H. et al. (2014)
168	Henan	Zhengzhou 郑州商城	113.68 , 34.75	1650–1600	Henansheng (2001)
169	Hubei	Dongyuecun 东岳村	112.26 , 30.33	1250–1050	Peng, J. (1987)

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170	Hubei	Guanzhuangping 官庄坪	110.76 , 31.02	700–600	Guowuyuan & Guojia (2005)
171	Hubei	Jingnansi 荆南寺	112.15 , 30.35	1600–1250	Jingzhou (2009)
172	Hubei	Jiufogang 九佛岗	112.70 , 29.65	1100–1000	Dai, X. (2000)
173	Hubei	Jiuliandun 九连墩	112.85 , 31.97	500–200	Wang, X. et al. (2018a; 2019)
174	Hubei	Liyang 李营	111.08 , 32.83	1700–1650	Zhou, N. (2014)
175	Hubei	Lujiahe 路家河	110.99 , 30.84	1600–1250	Changjiang (2002)
176	Hubei	Lutaishan 鲁台山	114.39 , 30.87	1000–900	Wei, Y. et al. (1982)
177	Hubei	Maojiazui 毛家咀	115.54 , 30.42	1100–950	Cheng, P. (2000); Zhang, Y. (1962)
178	Hubei	Meihuaiqiao 梅槐桥	112.02 , 30.39	1250–1050	He, N. (1990)
179	Hubei	Miaoxingcun 庙兴村	112.35 , 30.25	1250–1050	Wang, H. (1996)
180	Hubei	Pailou 牌楼	115.01 , 30.33	1250–1050	Ding, T. (1982)
181	Hubei	Panlongcheng 盘龙城	114.26 , 30.70	1550–1500	Hubeisheng (2001)
182	Hubei	Qunli 群力	113.61 , 30.85	1250–1050	Yu, J. (1986)
183	Hubei	Sujialong 苏家垄	113.31 , 31.33	800–500	Fang, Q. (2018); Tian, G. (2011)
184	Hubei	Tonglùshan 铜绿山	114.94 , 30.08	1200–1050	Huangshishi (1999)
185	Hubei	Wancheng 万城	111.99 , 30.41	1000–950	Chen, X. (2019); Li, J. (1963)
186	Hubei	Xinwuwan 新屋湾	115.52 , 30.42	1050–950	Wu, X. & Hong, G. (1997a; 1997b)
187	Hubei	Xiongjialaowan 熊家老湾	113.41 , 31.72	1250–1050	Wang, S. (1984)
188	Hubei	Yejiashan 叶家山	113.46 , 31.75	1050–980	Hubeisheng et al. (2013)
189	Hubei	Yugang 余岗	112.12 , 32.09	590–560	Xiangyangshi (2011); Zhang, J. (2019)
190	Hubei	Zaoshulin 枣树林	113.39 , 31.71	700–500	Guo, C. (2019)
191	Hubei	Zenghou Yi's tomb 曾侯乙墓	113.35 , 31.73	450–400	Hubeisheng (1989)
192	Hubei	Zhongbaodao 中堡岛	111.07 , 30.83	1400–1000	Guojia (2001)
193	Hubei	Zhouliangyuqiao 周良玉桥	112.28 , 30.31	1200–900	Peng, J. (1987); Wang, H. (1996)
194	Hunan	Baota 宝塔	111.39 , 29.58	1430–1240	Wang, W. & Long, X. (1987)
195	Hunan	Cendan 涇澹	111.92 , 29.68	1250–1200	Tan, Y. (1993)
196	Hunan	Gaoshaji 高砂脊	112.82 , 28.37	1050–880	Li, H. et al. (2019a); Xiang, T. (2001)
197	Hunan	Laoyazhou 老鸦州	113.23 , 29.12	1450–1200	Ma, J. (2018); Xu, W. (2006)
198	Hunan	Shuidongcun 水洞村	111.86 , 27.82	1250–1050	Dai, X. (1996)
199	Hunan	Tanheli 炭河里	112.09 , 28.15	1250–1200	Ma, J. (2016); Xu, J. (2006)
200	Hunan	Tonggushan 铜鼓山 (岳阳市)	113.29 , 29.51	1550–1350	Fu, X. et al. (2007); Xu, W. (2006)
201	Hunan	Yusishan 玉筍山	113.16 , 28.76	1250–1050	Guo, S. & He, J. (2007)
202	Hunan	Zaoshi 皂市	111.25 , 29.66	1600–1300	He, J. & Wang, W. (1992)
203	Hunan	Zhangshutan 樟树潭	113.10 , 29.17	1450–1040	Ma, J. (2018)
204	Inner Mongolia	Aluchaideng 阿鲁柴登	109.21 , 39.74	500–300	Tian, G. & Guo, S. (1980)
205	Inner Mongolia	Dadianzi 大甸子	120.60 , 42.29	1750–1600	Li, Y. et al. (2003); Zhongguo (1996c)
206	Inner Mongolia	Dajing 大井	118.27 , 43.73	1260–788	Li, Y. & Han, R. (2002); Wang, G. (1994)
207	Inner Mongolia	Dapaozi 大泡子	119.06 , 42.64	1000–850	Jia, H. (1984)
208	Inner Mongolia	Dashanqian 大山前	118.66 , 42.05	1600–1200	Peng, S. (2004); Zhu, Y. et al. (1998)
209	Inner Mongolia	Dayingzi 大营子	118.45 , 43.17	1511–801	Li, Y. et al. (2019)
210	Inner Mongolia	Erdaojingzi 二道井子	119.08 , 42.17	1750–1600	Cao, J. (2010); Wang, Y. (2013)
211	Inner Mongolia	Erliban 二里半	111.27 , 39.73	2200–1900	Lu, S. (1994)
212	Inner Mongolia	Guoxian Yaozi 崞县窑子	112.19 , 40.71	600–400	Chen, C. (2012); Wei, J. (1989)
213	Inner Mongolia	Habaqila 哈巴其拉	118.38 , 43.27	1250–1050	Li, C. et al. (2019)

ID	Province	Site	Location	Metal (start)	Reference
214	Inner Mongolia	Huogeqi 霍各乞	106.99 , 41.43	600–1	Guojia (2003)
215	Inner Mongolia	Jianshanzi 尖山子	119.20 , 42.88	1800–1400	Li, Y. et al. (2011)
216	Inner Mongolia	Longtoushan 龙头山	118.36 , 43.09	1440–1140	Cao, J. (1991); Wang, L. (2002)
217	Inner Mongolia	Maoqinggou 毛庆沟	112.28 , 40.49	700–500	Tian, G. & Guo, S. (1986)
218	Inner Mongolia	Nanpaoziya 南泡子崖	121.18 , 42.71	2000–1400	Hao, W. (1996); Liu, H. (2013)
219	Inner Mongolia	Nanshan'gen 南山根	118.78 , 41.54	900–700	Liu, G. & Xu, G. (1975)
220	Inner Mongolia	Sanzuodian 三座店	118.64 , 42.32	1600–1200	Guo, Z. & Hu, C. (2007)
221	Inner Mongolia	Sifendi 四分地	118.66 , 42.28	2000–1800	Li, G. et al. (1983)
222	Inner Mongolia	Taohongbala 桃红巴拉	109.15 , 39.70	700–500	Tian, G. (1976)
223	Inner Mongolia	Xiajiadian 夏家店	119.00 , 42.34	2000–1400	Liu, H. (2013); Zhongguo (1974b)
224	Inner Mongolia	Xiaoheishigou 小黑石沟	118.87 , 41.38	900–700	Neimenggu & Ningchengxian (2009)
225	Inner Mongolia	Xiaonailingao 小奈林稿	121.76 , 42.61	1210–970	Hu, C. et al. (2020)
226	Inner Mongolia	Xiaoyushulinzi 小榆树林子	119.16 , 41.54	2000–1400	Liu, H. (2013); Liu, T. (1965)
227	Inner Mongolia	Xicha 西岔	111.41 , 39.70	2200–1900	Lyu, Z. & Sun, Z. (2015)
228	Inner Mongolia	Xigoupan 西沟畔	110.79 , 40.05	700–500	Guo, S. & Tian, G. (1980)
229	Inner Mongolia	Xinzhou Yaozi 忻州窑子	112.32 , 40.49	600–400	Cao, J. et al. (2009)
230	Inner Mongolia	Xiquegou 喜鹊沟	117.24 , 43.35	1290–910	Wang, L. & Fu, L. (2015); Wang, L. et al. (2014)
231	Inner Mongolia	Zhukaigou 朱开沟	110.43 , 39.65	2000–1900	Neimenggu & E'erdusi (2000)
232	Jiangsu	Beishanding 北山顶	119.65 , 32.18	600–500	Zhang, M. & Liu, L. (1988)
233	Jiangsu	Beiyinyangying 北阴阳营	118.77 , 32.06	1600–1450	Nanjing (1993)
234	Jiangsu	Dafudun 大夫墩	119.45 , 31.97	800–700	Nanjing (1994); Zhi, X. (2019)
235	Jiangsu	Donggangtou 东岗头	119.12 , 31.77	980–880	Nanjing et al. (2016)
236	Jiangsu	Gaohuangmiao 高皇庙	117.32 , 34.50	1900–1500	Xie, C. (1958)
237	Jiangsu	Huashan 花山	120.30 , 31.85	1500–1150	Lu, J. et al. (2001)
238	Jiangsu	Kuanguangdun 宽广墩	119.00 , 31.40	900–700	Liu, J. et al. (1985)
239	Jiangsu	Liangshan 粮山	119.60 , 32.17	700–600	Zhi, X. (2019)
240	Jiangsu	Majishan 马迹山	119.47 , 32.19	1450–1150	Wang, S. et al. (2015); Xiao, M. (1983)
241	Jiangsu	Muzidun 母子墩	119.67 , 32.18	950–900	Xiao, M. (1984a; 1984b)
242	Jiangsu	Shecheng 佘城	120.33 , 31.84	1500–1150	Cao, W. et al. (2001); Diao, W. & Wu, H. (2004)
243	Jiangsu	Wushan 巫山	118.96 , 31.73	1100–1000	Liu, X. & Xiao, H. (1978)
244	Jiangsu	Yandunshan 烟墩山	119.67 , 32.20	1100–900	Jiangsusheng (1955; 1956)
245	Jiangsu	Zhenshan 真山	120.48 , 31.38	600–500	Ding, J. et al.(1999); Qian, G. et al. (1999)
246	Jiangxi	Dayangzhou 大洋洲	115.46 , 27.90	1250–1100	Jiangxisheng (1997)
247	Jiangxi	Qiaomailing 荞麦岭	115.83 , 29.44	1500–1400	Chen, Y. & Deng, S. (2014)
248	Jiangxi	Tongling 铜岭 (瑞昌市)	115.55 , 29.75	1450–1250	Cui, T. & Liu, W. (2017)
249	Jiangxi	Wucheng 吴城	115.29 , 27.98	1350–1250	Jiangxisheng & Zhangshushi (2005)
250	Jiangxi	Zhongling Shuiku 中垓水库	115.50 , 27.91	1200–1000	Peng, S. & Li, Y. (1983)
251	Jilin	Changsheshan 长蛇山	126.54 , 43.96	500–300	Zhang, X. (1980)
252	Jilin	Dongshantou 东山头	124.08 , 45.66	500–300	Kuang, Y. & Fang, Q. (1961)
253	Jilin	Hanshu 汉书	124.02 , 45.70	1100–500	Tang, M. (2018)
254	Jilin	Houshishan 猴石山	126.08 , 43.08	1000–600	Jia, Y. (1996); Zhang, Y. et al. (1993)
255	Jilin	Houtaomuga 后套木嘎	123.81 , 45.64	500–1	Liu, H. et al. (2019b); Zhao, J. et al. (2017)
256	Jilin	Saodagou 骚达沟	126.46 , 43.79	1000–300	Duan, Y. & Li, L. (1985)

ID	Province	Site	Location	Metal (start)	Reference
257	Jilin	Shuangta 双塔	122.95 , 45.39	500–1	Li, Y. et al. (2015b); Liu, H. et al. (2019a)
258	Jilin	Tuchengzi 土城子	126.56 , 43.91	500–300	Kang, J. (1955; 1957)
259	Jilin	Xingxingshao 星星哨	126.11 , 43.61	1000–300	Dong, X. (1978)
260	Jilin	Xituanshan 西团山	126.52 , 43.82	1000–800	Liu, J. (1984); Tong, Z. (1987)
261	Jilin	Yangtun 杨屯	126.46 , 44.13	700–500	Liu, Z. (1973)
262	Liaoning	Bagaidi 八盖地	119.55 , 41.35	2000–1400	Wang, L. et al. (2016)
263	Liaoning	Daihai 代海	121.53 , 42.42	1700–1400	Liaoningsheng (2012a)
264	Liaoning	Dazuizi 大嘴子	121.22 , 39.04	2000–1800	Dalianshi (2000)
265	Liaoning	Gangshang 岗上	121.43 , 39.01	800–700	Zhongguo (1996d)
266	Liaoning	Haidaoyingzi 海岛营子	119.60 , 40.95	1200–1000	Li, T. (1955)
267	Liaoning	Kangjiatun 康家屯	120.98 , 41.74	1700–1550	Xin, Y. & Li, W. (2001)
268	Liaoning	Kazuo 喀左	119.73 , 41.13	1200–1000	Liaoning & Chaoyang (1973); Beidong (1974)
269	Liaoning	Miaotaidi 庙台地	119.52 , 41.33	2000–1400	Wang, L. et al. (2016)
270	Liaoning	Niuheliang 牛河梁	119.45 , 41.27	2000–1400	Liaoningsheng (2012b); Li, Y. et al. (1999)
271	Liaoning	Ping'anbao 平安堡	122.51 , 42.48	1750–1550	Zhu, Y. et al. (1992a)
272	Liaoning	Pingdingshan 平顶山	121.24 , 42.08	1750–1450	Zhu, Y. et al. (1992b)
273	Liaoning	Shuangtuozi 双坨子	121.43 , 39.01	800–600	Zhongguo (1996d)
274	Liaoning	Shuiquan 水泉	119.95 , 41.68	1000–800	Jing, F. (1983)
275	Liaoning	Shuishouyingzi 水手营子	121.23 , 41.09	1600–1500	Qi, Y. & Liu, S. (1991)
276	Liaoning	Wanliu 湾柳	123.16 , 42.33	1500–1100	Cao, G. & Zhuang, Y. (1997); He, X. et al. (1989)
277	Liaoning	Weiyngzi 魏营子	120.31 , 41.03	1100–850	Liaoningsheng (1977)
278	Liaoning	Xianlingsi 仙灵寺	120.51 , 40.49	2000–1400	Liu, H. (2013)
279	Liaoning	Xiaobeishan 小北山	119.54 , 41.34	2000–1400	Wang, L. et al. (2016)
280	Liaoning	Xiaoheishan 小黑山	119.54 , 41.34	2000–1400	Wang, L. et al. (2016)
281	Liaoning	Yangtouwa 羊头洼	121.16 , 38.81	1400–1000	An, Z. (1993); Seiichi (1942)
282	Liaoning	Yujiatuotou 于家砣头	121.19 , 38.79	1400–1000	Dalianshi (2018)
283	Ningxia	Mazhuang 马庄	106.12 , 36.22	700–500	Xu, C. et al. (1993)
284	Ningxia	Sunjia Zhuang 孙家庄	106.17 , 35.98	1050–1000	Wei, J. & Shi, L. (2016)
285	Ningxia	Yaoheyuan 姚河塬	106.66 , 35.85	1100–1050	Ma, Q. (2020)
286	Ningxia	Yujia Zhuang 于家庄	106.15 , 36.09	700–500	Zhong, K. et al. (1995)
287	Qinghai	Ahatela 阿哈特拉	102.40 , 35.80	1600–750	Xu, X. (1983)
288	Qinghai	Banzhuwa 半主洼	101.76 , 36.17	1600–700	Liu, B. (1998); Miyake (2005)
289	Qinghai	Changning 长宁	101.76 , 36.82	2000–1500	Qiao, H. (2018)
290	Qinghai	Dahuazhongzhuang 大华中庄	101.19 , 36.71	1100–700	Qinghaisheng et al. (1985)
291	Qinghai	Dongcun Zhuanwa 东村砖瓦厂	102.06 , 36.52	1600–700	Miyake (2005)
292	Qinghai	Gamatai 尕马台	100.58 , 35.87	1700–1500	Qinghaisheng & Beijing (2016)
293	Qinghai	Hetaozhuang 核桃庄	102.75 , 36.30	1600–600	Qinghaisheng (2004)
294	Qinghai	Huabiliang 花鼻梁	101.18 , 36.72	1600–700	Miyake (2005)
295	Qinghai	Huangjiazhai 黄家寨	101.74 , 36.86	1700–1000	Gao, D. (1994)
296	Qinghai	Jinchankou 金蝉口	102.54 , 36.92	2000–1750	Qiao, H. (2018); Wang, Q. (2013)
297	Qinghai	Liuwan 柳湾	102.56 , 36.45	2000–1700	Qiao, H. (2018)
298	Qinghai	Luanshan 乱山	101.17 , 36.74	1600–700	Miyake (2005)
299	Qinghai	Panjialiang 潘家梁	101.56 , 36.76	1600–700	Guojia (1996)

