The Bronze Age Metallurgical Traditions of Tianshanbeilu in East Xinjiang, China

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Abstract

The Tianshanbeilu cemetery (TSBL) is the earliest and the largest Bronze Age site in East Xinjiang, China. The discovery of more than 3000 bronze artefacts presents the opportunity to examine the early development of bronze consumption and production throughout the second millennium BC of East Xinjiang, investigating technological and organisational changes that shed light on how people socialised and interacted in a material world.

This thesis combines the typological and stylistic study of copper alloy objects from TSBL, a consideration of their contextual and chronological variability and their chemical composition in order to characterise alloy technology, metallurgical tradition and the cultural connections across Xinjiang and neighbouring areas. Handheld portable X-ray fluorescence was employed to analyse 1352 bronze objects from TSBL, allowing coverage of a very significant proportion of this important assemblage. The diversity in alloy composition reveals diachronic change in the prevalence of different alloys, and their implications are considered both in terms of changes in technological practice, and in terms of spatial variability in objects that reveal regional traditions.

While separating the movement of objects themselves in inter-regional exchange from the spatial transmission of technological practices may be difficult to discriminate in these alloy compositions, their clear stylistic links with other neighbouring areas allows consideration of the role of the population of TSBL in the transmission of tin-bronze technology, perhaps being responsible for the promotion of tin bronze in the Hexi Corridor of Gansu and the Hami region.

There is no direct evidence of bronze production at TSBL and while this study argues that the production of metal in Hami began around 1600 BC, the scale of production was small, and possibly only a few rather unique bronze objects were produced locally in the Hami region, while most were probably introduced through trade and exchange with neighbouring cultures.

The contextual study of the spatial distribution in the cemetery, burial practice and grave goods shows a degree of continuity. suggesting that the population of TSBL lived a stable sedentary existence with their food and animal products used in networks of trade and exchange, driven by demand for bronzes that were consumed in personal adornment and body ornamentation. Thus the shifts in metal use and alloy technology are suggested to have been driven by social changes in consumption, movement, and sharing practices.

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List of Abbreviations

As	Arsenic
BC	Before the Christ
Cu	Copper
Fe	Iron
km	Kilometre
M	Tomb (“M” is often used to represent “tomb or grave” in Chinese reports)
Pb	Lead
pXRF	Portable X-ray fluorescence spectroscopy
Sb	Antimony
SEM-EDS	Scanning electron microscopy and energy dispersive spectrometry
Sn	Tin
TSBL	Tianshanbeilu
XIA	Xinjiang Institute of Archaeology

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Chapter 1 Introduction

1.1 Introduction

Current syntheses of the prehistory of the Eurasian steppe have tended to privilege globalising models of interaction at the expense of establishing the local conditions under which widely distributed cultural phenomena are taken up (Anthony 2007; Kohl 2007). Among the range of cultural artefacts, materials, and practices that are discussed in these syntheses it is metal objects and metallurgical practices are invariably used to highlight interaction among communities both in terms of exchange and adoption of cultural practices. To explore the specific conditions under which the communities of North West China interacted with wider Steppe communities this study undertakes a programme of work that aims to characterise attitudes towards aspects of specific elements of material culture, namely metals, during their early uptake. The major aim of this study is to generate a contextual understanding of metal use among the communities of North West China in the second millennium BC to broaden our understanding of community and cultural interaction in this region and its wider relations with the Eurasian steppe. The study area centres on the Xinjiang province sitting northwest of China (See Fig 1and Fig 2). Xinjiang is characterised by high mountain ranges, oases, vast deserts, steppe and river valleys that facilitate movement along an East-West transit route to the north of the arid Tarim Basin famous for its desiccated mummies and south of the formidable Altai Mountains. Xinjiang is well known as an important node in the exchange networks that have become known as the ancient Silk Route. Xinjiang is probably the most critical location in understanding east-west transit routes across the Steppe at several points in the past, especially for migrating and/or nomadic communities of the Bronze Age (Shui 2001). Its significance for historic exchange and migration is well documented and it is most likely that this region acted as a transit route for prehistoric nomadic communities in the same way that it acts as an essential transit route for mobile communities in the recent historic period.

Figure 1. Map of China

Figure 2. Map of Xinjiang and surrounding areas (Chen and Hiebert 1996, Fig 1)

From this perspective, the study region has a high potential for directly examining aspects of cultural interaction across the Eurasian steppe (Frachetti 2012) and especially for specialised and presumably complex cultural practices, such as metallurgy, which seem, according to some, to move eastwards from the Southern Urals at around this time (Kuzmina 1998, 2004; Anthony 2007; Kohl 2007, 2009a). Although there are several studies in the area, in terms of its importance to wider syntheses it remains significantly understudied, in particular in terms of systematic contextual analysis of material culture that may reveal differing strategies of procurement and consumption. By developing a deeper understanding of the strategies by which prehistoric communities participated in wide-ranging cultural phenomena such as the adoption of, complex bronze metallurgy and specific metal consumption habits (Hanks and Doonan 2012; Frachetti 2012) the study aims to reveal the specific material cultural and social relations which were established and maintained by the communities of Xinjiang. In Xinjiang, the east part was a marginal area influenced by the development of ancient Chinese civilisation, as well as at the forefront of where East and West ancient cultures collided, exchanged, and merged (Shao 2007; Betts et al. 2019). The region's unique natural geography and rich natural resources provided fertile soil for prehistoric people to thrive and exist for a long time. At the same time, different cultures from the East and West infiltrated and fused, resulting in a complex and diverse cultural identity in the region. Tianshanbeilu (TSBL) cemetery site (Fig 3) is the most important archaeological site discovered from the Bronze Age of East Xinjiang, it was the earliest and longest-lived site, and also contained the largest number (over 3000) of bronze objects found across Xinjiang. Thus, this thesis offers the contextual study of Bronze Age metal production, exchange and consumption at Tianshanbeilu (TSBL) in East Xinjiang of China and the Siba culture at Hexi corridor in northwest Gansu of China, an area linked with manufacturing activities in the landscape, especially in metals, and, as will be shown with the of some of the Andronovo style bronze objects from other parts of Xinjiang or as far as the

Central Eurasian steppe (Mei 2000; Betts et al. 2019). The bronze analysis considers the transformation of production, technology and consumption of personal ornaments and tools, as well as the broad exchange networks that connect Siba culture in Gansu China to the rest of Xinjiang. The thesis aims to produce a bronze study that contributes to the overall picture of Bronze Age East Xinjiang, as well as to understand what goods were moving and when these movements occurred, whether other materials besides metals were important, and how all of the evidence reflects. The study is timely and focuses on addressing agreed research objectives identified by some scholars currently working across the Xinjiang and Eurasian steppe (Frachetti 2012; Doonan et al 2013; Yang 2018; Liu et al 2020;).

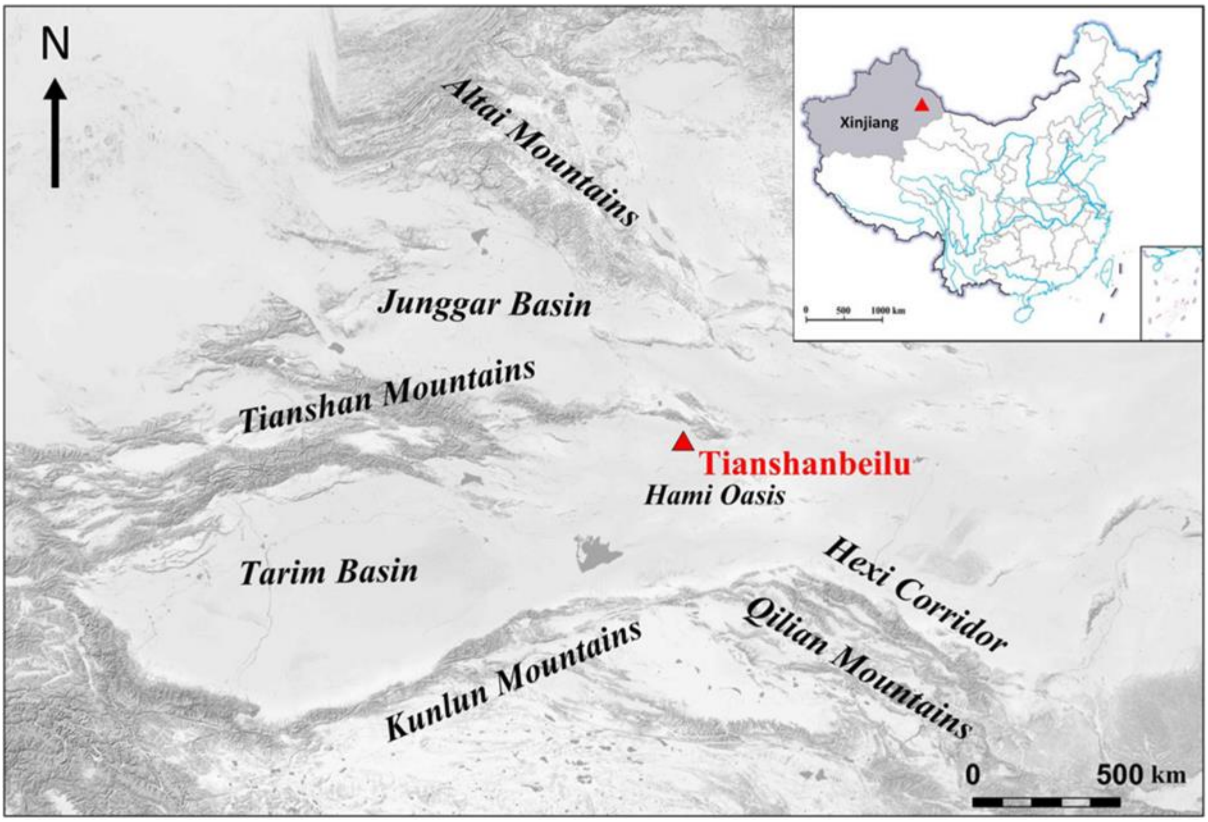

Figure 3. The location of the TSBL site (Tong et al. 2020, Fig 1)

1.2 Bronze Production, Consumption and Exchange of TSBL

To gain a better understanding of the underlying causes of transformations in social complexity, scholars analyse the production capacity, consumption, and exchange of material goods as a concentrated study of material culture. The investigation of bronze production, consumption, and exchange has become the foundation of this field of study and offers significant potential in this regard. Existing material culture studies, particularly those examining metal objects in Xinjiang, have concentrated on establishing important technical aspects of the material (Mei 2000; Qian et al. 2001; Qian 2004; Yang 2018; Liu et al. 2020), but have paid less attention to the investigation of technological change, the trade and exchange system and prehistoric economy, to characterise the social and economic organisation in the context of prehistoric Xinjiang. There is no systematic typological study of bronze objects in Xinjiang and TSBL, only a brief description of the individual objects. The intention was to determine whether there is a larger regional culture zone but lacked a detailed relative regional chronological sequence. Another problem was that the research was unable to move to the interpretation of technological practice and traditions, nor to convincingly assess indications of the circulation of bronzes.

The current study will establish a bronze typology and link it to a firm chronology of TSBL, as well as identify and characterise changes in bronze technology, thereby discussing the changing nature of production and organisation. The technological study concentrates on specific aspects such as alloy choice, the increasing diversity of alloys, raw materials, as well as the organisation of production. Consequently, the thesis will discuss key issues of technological change, which will be used to examine changes in the organisation of bronze manufacture, and then to discuss organisational changes concerning the consumption and exchange of bronzes at TSBL and its associated communities.

1.3 Research Approach and Research Aims

The study focuses on the extensive collections of 2nd millennium BC metalwork that have been retrieved from the TSBL site at the Hami region in East Xinjiang. This material has attracted the attention of scholars who normally refer to the broad types highlighted in preliminary reports in their attempts to model long distant interaction (Kohl 2007; Lindruff 2000). To date, few studies have studied this material in any significant detail and there is a total absence of studies that have attempted to look at the material from a holistic perspective that integrates contextual analysis of all funerary material with the more in-depth artefactual study.

The study aims to undertake a detailed contextual analysis of material recovered from TSBL cemeteries, including a complete catalogue of metal objects from the TSBL site. In addition to an analysis of contextual associations of metal artefacts, traditional typological classification and description will form an important part of the study which will in turn be supplemented by a detailed metal artefact study to observe the technology practice to explore the coherence of particular metal artefact typologies, will prioritise the identification of fabrication strategies i.e. casting, forging, carving and hollowed, etc,. Moreover, to study specific manufacturing processes, in particular, the radically changed choices of alloys, raw materials and new resources to examine the technological changes in bronze production, this thesis utilises an integrated analytical programme consisting of typological, contextural study and chemical composition analyses (pXRF) to investigate the stylistic, technological and organisational change in bronze of TSBL. By using these approaches, it allows:

- The establishment of a full catalogue of metal artefacts and metalworking debris for the TSBL. This database will permit a detailed interrogation of the various associations of material, artefacts and context with metal objects.

- The typological classification of Bronze Age metal artefacts from TSBL.
- A detailed understanding of variability in bronze objects in the TSBL cemetery and how technological change is related to changes in the organisation of production.
- The characterisation of consumption patterns at TSBL and of exchange systems involved in the movement of bronzes.
- The comparison between changes in bronzes at TSBL and the broader region of East Xinjiang, to explore established attitudes to the use of bronze in funerary contexts for the proposed micro-regional comparison with neighbouring or related regions.