ID	Province	Site	Location	Metal (start)	Reference
300	Qinghai	Shakacun 沙卡村	102.00 , 36.38	1600–700	Miyake (2005)
301	Qinghai	Shanpingtai 山坪台	101.38 , 36.02	1600–700	Miyake (2005)
302	Qinghai	Shenna 沈那	102.08 , 36.46	1700–700	Qiao, H. (2018)
303	Qinghai	Tawendaliha 塔温搭里哈	97.40 , 36.11	1000–800	Wu, R. (1963); Xi, G. & Li, Y. (2020)
304	Qinghai	Zongri 宗日	100.40 , 35.27	2000–1700	Chen, H. et al. (1998); Xu, J. (2010)
305	Qinghai	Zongzhai 总寨	101.91 , 36.72	1700–1500	Qiao, H. (2018)
306	Shaanxi	Anban 案板	107.91 , 34.35	980–770	Xibei (2002b)
307	Shaanxi	Andi 岸底	108.05 , 34.43	980–770	Shaanxisheng (1993)
308	Shaanxi	Anjiacun 安家村	107.38 , 33.19	1450–1050	Mei, J. & Chen, K. (2011)
309	Shaanxi	Baoshan 宝山	107.35 , 33.20	1450–1300	Chen, K. et al. (2012); Xibei (2002a)
310	Shaanxi	Beicun 北村	108.82 , 35.01	1580–1300	Lu, J. (1984)
311	Shaanxi	Beiliu 北刘	109.56 , 34.38	3900–3600	Zhang, R. (1986)
312	Shaanxi	Beilyu 北吕	107.87 , 34.28	1150–1100	Luo, X. (1985)
313	Shaanxi	Cuijiahe 崔家河	108.36 , 35.13	1200–800	Cao, F. & Jing, F. (1984)
314	Shaanxi	Daijiawan 戴家湾	107.23 , 34.37	1100–850	Chen, C. (2015); Ren, X. (2013)
315	Shaanxi	Dayuancun 大原村	108.71 , 34.19	980–770	Fu, Z. & Xu, L. (2016); Xu, L. (2004)
316	Shaanxi	Dianzicun 店子村	106.84 , 34.89	1050–980	Yang, Y. & Tian, Z. (1995)
317	Shaanxi	Dongjiacun 董家村	107.84 , 34.49	980–770	Pang, H. et al. (1976)
318	Shaanxi	Donglongshan 东龙山	109.97 , 33.85	1700–1600	Shaanxisheng & Shangluoshi (2011)
319	Shaanxi	Fanbacunxi 范坝村西	107.47 , 33.21	1450–1050	Zhao, C. (2006)
320	Shaanxi	Feifengshan 飞凤山	107.88 , 34.36	1100–1000	Liu, M. (1996a)
321	Shaanxi	Gaojiabao 高家堡	108.64 , 34.60	1100–900	Shaanxi (1995)
322	Shaanxi	Gaojiacun 高家村	107.07 , 34.36	1400–1000	Zhang, T. (1998)
323	Shaanxi	Gaomiaocun 高庙村	107.75 , 34.12	980–880	Liu, M. (1996b)
324	Shaanxi	Goukoucun 沟口村	110.68 , 37.33	1250–1050	Wu, L. & Zong, Y. (1988)
325	Shaanxi	Guantaoyuan 关桃园	106.52 , 34.50	1050–770	Baojishi & Shaanxisheng (2007)
326	Shaanxi	Heidouzui 黑豆嘴	108.77 , 34.78	1169–1102	Yao, S. (1986); Zhang, W. & Lin, Y. (2004)
327	Shaanxi	Hejiacun 贺家村	107.85 , 34.49	1500–980	Dai, Y. (1976); Yang, J. et al. (2003a)
328	Shaanxi	Hourenjiagou 后任家沟	110.47 , 37.41	1250–1050	Li, Z. (1982)
329	Shaanxi	Huaizhenfang 怀珍坊	109.23 , 34.15	1650–1400	Xi'an (1981); Zhangsun, Y. (2019)
330	Shaanxi	Huajiayuan 花家塬	110.26 , 36.84	1250–1050	Cao, D. (2014)
330	Shaanxi	Huangdui Laobaozi 黄堆老堡子	107.87 , 34.51	980–770	Luo, F. & Wei, X. (2005)
331	Shaanxi	Huanggou 黄沟	109.33 , 34.09	1500–1100	Fan, W. & Wu, Z. (1980)
332	Shaanxi	Huangjiahe 黄家河	108.05 , 34.42	1000–800	Liang, X. & Liu, S. (1988)
333	Shaanxi	Huoshiliang 火石梁 (榆林市)	109.60 , 38.36	2000–1900	Chen, K. et al. (2009b)
334	Shaanxi	Jiangzhai 姜寨	109.21 , 34.38	4900–4400	Xi'an (1988)
335	Shaanxi	Jingdang 京当	107.83 , 34.49	1260–1200	Wang, G. (1977)
336	Shaanxi	Kexingzhuang 客省庄	108.73 , 34.21	1050–770	Lu, L. (1987)
337	Shaanxi	Laoniupo 老牛坡	109.54 , 34.29	1500–1300	Liu, S. (2002)
338	Shaanxi	Liangdaicun 梁带村	110.50 , 35.51	900–800	Chen, K. et al. (2009a)
339	Shaanxi	Lijiaya 李家崖	110.44 , 37.07	1300–900	Shaanxisheng (2013)
340	Shaanxi	Linjiacun 林家村	107.06 , 34.38	1400–1000	Yan, H. (1988)
341	Shaanxi	Liuja 刘家	107.85 , 34.50	1400–1000	Yin, S. & Wang, J. (1984)
342	Shaanxi	Liujiayuan 刘家塬	110.37 , 36.79	1250–1050	Yan, C. & Lyu, Z. (1988)

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343	Shaanxi	Liulingdu 六陵渡村	107.48 , 33.20	1450–1050	Mei, J. & Chen, K. (2011); Zhu, F. (2011)
344	Shaanxi	Longtoucun 龙头村	107.25 , 33.17	1450–1050	Mei, J. & Chen, K. (2011); Zhao, C. (2006)
345	Shaanxi	Meiyang 美阳	107.89 , 34.42	1500–1100	Luo, X. (1978)
346	Shaanxi	Miaowangcun 庙王村	107.60 , 34.49	1400–1000	Pang, W. & Cui, J. (1990)
347	Shaanxi	Nalingaotu 纳林高兔	109.78 , 38.69	500–300	Dai, Y. & Sun, J. (1983)
348	Shaanxi	Nanbao 南堡	109.53 , 34.35	1500–1100	Zuo, Z. (1987)
349	Shaanxi	Nansha 南沙	109.71 , 34.49	1650–1400	Wang, Y. et al. (2017)
350	Shaanxi	Nanzhihuixicun 南指挥西村	107.35 , 34.47	1250–1050	Han, W. & Wu, Z. (1982)
351	Shaanxi	Nianzipo 碾子坡	107.90 , 35.15	1300–1100	Zhongguo (2007b)
352	Shaanxi	Puducun 普渡村	108.77 , 34.23	980–880	Dai, Y. (1988); He, H. (1957)
353	Shaanxi	Qijiacun 齐家村	107.86 , 34.48	1000–770	Shaanxisheng & Shaanxisheng (1963)
354	Shaanxi	Rujiazhuang 茹家庄	107.11 , 34.33	1000–900	Lu, L. & Hu, Z. (1988)
355	Shaanxi	Sanlidong 三里洞	109.10 , 35.09	1500–1100	Lu, J. (1982)
356	Shaanxi	Shaojiagou 邵家沟	108.91 , 34.81	1500–1100	Ma, Q. (1996)
357	Shaanxi	Shigushan 石鼓山	107.19 , 34.34	1100–1000	Liu, J. et al. (2013a; 2013b); Shao, A. et al. (2021)
358	Shaanxi	Shijiayuan 史家塬	107.79 , 34.68	1250–1200	Lei, X. et al. (2004)
359	Shaanxi	Shimao 石峁	110.33 , 38.57	2300–1900	Sun, Z. et al. (2020a; 2020b)
360	Shaanxi	Sucun 苏村	107.36 , 33.19	1450–1050	Zhao, C. (2006)
361	Shaanxi	Tuojiayuan 拓家塬	109.93 , 37.35	1250–1200	Qiao, J. et al. (2015)
362	Shaanxi	Wangjiazui 王家咀	107.83 , 34.49	1500–1000	Ji, H. (1984); Yang, J. et al. (2003b)
363	Shaanxi	Wujunxicun 五郡西村	107.81 , 34.36	1050–770	Liu, J. et al. (2007)
364	Shaanxi	Wulangmiao 五郎庙	107.32 , 33.18	1450–1050	Zhao, C. (2006)
365	Shaanxi	Xiejiagou 解家沟	110.50 , 37.22	1250–1050	Gao, X. (1984)
366	Shaanxi	Yangjiacun 杨家村	107.73 , 34.28	980–770	Liu, H. & Liu, J. (2003)
367	Shaanxi	Yangyuanfang 羊元坊	108.85 , 34.14	1300–1200	Zhang, T. (2003)
368	Shaanxi	Yanjiagou 阎家沟	109.07 , 36.44	1200–1060	Ma, Q. (2008)
369	Shaanxi	Yantou 塬头	110.56 , 37.49	1250–1050	Hei, G. & Zhu, J. (1975)
370	Shaanxi	Yijabao 壹家堡	107.85 , 34.34	1500–1100	Sun, H. & Liu, X. (1993)
371	Shaanxi	Yuanjiaya 袁家崖	109.12 , 34.31	1500–1100	Gong, Q. (1981)
372	Shaanxi	Yuquan 峪泉	107.14 , 34.35	1200–980	Cao, W. & Sun, Z. (2000); Wang, G. (1975)
373	Shaanxi	Zaoshugounao 枣树沟脑	108.51 , 34.85	1200–1000	Li, C. et al. (2012); Yang, Z. & Zhou, P. (2017)
374	Shaanxi	Zhangjiapo 张家坡	109.14 , 34.13	1050–996	Zhongguo (1999b)
375	Shaanxi	Zhaojiatai 赵家台	107.72 , 34.46	1050–880	Tian, X. & Liu, J. (1994)
376	Shaanxi	Zhaolicun 召李村	107.88 , 34.47	1100–980	Luo, X. et al. (1976)
377	Shaanxi	Zhengjiapo 郑家坡	108.12 , 34.33	1500–1200	Ren, Z. & Liu, J. (1984)
378	Shaanxi	Zhifangtou 纸坊头	107.13 , 34.38	1400–1000	Lu, L. & Hu, Z. (1988)
379	Shaanxi	Zhougongmiao 周公庙	107.60 , 34.49	1200–770	Xu, T. (2006)
380	Shaanxi	Zhuangbai 庄白	107.86 , 34.47	1050–770	Shaanxi (1978)
381	Shaanxi	Zhumazui 朱马咀	108.38 , 34.79	1500–1100	Qiu, W. & Sun, D. (1980)
382	Shaanxi	Zhuyuangou 竹园沟	107.10 , 34.32	1050–880	Lu, L. & Hu, Z. (1988)
383	Shaanxi	Zijing 紫荆	109.99 , 33.83	1650–1400	Shangxian et al. (1981)
384	Shandong	Changqing Xiaotun 长清小屯	116.70 , 36.46	1200–900	Tang, S. (1964)

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385	Shandong	Chengzi 呈子	119.43 , 35.88	2500–1900	Ren, S. (2004)
386	Shandong	Dafanzhuang 大范庄	118.52 , 35.11	2500–1900	Ren, S. (2004)
387	Shandong	Dahan 大韩村	117.25 , 34.95	1100–1050	Gao, J. (2010)
388	Shandong	Dakangliu 大康留村	117.25 , 34.92	1400–1300	Gao, J. (2010)
389	Shandong	Dawenkou 大汶口	117.09 , 35.95	2600–2300	Shandongsheng & Ji'nanshi (1974)
390	Shandong	Daxinzhuang 大辛庄	117.11 , 36.71	1500–1050	Fang, H. et al. (2004); Xu, J. (1995)
391	Shandong	Dianzi 店子	120.70 , 37.99	2500–1900	Ren, S. (2004)
392	Shandong	Guziping 姑子坪	118.15 , 36.21	1900–1500	Ren, X. et al. (2003)
393	Shandong	Haojiazhuang 郝家庄	118.54 , 36.62	1600–1500	Yan, M. et al. (2017)
394	Shandong	Hongfan 洪范	116.28 , 36.08	1250–1050	Yang, S. (1992)
395	Shandong	Houhuangzhuang 后黄庄	117.24 , 34.88	1100–1050	Gao, J. (2010)
396	Shandong	Huangxian 黄县	120.49 , 37.66	1600–1400	Li, B. & Lin, X. (1989)
397	Shandong	Jiaogudui 窖垆堆	117.50 , 35.64	1100–1050	Gao, J. (2010)
398	Shandong	Ligongcun 李宫村	116.77 , 35.63	1100–1050	Gao, J. (2010)
399	Shandong	Longgudui 龙垆堆	117.01 , 35.03	1200–1050	Gao, J. (2010)
400	Shandong	Lyulou 吕楼村	117.21 , 34.90	1400–1250	Gao, J. (2010)
401	Shandong	Qianzhangda 前掌大	117.22 , 34.90	1250–1050	Zhongguo (2005)
402	Shandong	Sanlihe 三里河	119.98 , 36.28	2100–1900	Zhongguo (1988)
403	Shandong	Sitai 寺台村	117.33 , 35.69	1250–1050	Zhao, Z. (1988)
404	Shandong	Subutun 苏埠屯	118.66 , 36.74	1260–1040	Xia, M. & Liu, H. (1996)
405	Shandong	Xianrentai 仙人台	116.67 , 36.34	900–800	Ren, X. & Cui, D. (1998)
406	Shandong	Xidingcun 西丁村	116.91 , 35.38	1100–1050	Gao, J. (2010)
407	Shandong	Xuanyuanzhuang 轩辕庄	117.25 , 34.93	1400–1250	Gao, J. (2010)
408	Shandong	Yangjiaquan 杨家圈	120.78 , 37.21	2500–1900	Beijing & Yantaishi (2000)
409	Shandong	Yaowangcheng 尧王城	119.38 , 35.31	2500–1900	Liang, Z. et al. (2015); Ren, S. (2004)
410	Shandong	Yingcheng 嬴城	117.58 , 36.32	1200–900	Li, Y. et al. (2013)
411	Shandong	Yinjiacheng 尹家城	117.27 , 35.68	1900–1500	Shandong (1990)
412	Shandong	Zhangzhuang 张庄	117.40 , 35.50	1250–1050	Xie, H. (1986)
413	Shandong	Zhaogezhuang 照格庄	121.58 , 37.38	1900–1600	Han, R. (1986)
414	Shandong	Zhongzhai 种寨村	117.10 , 35.08	1100–1050	Gao, J. (2010)
415	Shandong	Zhujiqiao 朱家桥	116.28 , 35.95	1250–1000	Zhao, L. (1961)
416	Shanghai	Maqiao 马桥	121.38 , 31.04	1700–1600	Shanghaishi (2002)
417	Shanxi	Baiyan 白燕	112.71 , 37.45	1600–1500	Xu, W. & Yang, J. (1989)
418	Shanxi	Caojiayuan 曹家垣	110.69 , 37.20	1250–1050	Yang, S. (1981b)
419	Shanxi	Dahekou 大河口	111.78 , 35.74	1050–700	Xie, Y. et al. (2011)
420	Shanxi	Dongxiafeng 东夏冯	111.30 , 35.23	1650–1600	Li, J. et al. (2018); Zhongguo (1988)
421	Shanxi	Erlangpo 二郎坡	110.83 , 37.01	1250–1050	Shanxisheng (1958)
422	Shanxi	Gaohong 高红	110.79 , 37.41	1300–1100	Yang, S. (1981a)
423	Shanxi	Geduping 圪堵坪	110.55 , 37.00	1250–1050	Cao, D. (2019)
424	Shanxi	Haojiapan 郝家畔	110.57 , 37.00	1250–1050	Cao, D. (2019)
425	Shanxi	Hengshui 横水	111.45 , 35.48	1000–1000	Shanxisheng (2012); Song, J. (2006)
426	Shanxi	Houlanjiagou 后兰家沟	110.77 , 37.10	1250–1050	Cao, D. (2019)
428	Shanxi	Jingjie 旌介	111.91 , 36.90	1100–1050	Shanxisheng (2006)
429	Shanxi	Jiuwutou 酒务头	111.43 , 35.33	1080–1040	Bai, S. (2019)
430	Shanxi	Liangsu 粮宿	111.45 , 34.84	1500–1300	Li, B. (1994)

ID	Province	Site	Location	Metal (start)	Reference
431	Shanxi	Liansigou 连寺沟	112.57 , 38.27	1250–1050	Cao, D. (2019)
432	Shanxi	Licheng 黎城	113.39 , 36.50	800–700	Zhang, C. (2020)
433	Shanxi	Linzheyu 林遮峪	111.00 , 38.82	1300–1000	Chang, H. (2014)
434	Shanxi	Nangou 南村	110.94 , 36.95	1250–1050	Cao, D. (2019)
435	Shanxi	Qianjinba 千金耙	111.56 , 35.26	1600–1400	Li, G. (2017); Tian, W. (2020)
436	Shanxi	Qiaobei 桥北	111.89 , 36.02	1250–900	Tian, J. et al. (2006)
437	Shanxi	Taohuazhuang 桃花庄	110.91 , 36.96	1250–1050	Xie, Q. & Yang, S. (1960)
438	Shanxi	Taosi 陶寺	111.49 , 35.89	2100–1700	Zhongguo & Shanxisheng (2015)
439	Shanxi	Tazishang 塔子上	110.82 , 37.08	1250–1050	Cao, D. (2014)
440	Shanxi	Tianma-Qucun 天马-曲村	111.57 , 35.74	1000–700	Beijing & Shanxisheng (2000)
441	Shanxi	Xiaojiata 肖家塌	110.74 , 36.96	1250–1050	Cao, D. (2019)
442	Shanxi	Xiaoshen 小神	113.07 , 36.23	1260–1200	Song, J. et al. (1996)
443	Shanxi	Xiaxinjiao 下辛角	110.53 , 36.61	1250–1050	Cao, D. (2019)
444	Shanxi	Xia Zhuang 下庄	111.00 , 36.95	1250–1050	Cao, D. (2019)
445	Shanxi	Xiwubi 西吴壁	111.54 , 35.50	1750–1550	Dai, X. & Tian, W. (2020); Dai, X. et al. (2020)
446	Shanxi	Xuejiaqu 薛家渠	110.11 , 37.22	1250–1050	Xu, T. (1988)
447	Shanxi	Yidie 义牒	110.57 , 37.00	1250–1050	Shilouxian (1972); Yang, S. (1974)
448	Shanxi	Yuanqu 垣曲商城	111.85 , 35.08	1650–1550	Cui, J. et al. (2009); Zhongguo et al. (2014)
449	Shanxi	Yuanwozhen 源涡镇	112.79 , 37.69	3100–2900	Wajima (1962)
450	Shanxi	Zhinan 指南	110.90 , 37.00	1250–1050	Cao, D. (2019)
451	Sichuan	Benjiadi 本家地	101.01 , 30.11	400–100	Tong, E. & Zeng, W. (1981)
452	Sichuan	Hanyuan 汉源	102.64 , 29.35	1200–900	Yue, R. (1983)
453	Sichuan	Jililong 吉里龙	99.80 , 31.67	400–100	Chen, D. et al. (1986)
454	Sichuan	Jinsha 金沙	104.01 , 30.68	1200–600	Chengdu & Chengdu (2017); Jin, Z. et al. (2004)
455	Sichuan	Luojiaba 罗家坝	107.75 , 31.53	550–450	Sichuansheng et al. (2015)
456	Sichuan	Sanxingdui 三星堆	104.20 , 31.01	1400–1250	Ma, J. et al. (2012); Sichuansheng (1999)
457	Sichuan	Shangyejie 商业街	104.06 , 30.66	500–450	Chengdu (2009)
458	Sichuan	Shierqiao 十二桥	104.05 , 30.66	1200–600	Sichuansheng & Chengdu (2009)
459	Sichuan	Yan'erlong 宴尔龙	100.56 , 31.46	1500–880	Jin, G. (2012)
460	Sichuan	Yingpanshan 营盘山	103.85 , 31.68	400–300	Chengdu et al. (2018)
461	Sichuan	Zhajinding 扎金顶	99.12 , 30.01	400–100	Tong, E. & Zeng, W. (1981)
462	Tianjin	Weifang 围坊	117.44 , 40.04	1500–1300	Li, J. & Liang, B. (1983)
463	Tianjin	Zhangjiayuan 张家园	117.27 , 40.02	1500–1300	Li, J. (1984); Ji, L. & Zhang, J. (1993)
464	Xinjiang	Adunqiaolu 阿敦乔鲁	80.54 , 45.02	1900–1700	Cong, D. et al. (2017); Tan, Y. et al. (2021)
465	Xinjiang	Aga'ersen 阿格尔森	82.41 , 43.49	1600–900	Wang, L. et al. (2019)
466	Xinjiang	Aletengyemule 阿勒腾也木勒	83.22 , 46.16	1760–1640	Wu, Y. et al. (2017)
467	Xinjiang	Ayituoan 阿依托汗	86.40 , 48.06	3500–2500	Li, S. (2018a)
468	Xinjiang	Baigetubie 拜格托别	92.36 , 43.52	1782–1439	Zhu, J. et al. (2021)
469	Xinjiang	Baiqi'er 拜契尔	93.70 , 43.34	500–200	Guo, J. (1997); Qian, W. (2006)
470	Xinjiang	Chawuhu 察吾呼	86.17 , 42.32	1150–450	Xinjiang (1999)
471	Xinjiang	Duogang 多岗	82.05 , 41.88	1000–900	Zhongguo et al. (2014)
472	Xinjiang	Dunna Gaosu 墩那高速	83.24 , 43.79	2900–2700	Liu, H. et al. (2018)

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473	Xinjiang	Duweilike 都维力克	77.26 , 38.00	600–300	Guojia (2012)
474	Xinjiang	Fuzhisuanchang 腐殖酸厂	93.53 , 42.59	2000–1550	Mei, J. (2000)
475	Xinjiang	Gongliu 巩留	82.49 , 43.58	1600–900	Wang, B. & Cheng, Z. (1989)
476	Xinjiang	Gumugou 古墓沟	88.94 , 40.68	1900–1300	Wang, B. (2014)
477	Xinjiang	Heigouliang 黑沟梁	93.62 , 43.38	600–400	Qian, W. (2006)
478	Xinjiang	Huahaizi 花海子	90.90 , 46.81	900–400	Guo, W. et al. (2016)
479	Xinjiang	Huoji'erte 霍吉尔特	83.92 , 46.37	2920–2750	Wang, Y. et al. (2018b)
480	Xinjiang	Husita (Husta) 呼斯塔	81.41 , 45.15	1700–1600	Jia, X. (2019)
481	Xinjiang	Jialekesikaente 加勒克斯卡茵特	82.90 , 43.83	500–200	Li, S. et al. (2011)
482	Xinjiang	Jiawa'airike 加瓦艾日克	85.51 , 38.17	750–100	Gong, G. & Qin, D. (1997)
483	Xinjiang	Jirentai Goukou 吉仁台沟口	82.77 , 43.84	1600–1500	Ruan, Q. & Wang, Y. (2017)
484	Xinjiang	Kan'erzi 坎儿孜	89.77 , 43.99	1200–300	Wang, M. (2013); Xue, Z. (1982)
485	Xinjiang	Liushugou 柳树沟	92.72 , 43.38	1610–970	Subei, N. (2019); Wang, Y. (2015)
486	Xinjiang	Nanwan 南湾	93.53 , 43.54	1300–900	He, X. (1987); Qian, W. (2006)
487	Xinjiang	Niya 尼雅	82.73 , 38.36	1500–1000	Yue, F. & Yu, Z. (1999)
488	Xinjiang	Nulasai 奴拉赛	82.47 , 43.77	750–200	Li, Y. & Mei, J. (2001); Mei, J. & Li, Y. (1998)
489	Xinjiang	Qiemu'er Qieke 切木尔切克	87.97 , 47.80	1200–500	Jia, P. & Betts (2010); Yi, M. (1981)
490	Xinjiang	Quanshuigou 泉水沟	82.35 , 44.84	1500–1100	Han, J. & Chen, X. (2017)
491	Xinjiang	Qunbake 群巴克	84.14 , 41.86	950–600	Cong, D. & Chen, G. (1991)
492	Xinjiang	Sa'ensayi 萨恩萨伊	87.20 , 43.31	1800–1500	Xinjiang (2013)
493	Xinjiang	Sangeqiao 三个桥	89.80 , 42.75	700–500	Xing, K. & Zhang, Y. (2002)
494	Xinjiang	Shangmiao'ergou 上庙尔沟	93.73 , 42.80	600–400	Qian, W. (2006)
495	Xinjiang	Shanpula 山普拉	80.12 , 37.00	600–AD 200	Xiao, X. & Zheng, B. (2000)
496	Xinjiang	Shengjindian 胜金店	89.63 , 42.94	200–1	Li, X. et al. (2013); Zhang, Y. et al. (2013)
497	Xinjiang	Shihezi Nanshan 石河子南山	85.67 , 43.10	1300–1000	Xing, K. et al. (1989)
498	Xinjiang	Sidaogou 四道沟	90.19 , 43.79	700–500	Yang, Y. (1982)
499	Xinjiang	Subeixi 苏贝希	88.57 , 42.63	500–200	Lyu, E. & Zheng, B. (2002)
500	Xinjiang	Tangbalesayi 汤巴勒萨伊	82.70 , 43.74	1900–1000	Ruan, Q. et al. (2012)
501	Xinjiang	Tianshanbeilu 天山北路	93.51 , 42.85	2000–1550	Liu, C. et al. (2020); Qian, W. et al. (2001)
502	Xinjiang	Tongtiandong 通天洞	86.14 , 47.18	1500–800	Yu, J. (2018); Yu, J. et al. (2018)
503	Xinjiang	Wupu 五堡	92.85 , 42.87	1400–800	Gao, J. et al. (2021); Mei, J. (2000)
504	Xinjiang	Xiabandi 下坂地	75.51 , 37.77	1500–1100	Xinjiang (2012)
505	Xinjiang	Xiangbaobao 香宝宝	75.23 , 37.77	700–400	Chen, G. (1981)
506	Xinjiang	Xiaohe 小河	88.67 , 40.34	1900–1300	Abuduresule et al. (2007); Mei, J. et al. (2013)
507	Xinjiang	Xintala 新塔拉	86.96 , 42.20	1500–1000	Lyu, E. (1988)
508	Xinjiang	Ya'erhu Goubei 亚尔湖沟北	89.06 , 42.95	200–AD 600	Lianheguo et al. (1998)
509	Xinjiang	Yanbulak (Yanbulake) 焉不拉克	92.91 , 43.06	1300–900	Zhang, P. et al. (1989)
510	Xinjiang	Yanghai 洋海	89.65 , 42.80	1250–1000	Tulufanishi et al. (2019)
511	Xinjiang	Yuantoushan 圆头山	82.41 , 43.64	1100–250	Wang, L. et al. (2019)
512	Xinjiang	Yutang 鱼塘	82.99 , 43.52	1600–900	Wang, L. et al. (2019)
513	Xinjiang	Zagunluk 扎滚鲁克	85.47 , 38.12	800–1	Wang, B. (2003)
514	Xizang (Tibet)	Chengbei 城北	98.27 , 30.86	400–100	Guo, Z. (1992)
515	Xizang (Tibet)	Gebusailu 格布赛鲁	79.80 , 31.57	600–200	Li, Y. et al. (2001)