1.4 Thesis Structure

In this section, the thesis structure is presented alongside a justification for this arrangement. Chapter 1 expresses a brief overview of the planned research and the intellectual context within which it was conceived. The methods employed are outlined, including a reference to the theoretical framework in which the methodology is embedded. Clearly stated aims and objectives of the research are outlined, followed by an introduction to the thesis structure.

Chapter 2 starts with a brief introduction to the physical environment of Xinjiang to better understand the ecological context of the Bronze Age cultures in the region. Recent progress in the study of prehistoric Xinjiang history is broadly reviewed, followed by a review of previous studies of the Bronze Age and a discussion of the frameworks that have been proposed by different scholars, providing a background for the present study. The last part of the chapter proposes the framework adopted for the present study and briefly discusses the issues that this thesis addresses.

Chapter 3 introduces the methodology and analytical approaches of this research, focusing on the integration of the conceptual approach and the use of pXRF as the analytical technique.

Chapter 4 explores the typological classification of Bronze Age metal artefacts from TSBL. For this purpose, a large amount of copper or bronze artefacts are analysed and a full catalogue of metal artefacts and metalworking debris for the TSBL is provided. Through the descriptive approaches used, this analysis aims to classify the metal artefacts and the metal artefacts from TSBL are classified into 14 categories that are studied in sequence, and a detailed study of the chronology associated with the typology of bronzes is presented. The final part summarises the general cultural characteristics of TSBL metal artefacts.

Chapter 5 presents technical studies that have been carried out on the early metal artefacts recovered in TSBL. Firstly, the contextual perspective of burial goods from TSBL is described and discussed. Secondly, the metallurgical examination of select samples from TSBL is presented, with all compositional analysis undertaken by handheld portable XRF. It allows the investigation of the technological and stylistic changes of bronze across the four phases of the site. Finally, the discussion of the results of these analyses is summarised.

Chapter 6 brings together the stylistic, contextual, provenance and technological information produced in the thesis research. Firstly, it integrates the analytical work to demonstrate the different technological traditions for the major shape categories in each phase at TSBL, from alloy recipes in metal manufacture, and the potential links of the bronzes to the other cultures whose products may have been consumed in the cemetery. Secondly, the organisation of bronze production of the bronzes recovered from TSBL will be discussed, followed by a section which highlights the exchange and consumption of bronzes found at TSBL. The chapter also compares the available archaeological data from different regions, focusing on the cultural relationships between TSBL and its neighbours to the east, west and north during the Bronze Age, with an emphasis on metal technologies.

The conclusions are presented in Chapter 7, which reviews the important understandings and implications produced by the research, and offers an account of technological traditions and the change of technological choices and practices in metal production, as well as consumption trends in the TSBL bronze assemblage. The end of this chapter also highlights the prospects for future research in light of the main conclusions of the study.

1.5 Summary

In studying the extensive collections of Bronze Age metalwork that have been retrieved from TSBL, and considering the relative lack of information in English about Xinjiang archaeology, this research intends to give a relatively detailed description of the TSBL site and associated materials and to include the most recent archaeological finds, presenting a full catalogue of metal artefacts and metalworking debris for the TSBL.

The research should, therefore, be understood as an attempt towards initiating micro-regional studies which aim to explore regional cultural trajectories on their terms without necessarily and automatically using them to elaborate on the interaction between communities which may be 1000 km and centuries apart. From this perspective, it should be seen as an opportunity to develop a regional research framework to direct subsequent studies. It is hoped to bring to light the continuous individual nature of the archaeological evidence in the expanse of land that makes up East Xinjiang and to provide evidence for the interpretation of greater, community identities that may have been played out within the metallurgical traditions.

Chapter 2 Prehistoric Xinjiang

2.1 Introduction

"The evidence for diverse pathways in the development of mobile pastoralist economies across the Eurasian steppe suggests that specialised adaptations were developed according to localized ecological and social conditions in the late 4th and 3rd millennia BC."

Frachetti (2013)

This quote could be applied to the whole region of the Eurasian steppe; Xinjiang appears to be no exception to this. There is very little information available about Xinjiang before the Bronze Age (Debaine-Francfort 1988; Jia et al. 2011;), but the largely discovered stone tools from the surface across Xinjiang proved there was a sparse pre-agricultural hunter-gatherer population active in the area (Betts et al. 2019). Recent archaeological discoveries indicate human activity around 40 k BP at the cave site of Tongtiandong in the southern Altai (Yu & He, 2017). The current scholarly consensus, based on previous research, is that the Bronze Age in Xinjiang is thought to have begun around 2000 BC, but with the increase in archaeological findings over the last few years some scholars have suggested that it can be dated back to around 3,000 BC (Betts et al. 2019), although no definitive date is available. Three distinct cultures exist in Xinjiang since its earlier Bronze Age stages, they are having own cultural identities different from the surrounding areas; they are also occupying their distinct environmental niche, which may have influenced their original development (Betts et al. 2019). Located in the northern mountains, the Qiemu'erqieke culture is characterized by massive anthropomorphic monolithic gravestones; in the south, the unique organically preserved cemetery of Xiaohe in the depths of a harsh desert represents a culture whose primary function was agriculture and cattle herding, with a highly complex symbolic culture. There is also a third culture to the east, the TSBL culture, characterised by the TSBL Cemetery, the most important and largest Bronze Age site in East Xinjiang, China. Stretching across the entire second millennium BC, it performed a prominent role in connecting the Hexi corridor, Central China and the steppe (Mei 2000; Qian 2006; Liu et al. 2020). A key question is how and why Xinjiang produced such broad cultural variations. One of the most important impacts could be the environmental and climate difference between the regions. Therefore, this chapter begins with a brief introduction to the physical environment of Xinjiang to understand the ecological context from which the Bronze Age cultures in the region can be better examined. It moves on to review the recent progress that has been made in the study of prehistoric Xinjiang. The next section reviews previous studies of the Bronze Age and discusses the frameworks that have been proposed by different scholars, providing a background for the present study. The last part of the chapter proposes the framework adopted for the present study and briefly discusses the issues that this thesis research addresses.

2.2 The Physical Environment of Xinjiang

2.2.1 General Information

Xinjiang is situated in the northwest of China and is a large sparsely populated area, spanning more than 1.6 million km^2, China's largest province in terms of its areal extent. In the modern context, Xinjiang shares 5,600km of the frontier with Mongolia in the northeast, in addition to Russia, Kazakhstan, Kyrgyzstan and Tajikistan in the west, and then Afghanistan, Pakistan and India in the southwest. It is surrounded by high mountains, forming a closed inland basin with restricted points of entry on the western flank: the Altai Mountains in the northeast, shared with Mongolia; the Tarbanhatai Mountains in the northwest; the Pamir and Karakoram ranges in the southwest; the Kunlun Mountains and Altun Mountains lie in the south, along the border with Tibet. The Tianshan mountains cross central Xinjiang, dividing the region into rather different north and south zones, the southern being known as the Tarim Basin and the northern known as the Junggar Basin. The Tianshan Mountains produce many wide flat valleys between the mountains and basins, such as the Yili River valley, Baicheng Basin, Yanqi Basin, and Turpan Basin (XGA 1993). Figure 4 illustrates the basic topography of Xinjiang.

Figure 4 Basic topographic map of Xinjiang

The most obvious characteristic of the geography of Xinjiang is the significant difference between the north and south zone created by the Tianshan Mountains (See Fig 5). The northern zone is the smaller of the two and comprises arid grassland and desert with more fertile valleys oriented east-west. The southern zone is far more expansive and is part of the Taklimakan Desert better known for the discovery of the so-called mummies of the Tarim Basin (Mallory and Mair 2000). As these spectacular mummified remains have shown, the area is notable for the variety of ethnicities which seem to have inhabited this area in the Bronze Age (Shui 2001; Mei 2000, 2003, 2004). While the Tarim finds have dominated discussion of the region, it is apparent that it witnessed the diverse interaction of different cultural and ethnic groups which would have undoubtedly been accompanied by the interplay of different cultural traditions and ideologies (Mei 2003a, 2003b; Lindruff 2000, 2004).

Figure 5. Tian Shan Mountains (red) dividing Xinjiang (yellow) into two parts

The steppe is often conceptualised as being a homogenous and expansive ecological zone (Anthony 2007) with the implication that the diverse communities that inhabit it have developed comparable cultural and economic subsistence strategies. The northern basin is surrounded by starkly different mountainous zones with differing watersheds and accompanying ecologies (Cheng et al 2003). Furthermore, the proximity of significant desert areas means that the region is characterised by contrasting climatic conditions, with humid warm sheltered environments to the east sitting in contrast to the dry windswept and exposed region to the west. In summary, Xinjiang is characterized by a range of micro-climates which require communities to have developed varied and flexible subsistence strategies of a type which defy simple generalisations (Ren Meier 1999: 336-79).

2.2.2 Geographical setting of East Xinjiang

This study focuses on the Tianshanbeilu site, which is in East Xinjiang. The oases of Hami and Turfan are two depressions located on the eastern section of the Tianshan Range, separated by its south-eastern spur, the Kuluketage Mountains. The area sits at the head of the Gansu Corridor, which lies on its eastern border, while on the north-western side the Dafeng Pass leads to Urumqi. The two oases are covered by loess, making them fertile lands suitable for agriculture. The region receives little precipitation annually, yet it is moistened by the meltwater from ice and snow that forms small streams flowing from the Tianshan Mountains. (XGA 1993; Festa 2018). In the valley these streams become rivers, the most important being the Kaidu, the Kongque, the Hei and the Shule. Additionally, in Turfan, meltwater originating from snow on the Tianshan Mountains funnels into three main gorges, which determine where the water enters in the oasis: the Toyuk Gorge, the Shengjinkou Gorge and the Turfan Gorge (Jiang et al. 1998). Several small, enclosed lakes, such as the Barkol and the Aiding, are mostly fed by limited rainfall (XGA 1993). East Xinjiang is located in the earth's temperate zone and is characterized by a continental desert climate. It has been affected by the "desiccation of Asia", a phenomenon which has led to the disappearance or substantial decrease of several rivers, in addition to significantly accelerated desert formation in the eastern and western sections of the oases (Zhang Linyuan 1981). This pattern is evident when one considers the conditions of the lakes: several examinations conducted on Barkol Lake have revealed that its surface used to be wider. It would also seem that the lake has gradually become more saline, due to the shortage of a freshwater supply and higher levels of evaporation (Zhang Linyuan, 1981; Yang Yichou, 1992; Xia Xuncheng, 1991). Similarly, the Aiding Lake, which is also saline, was at one time reached by streams and rivers flowing from the Turfan Gorge, while at present it is only fed by a low amount of precipitations and underground water. Sedimentological examinations of Barkol Lake have provided some data on the past regional climate (Yang Yichou 1992). It appears that during the Holocene the climate was characterized by fluctuations of warm-cold and dry-humid conditions. According to analyses on autogenetic carbonate stable isotopes, carbonate contents and grain size, the region around the lake was characterized by a dry-cold/temperate climate from around 4000 BC to 3000 BC, while roughly between 3000 and 2000 BC dry-warm conditions appeared (Jiang et al. 1998; Pan et al. 2004; Festa 2018). In the following period, until around 1000 BC the climate was cold and dry. Despite these climatic fluctuations, it seems that over the millennia the oases in Eastern Xinjiang have formed a fertile environment, which has allowed for agricultural practices, especially the cultivation of millet, wheat and grapes, in addition to livestock farming (Jiang et al. 1998; Festa 2018).

To sum up, we are still woefully short of good well-dated prehistoric climatic data. In light of the extreme environments of Xinjiang it is apparent that this data is very important as, without it, it is difficult to understand the conditions under which prehistoric communities and their social institutions emerged. A further concern is that, while broad datasets have highlighted the change in climatic conditions, the effect of these studies is to view human cultural development as simply responding to climate change. Climate no doubt played an important part in the prehistory of Xinjiang, but this period of human history needs to be understood in a more sophisticated way than simply believing that the climate was an all-determining force. It is the way that communities responded to these changes that should be the focus of future studies, yet fine-grained climatic studies are essential to these studies.

2.3 Previous Studies of Bronze Age Xinjiang

2.3.1 General Information

Prehistoric sites in Xinjiang were key points for East-West exchange, but it is only in the last thirty years that their crucial importance has been recognized. Indeed, from the 1980s more systematic studies on Xinjiang prehistory were conducted. In 1985, Wang Binghua established the existence of two periods, the Bronze Age and Iron Age, and placed them in 2000BC-1000 BC and 1000BC-200 BC respectively. After that, an increasing number of chronological frameworks have been proposed and, as a consequence, diverging opinions among scholars have emerged. While a group of experts has shown agreement with Wang Binghua on the existence of a Bronze Age and an Iron Age, some have advanced a more general division into an "early" and a "later" period and others have rejected both the ideas and insisted that most of the remains belong to one period, that is the Bronze Age (Debain-Francfort 1988; Shuitao 1993,2003; Chen & Hiebert 1995; Change 1996); Mei Jianjun 2000; Hanjianye 2005; Shaohuiqiu 2007). Further disagreements have occurred over the grouping of major sites, and, although their chronology and cultural context of many remain often uncertain, relevant progress in the research on prehistory in Xinjiang is represented by the studies of Debain-Francfort (1988), Shui Tao (1993), Chen & Hiebert (1995), Chen Ge (1996), Mei Jianjun (2000), Han Jianye (2005) and Shao Huiqiu (2007). Their works propose seven major temporal-cultural frameworks, to organize the early remains discovered in Xinjiang into several cultural or regional groups, thus showing agreement on the attribution of some remains, such as those at Gumugou, Xiaohe, Tianshanbeilu and Qiemuerqieke, although uncertainties about the chronological position of sites in the Altay, Yili-Tacheng region and East Xinjiang still linger. Despite this, Wang Binghua's periodization has been accepted by most scholars, as the division of prehistoric remains into the Bronze Age and Iron Age has generally been confirmed by the typological analysis of the remains combined with available carbon dating results. Wang Binghua's division has been accepted and combined with the other frameworks offered previously by Hanjieye (2005) and Shaohuiqiu (2007), thus delivering the three periods as Bronze Age (2000-1500BC), Late Bronze Age (1500-1200BC) and Early Iron Age (1200-1000BC). In considering these understandings of the prehistoric cultures in Xinjiang, there are broadly two categories of enquiry into the archaeology of the region.