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516	Xizang (Tibet)	Piyang-Dongga 皮央·东嘎	79.80 , 31.68	600–100	Huo, W. & Li, Y. (2001); Yao, J. & Huo, W. (2001)
517	Xizang (Tibet)	Qugong 曲贡	91.14 , 29.70	1750–1500	Zhongguo & Xizang (1999)
518	Xizang (Tibet)	Redilong 热底垄	97.21 , 31.06	400–300	Huo, W. (2014)
519	Xizang (Tibet)	Xiangbei 香贝	98.27 , 30.86	400–100	Guo, Z. et al. (1989)
520	Yunnan	Aofengshan 鳌凤山	99.83 , 26.31	1000–800	Kan, Y. (1986); Kan, Y. & Xiong, Y. (1990)
521	Yunnan	Dabona 大波那	100.76 , 25.50	500–350	Li, X. & Han, R. (2010); Min, R. et al. (2015)
522	Yunnan	Dahuashi 大花石	99.04 , 24.36	1600–1200	Yang, F. & Wan, Y. (2011)
523	Yunnan	Haimenkou 海门口	99.92 , 26.46	1700–1200	Li, X. & Han, R. (2006); Li, X. & Min, R. (2016)
524	Yunnan	Hebosuo 河泊所	102.69 , 24.71	1000–800	Yang, W. (2019)
525	Yunnan	Lijiashan 李家山	102.74 , 24.30	300–200	Yu, X. (1995); Zhang, X. (2001)
526	Yunnan	Nagu 纳古	98.68 , 28.76	1000–700	Zhang, X. (1983)
527	Yunnan	Shangri-La 香格里拉	99.42 , 28.17	1000–800	Li, K. & Min, R. (2011)
528	Yunnan	Shifodong 石佛洞	99.45 , 23.36	1400–1300	Li, K. & Min, R. (2011)
529	Yunnan	Shizhaishan 石寨山	102.69 , 24.72	700–500	Li, X. et al. (2004); Yunnansheng (2016)
530	Yunnan	Wangjiadun 王家墩	102.63 , 24.99	1100–800	Li, Y. & Wang, H. (1983)
531	Yunnan	Wanjiaba 万家坝	101.56 , 25.01	700–500	Li, X. et al. (2008); Qiu, X. et al. (1983)
532	Yunnan	Yeshishan 野石山	103.52 , 27.17	1300–900	Liu, X. (2009)
533	Yunnan	Yinsuodao 银梭岛	100.27 , 25.68	1200–900	Min, R. & Wan, J. (2009)
534	Zhejiang	Potang 坡塘	120.56 , 29.93	600–400	Mou, Y. (1984)
535	Zhejiang	Yangfushan 杨府山	120.68 , 27.86	950–850	Peng, S. & Sun, Y. (2011); Wu, X. et al. (2007)
536	Zhejiang	Yinshan 印山	120.51 , 29.93	500–450	Zhejiangsheng & Shaoxingxian (2002)
537	Zhejiang	Yushan 鱼山	121.55 , 30.04	1200–400	Wang, J. et al. (2016); Wang, Y. et al. (2019b)
538	Taiwan	Dapenkeng 大坌坑	121.41 , 25.15	800–300	Chen, K. (2011)
539	Taiwan	Tudigongshan 土地公山	121.44 , 24.95	800–300	Chen, K. (2011)
540	Taiwan	Yuanshan 圆山	121.52 , 25.07	800–300	Chen, K. (2011)

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541	Afghanistan	Dashly	66.40 , 37.09	2100–1800	Sarianidi (1976)
542	Afghanistan	Mundigak	65.52 , 31.90	2800–2100	Casal (1952)
543	Afghanistan	Tepe Fullol	69.32 , 36.18	2200–1700	Hiebert & Cambon (2008)
544	Afghanistan	Tillya Tepe	65.81 , 36.67	100–AD 100	Sarianidi (1985)
545	Armenia	Gegharot	44.22 , 40.71	3500–2900	Smith et al. (2004)
546	Azerbaijan	Ovçular Tepesi	45.07 , 39.59	4300–4000	Gailhard et al. (2017); Marro et al. (2009)
547	Bahrain	Qal'at al-Bahrain	50.52 , 26.23	2300–1700	Weeks (2003)
548	Bangladesh	Mahasthangarh	89.34 , 24.96	300–AD 800	Chattopadhyay & Chattopadhyay (2018)

ID	Country	Site	Location	Metal (start)	Reference
549	Bangladesh	Wari-Bateshwar	90.72 , 23.92	450–300	Chattopadhyay & Chattopadhyay (2018)
550	Bosnia and Herzegovina	Gornja Tuzla	18.76 , 44.56	5400–4550	Antonović Dragana (2002)
551	Bulgaria	Ai Bunar	25.45 , 42.50	4700–3950	Pernicka et al. (1997)
552	Bulgaria	Devnya	27.57 , 43.22	4300–4000	Anthony (2007)
553	Bulgaria	Durankulak	28.52 , 43.70	5000–4450	Todorova (1989)
554	Bulgaria	Ezero	26.02 , 42.47	3300–2700	Georgiev & Merpert (1966)
555	Bulgaria	Karanova VI	25.92 , 42.51	4500–3900	Mikov (1959)
556	Bulgaria	Slatina	24.57 , 42.68	5100–4900	Kitov et al. (1991)
557	Bulgaria	Suvorovo	27.60 , 43.33	4300–4000	Anthony (2007)
558	Bulgaria	Varna	27.86 , 43.21	4596–4341	Avramova (1991); Higham et al. (2018)
559	Cambodia	Prohear	105.52 , 11.54	100–100	Pryce et al. (2014)
560	Cyprus	Erimi	32.92 , 34.68	3900–2600	Muhly (1991)
561	Cyprus	Lempa	32.41 , 34.81	3900–2600	Muhly (1991)
562	Egypt	Abydos	31.92 , 26.19	3100–2900	Petrie & Weigall (1902–1904)
563	Egypt	Buto	30.74 , 31.20	4000–3500	Hartung (2013)
564	Egypt	Maadi	31.25 , 29.97	4000–3200	Killick (2014)
565	Egypt	Memphis (Kom Rabi'a)	31.25 , 29.84	3100–2900	Giddy & Leahy (1999)
566	Egypt	Naqada	32.72 , 25.90	3500–3200	Baumgartel & Petrie (1970)
567	Egypt	Wadi Dara	33.27 , 28.00	3000–2500	Castel et al. (1995); Craddock (2000)
568	Egypt	Wadi Um Balad	32.65 , 27.67	3000–2500	Helwing (2017)
569	Estonia	Mukhu	23.25 , 58.60	2200–1500	Chernykh (1992)
570	Georgia	Berikdeebi	44.78 , 41.72	3700–3500	Anthony (2007)
571	Greece	Aghios Kosmas	21.25 , 40.15	2800–2700	Mylonas (1959)
572	Greece	Argissa	22.29 , 39.74	3100–1050	Milojević et al. (1962)
573	Greece	Axiochori-Vardarophtsa	22.54 , 40.99	2650–2100	Maran (1998)
574	Greece	Chrysokamino	25.86 , 35.13	2200–2050	Muhly (2006)
575	Greece	Dikili Tash	24.29 , 41.01	3100–1050	Deshayes & Treuil (1992)
576	Greece	Dokathismata	25.86 , 36.82	2800–2600	Maran (1998); Rambach (2000)
577	Greece	Kephala	25.16 , 35.30	4300–3500	Coleman (1977)
578	Greece	Krasi (Kreta)	25.47 , 35.23	3100–2400	Muhly (2006)
579	Greece	Kythnos	24.42 , 37.38	3100–2200	Bassiakos & Philaniotou (2007)
580	Greece	Lithares	23.35 , 38.31	3000–2500	Kayafa et al. (2000)
581	Greece	Manika	23.66 , 38.42	2650–2500	Maran (1998); Sampson (1985)
582	Greece	Markiani	25.89 , 36.85	2650–2500	Andreopoulou-Mangou (2006)
583	Greece	Mycenae	22.76 , 37.73	1700–1050	Harding (1975)
584	Greece	Perivolaki-Saratse	23.04 , 40.74	2250–2100	Maran (1998)
585	Greece	Servia	22.00 , 40.18	3100–1050	Renfrew (2011)
586	Greece	Sitagroi	24.03 , 41.12	2800–2600	Whitehouse & Renfrew (1974)
587	Greece	Syros	24.90 , 37.45	2800–2300	Bossert (1967)
588	Greece	Tiryns	22.80 , 37.60	2650–2500	Schliemann & Gladstone (1878)
589	Hungary	Hencida	21.70 , 47.25	4100–3900	Anthony (2007)
590	India	Adichanallur	77.70 , 8.73	905–696	Gullapalli (2009); Rea (1915)
591	India	Agnigundala	79.73 , 16.19	900–500	Gullapalli (2009)

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592	India	Ahar	73.80 , 24.57	2600–2000	Sankalia et al. (1969)
593	India	Akhuldoba	86.69 , 22.68	1500–1000	Yule et al. (1989)
594	India	Amroha	78.43 , 28.90	1500–1000	Yule et al. (1989)
595	India	Bagor	74.37 , 25.36	2800–600	Lukacs et al. (1982); Misra (1973)
596	India	Balathal	73.98 , 24.72	2600–2000	Mishra (2003); Misra (1997)
597	India	Banawali	75.39 , 29.60	2500–2300	Bisht (1993)
598	India	Bandua	84.40 , 23.17	1500–1000	Yule et al. (1989)
599	India	Bangarh	88.53 , 25.41	300–200	Gosvāmī (1948)
600	India	Bareilly	81.23 , 26.23	1500–1000	Yule et al. (1989)
601	India	Barrajpur	80.14 , 27.67	1500–1000	Yule et al. (1989)
602	India	Bhagada	87.01 , 22.00	1500–1000	Yule et al. (1989)
603	India	Bithur	80.27 , 26.62	1500–1000	Yule et al. (1989)
604	India	Burzahom	74.87 , 34.17	2600–1800	Yattoo (2012)
605	India	Chandraketugarh	88.69 , 22.70	300–200	Haque (2001)
606	India	Daimabad	74.68 , 19.52	2500–2300	Yule et al. (1989)
607	India	Dholavira	70.21 , 23.89	2650–2550	Bisht (2015)
608	India	Dihar	87.30 , 23.07	1200–1000	Agrawal & Kharakwal (2003)
609	India	Gajole	88.20 , 25.22	100–AD 200	Pryce et al. (2014)
610	India	Ganeshwar	75.88 , 27.63	1750–1250	Yule et al. (1989)
611	India	Ghangharia	80.12 , 22.26	1500–1000	Yule et al. (1989)
612	India	Hallur	75.62 , 14.33	2000–1200	Yule et al. (1989)
613	India	Hami	84.07 , 23.43	1500–1000	Yule et al. (1989)
614	India	Hans	75.96 , 29.16	1500–1000	Yule et al. (1989)
615	India	Hulas	77.36 , 29.69	2000–1000	Dikshit (1993)
616	India	Inamgaon	74.09 , 18.41	1800–1200	Chakrabarti & Lahiri (1996)
617	India	Jajmo	80.41 , 26.43	1500–1000	Yule et al. (1989)
618	India	Jamboni	86.84 , 20.53	1500–1000	Yule et al. (1989)
619	India	Jhatibani	86.98 , 22.56	1500–1000	Yule et al. (1989)
620	India	Jorwe	74.67 , 19.53	1800–1200	Sankalia & Deo (1955)
621	India	Kalibangan	74.13 , 29.47	3300–2800	Lal (2003)
622	India	Kayatha	76.02 , 23.24	2200–2000	Ansari & Dhavalikar (1975)
623	India	Keonjhar	85.61 , 21.64	1500–1000	Yule et al. (1989)
624	India	Kesli	78.80 , 23.42	1500–1000	Yule et al. (1989)
625	India	Kesna	85.83 , 21.90	1500–1000	Yule et al. (1989)
626	India	Khapa	78.95 , 20.92	900–600	Deo (1970); Munshi & Sarin (1970)
627	India	Kosam	82.03 , 25.36	1500–1000	Yule et al. (1989)
628	India	Kunal	75.66 , 29.62	4000–3000	Chakrabarti & Lahiri (1996)
629	India	Lothal	72.25 , 22.52	2600–2450	Lal (1985); Rao (1979)
630	India	Ludurapada	85.68 , 21.50	1500–1000	Yule et al. (1989)
631	India	Mahurjhari	79.95 , 22.05	900–600	Deo (1973)
632	India	Mallah	77.49 , 27.20	1500–1000	Yule et al. (1989)
633	India	Mitathal	76.17 , 28.89	3200–2800	Shinde et al. (2008)
634	India	Naikund	79.20 , 21.37	600–400	Deo & Jamkhedkar (1982)
635	India	Nandlalpura	76.03 , 26.56	1500–1000	Yule et al. (1989)
636	India	Nankom	85.37 , 23.35	1500–1000	Yule et al. (1989)

ID	Country	Site	Location	Metal (start)	Reference
637	India	Narnaond	76.15 , 29.22	1500–1000	Yule et al. (1989)
638	India	Narsimhapur	79.20 , 22.95	1500–1000	Yule et al. (1989)
639	India	Navdatoli	75.58 , 22.16	1600–1300	Sankalia et al. (1958; 1971)
640	India	Pandu Rajar Dhibi	87.65 , 23.57	1600–750	Das Gupta (1964)
641	India	Parihati	86.85 , 22.52	1500–1000	Yule et al. (1989)
642	India	Perua	87.65 , 22.20	1500–1000	Yule et al. (1989)
643	India	Pochampad	78.12 , 18.79	900–600	Kennedy (2002)
644	India	Pondi	81.38 , 25.00	1500–1000	Yule et al. (1989)
645	India	Rakhigarhi	76.11 , 29.29	2600–1900	Nath (2015)
646	India	Ramapuram	78.08 , 15.08	1500–1000	Yule et al. (1989)
647	India	Ranchi	85.31 , 23.36	1500–1000	Yule et al. (1989)
648	India	Rangpur	71.71 , 22.36	2000–1500	Rao (1963)
649	India	Rewari	76.61 , 28.20	1500–1000	Yule et al. (1989)
650	India	Rojdi	71.07 , 21.68	2500–2000	Lahiri (1995)
651	India	Rupnagar (Rupar)	76.53 , 30.97	2000–1000	Dutta et al. (1987)
652	India	Sabania	74.05 , 28.97	1500–1000	Yule et al. (1989)
653	India	Saipai Lichchwai	79.06 , 26.92	1500–1000	Yule et al. (1989)
654	India	Sandhay	77.28 , 30.20	1500–1000	Yule et al. (1989)
655	India	Sankarjang	84.99 , 20.87	1500–1000	Yule et al. (1989)
656	India	Santal Parganas	86.37 , 23.33	1500–1000	Yule et al. (1989)
657	India	Shahabad	79.94 , 27.63	1500–1000	Yule et al. (1989)
658	India	Shavinipatti	78.86 , 9.34	1500–1000	Yule et al. (1989)
659	India	Sonpur	84.94 , 24.96	1100–900	Yule et al. (1989)
660	India	Surkotada	70.21 , 23.89	2100–1950	Lahiri (1995)
661	India	Takalghat	78.95 , 20.92	900–600	Deo (1970); Munshi & Sarin (1970)
662	India	Taradih	84.98 , 24.78	1500–1000	Yule et al. (1989)
663	India	Tilpi	88.63 , 24.25	200–100	Pryce et al. (2014)
664	India	Viratgarh	85.84 , 22.92	1500–1000	Yule et al. (1989)
665	Iran	Ali Kosh	47.32 , 32.56	7200–7000	Hole & Flannery (1962); Smith (1969)
666	Iran	Arisman	52.00 , 33.66	3700–3400	Chegini et al. (2000); Pernicka (2004)
667	Iran	Bampur	60.46 , 27.19	2800–2300	de Cardi (1968; 1970)
668	Iran	Bani Surmah	46.29 , 33.71	2800–2200	Haerinck & Overlaet (2006)
669	Iran	Cheshmeh Ali	51.45 , 35.61	4600–4000	Basafa & Rezaei (2014)
670	Iran	Darvazeh Tepe	52.87 , 29.63	1600–1300	Jacobs (1980)
671	Iran	Godin Tepe	48.07 , 34.52	3300–3050	Frame (2010)
672	Iran	Kalleh Nisar	46.07 , 33.77	3200–2800	Haerinck & Overlaet (2008)
673	Iran	Khinaman	56.36 , 30.42	2500–1800	Curtis (1988)
674	Iran	Konar Sandal	57.78 , 28.45	2880–2200	Madjidzadeh & Pittman (2008)
675	Iran	Kutal-i Gulgul	46.60 , 33.40	1300–1150	Haerinck et al. (2004)
676	Iran	Marlik	49.46 , 36.83	1500–800	Nigahbān (1996)
677	Iran	Parchinah	46.79 , 32.89	4200–3800	Haerinck & Overlaet (1996)
678	Iran	Persepolis	52.89 , 29.93	515–330	Schmidt (1953–1957)
679	Iran	Sang-i Chakmaq	55.00 , 36.50	6300–5200	Tsuneki (2014a; 2014b)
680	Iran	Shah Tepe	54.35 , 36.94	2000–1600	Arne (1945)
681	Iran	Shahdad	57.71 , 30.43	2500–1800	Ḥakīmī (1997)

ID	Country	Site	Location	Metal (start)	Reference
682	Iran	Shahr-e Sukhteh	61.33 , 30.60	2800–2500	Artioli et al. (2005); Keykhaei et al. (2012)
683	Iran	Susa	48.26 , 32.19	4400–3950	Aruz et al. (1992)
684	Iran	Tal-e Malyan	52.08 , 29.67	2900–2600	Pigott et al. (2003); Sumner (1974)
685	Iran	Tal-i Iblis	55.57 , 29.57	5300–4400	Caldwell (1968); Pigott & Lechtman (2003)
686	Iran	Tepe Ghabristan	49.90 , 35.77	4000–3700	Madjidzadeh (2008)
687	Iran	Tepe Hissar	54.39 , 36.15	4000–3700	Gürsan-Salzmänn (2016); Thornton (2009)
688	Iran	Tepe Sialk	51.40 , 33.97	5600–5200	Nezafati et al. (2008); Pernicka (2004)
689	Iran	Tepe Yahya	56.87 , 28.33	5500–4500	Potts et al. (2001)
690	Iran	Tureng Tepe	54.59 , 36.94	3100–2600	Olson & Thornton (2021); Wulsin (1932)
691	Iran	War Kabud	46.31 , 33.71	800–650	Fleming et al. (2006)
692	Iraq	Aššur	43.26 , 35.46	2500–AD 1400	Andrae (1913); Miglus & Heidemann (1996)
693	Iraq	Girsu (Lagash)	46.18 , 31.56	2950–2350	Biggs (1976)
694	Iraq	Jemdet Nasr	44.78 , 32.72	2950–2700	Matthews (1989; 1990)
695	Iraq	Nineveh	43.15 , 36.36	2900–2600	Layard (1849; 1853)
696	Iraq	Tell al-‘Ubaid	46.03 , 30.97	2950–2350	Carter & Philip (2010); Delougaz (1938)
697	Iraq	Tepe Gawra	43.26 , 36.50	2950–2350	Speiser & Tobler (1935)
698	Iraq	Ur	46.10 , 30.96	2950–2700	Pollock (1997); Salzmänn (2019)
699	Iraq	Uruk	45.64 , 31.32	3350–3200	Heinrich (1936); Rothman (2001)
700	Iraq	Yarim Tepe	42.37 , 36.32	5500–5000	Merpert & Munchaev (1987)
701	Israel	Abu Matar	34.78 , 31.23	4200–4000	Perrot (1955); Shugar (2000)
702	Israel	Beer Safadi	34.78 , 31.23	4500–3600	Eldar & Baumgarten (1985)
703	Israel	Bet Shemesh	34.98 , 31.72	4540–4000	Erez et al. (2016)
704	Israel	Givat Oranim	35.21 , 31.76	4500–3600	Namdar et al. (2004)
705	Israel	Khirbet el-Kerak (Beth Yerah)	35.57 , 32.72	3500–2200	Albright (1949); Maisler et al. (1952)
706	Israel	Nahal Ashan (Beer Sheva)	34.76 , 31.27	4500–3600	Goren (2008)
707	Israel	Nahal Mishmar	35.36 , 31.38	4500–3600	Sebbane (2014); Tadmor et al. (1995)
708	Israel	Nahal Qanah	34.90 , 32.13	4500–3600	Gopher et al. (1996)
709	Israel	Nahal Ze’elim	35.30 , 31.38	4500–3600	Goren (2008)
710	Israel	Peqi’in	35.33 , 32.97	4500–3600	Gal et al. (1997)
711	Israel	Shiqmim	34.72 , 31.29	4400–3700	Golden et al. (2001)
712	Italy	Buccino	15.38 , 40.63	3350–2500	Holloway & Corrain (1973)
713	Italy	Case Bastione	14.17 , 37.58	2700–2200	Giannitrapani & Ianni (2011)
714	Italy	Lipari	14.95 , 38.47	4000–3600	Bernabò Brea & Cavalier (1980)
715	Italy	Madonna del Piano	14.64 , 37.21	1200–800	Giumlia-Mair et al. (2010)
716	Italy	Pianura Chiusa	15.38 , 38.02	2700–2200	Villari (1981)
717	Italy	Villafrati	13.48 , 37.90	2700–2200	Leighton (1999)
718	Japan	Katada 堅田	135.17 , 33.86	100–AD 100	Obōshi (2003)
719	Japan	Yokoguma-Nabekura 横隈鍋倉	130.57 , 33.43	100–AD 100	Kataoka (2019); Ogoorishi (2020)
720	Japan	Yoshinogari 吉野ヶ里	130.39 , 33.32	100–AD 100	Sagaken (2016)
721	Jordan	Faynan	35.45 , 30.61	3000–2500	Hauptmann (2007); Hauptmann et al. (1992)
722	Jordan	Hujayrat al-Ghuzlan	35.03 , 29.57	3000–2500	Khalil & Schmidt (2009)

ID	Country	Site	Location	Metal (start)	Reference
723	Jordan	Teleilat el Ghassul	35.60 , 31.80	4400–3500	Gilead (2011)
724	Kazakhstan	Ak-Mustafa	71.32 , 48.40	1500–1000	Frachetti (2008)
725	Kazakhstan	Alekseevka	69.52 , 53.51	1800–1500	Chernykh (1992)
726	Kazakhstan	Atasu	71.63 , 48.68	1500–1000	Chernykh (1992)
727	Kazakhstan	Atken-Sai	63.82 , 49.21	1500–1000	Frachetti (2008)
728	Kazakhstan	Begash	78.50 , 44.90	1625–1000	Frachetti (2008)
729	Kazakhstan	Berel	86.44 , 49.37	400–200	Samashev (2007)
730	Kazakhstan	Berlik	66.71 , 54.52	2000–1800	Frachetti (2008)
731	Kazakhstan	Bestamak	57.35 , 50.05	2000–1800	Chechushkov & Epimakhov (2018)
732	Kazakhstan	Buguly	72.05 , 49.45	1500–1000	Frachetti (2008)
733	Kazakhstan	Dongal	76.03 , 49.35	1000–750	Frachetti (2008)
734	Kazakhstan	Dzhartas	81.03 , 50.25	2000–1500	Kuzmina (2007a)
735	Kazakhstan	Ekibastuz	75.42 , 51.71	2300–1700	Merts (2017)
736	Kazakhstan	Issyk	77.62 , 43.33	400–200	Kuzmina (2007a)
737	Kazakhstan	Karagash	73.13 , 49.76	3700–3300	Anthony (2007)
738	Kazakhstan	Kopa	75.68 , 49.43	1500–1000	Frachetti (2008)
739	Kazakhstan	Krasnyi Yar	70.37 , 53.50	3700–3100	Frachetti (2008)
740	Kazakhstan	Kuigan	79.14 , 44.76	1400–1200	Goryachev (2004)
741	Kazakhstan	Kul'saj	78.41 , 43.07	1500–1000	Goryachev (2004)
742	Kazakhstan	Kyzyl-Bulak	78.79 , 43.52	1700–1400	Bendezu-Sarmiento (2004)
743	Kazakhstan	Mirzhik	71.51 , 53.60	1500–1000	Frachetti (2008)
744	Kazakhstan	Mukri	78.11 , 45.00	1800–1500	Frachetti (2008)
745	Kazakhstan	Oy-Dzhaylyau	78.41 , 43.59	1500–1300	Goryachev (2004)
746	Kazakhstan	Petrovka	68.25 , 54.28	2000–1800	Chernykh (1992); Molodin & Polos'mak (2014)
747	Kazakhstan	Sergeyevka	67.42 , 53.88	2800–2600	Anthony (2007)
748	Kazakhstan	Sokolovka	69.20 , 55.12	1800–1500	Zdanovich (1988)
749	Kazakhstan	Tagisken	63.66 , 44.27	1500–1200	Bonora (2018)
750	Kazakhstan	Talpty	79.01 , 44.72	1100–900	Goryachev (2004)
751	Kazakhstan	Tamgaly	75.54 , 43.80	1500–1300	Goryachev (2004)
752	Kazakhstan	Tasty-Butak	59.85 , 49.63	2000–1800	Frachetti (2008)
753	Kazakhstan	Tyumen 3	79.75 , 50.71	2300–1700	Merts (2017)
754	Kazakhstan	Übagan	64.75 , 54.40	3700–3300	Anthony (2007)
755	Kazakhstan	Uzunbulak	78.90 , 43.39	1500–1000	Goryachev (2004)
756	Kazakhstan	Varfolomievka	49.76 , 49.09	4800–4600	Anthony (2007)
757	Kazakhstan	Vasilkovka	68.91 , 53.53	1500–1000	Frachetti (2008)
758	Kazakhstan	Yavlenka	69.03 , 55.07	1800–1500	Frachetti (2008)
759	Kyrgyzstan	Sangru	70.12 , 48.01	2000–1500	Kuzmina (2007a)
760	Kyrgyzstan	Tash-Tyube	72.07 , 42.62	2000–1500	Kuzmina (2007a)
761	Kyrgyzstan	Tegermen-say	74.50 , 42.90	2000–1500	Kuzmina (2007a)
762	Laos	Xepon	106.21 , 16.70	200–AD 200	Pryce et al. (2014)
763	Lebanon	Byblos	35.65 , 34.12	2000–1800	Dunand & Cauvin (1937); Morr & Pernot (2011)
764	Moldova	Borodino Hoard	28.98 , 46.33	2200–2000	Gimbutas (1957); Shishlina & Loboda (2019)
765	Moldova	Branzeni VIII	28.48 , 47.65	4800–3000	Kohl (2007)