The first category involves the organisation of the early remains discovered in Xinjiang into several cultures, or regional groups. Several archaeological cultures have been identified, and have been named the Yanbulake culture, Chawuhuwen culture, Yili river valley culture and Subeixi culture. In 1993, Shui Tao offered a systematic analysis of Xinjiang's prehistory. He proposed the organisation of all the Bronze Age remains into eight regional zones, summarizing and analysing the cultural features individually for each zone. At the same time, he explored the relationship between cultures within the region, as well as with the neighbouring, connected cultural groups in Eurasia and West China. On account of the relative lack of data, the relationship of significant chronological and cultural patterns to specific regional evidence was difficult, but this was the first comprehensive systematic analysis of the Xinjiang prehistoric culture pattern, basically developing the whole outline of the prehistoric culture system, and the results stimulated a new level in research on the prehistoric cultures of Xinjiang. Based on Shui Tao's framework, An Zhiming (1996) suggested 10 regional zones around the Tarim Basin, based on what he considered obvious differences in the archaeological remains between different regions, representing different cultural groups. He also established the existence of three periods, early (2000-1500 BC), middle (1500-1000 BC) and late (1000-300 BC), comprising three stages of continuous development. In 2005, Hanjieye (2005) proposed the existence of two periods, the Bronze Age and Early Iron Age, and placed them to 1900-1300 BC and 1300-100 BC respectively. This substantial work was based on pottery typology and took into account nearly all prehistoric remains published in Xinjiang. Currently, this is the most comprehensive research on early Xinjiang.

Beyond the establishment of cultural groups or zones, the second category of enquiry is focused on the cultural interaction between Xinjiang and its neighbouring regions. Due to the special location of Xinjiang, in the interior of the Eurasian continent, it forms an important corridor between East and West. The interactions between Xinjiang and Central Asia and the inland of China can be traced back to the Bronze Age and this makes it particularly important for the study of eastern and western cultural exchange. Many scholars, such as Shui Tao (1993, 2001, 2017), Chen & Hiebert(1995), Li Shuichng (2002), Lin Meicun (2002), Mei Jianjun (2000, 2001, 2003) and Shao Huiqiu (2005, 2007) contributed to the valuable discussion on this topic. Shui Tao indicated that the copper objects occurring in Tianshanbeilu show strong connections with the Siba and Machang cultures. Therefore, Shui Tao suggested that East Xinajing comprises the important channel for interaction between Xinjiang and Northeast China and that the transmission of bronze technologies most likely went from East to West. Lin Meicun (2002), indicates the connection between the Qiemuerqieke site in north Xinjiang and the Gumugou sites in Lop Nur Region. He speculates that both remains are the result of human migration and that the origin of these populations can be traced back to an area North of the Black Sea and the Yamnaya culture in the Urals. Although some scholars disagree, this remains an interesting and valid hypothesis. Mei Jianjun (2000) has emphasised the cultural interaction between Xinjiang and its neighbours and its influence on the adoption of metallurgy, though the study of copper and bronze remains. He suggests that Xinjiang is a unique region that was always open to a variety of cultural influences from surrounding areas, while at the same time being isolated enough to develop its own distinctive culture. Shao Huiqiu (2007) summarized all of the research mentioned previously, and analyzed the history and current situation of the discoveries and research in Xinjiang prehistorical archaeology, raising some existing problems in current research. He proposed a new space-time framework for archaeological cultures in the Xinjiang area and systematically listed all prehistorical cultures in Xinjiang. In addition, he summarized the developmental process of cultural patterns and explained the role that the cultures in the East and the West would play in the course of this sequence. At the same time, he commented on the direction of cultural influences between the East and the West.

Furthermore, the study of bronzes has been an important part of prehistoric research in Xinjiang. Shui Tao and Li Shuicheng have both studied the bronzes of East Xinjiang from a typological perspective (Shui 1993; Gong 1997; Li 2003, 2009), but due to the paucity of available archaeological material, no systematic research material has been developed. In addition, while typological studies continue to dominate the archaeometallurgical field in Xinjiang, there is a growing awareness that deposit location, composition and structure of metal artefacts can provide useful information on local metal technology and interactions with neighbouring regions. Modern mineralogical research in Xinjiang has been mostly conducted by Chinese scholars, notably by Mei Jianjun (Mei 2000, 2001, 2012) over the last two decades, who has analysed a large number of bronze or copper objects from various areas of Xinjiang. Since 2016, new analyses and studies of prehistoric bronzes from Xinjiang, mainly from the Yili region in Northwest Xinjiang and East Xinjiang, and particularly for the TSBL cemetery, have been carried out by Northwestern University of China, giving the most recent chronological analyses, which are also the absolute dates used in this thesis.

2.3.2 The Chronology

In terms of prehistory studies, Xinjiang is still in its infancy and faces numerous challenges, chronology is the main issue. Xinjiang's Mesolithic, Neolithic, and Bronze Age periods are generally vague, especially in the absence of the Neolithic archaeological site directly causing difficulty in defining the time of the beginning of the Bronze Age of Xinjiang. Due to a lack of stratigraphic studies, it is difficult to formulate relative chronologies of single and group sites in Xinjiang. Further, absolute dating for Xinjiang prehistory has several problems, including not enough carbon dating results and the results falling in a range of probabilities, reducing their reliability. The problem is even more complex in TSBL due to the stratigraphic sequence of the cemeteries being very difficult to determine. Previous studies have divided the bronze objects discovered in Xinjiang from the Bronze Age into different stages based on many factors such as the geographic environment, cultural connotations and coexisting artefacts in Xinjiang (Gong 1997). Starting from 2000 BC, various regions of Xinjiang entered the Bronze Age one after another. By c.1000 BC, bronze objects were widely used in communities and the period of rising prosperity of bronze culture. Therefore, the absolute date of the Bronze Age in Xinjiang is generally between 2000BC and 1000BC. The bronze artefacts unearthed in the prehistoric period in the Hami area can be divided into three stages: the first stage is the early Bronze Age cultural remains, the site is TSBL cemeteries, dating from 2000BC to 1200BC; The second stage is from the Bronze to early Iron Age, the site including Nanwan Cemetery (1300BC-900BC) and Yanbulak Cemetery (1300BC-600BC). The third stage comprises remains dating fully to the Iron Age, such as the assemblages of sites including the Hegouliang Cemetery (600BC-400BC), Baichel Cemetery (500BC-200BC) and Shangmiaoergou cemetery Cemeteries (600BC-400BC).

The chronology problem is complex in TSBL due to the stratigraphic sequence of the cemeteries being very difficult to determine. TSBL's absolute chronology has been primarily discussed using only six radiocarbon dates published in the 1990s, among which one may be out of chronological consideration (ZK2790, 7176±110 BCE, IA CASS 1996). Using Bayesian modelling in OxCal (Bronk Ramsey 1998), Wang et al. (2017) provide four more radiocarbon dates, the boundary for the start and end falls between 1943-1763 BC and 1127-931 BC (95.4% probability). Thus, the major body of TSBL refers to the period from around 1800 BC to 1000 BC, according to estimates from kernel density estimation and summation in OxCal (Bronk Ramsey 2018). Recently, a further 37 radiocarbon dates were published by Tong et al. (2020). This work has been conducted by the Northwest University of China, as part of the TSBL chronology reconstruction, 37 human bone samples were analysed using AMS. As well as the four new radiocarbon dates published by Wang et al. (2017), have 41 radiocarbon dates calibrated by AMS. The discovery of these 41 new radiocarbon dates has allowed them to develop a more precise chronology for TSBL. According to the results, the TSBL cemetery was in use from approximately 2022 to 1802 BC and remained in use from 1093–707BC (Tong et al 2020). This indicates that TSBL is the earliest and longest-used known cemetery in East Xinjiang. The development of the TSBL cemetery has been divided into four phases by considering the typology of artefacts and stratigraphy of the site. A period of 2011-1772 BC was the first phase, a period of 1660-1408 BC was the second, a period of 1385-1256 BC was the third, and a period of 1214-1029 BC was the fourth (Tong et al 2020). This is the chronology and corresponding absolute date used within this thesis.

2.3.3 The Bronze Age Cultures of Xinjiang

According to the study of the previous research, during the Bronze Age, the Xinjiang territory exhibited cultural diversity, with strong cultural characteristics in its different regions.

As mentioned above, one of the earliest known Bronze Age cultural traditions in Xinjiang is that of Qiemu'erqieke in northern Xinjiang, centred in the Altay foothills, with links to southern Siberia and Mongolia (Fig 6)(XIA 1985; Kovalev et al. 2008; Jia & Betts, 2010; Festa 2018). It has ceramic assemblages characterised by grey wares with sophisticated patterns of incised decoration (Fig 7). The Qiemuerqieke tradition has been argued (Jia & Betts, 2010) to have been associated with the Okunevo southern Siberian culture, dating to between the 3rd and early 2nd millennium BC (Svyatko et al., 2013; Mu 2018). A cultural assemblage found at Qiemuerqieke includes distinctive incised ovoid round-bottomed jars, stone vessels of the same design with few or no incisions, and well-made flaked stone arrowheads (Fig 7). It is common for graves to be buried within stone enclosures that contain large stone cists. The stone slabs of the cists often contain geometric designs painted on their interiors. There are usually anthropomorphic stelae representing men and women at the entrances to enclosures (Fig 8). They carved clusters of stylised human faces on rocks near the burial grounds of the Qiemu'erqieke people. Although Qiemuerqieke's culture is highly developed and distinctive, its roots can be found in the early Bronze Age cultures of the Altai and southern Siberia, as well as the Afanasievo and Okunevo. Among these are cist burials, ceramics with etched patterns, some with rounded bottoms, stone arrowheads, and anthropomorphic stelae. It appears that Qiemuerqieke were predominantly mobile pastoralists, as were the Afanasievo and Okunevo peoples, although there is almost no evidence for their economic practices (Frachetti 2008:39-40).

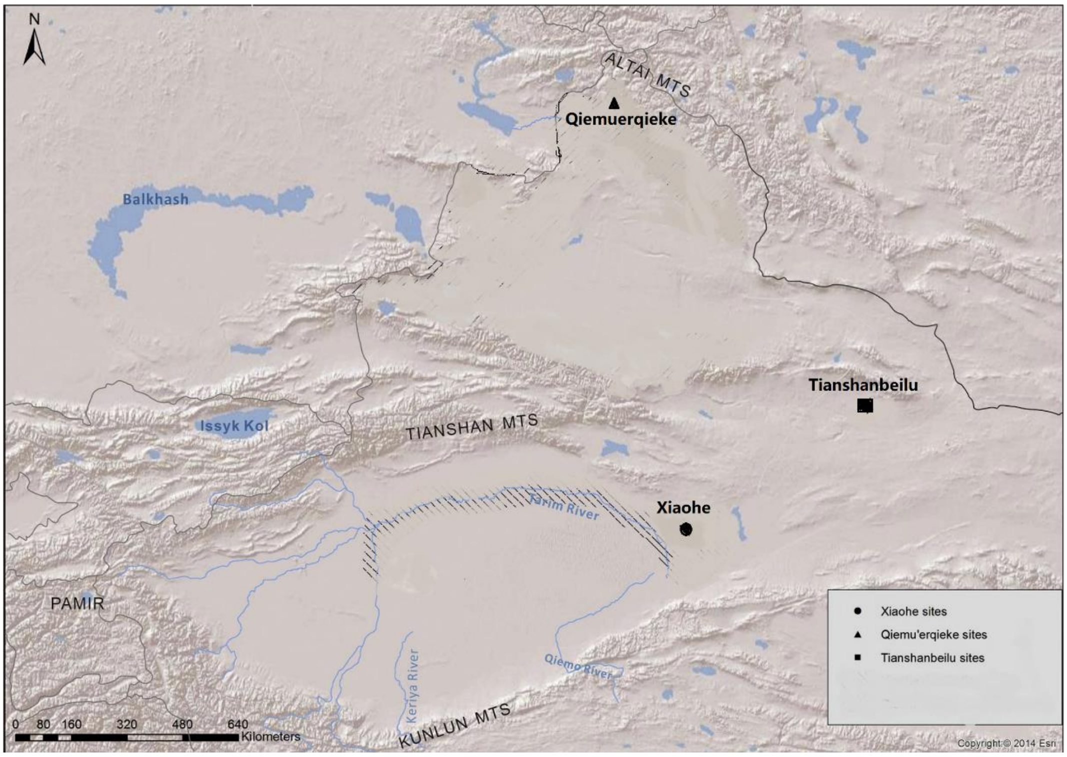

Figure 6 Distribution of Early Bronze Age sites in Xinjiang (Betts et al 2018, Fig 3