ID	Country	Site	Location	Metal (start)	Reference
766	Moldova	Brynzeny	27.47 , 47.99	3300–2900	Anthony (2007)
767	Moldova	Cărbuna	28.95 , 46.71	4800–4000	Greeves (1975)
768	Moldova	Giurgiulești	28.20 , 45.48	4300–4000	Anthony (2007)
769	Moldova	Kainari	28.81 , 46.82	4300–4000	Anthony (2007)
770	Moldova	Novye Ruseshty	29.30 , 46.77	4000–3500	Greeves (1975)
771	Mongolia	BGC (Baga Gazaryn Chuluu)	106.03 , 46.20	1300–900	Park et al. (2011)
772	Mongolia	Iagshiin Khödöö 1	91.57 , 46.12	2500–1800	Kovalev & Erdenebaatar (2009)
773	Mongolia	Iagshiin Khödöö 3	91.57 , 46.12	2500–1800	Kovalev & Erdenebaatar (2009)
774	Mongolia	Kheviin Am 1	91.09 , 46.93	1400–900	Kovalev & Erdenebaatar (2009)
775	Mongolia	Khotuu Davaa 1	91.84 , 47.05	1700–1450	Kovalev & Erdenebaatar (2009)
776	Mongolia	Khuurai-gov' 1 (Kurgak govi)	89.43 , 49.04	3000–2500	Kovalev & Erdenebaatar (2009); Honeychurch et al. (2021)
777	Mongolia	Kumdi govi	89.43 , 49.04	2500–1500	Kovalev & Erdenebaatar (2009)
778	Mongolia	Tevsh	101.27 , 44.85	1400–1000	Miyamoto & Obata (2016)
779	Mongolia	Tsagaan Asga	89.01 , 48.50	1626–1530	Taylor et al. (2020)
780	Mongolia	Ulaan Goviin Üzüür 1	91.84 , 47.05	1800–1300	Kovalev & Erdenebaatar (2009)
781	Mongolia	Ulaan Khudag 2	91.51 , 47.94	2500–1800	Kovalev & Erdenebaatar (2009)
782	Mongolia	Uliastain Gol III	91.09 , 46.93	1400–1000	Kovalev & Erdenebaatar (2009)
783	Montenegro	Velika Gruda	18.74 , 42.38	3000–2800	Primas & Della Casa (1996)
784	Myanmar	Htan Ta Pin	96.05 , 20.59	500–AD 200	Pryce et al. (2018)
785	Myanmar	Kokkokhahla	96.04 , 21.10	500–AD 200	Pryce et al. (2018)
786	Myanmar	Mon Htoo	95.65 , 21.10	500–AD 200	Pryce et al. (2018)
787	Myanmar	Myin Oo Hle	95.14 , 22.38	1100–500	Pryce et al. (2018)
788	Myanmar	Myinthe	96.25 , 21.34	500–AD 200	Pryce et al. (2018)
789	Myanmar	Myo Hla	96.05 , 20.35	1000–1	Pryce et al. (2014)
790	Myanmar	Nyaung-gan	95.07 , 22.40	1100–500	Moore & Pauk (2001)
791	Myanmar	Oakaie	95.13 , 22.38	1000–600	Pryce et al. (2015)
792	Myanmar	Supan	96.04 , 21.10	500–AD 200	Pryce et al. (2018)
793	Myanmar	Ywa Gon Gyi	96.03 , 20.94	1000–1	Pryce et al. (2014)
794	North Korea	Geumtan-ri 金灘里	125.88 , 39.02	1500–1000	Chaoxian (1983)
795	North Korea	Gonggwili 公貴里	126.59 , 40.97	1500–1000	Chaoxian (1983)
796	North Korea	Sinheung-dong 新興洞	126.41 , 38.33	1500–1000	Chaoxian (1983)
797	Oman	Ras Al-Hadd HD-6	59.77 , 22.52	3200–2600	Giardino (2019)
798	Oman	Maysar	58.13 , 22.80	3000–2500	Giardino (2019)
799	Oman	Ras al-Jinz	59.84 , 22.42	3200–2600	Giardino (2019)
800	Pakistan	Amri	67.92 , 25.91	3600–3000	Chakrabarti & Lahiri (1996)
801	Pakistan	Balakot	66.82 , 25.69	3500–2500	Chakrabarti & Lahiri (1996); Dales (1974)
802	Pakistan	Barikot	72.21 , 34.68	1400–800	Chakrabarti & Lahiri (1996)
803	Pakistan	Chanhu-daro	68.32 , 26.17	2600–2450	Mackay (1943)
804	Pakistan	Damb Sadaat	67.53 , 29.60	4500–3500	Chakrabarti & Lahiri (1996)
805	Pakistan	Ghalegay	72.25 , 34.70	1400–800	Chakrabarti & Lahiri (1996)
806	Pakistan	Ghazi Shah	67.64 , 26.77	3600–3000	Chakrabarti & Lahiri (1996)
807	Pakistan	Gumla	70.12 , 32.65	3200–2600	Chakrabarti & Lahiri (1996)
808	Pakistan	Harappa	72.86 , 30.63	2600–2450	Miller (1994); Miller (2005)

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809	Pakistan	Jalilpur	71.31 , 29.91	3200–2600	Chakrabarti & Lahiri (1996); Mughal (1972)
810	Pakistan	Kili Gul Muhammad	65.44 , 28.68	4400–4100	Chakrabarti & Lahiri (1996)
811	Pakistan	Kot Diji	68.71 , 27.35	3200–2600	Chakrabarti & Lahiri (1996)
812	Pakistan	Lewan	70.71 , 32.86	3000–2600	Chakrabarti & Lahiri (1996)
813	Pakistan	Loe Banr	72.39 , 34.75	1400–800	Chakrabarti & Lahiri (1996)
814	Pakistan	Mehi	65.99 , 27.06	2500–2000	Asthana (1993)
815	Pakistan	Mehrgarh	67.62 , 29.38	5500–4800	Chakrabarti & Lahiri (1996)
816	Pakistan	Mohenjo-daro	68.14 , 27.33	2600–2450	Marshall (1931); Miller (1994)
817	Pakistan	Rehman Dheri	70.79 , 31.97	3300–3100	Durrani (1986)
818	Pakistan	Shahi Tumb	63.29 , 25.96	2500–2000	Asthana (1993)
819	Pakistan	Siah Damb	65.29 , 27.22	2500–2000	Asthana (1993)
820	Pakistan	Sohr Damb	66.31 , 27.69	2700–2400	Chakrabarti & Lahiri (1996)
821	Pakistan	Tarakai Qila	70.48 , 32.95	3200–2600	Chakrabarti & Lahiri (1996)
822	Pakistan	Taxila	72.79 , 33.75	1000–AD 500	Marshall (1951)
823	Philippines	Savidug	121.87 , 20.33	200–AD 200	Pryce et al. (2014)
824	Poland	Ośłonki	18.80 , 52.62	4600–4100	Budd et al. (2020)
825	Romania	Brad	26.95 , 46.72	3500–3000	Greeves (1975)
826	Romania	Casimcea	28.38 , 44.72	4300–4000	Anthony (2007)
827	Romania	Cucuteni	26.93 , 47.27	4000–3500	Greeves (1975)
828	Romania	Dealul Fântânilor	27.03 , 46.63	4800–3000	Greeves (1975)
829	Romania	Decea Mureşului	23.76 , 46.38	4100–3900	Anthony (2007)
830	Romania	Drăguşeni-Ostrov	27.76 , 45.98	4000–3500	Greeves (1975)
831	Romania	Hăbăşeşti	26.96 , 47.15	4000–3500	Greeves (1975)
832	Romania	Horodnitsa II	26.18 , 48.58	3500–3000	Greeves (1975)
833	Romania	Izvoare	26.47 , 46.91	4800–3500	Greeves (1975)
834	Romania	Truşeşti	27.02 , 47.77	4000–3500	Greeves (1975)
835	Russia	Abakan	91.43 , 53.72	1400–1050	Chernykh (1992)
836	Russia	Abashevo	47.35 , 55.98	2500–1900	Anthony (2007)
837	Russia	Abylah	98.00 , 74.00	1200–1100	Feng, E. (2002)
838	Russia	Afanasieva Gora	90.83 , 54.23	2900–2500	Poliakov et al. (2019); Svyatko et al. (2009)
839	Russia	Alakul	46.38 , 51.94	2000–1500	Salnikov (1952); Tigeyeva (2013)
840	Russia	Apshuyakhta	85.90 , 51.23	3500–2500	Khavrin (2010)
841	Russia	Arkaim	59.57 , 52.65	2100–1800	Anthony (2007)
842	Russia	Arzhan	93.60 , 52.06	810–745	Chugunov et al. (2006); Chugunov et al. (2010)
843	Russia	Askыз	90.38 , 53.61	1400–1050	Chernykh (1992)
844	Russia	Baitu	59.29 , 50.96	1500–1000	Frachetti (2008)
845	Russia	Balanbash	55.80 , 53.48	2500–1900	Priakhin & Besedin (1999)
846	Russia	Beiskaya Shakhta	90.38 , 53.61	1400–1050	Chernykh (1992)
847	Russia	Bertek 33	87.50 , 49.33	3500–2500	Molodin (1992)
848	Russia	Boldyrevo	52.84 , 51.81	3400–2800	Koryakova & Epimakhov (2007)
849	Russia	Charkov Ulus	90.38 , 53.61	1400–1050	Chernykh (1992)
850	Russia	Chernorechye	60.18 , 54.01	2100–1800	Chechushkov (2018)
851	Russia	Chernovaya	90.33 , 53.71	2500–2000	Chernykh (1992)

ID	Country	Site	Location	Metal (start)	Reference
852	Russia	Diring-Yuryakh	125.10 , 60.70	2464–2146	Dyakonov et al. (2019)
853	Russia	Elekmonar-I	86.01 , 51.46	3500–2500	Khavrin (2010)
854	Russia	Elenovka	59.52 , 51.14	1800–1500	Frachetti (2008)
855	Russia	Elo	85.56 , 50.77	3500–2500	Khavrin (2010); Stepanova (2012)
856	Russia	Elunino	82.86 , 53.38	2050–1750	Degtyareva et al. (2010)
857	Russia	Eustaphy-Oleg 1	134.98 , 43.47	1332–920	Kuzmin et al. (1994)
858	Russia	Evdik	45.20 , 47.34	3700–3000	Anthony (2007)
859	Russia	Fedorova Ulus	90.38 , 53.61	1400–1050	Chernykh (1992)
860	Russia	Filippovka	53.50 , 51.48	450–300	Yablonsky (2010)
861	Russia	Gorny	54.12 , 51.73	1740–1000	Frachetti (2008)
862	Russia	Inskoy Dol	83.03 , 51.07	3000–2700	Dashkovsky (2018)
863	Russia	Iska	64.10 , 55.77	2200–1800	Anthony (2007)
864	Russia	Izobilnoye	54.37 , 51.06	3400–2800	Koryakova & Epimakhov (2007)
865	Russia	Kalyvanskoe-I	82.20 , 51.17	2500–1700	Zhang, L. et al. (2017)
866	Russia	Kamennyi Ambar	60.30 , 52.81	2100–1800	Chechushkov (2018)
867	Russia	Kaninskaya Cave	57.56 , 62.17	2200–1500	Chernykh (1992)
868	Russia	Kara Koby (Karakol)	85.56 , 50.80	3500–3000	Anthony (2007); Khavrin (2010); Stepanova (2012; 2015)
869	Russia	Karasuk	90.79 , 54.87	2900–2500	Chernykh (1992); Kiselev (1937)
870	Russia	Kargaly	54.58 , 51.57	2900–2700	Anthony (2007)
871	Russia	Khokholskoe	38.83 , 51.02	2500–1900	Chernykh (1992)
872	Russia	Khvalynsk	48.10 , 52.48	5200–4600	Anthony (2007)
873	Russia	Khuzhir-Nuge XIV	106.81 , 53.08	2200–1600	Weber et al. (2005); (2008)
874	Russia	Krasnosamarskoe	51.66 , 53.29	2000–1500	Frachetti (2008)
875	Russia	Krivoe Ozero	60.19 , 54.05	2100–1800	Anthony (2007); Chechushkov (2018)
876	Russia	Kukhmar	39.28 , 56.69	2500–1900	Chernykh (1992)
877	Russia	Kulevchi	61.96 , 54.20	1800–1500	Frachetti (2008)
878	Russia	Kupukhta	59.21 , 50.85	2000–1500	Kuzmina (2007a)
879	Russia	Kur-Kechu	86.51 , 50.61	3500–2500	Khavrin (2010)
880	Russia	Kurma XI	106.96 , 53.18	2200–1600	Metcalf (2006)
881	Russia	Kutuluk	51.20 , 53.20	2900–2700	Anthony (2007)
882	Russia	Lebedi I	38.69 , 45.94	3000–2500	Anthony (2007)
883	Russia	Lebedi II	79.31 , 52.87	3500–2500	Anthony (2007)
884	Russia	Lidovka 1	135.88 , 44.42	806–658	Kuzmin et al. (1994)
885	Russia	Maikop	40.08 , 44.60	3700–3000	Betancourt (1970); Courcier (2014)
886	Russia	Mal'ye Koreny	91.03 , 54.48	1400–1050	Chernykh (1992)
887	Russia	Mal'j Mys	84.99 , 56.50	2000–1500	Gimbutas (1965); Komarova (1952)
888	Russia	Maslovskoe	39.76 , 51.46	2000–1200	Chernykh (1992)
889	Russia	Meshoko	40.05 , 44.57	4500–3900	Courcier (2014)
890	Russia	Mikhailovka Ovsianka	49.63 , 52.39	1500–1130	Anthony (2007)
891	Russia	Nalchik	43.62 , 43.48	5000–4500	Anthony (2007)
892	Russia	Nizhne Churakaevo	55.61 , 53.76	2500–1900	Chernykh (1992)
893	Russia	Novonikolskoe-I	46.35 , 50.82	2000–1800	Chernykh (1992)
894	Russia	Novoselischche 4	131.78 , 44.62	1335–1122	Kuzmin et al. (1994)
895	Russia	Novosvobodnaya	40.41 , 44.35	3400–3000	Anthony (2007)

ID	Country	Site	Location	Metal (start)	Reference
896	Russia	Orak-Sukhoe	90.38 , 54.97	1400–1050	Chernykh (1992)
897	Russia	Pazyryk	88.15 , 49.58	400–200	Rudenko (1970); Törbat et al. (2009)
898	Russia	Pepkino	46.55 , 56.21	2400–2200	Anthony (2007)
899	Russia	Pershin	55.62 , 52.34	2900–2700	Anthony (2007); Zhang, L. (2007)
900	Russia	Pokrovka-4	81.87 , 52.77	3500–2500	Khavrin (2010)
901	Russia	Preobrazhenka	77.02 , 55.50	2400–2000	Marchenko et al. (2017)
902	Russia	Reshnoe	41.07 , 55.70	2200–1500	Chernykh (1992)
903	Russia	Rostovka	73.59 , 55.02	2400–2000	Marchenko et al. (2017)
904	Russia	Rublevo	80.35 , 51.74	2000–1600	Grushin et al. (2009); Kiryushin et al. (2006)
905	Russia	Serovo	103.16 , 54.52	2200–1600	Weber et al. (2005)
906	Russia	Shandasha	59.91 , 51.07	1800–1500	Frachetti (2008)
907	Russia	Shigony	49.28 , 53.37	2500–1900	Chernykh (1992)
908	Russia	Shilovskoe	39.76 , 51.46	2000–1200	Chernykh (1992)
909	Russia	Shumilikha	103.68 , 52.84	1800–1000	Feng, E. (2002); Weber et al. (2010)
910	Russia	Sinie Skaly	135.23 , 43.73	1260–830	Kuzmin et al. (1994)
911	Russia	Sinii Gai A	132.60 , 44.47	1125–915	Kuzmin et al. (1994)
912	Russia	Sintashta	60.19 , 52.49	2800–2700	Gening et al. (1992); Jones-Bley (2000)
913	Russia	Sopka	76.74 , 55.62	2400–2000	Marchenko et al. (2017); Molodin (2012)
914	Russia	Staraya Toida	40.62 , 51.71	2500–1900	Chernykh (1992)
915	Russia	Stepnoye	60.44 , 54.08	2100–1800	Chechushkov (2018)
916	Russia	Surush	51.15 , 53.37	2500–1900	Chernykh (1992)
917	Russia	Suvorovo 6	135.33 , 44.23	1370–378	Kuzmin et al. (1994)
918	Russia	Svobodnoe	39.38 , 44.99	4500–3900	Courcier (2014)
919	Russia	Tagar	91.63 , 53.68	1400–1050	Bokovenko (1995)
920	Russia	Tamar-Utkul VIII	54.46 , 51.06	3400–2800	Koryakova & Epimakhov (2007)
921	Russia	Tapsher	51.94 , 57.02	2500–1900	Chernykh (1992)
922	Russia	Tartas I	76.74 , 55.64	1880–1120	Marchenko et al. (2017)
923	Russia	Tashkovo II	64.44 , 55.95	2200–1800	Anthony (2007)
924	Russia	Terekta	85.87 , 50.29	3500–2500	Khavrin (2010)
925	Russia	Tes	92.19 , 53.87	1400–1050	Kiselev (1937)
926	Russia	Tolgoyek	86.05 , 51.33	3500–2500	Khavrin (2010)
927	Russia	Toora-Dash	92.23 , 51.75	2500–2000	Vasil'ev & Semenov (1993)
928	Russia	Turbino	56.32 , 58.00	2200–2000	Chernykh (1992)
929	Russia	Uibat	90.37 , 53.73	2200–1900	Görsdorf et al. (2001)
930	Russia	Ulakhan-Keteme	126.36 , 61.22	1450–50	Dyakonov et al. (2019)
931	Russia	Urnyak	53.99 , 53.55	2500–1900	Chernykh (1992)
932	Russia	Ushkatty	59.74 , 50.90	1500–1000	Frachetti (2008)
933	Russia	Ust'e	61.22 , 53.09	2100–1800	Anthony (2007)
934	Russia	Ust'-Mil'	133.10 , 59.63	1450–50	Dyakonov et al. (2019)
935	Russia	Ustyanka	84.95 , 52.18	2200–1500	Chernykh (1992)
936	Russia	Utyevka	50.99 , 52.91	3000–2700	Anthony (2007)
937	Russia	Uznezya-1	85.94 , 51.53	3500–2500	Khavrin (2010)
938	Russia	Velikent	48.07 , 42.19	3500–2800	Kohl & Magomedov (2014)
939	Russia	Verkhnyaya Alabuga	64.93 , 54.57	3700–3300	Anthony (2007)

ID	Country	Site	Location	Metal (start)	Reference
940	Russia	Verkhne-Kizilski	59.22 , 53.88	2500–1900	Epimakhov (2003)
941	Russia	Verkholensk	105.55 , 54.14	2200–1600	Weber (1995)
942	Russia	Yazevo	64.85 , 55.36	1800–1500	Frachetti (2008)
943	Russia	Ymyyaktakh	129.88 , 62.46	2200–1300	Feng, E. (2002)
944	Russia	Yukalekulevo	56.37 , 55.52	2500–1900	Chernykh (1992)
945	Saudi Arabia	Qurayyah	35.66 , 28.64	1300–1100	Liu, S. et al. (2015)
946	Saudi Arabia	Tayma	38.52 , 27.61	1300–1100	Liu, S. et al. (2015)
947	Serbia	Belovode	21.84 , 43.02	5400–5200	Šljivar & Kuzmanovic-Cvetkovic (2006)
948	Serbia	Divostin	20.85 , 44.02	4900–4600	Antonović Dragana (2002)
949	Serbia	Gomolava	19.75 , 44.89	4900–4600	Antonović Dragana (2002)
950	Serbia	Grivac	20.71 , 44.00	5400–4550	Antonović Dragana (2002)
951	Serbia	Petnica	19.93 , 44.25	5053–4855	Borić (2009)
952	Serbia	Pločnik	21.36 , 43.20	5200–4650	Antonović Dragana (2002)
953	Serbia	Ratina	20.75 , 43.70	5400–4550	Antonović Dragana (2002)
954	Serbia	Selevac	20.87 , 44.50	5400–4550	Antonović Dragana (2002)
955	Serbia	Stapari	19.74 , 43.86	5400–4550	Antonović Dragana (2002)
956	South Korea	Daegok-ri 대곡리 大谷里	127.15 , 35.07	200–100	Choi et al. (1989)
957	South Korea	Daepyeong-ni 대평리 大坪里	128.02 , 35.39	500–200	Ggblib (1994)
958	South Korea	Songguk-ri 송국리 松菊里	127.03 , 36.27	650–450	Kungnip (1978)
959	Sri Lanka	Mantai	79.96 , 8.96	1800–1600	Shinde (1987)
960	Sudan	Buhen	31.28 , 21.92	2700–2200	Killick (2014)
961	Sudan	Kerma	30.41 , 19.60	2200–2000	Bonnet (1986); Killick (2014)
962	Syria	Ras Ibn Hani	35.75 , 35.59	1600–1300	Lagarce (1986)
963	Syria	Tell Beydar	40.59 , 36.74	2550–2350	De Ryck et al. (2005)
964	Syria	Tell Brak	41.06 , 36.67	2350–2200	De Ryck et al. (2005)
965	Syria	Tell Leilan	41.51 , 36.96	2000–1000	De Ryck et al. (2005)
966	Syria	Tell Qara Quzaq	38.02 , 36.17	2900–2750	Valdés Pereiro (2007)
967	Syria	Urkesh	41.00 , 37.06	2550–2000	De Ryck et al. (2005)
968	Tajikistan	Kangurt-Tut	69.92 , 38.40	1200–1000	Vinogradova & Kuzmina (1996)
969	Tajikistan	Mushiston	69.24 , 39.78	2400–1900	Garner (2015)
970	Tajikistan	Sarazm	67.57 , 39.52	3500–3000	Isakov (1981); Isakov et al. (1987)
971	Tajikistan	Tandyriul	68.98 , 38.35	1350–1000	Vinogradova & Kuzmina (1996)
972	Tajikistan	Zardcha-Khalifa	67.65 , 39.51	2000–1800	Anthony (2007)
973	Thailand	Ban Chiang	103.24 , 17.41	1600–1450	Higham et al. (2011)
974	Thailand	Ban Dong Phlong	103.27 , 14.78	300–1	Nitta (1997)
975	Thailand	Ban Lum Khao	102.35 , 15.25	1050–400	Higham & Thosarat (2004)
976	Thailand	Ban Mai Chaimongkol	100.33 , 15.27	1600–1200	Onsuwan (2000)
977	Thailand	Ban Na Di	102.34 , 16.80	1400–400	Higham & Amphan (1984)
978	Thailand	Ban Non Wat	102.27 , 15.27	1050–1000	Higham (2014); Higham & Higham (2009)
979	Thailand	Khao Sam Kao	99.18 , 10.53	400–1	Bellina (2017); Murillo-Barroso et al. (2010)
980	Thailand	Khok Din	100.74 , 14.79	1200–800	Higham et al. (2020)
981	Thailand	Nil Kham Haeng	100.66 , 14.96	1200–800	Higham et al. (2020)
982	Thailand	Noen Din	100.75 , 14.80	1200–800	Higham et al. (2020)

ID	Country	Site	Location	Metal (start)	Reference
983	Thailand	Non Mak La	100.68 , 14.96	1200–800	Higham et al. (2020)
984	Thailand	Non Nok Tha	102.30 , 16.80	1500–1300	Bayard (1981); Selimkhanov (1979)
985	Thailand	Non Pa Wai	100.69 , 14.98	1200–800	Higham et al. (2020)
986	Thailand	Phu Lon	101.73 , 17.49	1000–1	Pigott & Weisgerber (1998); Vernon (1996)
987	Turkey	Arslantepe	38.36 , 38.38	3800–3350	(Palmieri & Di Nocera 1999)
988	Turkey	Aşıklı Höyük	34.23 , 38.35	9000–6000	Esin (1995; 1999)
989	Turkey	Çamlıbel Tarlası	34.86 , 39.77	3590–3470	Schoop (2008; 2009; 2010)
990	Turkey	Çatalhöyük	32.83 , 37.67	9000–6000	Birch et al. (2013); Mellaart (1967)
991	Turkey	Çayönü	39.73 , 38.22	7250–6750	Maddin et al. (1999)
992	Turkey	Değirmentepe	38.59 , 38.35	6000–4000	Esin & Harmankaya (1988); Özbal (1985)
993	Turkey	Demircihöyük	30.52 , 39.78	3000–2700	Massa et al. (2017); Seeher (2000)
994	Turkey	Domuztepe	37.04 , 37.32	9000–6000	Carter et al. (2003)
995	Turkey	Gaziantep	37.38 , 37.07	3000–2000	Duru (2006);
996	Turkey	Hacılar	30.10 , 37.60	6000–4000	Mellaart (1961; 1958)
997	Turkey	Hacınebi	37.97 , 37.06	4100–3800	Özbal et al. (1999); Stein et al. (1997)
998	Turkey	İkiztepe	34.92 , 41.90	4000–3000	Bilgi (1984); Weeks (2003)
999	Turkey	Ilıpınar	34.61 , 40.02	4000–3000	Begemann et al. (1994); Roodenberg (2011)
1000	Turkey	Kumtepe	26.20 , 39.95	3500–3000	Schoop (2011)
1001	Turkey	Mersin (Yumuktepe)	34.63 , 36.80	6000–4000	Caneva (2000); Garstang (1953); Yalçın (2000)
1002	Turkey	Sos Höyük	41.52 , 39.99	3500–3000	Sagona (2000; 2010); Sagona et al. (1998)
1003	Turkey	Tell Judaidah	36.59 , 36.27	3000–2000	Braidwood et al. (1960)
1004	Turkey	Tepecik	38.76 , 38.81	4000–3000	Çukur & Kuş (1989)
1005	Turkey	Troy	26.24 , 39.96	3000–2550	Jablonka (2011); Schliemann & Virchow (1880)
1006	Turkey	Ulu Burun (shipwreck)	29.69 , 36.13	1305–1300	Bass (1986); Bass et al. (1989); Pulak (1988)
1007	Turkmenistan	Adzhi Kui	61.78 , 38.19	2100–1800	Salvatori (2002)
1008	Turkmenistan	Altyndepe	60.43 , 36.86	4000–3500	Masson (1988); Salvatori et al. (2002)
1009	Turkmenistan	Anau	58.53 , 37.88	3600–3300	Hiebert et al. (2003); Chernykh (1962)
1010	Turkmenistan	Gonur	62.04 , 38.21	2400–1600	Kraus (2016); Sarianidi (2007)
1011	Turkmenistan	Ilgynly-depe	60.49 , 36.82	3800–3640	Solovyova et al. (1994); Salvatori et al. (2009)
1012	Turkmenistan	Kalaly-gyr	59.54 , 41.80	500–300	Vaynberg (2004)
1013	Turkmenistan	Monjuklidepe	60.42 , 36.85	5000–4500	Pollock & Bernbeck (2011)
1014	Turkmenistan	Namazga-depe	59.56 , 37.37	4000–3500	Khlova (1981)
1015	Turkmenistan	Togolok 21	62.00 , 38.12	2100–1800	Sarianidi (1986)
1016	Turkmenistan	Ulug-depe	60.03 , 37.15	3000–2600	Lhuillier (2016)
1017	UAE	Al Sufouh	55.07 , 24.96	2600–2000	Weeks (2014)
1018	UAE	Jebel Hafeet	55.78 , 24.06	3200–2600	Magee (2014)
1019	UAE	Shimal	56.10 , 26.01	2600–2000	Weeks (2014)
1020	UAE	Tell Abraq	55.55 , 25.48	2300–2100	Weeks (2014)
1021	UAE	Umm an-Nar	54.52 , 24.44	2600–2000	Weeks (2014)
1022	Ukraine	Berezovskaya	29.90 , 48.17	4000–3500	Greeves (1975)

ID	Country	Site	Location	Metal (start)	Reference
1023	Ukraine	Bilsk	34.63 , 50.09	500–300	Suprunenko (1996)
1024	Ukraine	Bodaki	25.80 , 49.89	3500–3000	Greeves (1975)
1025	Ukraine	Chapli	35.37 , 48.35	4300–4000	Anthony (2007)
1026	Ukraine	Chersonesus	33.49 , 44.61	600–AD 1400	Carter & Mack (2003)
1027	Ukraine	Dereivka	33.78 , 48.91	4400–3500	Telegin & Mallory (1986)
1028	Ukraine	Kondrashovka	37.58 , 49.77	2500–1900	Chernykh (1992)
1029	Ukraine	Konstantinovka	37.72 , 48.53	3700–3000	Anthony (2007)
1030	Ukraine	Krivoy Rog	33.21 , 47.72	4300–4000	Anthony (2007)
1031	Ukraine	Luka-Vrublevetskaya	26.58 , 48.68	4800–4600	Anthony (2007)
1032	Ukraine	Mayaki	30.27 , 46.41	3300–2900	Anthony (2007)
1033	Ukraine	Mikhailovka	33.65 , 47.41	3300–3000	Anthony (2007)
1034	Ukraine	Nezvisko	25.25 , 48.77	3500–3000	Greeves (1975)
1035	Ukraine	Nikol'skoe	35.07 , 48.16	5200–4200	Anthony (2007)
1036	Ukraine	Novodanilovka	36.59 , 47.50	4300–4000	Anthony (2007)
1037	Ukraine	Orel-Samara	34.81 , 48.88	3800–3300	Anthony (2007)
1038	Ukraine	Panticapaeum (Kerch)	36.47 , 45.35	600–AD 370	Minns (2010)
1039	Ukraine	Petro-Svistunovo	34.96 , 47.32	4300–4000	Anthony (2007)
1040	Ukraine	Shcherbanevka	30.17 , 50.36	3500–3000	Greeves (1975)
1041	Ukraine	Tripolye	30.77 , 50.12	3500–3000	Greeves (1975)
1042	Ukraine	Usatovo	30.72 , 46.48	3300–2900	Chernykh (1992)
1043	Ukraine	Verem'e	30.65 , 50.10	3500–3000	Greeves (1975)
1044	Ukraine	Zaleshchiki	25.74 , 48.65	3500–3000	Greeves (1975)
1045	Uzbekistan	Chust	71.24 , 41.00	1200–800	Kuzmina (2007a)
1046	Uzbekistan	Dzarkutan	66.97 , 37.73	2000–1700	Kaniuth (2007)
1047	Uzbekistan	Dzham	66.41 , 39.44	2000–1600	Kuzmina (2007a)
1048	Uzbekistan	Sapallitepe	66.66 , 37.47	2000–1700	Kaniuth (2007)
1049	Uzbekistan	Tugai	67.23 , 39.61	2000–1800	Anthony (2007)
1050	Uzbekistan	Vuadil	71.72 , 40.18	1800–1500	Kuzmina (2007a)
1051	Vietnam	Cẩm Thủy	105.55 , 20.27	100–AD 100	Pryce et al. (2014)
1052	Vietnam	Đào Thịnh	104.79 , 21.80	100–AD 100	Pryce et al. (2014)
1053	Vietnam	Doc Chua	106.86 , 11.07	1000–500	Hai, N. (2005)
1054	Vietnam	Dọc Hồng	105.08 , 20.99	200–AD 9	Hai, N. (2005)
1055	Vietnam	Đồng Đậu	105.59 , 21.23	1600–1000	Pryce et al. (2014)
1056	Vietnam	Đồng Nai	107.16 , 11.02	1000–500	Pryce et al. (2014)
1057	Vietnam	Động Xá	106.08 , 20.73	200–AD 100	Pryce et al. (2014)
1058	Vietnam	Giới Phiên	104.89 , 21.70	100–AD 100	Pryce et al. (2014)
1059	Vietnam	Làng Vạc	105.44 , 19.28	200–1	Pryce et al. (2014)
1060	Vietnam	Nghĩa Lập	105.50 , 21.30	1400–1000	Sichuansheng et al. (2016)
1061	Vietnam	Thanh Den	105.77 , 21.12	1600–1000	Hai, N. (2005)
1062	Yemen	al-Midamman	43.24 , 13.96	1400–900	Weeks et al. (2009)
1063	Yemen	Sabir	45.39 , 13.82	1400–700	Weeks (2014)