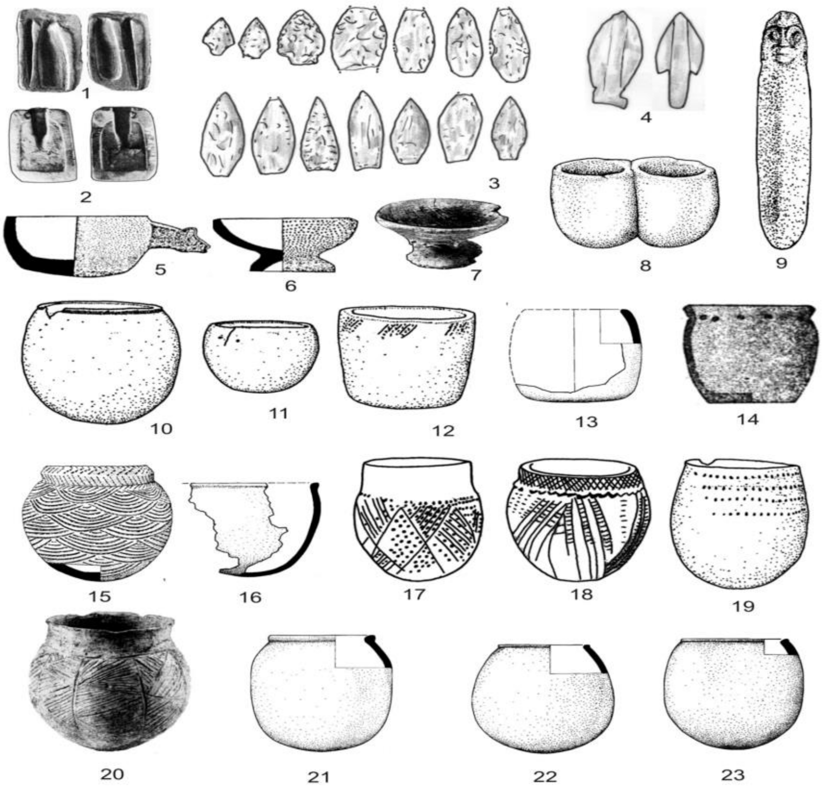

Figure 7 Artefacts of the Qiemuerqieke tradition(Jia and Betts 2010, Fig 7)

1–3, 8, 9, 11, 12, 15, 18 (Xinjiang Institute of Archaeology, Academy of Social Science, 1985): Plates 66, 68–70, 72–75; 4, 14, 16, 17 (Xinjiang Bureau of Relics et al., 1999: 298, 336, 340); 5, 6 (Xinjiang Institute of Archaeology, Academy of Social Science, 1981); 7, 22 (Zhang, 2007); 10, 13, 19–23 (Kovalev, 1999). 1. Knife mould; 2. Spade mould; 3. Various stone arrowheads; 4. Bronze arrowheads; 5. Stone vessel; 6–7. Ceramic lamps; 8. Stone double vessel; 9. Stone figurine; 10–11 Stone jar; 12–20. Ceramic jars; 21–23. Stone jars.

Figure 8 Stone stelae, Kayinar Cemetery, Qiemuerqieke (Betts et al. 2015, Fig 5)

The second well-documented early tradition in Xinjiang is Xiaohe, a largely aceramic culture based in the Tarim Basin's rivers and oases (Fig 6 and 9) (Abuduresule et al., 2007). It is unlike any other contemporary culture in Xinjiang or elsewhere, and it is best known for its highly elaborate nature and impressive organic preservation of burial goods (Fig 10 and 11). The Xiaohe culture is best known through two key sites: the Xiaohe Cemetery and Gumugou Cemetery in the same region (Han 1986; Wang 2014). The Xiaohe people probably grew wheat and barley on a small scale and herded cattle (Abuduresule et al., 2007; Cai et al., 2014; Mai et al., 2016). The Xiaohe culture began to develop in the Tarim Basin's central and eastern regions between 2000 BC and 1450 BC (Abuduresule et al., 2018). This distinct Xiaohe culture appears to have emerged in the Tarim Basin without obvious antecedents, but it, too, may have absorbed elements of a pre-Bronze Age indigenous population, as did the Qiemu'erqieke culture.

Figure 9 The Tarim River in the Taklamakan desert (Betts et al. 2018, Fig 8)

Figure 10 Xiaohe Cemetery before excavation (Betts et al. 2018, Fig 9; I. Abuduresule)

Figure 11 Xiaohe: Burial M13. Female body (Betts et al. 2018, Fig 10; I. Abuduresule)

2.3.3.1 Tianshanbeilu Site

The third early tradition in Xinjiang, in the East, is that of TSBL, known from the site that forms the focus of this thesis. Here is the detailed site information of the TSBL as follow;

In the oasis of Hami, archaeologists have identified a culture they named TSBL. The TSBL cemetery is located in modern Hami city, East Xinjiang (E 92°50′31″, N 42°53′23″) (Fig 6 and 12). It occupies a geographically important location as the next stop after Hami on the eastward journey is the well-known Hexi corridor. TSBL site was initially called the Linya Cemetery or Yanmansu Kuanglinchang Banshichu Cemetery. A series of excavations were carried out between 1988 and 1997 by local institutions, which discovered more than 1000 tombs with 706 tombs excavated and recovering more than 10000 artefacts, including pottery, copper-based objects, gold, bone objects, stone tools, shell, shells ornaments, turquoise and carnelian beads, etc (Fig 13) (Shui 1993; Chen 1995; Gong 1997; Liu et al 2020; Tong et al 2020).

The TSBL tombs were all small rectangular pits, 1.5 metres long, 1.2 metres wide, and 1 metre deep. TSBL is a large cemetery; however, closer inspection reveals some variation in density within the cemetery, which can be divided into several sections. In 60% of the tombs, the burial body was placed in chambers built with sundried mud bricks at the bottom of the tomb pit, while the other 40% had no burial containers (Festa 2018; Tong et al. 2020). The majority of the tombs were single burials, and many had been disturbed in ancient times. Most of the bodies were buried in flexed side-lying positions, with 55% facing northeast and 37% facing southwest (Festa 2018; Tong et al. 2020)

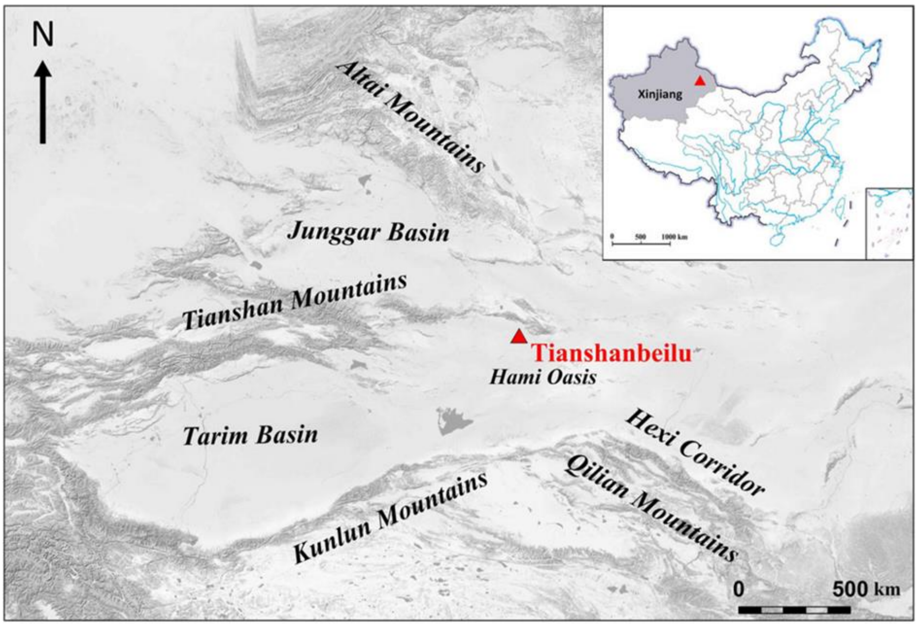

Figure 12 The location of the Tianshanbeilu site (Tong et al. Fig 1, 2020)

Figure 13 Burial Goods form TSBL (Tong et al. Fig 3, 2020)

A) tomb M30; B) bone plaques (tomb M30); C) stone pestle (M42); D) whetstone (M471);E) stone decoration (M330); F) faience beads (M200); G) stone plaques (M73); H) Shell (M529); I) talcum beads necklace (M397); J) carnelian beads (M284); K) turquoise beads necklace (M227); L) turquoise beads necklace (M190); M) stone stick (M24); N) whetstone (M66); O) stone arrowheads (M446)

TSBL site is the most important and largest Bronze Age cemetery site in East Xinjiang, with a rich corpus of elaborately painted ceramics and a large number of unearthed bronze objects (over 3000). The unique cultural assemblage only known from this cemetery in Hami City shows its own cultural identity, which is located near the southeast end of the Tianshan and the northwest end of the Hexi corridor connecting central China and Eurasia (Li 2009 2017). TSBL's material culture is comprised of two major groups of artefacts: pottery and copper-based objects. The repertoire of pottery, particularly the painted wares, provides a clear typological link to those of the contemporary Qijia and Siba cultures in the Hexi Corridor, implying a strong East connection (Mei 2000; Li 2006; Han 2007; Mei et al., 2012; Liu et al. 2020). The hand-painted redware pottery and designed painting patterns are mostly black, some of them with a touch of purplish-red paint. Globular jars with two handles are among the most common. Taller cylindrical jars with double handles and painted decorations are also available (Shui 1993; Li 1993, 1999). An initial study of the metalwork from the site also supported this connection. The personal ornaments and small tools which dominate the assemblage of earrings, bangles, buttons, tubes beads, plaques, knives, awls, and axes show close similarities in typology to those recovered from Qijia and Siba sites (Mei 2000; Qian 2006; Yang 2018;). Similar alloying practices are also widely shared across whole Hami regions. The careful archaeometallurgical examination has attested to the simultaneous employment of pure copper, tin-bronze, leaded bronze, arsenic copper and arsenic bronze, together with the techniques of casting, forging, annealing and cold-working in both East Xinjiang and the Hexi Corridor (Liu 2019; Yang 2018; Shao 2018; Li 2009; Qian 2006; Mei 2000; Li and Shui 2000; Shui 1993). However, the metalwork at TSBL also shows connections stretching out to the north and west into the Eurasian steppe. Typologically speaking, the closest ties with neighbouring areas of the steppe are seen in the Bronze Age, associated with the late Andronovo and Corded Ware horizons in Eastern Kazakhstan and southern Siberia (Kuzmina, 2007; Shao 2018; Liu et al. 2020).

In addition to pottery and bronze, many stone tools have been excavated from the TSBL, including stone pestles, stone grinders, and stone scythes, which are evidence of the development of agriculture, and the TSBL population also shows a strong demand for ornaments, with a large number of turquoise beads, carnelian beads, stone beads, and other personal adornments excavated in addition to bronze ornaments, totalling over 5000. The prevalence of personal ornaments is a common phenomenon of social culture in the entire Xinjiang of the Bronze Age, but at the same time carries a strong regional cultural identity, with the different materials and shapes of the various types of adornment reflecting common or different fashion trends in different regions of Xinjiang, which is closely related to the different social and economic developments. Sheep and cattle bones are commonly buried in the cemetery, with sheep bones predominating, reflecting that animal husbandry was also relatively well-developed. Bone collagen nitrogen isotope ratios indicate that TSBL inhabitants primarily consumed meat, primarily mutton and beef (Zhang et al. 2010). Carbon isotope ratios of bone collagen indicate that the majority of plant products came from C3 plants, most of which were wheat, and a small number of plant products came from C4 plants, such as millet (Zhang et al. 2010). The TSBL people consumed both wheat and millet in their diet, demonstrating the interaction and exchange between Eastern and Western cultures. The quantity and level of sophistication of burial goods found in different tombs could reflect the social class distinctions and the degree of wealth in the society at that time, from the current distribution of burial goods in tombs, there doesn't appear to be a particularly distinct class or wealth disparity in the Tianshanbeilu site. Together, these contextual backgrounds outline a complete picture of human activity at TSBL during the Bronze Age. Both the study of pottery and bronze are part of the social culture of the TSBL population, and they are interwoven with the natural environment and social context of the time to form a complex material culture of TSBL, at the same time these were related to the level of interaction between different communities.

2.3.4 The Bronze Age of the Hami Region in East Xinjiang and Surrounding Areas

2.3.4.1 The Hami Region

The TSBL cemetery is located in the Hami region of East Xinjiang. The Hami region comprises the eastern section of Tianshan in the middle, the Hami oasis to the south, and the Barkol Plain to the north. Hami is the most active area of Bronze Age development in Xinjiang, and current archaeological findings indicate that the region had the highest number of burials and bronze artefacts between 2000 and 1000 BC (Shao 2008; Yang 2018). The first and second phases of the TSBL cemetery represent the early bronze culture in Xinjiang, while from the third phase onwards, a flourishing bronze culture can be seen throughout the region. The Liushugou (1610BC-970BC), Yanbulake (1500BC-1100BC), Wupu (1400BC-1000BC), and Nanwan (1300BC-900BC) cemeteries in the Hami area represent bronze age cultures coexisting with Phase 3 and Phase 4 of the TSBL (Festa 2018; Betts 2019; Gao et al., 2021). Previous studies have shown that they are all directly and closely related to the TSBL culture (Festa 2018; Yang 2018; Subei et al., 2019; Gao et al., 2021). In recent years, research has indicated that the Liushugou site is associated with the second phase of the TSBL culture. Based on burial practices, bronze objects, and alloy technology of the bronze, the site is believed to be the inheritor and continuation of the TSBL culture. The Wupu cemetery corresponds to the late third to fourth phases of the TSBL, and the similar bronze bell and bronze mirror excavated also show strong links with the TSBL, but the painted pottery presents a rupture from TSBL, both forms and motifs are different from those of TSBL, also the new type of the bronze knives and earrings, as well as the different burial practice shows distinct cultural characteristics. The bronze inventory of Yanbulake displays continuous development from TSBL, inheriting personal ornaments such as plaques, earrings, and buttons (Mei 2004). The preference for body ornaments persisted; but certain types of bronze artefacts, such as large plaques and spiral tubes of TSBL disappeared, whereas iron artefacts emerged into use during this period (Mei 2004). As a general trend, the bronze artefacts turn smaller and cruder in quality and may witness degeneration. These cultures mentioned above demonstrate the profound influence that the TSBL had on the material culture of the Hami region in terms of bronzes, which represent a continuation of the technology transmission, economic patterns and consumption habits in the region over a certain period, which will be discussed later in this thesis.