Appendix 2

Published Chemical Analyses of Early Copper-Based Objects

Scientific analyses of early copper-based objects discovered on the modern territory of China are being published every year. These reports are fundamental to most discussion in this thesis. This section is a summary of the reports cited in the thesis. Some chemical results are not published in reports but mentioned in papers and theses. These references are also included here. A more detailed table with the compositional data is provided as the supplementary material of this thesis.

In this thesis, I also cite some analyses of objects from other regions, such as Mongolia and South Asia. These references are also included in the table.

ID	Province	Site	Date of the objects (BC)	Reference
1	Beijing	Zhangying	1650–1450	Cui et al. (2008)
2	Fujian	Hulinshan	1200–1000	Fujian et al. (2003: 120)
3	Gansu	Dahezhuang	1700–1500	Sun, S. & Han, R. (1997)
4	Gansu	Donghuishan	1700–1500	Sun, S. (1998); Sun, S. & Han, R. (1997)
5	Gansu	Ganguya	1700–1500	Sun, S. (2016)
6	Gansu	Gaomuxudi	2300–2000	Sun, S. (2011b)
7	Gansu	Huangniangniangtai	2000–1800	Sun, S. & Han, R. (1997)
8	Gansu	Huoshagou	1800–1500; 700–400	Chen, K. et al. (2018a; 2018b); Sun, S. et al. (2003); Xu, J. (2009)
9	Gansu	Jiangjiaping	2300–2000	Sun, S. & Han, R. (1997)
10	Gansu	Lianhuatai	1250–1000	Xie, D. (1980)
11	Gansu	Mogou	1700–1500	Xu, J. (2009)
12	Gansu	Qijiaping	1700–1500	Sun, S. & Han, R. (1997)
13	Gansu	Qinweijia	1700–1500	An, Z. (1981); Sun, S. & Han, R. (1997)
14	Gansu	Xichengyi	2000–1500	Chen, G. et al. (2015a); Li, Y. et al. (2015a)
15	Gansu	Xinglin	1700–1500	Sun, S. & Han, R. (1997)
16	Gansu	Xiping	1700–1500	Sun, S. & Han, R. (1997)
17	Gansu	Xitugou	1900–1700	Li, Y. et al. (2018)
18	Gansu	Xujianian	1150–1050	Zhao, C. (2006)
19	Gansu	Yingwoshu	1700–1500	Sun, S. (2011a)

ID	Province	Site	Date of the objects (BC)	Reference
20	Gansu	Yujiawan	1200–880	Zhang, Z. & Ma, Q. (2008; 2009)
21	Gansu	Zhanqi	1200–1000	Wang, L. et al. (2016)
22	Gansu	Zhaobitan	2300–2000	Sun, S. (2011b)
23	Hebei	Dachengshan	1530–1300	Sun, S. & Han, R. (1981)
24	Hebei	Qianbao	1515–1327	Chen, K. et al. (2017b)
25	Hebei	Sanguan	1520–1315	Chen, K. et al. (2017b)
26	Hebei	Zhuangke	1600–1250	Chen, K. et al. (2017b)
27	Henan	Erlitou	1750–1550	Chen, G. (2006); Jin, Z. (2000); Li, M. (1984); Xu, H. & Chen, G. (2002); Zhongguo (1999b: 399; 2014b: v. 3, 1500–1543)
28	Henan	Getengshan	1250–1050	He, T. & Ou, T. (1994)
29	Henan	Runlou	1200–1050	Liu, Q. et al. (2016)
30	Henan	Tianhu	1250–1150	Xiao, M. et al. (2016)
31	Henan	Wangchenggang	2200–1835	Sun, S. (1992)
32	Henan	Wangjinglou	1600–1300	Yao, Z. & Wu, Q. (2018)
33	Henan	Xiaohucun	1250–1100	Jin, R. et al. (2019); Wang, X. et al. (2018b)
34	Henan	Xinzhai	1800–1700	Zhang, X. & Yuan, S. (2008)
35	Henan	Yangzhuang	1650–1600	Beijing & Zhumadianshi (1998: 183–187)
36	Henan	Yanshi Shang City	1500–1400	Tian, J. (2013: 109)
37	Henan	Yinxu	1260–1040	Ji, L. (1997); Li, M. (1982); Liu, Y. et al. (2007a; 2007b); Uchida & Iizuka (2015); Zhao, C. (2004); Zhao, C. et al. (2008)
38	Henan	Zhengzhou Shang City	1550–1400	He, T. (1997); Peng, Z. et al. (2001); Sun, S. (1999); Tian, J. (2013); Tian, J. et al. (2013); Yang, Y. et al. (1983)
39	Hubei	Panlongcheng	1550–1300	Chen, J. et al. (2001); Hao, X. & Sun, S. (2001); He, T. (2001); Peng, Z. et al. (2001)
40	Hubei	Tanheli	1250–1200	Ma, J. et al. (2018a)
41	Hunan	Laoyazhou	1450–1200	Ma, J. et al. (2018b)
42	Hunan	Tonggushan	1550–1350	Ma, J. et al. (2018b)
43	Hunan	Yusishan	1250–1050	Ma, J. et al. (2018b)
44	Hunan	Zhangshutan	1450–1040	Ma, J. et al. (2018b)
45	Inner Mongolia	Dadianzi	1750–1450	Li, Y. et al. (2003)
46	Inner Mongolia	Dashanqian	1600–1200	Wang, Y. et al. (2018a)
47	Inner Mongolia	Erdaojingzi	1750–1600	Wang, Y. et al. (2013)
48	Inner Mongolia	Sanzuodian	1600–1200	Mei, J. (2011); Wang, Y. et al. (2018a)
49	Inner Mongolia	Zhukaigou	2000–1300	Li, X. & Han, R. (1996; 2000)
50	Jiangsu	Beiyinyangying	1600–1000	Nanjing (1993: 146)
51	Jiangxi	Dayangzhou	1250–1100	Fan, X. (1997)
52	Liaoning	Dazuizi	2000–1800	Dalianshi (2000: 295)
53	Liaoning	Wanliu	1500–1100	Wang, Y. & Wang, H. (2019); Wang, Y. et al. (2020)
54	Qinghai	Gamatai	1700–1500	Luo, W. et al. (2016); Xu, J. (2009)
55	Qinghai	Tawendaliha	1000–800	Xi, G. & Li, Y. (2020)
56	Qinghai	Zongri	2000–1700	Xu, J. et al. (2010)
57	Shaanxi	Anjiacun	1450–1050	Mei, J. & Chen, K. (2011)

ID	Province	Site	Date of the objects (BC)	Reference
58	Shaanxi	Baoshan	1450–1050	Chen, K. et al. (2012)
59	Shaanxi	Fanbacunxi	1450–1050	Wang, H. et al. (2008)
60	Shaanxi	Goukoucun	1250–1050	Shaanxisheng (2009)
61	Shaanxi	Hejiacun	1500–980	Yang, J. et al. (2003a)
62	Shaanxi	Hourenjiagou	1250–1050	Cao, D. (2014)
63	Shaanxi	Huajiayuan	1250–1050	Cao, D. (2014)
64	Shaanxi	Huoshiliang	2000–1900	Chen, K. et al. (2009)
65	Shaanxi	Liujiayuan	1250–1050	Cao, D. (2014)
66	Shaanxi	Liulingdu	1450–1050	Mei, J. & Chen, K. (2011)
67	Shaanxi	Longtoucun	1450–1050	Mei, J. & Chen, K. (2011); Zhangsun, Y. et al. (2020a)
68	Shaanxi	Nianzipo	1300–1100	Mei, J. & Han, R. (2007)
69	Shaanxi	Shigushan	1100–1000	Shao, A. et al. (2021)
70	Shaanxi	Sucun	1450–1050	Mei, J. & Chen, K. (2011)
71	Shaanxi	Tuojiayuan	1250–1200	Liu, J. et al. (2015)
72	Shaanxi	Wangjiazui	1500–1000	Yang, J. et al. (2003b)
73	Shaanxi	Wulangmiao	1450–1050	Mei, J. & Chen, K. (2011)
74	Shaanxi	Xiejiagou	1250–1050	Cao, D. (2014)
75	Shaanxi	Yantou	1250–1050	Cao, D. (2014)
76	Shaanxi	Zaoshugounao	1200–1000	Yang, Z. & Zhou, P. (2017)
77	Shandong	Qianzhangda	1250–900	Wang, X. et al. (2014); Zhao, C. (2005)
78	Shandong	Sanlihe	2100–1900	Zhongguo (1988)
79	Shandong	Yinjiacheng	1900–1500	Sun, S. (1990)
80	Shandong	Zhaogezhuang	1900–1600	Sun, S. & Han, R. (1981)
81	Shanghai	Maqiao	1700–1400	Huang, X. (1978)
82	Shanxi	Caojiayuan	1250–1050	Cao, D. (2014)
83	Shanxi	Dongxiafeng	1750–1550	Chen, G. (2006); Li, J. et al. (2018)
84	Shanxi	Erlangpo	1250–1050	Cao, D. (2014)
85	Shanxi	Gaohong	1300–1100	Cao, D. (2014)
86	Shanxi	Geduping	1250–1050	Cao, D. (2014)
87	Shanxi	Haojiapan	1250–1050	Cao, D. (2014)
88	Shanxi	Houlanjiagou	1250–1050	Cao, D. (2014)
89	Shanxi	Jingjie	1100–1050	Chen, K. & Mei, J. (2006)
90	Shanxi	Liansigou	1250–1050	Cao, D. (2014)
91	Shanxi	Linzheyu	1300–1000	Cao, D. (2014)
92	Shanxi	Nangou	1250–1050	Cao, D. (2014)
93	Shanxi	Taohuazhuang	1250–1050	Cao, D. (2014)
94	Shanxi	Taosi	2300–1650	Gao, J. (2014)
95	Shanxi	Tazishang	1250–1050	Cao, D. (2014)
96	Shanxi	Xiaojiata	1250–1050	Cao, D. (2014)
97	Shanxi	Xiaxinjiao	1250–1050	Cao, D. (2014)
98	Shanxi	Xiazhuang	1250–1050	Cao, D. (2014)
99	Shanxi	Xuejiaqu	1250–1050	Shaanxisheng (2009)
100	Shanxi	Yidie	1250–1050	Cao, D. (2014)

ID	Province	Site	Date of the objects (BC)	Reference
101	Shanxi	Yuanqu Shang City	1600–1300	Cui, J. et al. (2009); Yao, Q. (1996)
102	Shanxi	Zhinan	1250–1050	Cao, D. (2014)
103	Sichuan	Jinsha	1200–600	Xiao, L. et al. (2004)
104	Sichuan	Sanxingdui	1400–1100	Cui, J. & Wu, X. (2013); Jin, Z. et al. (1995); Ma, J. et al. (2012)
105	Xinjiang	Adunqiaolu	1900–1700	Tan, Y. et al. (2021)
106	Xinjiang	Fuzhisuanchang	2000–1550	Mei, J. (2000)
107	Xinjiang	Gumugou	1900–1300	Ling, Y. (2008)
108	Xinjiang	Liushugou	1400–1100	Subei, N. (2019)
109	Xinjiang	Nanwan	1300–900	Qian, W. (2006)
110	Xinjiang	Tianshanbeilu	2000–1550	Liu, C. et al. (2020); Mei, J. (2000); Qian, W. (2006); Qian, W. et al. (2001)
111	Xinjiang	Wupu	1400–800	Mei, J. (2000)
112	Xinjiang	Xiaohe	1900–1300	Mei, J. et al. (2013)
113	Xinjiang	Yanbulak	1300–900	Mei, J. (2000); Qian, W. (2006)
114	Xizang	Qugong	1750–1500	Sun, S. & Mei, J. (1999)
115	Yunnan	Haimenkou	1700–1200; 1100–500	Li, X. & Han, R. (2006); Li, X. & Min, R. (2016)
116	Yunnan	Wangjiadun	1100–800	Li, K. & Min, R. (2011)
117	Zhejiang	Yushan	1200–400	Wang, Y. et al. (2019b)

ID	Country	Site	Date of the objects (BC)	Reference
118	India	Lothal	2600–1900	Lal (1985)
119	India	Rangpur	2000–800	Chakrabarti & Lahiri (1996: 55)
120	India	Surkotada	2100–1700	Chakrabarti & Lahiri (1996: 60)
121	India	various copper hoards	1500–1000	Yule et al. (1989)
122	Iran	Hissar	4000–1650	Thornton (2009)
123	Mongolia	Baga Gazaryn Chuluu	1300–AD 200	Park et al. (2011)
124	Pakistan	Chanhudaro	2600–1900	Chakrabarti & Lahiri (1996: 54–55)
125	Pakistan	Harappa	2600–1900	Chakrabarti & Lahiri (1996: 51)
126	Pakistan	Mohenjo-daro	2600–1900	Chakrabarti & Lahiri (1996: 45–48)

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