2.3.4.2 The Other Parts of Xinjiang

The present research suggests that the earliest bronze culture in Xinjiang is the Qiemuerqieke culture, which is located in the Altai region in the north of Xinjiang. The chronology of the Qiemuerqieke culture has been controversial, but there is now general agreement that the early Qiemuerqieke culture can be traced back to 2400-1700BC. A range of materials is included in the grave goods including pottery, stone, stone moulds and metal. A total of 7 copper and bronze objects were recovered from the Qiemuerqieke site, including a knife, spearhead, drill and arrowheads. In addition, two stone moulds were recovered, which have been a long time indicating relatively advanced metallurgy of the Qiemuerqieke early phase. One mould was intended for casting knives and awls. The second mould was intended for casting spades with a peculiar loop on one side. Therefore, only a few small artefacts were found in the Qiemuerqieke site, and its metallurgy is characterized by a basic production of a few simple tools.

The earliest metal production site in the Bronze Age of Xinjiang was the Jirentaigoukou site discovered in the Nileke Township of the Ili region in the Northwest of Xinjiang. Jirentaigoukou site is the largest and earliest Bronze Age settlement discovered in the Ili region to date also including the cemeteries. The Bronze Age settlement dates to two phases, the first phase is 1600BC-1400BC, and the second phase is 1400BC-1200BC. The cemeteries of the site are dated 1200BC-1000BC (Wang et al., 2019; Yuan et al., 2020). The site is 400 meters from east to west and 200 meters from south to north, covering an area of 80,000 square meters. From 2015 to 2018, 37 house foundations and 8 tombs were excavated, discovered around 1000 pieces (sets) of artefacts, including pottery, stone, bronze, and bone artefacts. Only a small amount of the bronze objects were recovered from Jiretaikoukou, including the knife, drill, needle and earring, etc (Wang et al. 2019). Nonetheless, there is a large amount of metalworking-related finds were discovered, such as ceramic moulds, smelting furnaces, copper ore, copper ingots, windpipes, crucibles and slag, which is the first discovery of the complete metallurgical production evidence in prehistoric Xinjiang. There are only very few copper ore and slag were found, therefore the excavator suggest that the raw material source of copper ore processing into copper ingot at the mine nearby and transported to the site, then processed to make the bronze object. Hence, the site is the second production site, which these ancient residents mainly undertake to make finished bronze products, with fewer smelting activities (Yuan et al., 2020). There are three ancient copper mine sites in the vicinity of the Jirentaigoukou site, were Nulasai, Yuantoushan and Kezilakezangbei. The Nulasai copper mine is thought to have been one of the possible sources of ore for the bronzes of the Hami region (Mei 2000; Yang 2018, Liu et al. 2020). There are other Bronze Age sites discovered in Neleke county coherent with Jirentaohoukou, including Kuokesuxi II cemetery, Wutulan cemetery, Kalasu settlement, Qianegeer settlement, and Tangbalesayi cemetery. The excavator believes that Kuokesuxi II, Tangbalasayi, Qialegeer and Wutulan share similar burial practices, similar pottery types, linked with Andronovo but with its unique regional cultural identity, presented the Andronovo Culture “Tangbulesayi” type (Ruan 2014). Shuitao suggests that all these sites have a strong connection with Jirentangoukou during the period, he argues that Jirentaigoukou is the centre of the Ill valley, and the population itself has closely related to metallurgical production. Around the site, there were relatively large social groups that operated and lived around the metallurgical industry (Shui per comm).

As previously mentioned, another well-known early Bronze Age culture is Xiaohe and Gumugou in the Tarim Basin, which has a distinct cultural identity in many ways, such as strong symbolic burial practises and distinctive organic preserved burial goods that are unlike any other contemporary culture in Xinjiang or elsewhere. Although the Xiaohe culture was a rather closed society in terms of both geographical location and cultural factors, it does not mean that the societies were isolated, it is still possible to see exchanges with neighbouring cultures of the same period, due to the different cultural elements in the burial goods, such as bronzes, camel hair (from Central Asia), grains of wheat (from the west) and millet (from the east), etc (XIA 2007; Zhang and Zhu 2011). There are in total of 14 pieces of bronze objects discovered from Xiaohe, including 12 small pieces of bronze sheet, 1 tube and 1 arrowhead. There are also 7 silver gold earrings and 1 pure tin earring found from Xiaohe (XIA 2007; Mei et al. 2013). The result of the SEM indicates that most of the bronzes were tin bronzes, with one pure copper, one arsenic copper and one leaded arsenic bronze showing the diversity of the alloys, suggesting that all of the metal objects from Xiaohe obtained through exchange or trade with the surrounding area (Mei et al. 2013), and TSBL could be one of the origin resource, especially the object made with low arsenic alloys, as the TSBL is the earliest site to use the arsenic copper in the Xinjiang during Bronze Age.

In previous research, it was pointed out that the culture of TSBL is very diverse, and there are many cultural influences from the external Eurasian steppe, such as the bronze handle mirror, the knives with grooved or decorated handles and the short sword all show the strong style of the Eausian steppe culture (Mei 2000; Festa 2018). There is no evidence of direct contact with TSBL to these Eurasian steppe cultures so more likely that the cultural interaction was obtained indirectly from the surrounding area, and at the same time, they also accepted the influence brought by the culture of TSBL, especially the dissemination of bronze technology. The main cultural groups mentioned above and the TSBL culture together form a channel and network for interaction. The changes in population, technology, culture and economy under this network have formed the context of human activities in the Bronze Age of Xinjiang, which is also one of the focuses of the subsequent discussion of this paper.

2.3.4.3 The Hexi Corridor in Gansu, China

The Hexi Corridor is located in Gansu's northwestern region and borders the Hami region to the east of Xinjiang, a region with a unique geographical location that led to the development of early cultures with their complex diversity, and this region played an important role in prehistoric cultural exchange between East and West. As a result of decades of archaeological research and discovery in Gansu, it has been possible to determine the sequence in which archaeological cultures developed during the prehistoric period, defining their connotations and chronology, such as the Majiayao (3300BC-2000BC), Xichangyi (2100BC-1600BC), Qijia (2000BC-1500BC), Siba (1700BC-1300BC), Xindian (1500BC-1000BC), Siwa (1400BC-1100BC), Kayue (900BC-600BC), and Shajing (900BC-500BC). During the past few years, research on bronzes from Gansu has revealed that the Hexi Corridor, which spanned the Majiayao-Machang (2000-1800BC), phase of the Majiayao culture-Xichengye-Siba cultures had mastered metallurgy at an early stage, resulting in large-scale, high-intensity metallurgical production activities (Chen et al., 2018). The Hexi Corridor was the mainstay of arsenical copper technology, and the Xichengyi site is the earliest metallurgy production centre found in northwest China (Chen et al., 2015). Research conducted by scholars such as Shui Tao and Li Shuicheng has revealed that artefacts excavated from the TSBL are closely related to Siba culture from the Hexi Corridor. Li Shuicheng (2009) points out that the painted pottery excavated from the TSBL cemetery shares many similarities with Siba Culture pottery, that the pottery types are closest to the Ganguya cemetery site of the Siba Culture, and that the bronze excavated from the TSBL cemetery is very similar to those from the Siba Culture, with major ornaments, tools, and weapon types all being found in the Siba Culture. Thus, these similarity factors show evidence of the two communities possibly share the same bronze consumption habits and bronze technology and are culturally comparable.

2.4 Metallurgy

In Bronze Age Eurasia two copper alloys prevailed: arsenical copper and tin bronze. The former had been in use since the late fifth millennium BC in Western Asia (Eaton and Mckerre, 1976; Muhly 1988; Chernykh, 1992; Festa 2018). Until ca. 2000 BC, arsenic bronze had spread in Eurasia and remained the more common of the two bronze alloys throughout this territory. The intensive use of arsenic bronze was facilitated by the greater availability of raw materials, while tin ores were rarer, being located in a narrow belt stretching from Europe to Southeast Asia. From the early second millennium BC, tin bronze replaced the arsenic variety throughout most of Western and Central Asia (Mei 2003a). Diverse theories have been formulated to explain the abandonment of arsenic copper alloys and their gradual replacement by tin bronze, such as the superior properties of the latter (when compared with arsenic bronze, the tin-copper alloy is harder and stronger, and shows better mechanical properties, its controllable composition versus the difficulty to control that of arsenic bronze alloy (due to the high volatility of arsenic and its compounds), and the toxicity of fumes produced by arsenic, thus posing the risk of poisoning (Tylecote 1976; Ravich and Ryndina 1995; Festa 2018). Although the reason behind the replacement of arsenic bronze is still unknown, the employment of tin bronze most likely signifies the Bronze Age communities' achievement of new metal technology and the existence of tin trade networks. The use of tin bronze and arsenic bronze not only demonstrates the different alloying techniques, but also the different sources of raw materials and the use of resources. The different sources of raw materials may have had a variety of effects, including population, migration, technology and trade, all of which were part of the productive and economic activities of the society. Through the study of bronze, we seek to explore further the use of the raw material and the social implications behind it, in order to understand the role and significance of bronze use and technology in society at the time.

The early use of both tin and arsenic bronze in Xinjiang, verified in the early second millennium BC in East Xinjiang, is TSBL cemetery, which is the largest Bronze Age cemetery site in East Xinjiang. This thesis will offer a detailed study of the bronze objects discovered in the TSBL, in terms of typology and alloys technology associated with the production and technology in order to understand the social drive for acceptance and adoption of these sophisticated changes.

As previously mentioned, the material culture at Tianshanbeilu consists of two major bodies of artefacts: pottery and copper-based objects. The repertoire of pottery, particularly the painted wares, provides a clear typological connection to those of the contemporary Siba and Qijia cultures in the Hexi Corridor, strongly implying an East connection (Mei, 2000; Li, 2005; Han, 2007; Mei et al., 2015). An initial study of the metalwork from the site also supports this connection. The personal adornments and small implements which dominate the assemblage, earrings, bracelets, mirrors, beads, plaques, buckles, knives, awls, axes and tubes show close similarities in typology to those recovered from Siba and Qijia sites (Qian, 2006; Mei, 2000). Similar alloying practices are also widely shared across these regions.

The metalwork at TSBL also shows connections stretching out to the north and west into the Eurasian steppe. Typologically speaking, the closest ties with neighbouring areas of the steppe are seen in the Late Bronze Age, associated with the late Andronovo and Corded Ware horizons in East Kazakhstan and southern Siberia (Kuzmina 2007: 265). In their initial review of this material evidence for contact between western Xinjiang and the steppe, Mei and Shell (1999) concluded that the East boundary of ‘Andronovo cultural influence’ may have reached as far as the Hami region. The finds from Tianshanbeilu may suggest a somewhat broader chronological pattern of contact. It has been suggested that general material categories seen at Tianshanbeilu find parallels with both the earlier Middle Bronze Age communities of the Sayan-Altai and the characteristic material of the Karasuk culture (Zhang 2017).

The similarities shown between these objects and the surrounding culture at TSBL, in addition to demonstrating the exchange or trade between the community, may also encompass a range of socially relevant issues such as population migration, cultural influences and integration, and the acceptance and spread of technology, resulting in its complex and diverse material culture. Through the connection of bronzes from TSBL with those of the surrounding area to understand its relationship, which is the significance of this study, to understanding the extent and impact of the interaction between TSBL and the different cultures of the surrounding area. The following table shows the region and chronology of all the cultures in Xinjiang that mentioned in this chapter

Region	Location	Site Name	Period
North Xinjiang	Alety	Qiemuerqieke	1100BC
Nourtheast Xinjiang (Ili)	Nileke Township	Jirentaigoukou	1600BC-1000BC
	Nileke Township	Wutulan	1600BC-1400BC
	Nileke Township	Kalasu	1200BC-1000BC
	Nileke Township	Qialegeer	1600BC-1500BC
	Nileke Township	Tangbasaleyi	1600BC-1500BC
	Siteke Township	Kuokesuxi II	1500BC-1300BC
Southeast Xinjiang (Tarim Basin)	Lop Nur	Xiaohe	2000BC-1500BC
East Xinjiang	Hami	Liushugou	1610BC-970BC
		Yanbulake	1500BC-1100BC
		Wupu	1400BC-1000BC
		Nanwan	1300BC-900BC

Table 1 The cultures in Xinjiang mentioned in this chapter

2.5 Summary

The overview of Xinjiang research within this chapter has a brief introduction to the physical environment of Xinjiang to better understand the ecological context of the Bronze Age cultures in the region. Recent progress in the study of prehistoric Xinjiang history is broadly reviewed, followed by a review of previous studies of the Bronze Age and a discussion of the frameworks that have been proposed by different scholars, providing a background for the present study. The last part of the chapter proposes the framework adopted for the present study and briefly discusses the issues that this thesis addresses. Therefore, this chapter highlighted how the development of particular paradigms has directed the analysis and understanding of the material culture, and the Bronze Age as a period generally. The emphasis placed on the diversity and complexity of cultural differences between the regions has left us with a conflicting and incomplete picture of the Bronze Age of East Xinjiang. Using the conceptual approaches and analytical methodology outlined in the following chapters this thesis builds on, and adds detail to, the current understanding of metallurgy tradition during the Bronze Age of East Xinjiang. This will provide a coherent picture of metallurgy transmission, the location and interaction between potting communities, and explore the motivations behind their choice.

Chapter 3 Methodology and Analytical Approaches

3.1 Introduction

The study of Bronze Age Xinjiang, discussed in the previous chapter, has involved a large number of scholars, whilst excavations and targeted studies have intensified recently as interest has grown in the mobility of humans and technologies from the Far East across the Eurasian continent. Collectively, the studies make a significant contribution to our understanding of ancient Xinjiang and encompass a wide variety of perspectives. Some are exemplified by the study of metallurgy, others of climatic change, landscape, technologies, craft production, chronology, human diet, social organization, ritual practice, and ultimately, human interaction. This thesis chooses to focus on copper alloys and artefacts, products of a technology which comprises a key innovation in prehistory. The transmission of technologies and styles across the important corridors of Xinjiang has great potential to look at the movement of people, ideas and practice. In choosing to focus on the rich site of TSBL, this thesis aims to integrate chemical analysis and insights into alloying practice. Crucial to this approach, and the fostering of a new dialogue is to develop an innovative methodology. The role of this chapter is to provide such a background to the study.

The aim is to explore metal use among TSBL Bronze Age communities in terms of typology and contextual perspective. As a result of the typology study, the bronzes of TSBL could be understood in terms of different categories and certain aspects of style developments of the time were revealed, as well as the difference between the four periods of the technology practice. The contextual analysis is opposed to a temporal or simple technological perspective, one of the cores of this project is to generate a contextual study that identifies the presence of metal in funerary contexts and at times its absence, whilst integrating an extensive compositional study of the metal objects to extend our understanding of the different ways in which they were manufactured. The contextual study is based on a wealth of archaeological reports and publications ranging from unpublished reports or grey literature, along with details of specialist institutional excavations. The excavation report of TSBL has not yet gone to print, but thanks to the generous granting of access to a range of data, the full catalogue of the site and its metal objects site are supplemented in this study by targeted study and analysis. The study's task is to integrate the dispersed finds and results from the excavation so that they can be subjected to a general investigation of metal consumption in the cultural processes of TSBL while contextualising the artefacts' style and distribution with some details of their manufacture. The intention is to highlight the close association between metal, other materials, artefacts and funerary practice as well as human remains. While this is a formidable task, dependent on the collaboration of a wide academic network sharing data, it is hoped to produce an integrated study of the Bronze Age communities in Eastern Xinjiang. Metal objects discovered among the archaeological remains have been analysed typologically and in particular, this study undertakes an extensive analytical study to explore the alloy variation of the TSBL site.

Combining previously published analytical results with existing data from the published literature, it is clear that multiple alloy compositions were employed at TSBL (Mei, 2000; Qian, 2006; Liu et al. 2020;). At present, 123 metal analyses have been published, a small sample compared to the total amount of metal objects recovered from the site. TSBL is the largest Bronze Age site in Xinjiang, with 706 tombs of which 409 contain metal artefacts that total more than 3000. This research analyses 1352 metal objects, derived from 406 graves from the TSBL site, representing an almost complete coverage of the graves with metal. This is the first time that such a large amount of data has been collected and analysed on metal objects in a single cemetery site in China. Whilst accepting the analytical limitations of pXRF, this project aims to use its important potential to take chemical analysis into the field and the storeroom, to conduct compositional analysis on a large scale and on objects that would not otherwise be available for analysis. This might be thought of as an exercise in "big data", as one of the key research purposes of this thesis is to find out what sort of insights can be achieved with such a large-scale analysis of total assemblages in archaeometallurgy. With the results of the analysis, it is hoped to devise a straightforward set of tools that allow us to see how humans interact with metals over time. Combined with the new and more accurate chronology for TSBL developed recently (Tong et al. 2020), and taking into consideration the social context of TSBL assemblage, it focuses on the social and technological significance of metal artefacts and alloy types in the Bronze Age to discuss the critical role of Eastern Xinjiang and its relationship with other regions in the Eurasian Steppe.

3.2 Theoretical Approaches

Archaeological studies are fundamentally concerned with material culture, mainly the study of the physical remains of human action (Sackett 1990). Questions about material culture necessarily relate to the behaviour of people and the activities in which they took a part (Sackett 2011). Among the range of cultural artefacts, materials, and practices that are discussed in these syntheses it is metal objects and metallurgical practices are often used to highlight interaction among communities both in terms of exchange and adoption of cultural practices. Existing material culture studies of Bronze Age Xinjiang, especially those examining metal objects in the area, have focused on establishing important technical aspects of the material (Mei 2000; Jia et al. 2019) while also integrating such studies into wider narratives of cultural interaction across the Steppe region (Kohl 2007, Anthony 2007). Indeed, the issue of cultural transmission (a term worthy of critical analysis, as will be discussed) and interaction across the Steppe has emerged as a central research focus for many scholars in recent years despite the significant lack of data and evidence to stimulate academic debate. Instead of the close study of regionalised material, academic interest has tended to focus on abstract models and the extrapolation of these limited and localised datasets across expansive geographical zones. This overwhelming tendency among western scholars to simply deploy existing fragmentary and isolated datasets toward addressing fine-grained issues of cultural interaction has meant that many syntheses remain unconvincing (Kohl 1987; Roberts et al. 2009; Anthony 2007, 2009) or problematic (Frachetti 2012; Hanks & Doonan 2012; Mei 2013). It is widely accepted that there is a need for fresh data that has emerged from projects which have adopted a fine-grained micro-regional approach that seeks to establish the local conditions that inform how material culture is employed in these communities. It is precisely this aspect that this study aims to address.

Aspects of material culture that derive from complex cultural practices such as copper metallurgy have become the focus of many studies because their complexity allows for many elements to be subjected to the comparative analyses that are at the heart of cultural transmission studies. The complexity of copper metallurgy and the apparent similarity in some aspects of material culture (Roberts et al. 2009; Anthony 2007) have been argued to indicate the transmission of this technology and that it represents the traceable movement of communities, ideas and things. Such studies are not only frustrating because they fail to address the precise mechanisms and local conditions responsible for such assumed transmission but in addition, they cannot be considered credible until they more fully consider the extensive bodies of material evidence that are too often entirely eclipsed by the explanation of the "model" itself. In a previous debate, (Frachetti 2012, see also replies to the paper) the problems that attend the study of early steppe pastoralism have been highlighted while emphasising the fragmentary and dispersed nature of archaeological data, the absence of coherent dating and critically the tendency of scholars to conflate varied steppe communities into "monolithic units" of study (Hanks and Doonan 2012). To summarise the debate, the challenges of how we are to address social development and interaction in this area were discussed along with the clear conclusion that it is now important to generate robust data sets for specific geographic regions through which local traditions can be understood before the integration of such datasets into larger broad-ranging (and often unwieldy) syntheses (see comments and replies to Frachetti's article in Vol. 53 of Current Archaeology). To some degree, Frachetti acknowledges this issue with his thesis on multiregional trajectories in the Inner Asian Mountain Corridor. Yet despite the clear lack of resolution in the archaeological material he discusses, he remains committed to offering a broad synthesis. The overview of zooarchaeological evidence for the region is certainly convincing, yet this can tell us little directly about specific transmission mechanisms and processes nor of other activities particularly the movement and use of material culture and especially metals which traditionally have been held as one of the pivotal artefact types and technologies in the transmission of cultural practices.

The study was undertaken here, therefore, acknowledges these issues and develops a programme of work that seeks to establish the variability in approaches to the procurement and use of metal goods in this region at a critical period in Eurasian prehistory. This is, of course, a significant ambition as although it is held that Steppe communities developed along historically specific trajectories, there is an implicit assumption in the definition of wide geographies of study that these communities were undoubtedly connected in intense and organised interaction, this is most often seen as long-distance elite interaction for prestige goods and practices (from metallurgy to political organisation to horsemanship and possibly marriage partners) (Anthony 2007; Frachetti 2012). The presumed long-distance interaction under the control of elite groups has in turn stimulated an academic tradition of sophisticated and far-reaching model building. In short, the understanding of steppe communities has been conceptualised as a wide-ranging problem that needs to be addressed or explained at a continental scale and is therefore one that presents a significant intellectual challenge. Unfortunately, the challenge of the grand synthesis has lured scholars away from detailed contextual studies of material in favour of generating endless models for political control and interaction, with the result that much of the material culture, not to mention cemetery and settlement evidence, remains unstudied across much of the region that such encompassing models seek to explain. The programme outlined below questions the intellectual sentiments that have framed the majority of studies that have addressed steppe communities. It proposes a different perspective explore this important region which has more commonly been subsumed within extensive studies of steppe socio-political and economic interaction. There is a need to move away from the archaeology of the Eurasian steppe that is centred on large-scale models and grand narratives toward micro-regional studies which aim to explore regional cultural trajectories on their terms without necessarily and automatically being pressed to elaborate on the interaction between communities which may be 1000km and centuries apart. Therefore, it is with this background that this thesis undertakes a contextual investigation of material culture from the TSBL cemetery site in the Easter of Xinjiang, China.

Numerous analytical works over the last 30 years by Mei (2000, 2013), Qian et al. (2001), Liu (2020, 2021), and Gao (2021) have applied science-based approaches to the study of metalwork from Xinjiang to address archaeological questions of alloy selection, development, distribution, and provenance. But none of the work has drawn broader conclusions by placing these chemical characteristics within a wider social or historical context due to the lack of established chronological sequences and typological studies. Responses to the questions are not straightforward, even when cutting-edge analytical tools are being used (Liu et al. 2020, 2021). It would be advantageous to combine such work with precise chronology and detailed typology study to promote a better understanding of the metallurgical tradition of TSBL Bronze Age communities.

The typological study of Bronze Age metal artefacts from TSBL will be classified at a functional level into 14 categories: knives, socketed axes, awls, short swords, mirrors, plaques, pao (circle dress ornament), tubes, buttons, bangles, earrings, buttons, bells and beads. The sub-groups identified in these categories of function are made based on stylistic differentiation. Additionally, it aims to systematically examine the major types of metal artefacts from a wider, comparative perspective in the light of the temporospatial criteria, examining regional patterning along with the chronological sequence. By highlighting the potential of alloying composition analysis, it is possible to identify and characterise changes in metal technology and thus discuss transformation in production and organisation. However, one needs to keep in mind that TSBL is a consumption assemblage and that material will be from a variety of sources. Therefore, any attempt to look at diachronic technological change and production must first establish what is like to be broadly local material. In this work, such indications are approached in the first instance through the artefact style, but this also highlights the need for further well-dated excavation evidence in the future over wider areas.

3.3 Overview of Recent Archaeometallurgical Study in Xinjiang, China

3.3.1 The Past to Present

Bronze is the distinguishing metal of the China Bronze Age and has been the focus of archaeological and scientific inquiry for more than a century. The majority of archaeometallurgical research has concentrated on identifying the geological origins of the primary metals, copper and tin, as well as their transit from producer to consumer sites. Recently, there has been a lot of focus on the temporal and geographical impacts of recycling on the composition of the circulating metal supply. Furthermore, scholarly debates on the value and perception of bronze, both as individual artefacts and as hoarded material, persist. The following section's major goal is to present an overview of recent archaeometallurgical research on copper-based metals in Bronze Age Xinjiang, China.

Quantitative chemical investigation on Chinese copper-based metal items dates back to the 1770s, but for a long time, all attention was focused on the central plain (Liu et al. 2015). China has given extraordinary finds of copper alloys since 1928 when Yinxu (the late Shang capital of 1250-1046 BC) of contemporary Anyang was systematically unearthed. Yinxu, or Anyang, is commonly recognised today as one of the Chinese Bronze Age's (1900-200 BC) pinnacles (Liu and Chen 2012). However, as previously stated, chemical analysis of copper-based artefacts predates these findings substantially. The majority of those carried out after World War II have occurred in Europe and North America, although others date back far further. In general, the history of chemical analyses in China has been very little discussed in the English language literature. Research on metal objects unearthed in Xinjiang has been relatively even less compared to what has been published on the Central Plains. Until the 1980s, metal artefacts in Xinjiang have just begun to be the subject of scientific studies (Mei 2000; Qian et al. 2001). Despite the recent interest in the topic, relatively few elemental and metallographic studies have been performed on Bronze Age remains. A great contribution has been provided by Mei Jianjun, He tried to reconstruct the early history of metallurgy in Xinjiang by conducting technical analysis on 168 samples taken from early metals and slags from different parts of Xinjiang, with 19 samples being taken from Tianshnbeilu (Mei 2000). Qian (2006) published data from the analysis of 89 copper alloy objects from Tianshnbeilu. Their compositional analyses of the metal objects were conducted using SEM-EDS (scanning electron microscopy and energy dispersive spectrometry). As the result, in the early stages of metallurgical research in Xinjiang great efforts were largely directed toward disentangling the relationship between alloying elements in objects and related technologies. Additionally, metallography was used by scholars to investigate production techniques, such as casting, annealing, cold working, and so on. Unfortunately, in part due to the lack of chronology sequences in both research, it was difficult to draw broader conclusions by placing these chemical characteristics within a wider social or historical context. Xinjiang's steppe culture sites are more difficult to date than those of Central China where chronology and stratigraphy can be applied, as well as textual evidence such as bronze inscriptions and oracle bones. The problem is even more complex in TSBL due to the stratigraphic sequence of the cemeteries being very difficult to determine.

The archaeometallurgy work during the last three decades in China involves several important topics. These topics include the origins of Chinese metallurgy technology, smelting technology, piece-mould casting, simulation experiment, special manufacturing technology and provenance. Provenance, or the sources of metal, forms a key concept which assumes that there is a chemical connection between a metal's composition and the ore from which it was obtained. Copper alloys have been the subject of provenance questions since the 1840s in Europe (Pollard 2013; Liu 2016), but it was not until after World War II that modern analytical instruments such as optical emission spectroscopy became widely employed for the chemical analysis of archaeological metal artefacts, thus increasing the number of analyses conducted (Liu 2016). A key component of provenance studies is the use of trace elements, as they can elucidate the relationship between objects and a particular mine or between objects themselves. Scholars state that, by comparing concentrations of a group of selected elements in finished objects and copper ores, it is possible to reveal the provenance of these metal objects, or at least rule out some candidates. For instance, based on geological background, partitioning of trace elements in smelting, measurements of copper ores and statistical analyses, the provenance research performed by the University of Science and Technology China (USTC) proposes Au, Ag, As, Sb, Bi, Se, Te, Co, Ni as the proxy for the copper source (Qin *et al*., 2004; Qin *et al*., 2006; Li 2010; Liu et al., 2015). This is because concentrations of these elements theoretically characterize and distinguish different copper mines and object assemblages. By comparing the results of copper sources and that of artefacts, the team in USTC asserts that it is theoretically possible to (dis)connect one to another. The Freer and Sackler collections in the West are the two most widely-known databases concerning trace element chemistry in Chinese bronzes (Bagley 1987; Pope et al., 1967; Rawson 1990; So 1995; Liu et al., 2015)). The researchers in China have conducted more trace element measurements, such as the sites in Yinxu, Hanzhong (1400–1046 BC), later phases of Panlongcheng (1400 1250BC) and Qianzhangda (1250–1046 BC) (Qin et al., 2004, 2006; Wei 2007; Li 2010; Liu et al., 2015). Despite the growing amount of available data, its quality and therefore its usability vary greatly. Most publications contain no information about the calibration standards or analytical precision or limits of detection. It is very hard to evaluate data quality when no such information is available since most instruments compare unknown samples to known ones (primary standards) and estimate precision and limits of detection based on multiple measurements of secondary standards. (Pollard 2007; Liu et al., 2015).

Another line of tackling the provenance question is to use lead isotopes. Lead isotopes have been widely used in archaeological research since the 1960s to investigate copper sources (Liu et al., 2015). The first lead isotopic analysis of a Chinese bronze is that of a ritual vessel from the Western Zhou reported by Brill and Wampler (1967), in what was also the first paper on the lead isotope analysis of any archaeological metals and glass. Later, much larger-scale research projects were undertaken in cooperation between Chinese, Japanese, and western scholars. It also produced databases of lead isotopes and trace elements. Relative to those large-scale scientific projects in Europe which produced tens of thousands of analyses, the work of using trace elements to characterize and source metals in the central plain of China is still in its infancy, with only around one thousand analyses (Liu et al. 2015). The published lead isotopic data of metals found in Xinjiang is relatively small compared to those found in the Central Plains. In total, 220 lead isotope measurements have been published on copper-based objects from Xinjiang (Mei et al. 2012; Subei et al 2019; Liu et al. 2020; Gao et al, 2021; Liu et al. 2022). It is only available for the metal assemblage in Ili, the TSBL Cemetery, Wupu Cemetery and the Liushugou Cemetery at Hami (Subei et al. 2019; Liu et al. 2020).

The main issue of concern is the behaviour of trace elements throughout the life cycle of copper alloy objects from extraction through smelting and casting to mixing and recycling is complicated. Without examining the biography of the object and the behaviour of the trace elements in the copper, it is impossible to definitively associate any given copper alloy with an ore source. Metals, especially tin, are scarce resources, so ancient societies recycled metals or mixed them, Budd et al. (1996) suggest that this must have been a common practice. By using such practices, any chemical link between the ore source and metal artefact would potentially be broken (Hsu et al., 2016). In fact, Ixer (1999) claims that ore deposits vary so widely in geochemistry and mineralogy that attempting to reconstruct precisely this relationship is tough (Hsu et al., 2016). Another thing to keep in mind is that the key step following analysis is determining how these data should be interpreted archaeologically. Statistical techniques used included cluster analysis, principal component analysis, and discriminant analysis (Liu et al 2015). These methods must be used critically and correctly to extract meaningful chemical groups. The amount of information required for archaeologists to interpret clusters of artefacts can be dramatically reduced by selecting the appropriate statistical method. Even minor changes in parameters can result in dramatically different results (Liu et al ., 2015). In response, Pollard (2009) recommended that interpretations should only be considered if they have been reproduced using multiple independent statistical methodologies and that details of the analysis should be fully recorded and published (Pollard, 2009). So recently, Pollard has disputed the analytical usefulness of techniques that aim to identify clusters within metal chemistry datasets, as recycling, mixing, and differential oxidation would stretch out and smear signatures rather than lead to isolated clusters of data.

3.3.2 The Oxford System

Being aware of the problem outlined above, in recent years, The University of Oxford's Research Laboratory for Archaeology and History of Art has developed a systematic approach to metal chemistry that uses trace elements, alloying elements, and lead isotopes to provide perspective on the overall metal flow underlying an assemblage of materials. Especially as part of the FLAME ERC project, they have explicitly presented an integrated system from philosophy to practical tools to characterize metal chemistry in archaeology, which now has become known as the Oxford system (Bray et al. 2015; Pollard et al. 2017; Liu et al. 2020). Through tracking the chemical variations between different metal assemblages on different scales, the aim is to capture and comprehend changes in metal or copper-based artefacts across time and space. This result on its own is rather useful because it creates a basis for scholars to discuss the movement of metal, local management, an agency of raw metal and objects, economic crises and so on, particularly when it accommodates both provenance and mixing/recycling. The Oxford group also introduced a new set of diagrams of lead isotopes, which plot the reciprocal of lead concentrations against one lead isotopic ratio (Pollard and

Bray 2015). This new set of graphical methods developed by Oxford has allowed them to combine lead percentages, lead isotopes and trace elements altogether.

This new approach has been applied to many social systems, such as the British Bronze Age (Bray and Pollard, 2012; Bray et al., 2015) and Roman Britain (Pollard et al., 2015), Age Alps (Perucchetti et al., 2015), the Iranian plateau (Cuénod et al., 2015), the Eurasian steppe (Hsu, 2016; Hsu et al., 2016), and Shang China (Liu 2016, Liu et al 2020). The most recent work includes 46 samples selected from copper-based objects from the TSBL cemetery (Yang 2018; Liu et al. 2020), 44 objects from the Ili region and one copper ore from the Nulasai mine in Xinjiang China (Liu et al. 2022). This new method is combining lead isotopes, trace elemental, and alloying data that demonstrates the great potential of the small number of samples collected and indicates that the TSBL should have different sources of ore, one of which is likely to be the Nanusai copper mine in Ili, while the same source is likely to have been used as the Huoshaogou site of the Siba culture (Yang 2018; Liu et al. 2020; Gao 2021). As this method relies on sample data to reconstruct flow within the metallurgical network, it is bound to encounter issues such as insufficient information and sampling bias and sometimes chronological uncertainty. The general lack of data, which limits the ability to work in detail on relationships between typology and composition, is perhaps the most significant problem encountered, as only 46 samples were taken from TSBL and analyses were performed without information on typology and chronology. The difference between the number of samples collected and the very large assemblage makes it lose the resolution to reconstruct the movement of metals and difficult to make draw conclusions about the overall characteristics of the metal objects found in TSBL. Therefore, this study is building on the firm foundations of this previous work, but opposite to the previous work, this thesis will be applied to much larger numbers of samples rather than focus on the small number of samples, as well as closely contextualised according to their typology and chronology, to extend insights from metallurgical analysis across the whole assemblage of TSBL. In this way, it is hoped that the combination of the existing data produced by an array of analytical techniques can be combined with chemical analysis by pXRF to provide alloying information on the whole assemblage that can be correlated with object function, style, date and cultural associations according to the individual graves in which the objects are found. Despite the potential analytical drawbacks of the pXRF method, its potential to analyse the majority of the whole assemblage will offer insights to change over time and alloying practice in different stylistic zones, to trace mobility and change over time in Bronze Age Xinjiang.

3.4 Handheld portable X-ray fluorescence (pXRF)

It is widely recognised that it is increasingly difficult to collect samples from bronze objects because of museum curation. Though museums themselves agree to be more involved with scientific studies, they would favour non-destructive analysis without taking the object out of the museums, such as portable X-ray fluorescence (pXRF). Portable X-ray fluorescence is an effective method for analysing the chemical composition of metal objects and is increasingly popular in the evaluation of archaeological sites or museums due to its non-destructive, non-invasive nature and its ability to examine artefacts, as well as its relatively low cost compared with other means of analysis (Frahm and Doonan 2013). Despite the technical capability to analyse archaeological materials using portable instruments, it is not always true that the methodological and theoretical frameworks exist that enable such activities to be archaeologically successful and significant (Frahm and Doonan 2013). The TSBL site has produced over 3000 metal objects, stored at the Hami Museum in Xinjiang. It is impossible for taking samples from all of them for SEM or other destructive analyses for chemical composition, with this large quantity of samples, which makes pXRF a very suitable analysis method.

The pXRF instrument used in this thesis was a Niton-XL3t (see Appendix for instrument specification). The instrument can be used for the analysis of metal alloys with alloy chemistry in as little as 3 to 5 seconds. A total of 1352 metal objects were analysed in this research. The measurements were conducted at three to six spots on the objects' surfaces, depending on their size. A measurement on each spot was taken for 50 seconds at 4,096 channels were taken for each sample at an acceleration voltage beam current of 50kV and a maximum beam current of 100 μA.

3.5 Data Quality

A major problem is that the copper objects from Xinjiang are invariably corroded, sometimes extensively, producing high but variable oxygen values as a result of a variable proportion of oxidized metal in the analysis. Therefore, a high oxygen concentration means the remainder of the analysis does not necessarily reflect core metal, but a mixture of core metal and oxidized corrosion products. In addition, it may not give an accurate analysis, since the corrosion product may also have elements introduced from the local environment, and corrosion can lead to the selective depletion of some elements, thus enriching the others. These restrictions have already been recognised in previously published data from Xinjiang. Recently, 46 metal objects were selected from TSBL for SEM analysis as part of a conservation project on Xinjiang bronzes that is being held by the Northwest University of China (Mei 2000; Qian 2006; Liu et al. 2020; Gao 2021). As a result of heavy corrosion, only 16 out of 46 objects were found to have a reliable composition. Therefore the substantial problems at TSBL and more widely in Xinjiang with corrosion of objects were recognised before the present analytical project. In an attempt to mitigate these issues, the selection of objects and the areas of analysis were chosen very carefully.

3.5.1 Sampling at TSBL

From over 3000 metal objects discovered from TSBL, 1352 were selected for analysis. In the sample selection process, all objects that appeared to be very damaged or severely corroded with the naked eye were passed over, while complete objects with a relatively smooth surface were preferred for analysis. This sample selection illustrates the advantage of using pXRF as an analytical approach due to its non-destructive, non-invasive nature. It was conventional for analyses to choose fragments that were damaged or incomplete as samples, and to discard intact and less severely damaged objects, making the data results more prone to error. In this way, the number of samples was rather limited and incomplete and failed to cover all types of metal objects. In that way, it was difficult to develop a comprehensive understanding of metal use in TSBL Bronze Age communities.

In this study, each sample was subjected to a simple cleaning before testing, mainly to remove any soil and dirt remaining on the surface of the article, but not removing surfaces changed by corrosion. For objects such as knives, axes, mirrors, plaques, pao (circular dress ornaments) and buttons, three different spots on each side of the surface were chosen to take measurements. In the case of tubes, rings, awls, bangles and earrings, five different spots were chosen for analysis. In the case of small-sized objects like beads, three measurements were taken at different angles. Thus, each object had between three and six value records. Any out-of-range values were removed, and the average of the remaining values was used as the final data result. The final alloy result follows the previously performed analytical study using a cut-off value of 1% for deliberate alloying (Mei, 2000; Qian, 2006; Pollard et al., 2017; Liu et al. 2020; Gao 2021).

Even though pXRF instruments and their applications have gained considerable attention in the archaeological community in recent years, criticism of their comparability and reliability has so far dominated the debate. Being well aware of the critical nature of the analytical performance of pXRF before selecting it as the analytic method, in this study a great deal of caution was exercised when interpreting pXRF data. Such portable equipment does have some technical limitations as well as issues related to the changes in the composition of ancient surfaces that need to be considered. Throughout this thesis, the main analytical focus has been on the alloy types used in the metal artefacts. The analytical investigation shows that pXRF is suitable for obtaining data of acceptable quality concerning the nature and approximate concentrations of the main components present in copper-based alloys such as tin and lead (Orfanou and Rehren 2014).

One way of examining the performance of the pXRF is to analyse the same objects with different instrumentation, Therefore 16 objects also analysed by SEM by the Northwest and the Oxford team have also been analysed in this research. It is encouraging that the alloy compositions are comparable between the published SEM data and the pXRF in this study in 15 of the 16 samples (Tables 2 and 3). The samples with varied analytical results can be seen to be due to a mistake made with data classification in the Northwest / Oxford study (see Table 2 and 3). Accordingly, pXRF is suitable as the main analytical method in this research study. This study used the same approaches to define the alloy type from the results as the Oxford team, 1% is used as the cut-off for the lower limit of copper alloying elements (Liu et al. 2020). When the content of elements such as Sn, Pb and As in bronze is greater than or equal to 1%, the element is considered to be the corresponding copper alloy type, and elements containing less than 1% are considered trace elements. When bronze is a multi-alloy, the metal elements are sorted according to their content, e.g. if the bronze contains both Sn and Pb, and the Sn content is greater than the Pb content, the material type is a Cu-Sn-Pb alloy (Cu-Sn-Pb), and when the Pb content is greater than the Sn content, it is a Cu-Pb-Sn alloy (Cu-Pb-Sn). elements such as Fe, S and O, are not involved in the alloy classification (Liu et al., 2020).

Object type	Arch. Num	Cu	Sn	Pb	As	Sb	Bi	Ag	Zn	Ni	Co	Fe	O	S	Total	Number of measurements	Elements over 1%
Plaque	M1:2-2	90.3	4.40	0.19	2.85	0.26	0.00	0.12	0.12	0.03	0.03	0.01	1.73	0.00	100.0	4	Cu-Sn-As
Plaque	M34:7	96.0	1.26	0.09	1.32	0.34	0.02	0.06	0.01	0.30	0.05	0.07	0.52	0.00	100.0	5	Cu-Sn-As
Tube	M37:2-1	90.5	7.33	0.18	0.15	0.11	0.01	0.08	0.03	0.10	0.03	0.10	1.36	0.00	100.0	5	Cu-Sn-As
Ornament	M53:1	78.1	12.20	0.23	0.11	0.04	0.00	0.04	0.00	0.02	0.04	0.19	8.99	0.00	100.0	2	Cu-Sn
Knife	M59:5	89.5	8.09	0.37	0.48	0.26	0.00	0.04	0.10	0.03	0.04	0.07	1.00	0.00	100.0	5	Cu-Sn
Earring	M64:5	88.1	5.33	1.09	0.48	0.34	0.00	0.18	0.00	0.05	0.06	0.14	3.74	0.50	100.0	4	Cu-Sn-Pb
Tube	M80:5	87.1	7.65	0.22	0.63	0.02	0.00	0.26	0.05	0.00	0.03	0.07	3.93	0.00	100.0	4	Cu-Sn
Bead	M93:3	84.8	9.43	0.98	0.06	0.03	0.00	0.03	0.06	0.03	0.01	0.00	4.54	0.00	100.0	4	Cu-Sn
Pao	M145:8	68.5	20.90	0.31	0.05	0.41	0.00	0.24	0.05	0.04	0.04	0.08	9.07	0.28	100.0	4	Cu-Sn
Tube	M202:3	96.8	0.65	0.24	0.07	0.03	0.00	0.04	0.00	0.06	0.06	0.10	1.94	0.00	100.0	5	Cu
Earring	M261:2	90.6	7.08	0.33	0.34	0.17	0.01	0.15	0.00	0.01	0.01	0.15	1.20	0.00	100.0	5	Cu-Sn
Ring	M298:6	79.9	11.80	0.67	0.27	0.10	0.00	0.09	0.06	0.05	0.03	0.28	6.31	0.54	100.0	4	Cu-Sn
Plaque	M376:7	91.9	4.97	0.13	1.90	0.17	0.03	0.10	0.09	0.00	0.02	0.06	0.61	0.00	100.0	5	Cu-Sn-As
Plaque	M571:2	73.8	14.70	0.28	2.23	0.07	0.00	0.36	0.09	0.03	0.11	0.18	8.13	0.00	100.0	2	Cu-Sn-As
Pao	M81:6	85.2	6.98	0.41	0.48	0.38	0.00	0.06	0.11	0.14	0.00	0.03	6.20	0.00	100.0	3	Cu-Sn-As
Plaque	M198:7	87.9	9.28	0.08	0.60	0.27	0.04	0.10	0.07	0.01	0.05	0.07	1.54	0.00	100.0	5	Cu-Sn

Table 2 Compositional results based on SEM-EDS from the Oxford team

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My compositional result based on pXRF

Object Type	M Number	Cu	Sn	Pb	As	Sb	Bi	Ag	Zn	Ni	Co	Fe	O	S	Alloy Type
Plaque	M1.2.2	91.119865	4.490625		3.876241							0.191032			Cu-Sn-AS
Plaque	M 34：7	95.9428261	1.566284	0.176546	1.080781							0.906498			Cu-Sn-As
Tube	M 37：2-1	93.2298149	6.00534	0.111414	0.31718				0.17465			0.161601			Cu-Sn-As
Pao	M 53：1	88.68258	9.928601						0.151635			1.220112			Cu-Sn
Knife	M 59：5	87.8272018	11.0524	0.346711								0.77369			Cu-Sn
Earring	M 64:5	85.9577445	8.635603	1.631831								3.774821			Cu-Sn-Pb
Tube	M80.5	94.615032	4.265135												Cu-Sn
Bead	M 93：3	93.5920772	6.053816									0.354106			Cu-Sn
Pao	M 145:7-8	70.3510729	29.00715		0.143054							0.49872			Cu-Sn
Tube	M 202:3	98.7398652	0.803807	0.097685								0.358643			Cu
Earring	M 261:2	93.2741574	6.27029	0.065079					0.155188			0.235285			Cu-Sn
Ring	M 298：6	86.1209446	12.35439	0.650366								0.874298			Cu-Sn
plaque	M 376：7	93.3152913	4.253156	0	1.285838				0.333823			0.811891			Cu-Sn-As
Plaque	M 571:2	91.194937	5.453141	0.130386	2.629784				0.134398			0.457354			Cu-Sn-As
Pao	M 81：6	88.9956954	8.22126		0.266293				0.19466			1.266293			Cu-Sn
Plaque	M 198:7	90.8186028	9.490337		0.16246							0.322495			Cu-Sn

Table 3 Comparable compositional results based on pXRF for this study

3.6 Analytical Approaches

The analytical approach of this thesis proposes to examine three aspects. The first is intended to undertake a contextual investigation of material culture from the TSBL cemetery site in East Xinjiang. Material associations will be established systematically through the population of a database that includes all artefactual evidence from site contexts. The burial and residential structures, human remains, grave goods and other findings are taken into consideration. This analysis allows for the establishment of the existence of the preconditions for the development of metallurgy (social organization, pyrotechnical knowledge etc…) and the cultural context in which metal production developed. So the overarching picture at the end is one of the distinctive patterns and meaningful variance across TSBL and between periods. An inter-grave comparison is undertaken using the database and chronology refined through the inclusion of recent radiocarbon dates from Northwest University. By incorporating the typology of artefacts and stratigraphic relationships, the development of the TSBL cemetery was divided into four phases. The first phase was from 2011–1672 BC, the second phase was from 1660–1408 BC, the third phase was from 1385–1256 BC, and the fourth phase was from 1214–1029 BC (Tong et al. 2020). Thus, it is possible to explore broad chronological changes as expressed by metal and critically see how metal was consumed in burial practices. In this three-stage analysis, the second stage is typology study, to characterize all copper-based objects into 14 categories, including knives, axes, awls, mirrors, plaque, pao (circle dress ornaments), tubes, buttons, bangles, earrings, arrowheads, bells, short swords and beads. Then the quantity of each category is calculated, and sub-groups are identified following the different styles of each category. This allows us to find out the distribution of the copper-based object under the typological category and then to further categorise those according to the four phases of the Tianshnbeilu site.

The third main aspect of the thesis involves the extensive physical analysis coupled with chemical analysis, focused on the composition of copper alloys at the Tianshnbeilu site. An examination of metal objects discovered among the archaeological remains has been carried out typologically, and then an extended analysis was undertaken to evaluate the different alloys found at the Tianshnbeilu site. Furthermore, the alloy groups are related to chronology/phasing to determine the technology choice or change over time, to have more understanding of the characteristic of the metal object of each phase, and to discover the trend of metallurgical tradition and metal usage.

Notwithstanding, in most objects analysed in this thesis, it is safe to argue that all objects are copper-based (as already indicated by their green corrosion surfaces) and that tin, arsenic and occasionally lead are the main alloying agents, even if it is not possible to give an accurate estimation of the original alloy composition. The most obvious issue is whether tin bronze is a later development or the product of one production region / technological tradition (or indeed a combination of the two). Arsenic content in raw materials will have an impact on the choice of the raw material, so we could ask whether it is an intentional choice to use arsenic-rich copper ore or the intentional alloying of copper with arsenic. There is also involved with leaded alloys such as leaded bronze (Cu-Sn-Pb), leaded copper and leaded arsenic bronze (Cu-Sn-Pb-As). This wide range of alloy types is quite typical of steppe metal assemblages (Chernykh, 1992; Hsu, 2016; Pollard et al., 2018). As a reference to the pattern of the result, we will see more discussion related to cultural influence and metal in circulation and distribution in Chapter 6. Furthermore, the relevant results will also be considered and studied in comparison to Geology and Mineral Resources, to increase the value of the information gathered from the samples that have been found at TSBL and better understand the state of exchange between the TSBL and neighbouring cultures. The final attention will be focused on the recent work done by Northwest university and Oxford team that produced 46 samples with lead isotopes. While 46 samples are not a large overlap, it at least gives some confirmation/touching point of the Oxford team's comments on some Lead Isotope data on those objects which can throw light on provenance.

3.7 Summary

This chapter introduced the methodology and analytical approaches of this research, focusing on the integration of the conceptual approach and the use of pXRF as the analytical technique. The method of analysis used in this chapter has been fully described. It has been argued that, though this might not mitigate all problems, the use of pXRF was chosen to allow the analysis of very large numbers of object compositions that would not have been possible to contemplate with destructive analysis and SEM. In other words, this thesis comprises a rather different, complementary approach which has its strengths, as well as weaknesses shared with all other similar projects.

Accordingly, the integrated approach put forward is well suited to answering the questions relating to major metallurgical traditions and metal consumption during the Bronze Age period in Tianshnbeilu. The successful integration of the conceptual approach and the analytical techniques presented will facilitate the identification of the methods of metallurgical tradition for TSBL metal objects which are presented in Chapters 5,6 and 7. In addition, it will also provide information on the interaction between metal objects and their materials, revealing the alloy choice and difference in practice over time in the region. Therefore, it will be possible to examine the metal circulation and distribution of particular alloy groups across the study area and beyond, revealing patterns of exchange and spheres of interaction between different communities during this period.

Chapter 4

Typology of the metal objects from Tianshanbeilu

4.1 Introduction

The earlier use of copper and other metals was one of the most important technological developments in prehistoric Xinjiang, and the form of metal artefacts is especially useful in indicating cultural interaction between different regions. To provide a further understanding of the interaction of different metallurgical traditions and the role that metals played in early Xinjiang, this chapter will systematically examine the major types of metal artefacts from the TSBL site. The objects considered derive mostly from the 409 graves at TSBL that contained metal objects. Typology has been used to inform issues such as the existence of Siba metal forms in Xinjiang, and the eastward spread of Andronovo culture/complex, originally derived from the central Eurasia steppe (Kuzmina, 2007). However, the overall picture of metal forms and their use in prehistoric Xinjiang still lacks clarity. This chapter seeks to shed some light on this issue.

4.2 Characterisation of the wider regional traditions of metallurgy

The Chinese north and northwest frontiers include Inner Mongolia, northern Shaanxi, the Hexi Corridor, and Xinjiang, all of which are steppe or semi-steppe areas where the pastoralist lifestyle prevails. The landscape is different from that of the agriculture-based societies in the Central Plains and Southern China. As a result of dramatic differences in geography, climate, and lifestyles, the way of using copper and copper alloying also appear to have been different (Mei, 2000; Linduff, 2004; Hsu et al., 2016; Pollard et al., 2017; Rawson, 2017; Liu 2021). In the Central Plains that were the heartland of the Bronze Age Shang and Western Zhou dynasties, one can often encounter tombs with strikingly rich amounts of metals, sometimes hundreds of kilograms (e.g., the Late Shang Fu Hao tomb with ca.1.6 tons of bronze) (Liu et.al 2022). Similar cases can be also found along the Yangtze River, such as Panlongcheng, Sanxingdui, and Xin'gan Dayangzhou (Liu et al. 2022). The prime object type is a ritual vessel made by complex piece-mould casting (this is a technique used for casting bronze) (Hsu et al. 2016; Pollard et al., 2017). In sharp contrast, metal production in the region of pastoral lifestyle such as Xinjiang is often characterized by small objects, including knives, tubes, beads, earrings, buttons, mirrors, etc. Some larger vessels have been found, but they only start appearring in the earlier Iron Age of Xinjiang around 1200 BC. Copper and bronze objects are found in most of the sites in Bronze Age Xinjiang, but there seems to be regional differentiation in terms of the quantities found. In general, the numbers of copper and bronze objects unearthed in Bronze Age Xinjiang contexts are larger in East Xinjiang than in the other regions. A broad regional differentiation exists also between the areas on either side of the Tian Shan mountains, with more metal found in the North than in the South. The total amount of metal recovered from the largest cemetery complex in Xinjiang is Tianshanbelu at Hami, with only around 20-30 kg (Liu et al. 2022). There is no evidence of metallurgical production has been discovered from Eastern Xinjiang during the Bronze Age period. The discovery of different types of bronze objects in Eastern Xinjiang points toward the existence of strong connections with the cultural groups of Siba and Kayue in Gansu, and also with western and northern communities that made use of bronze.

4.3 Classification of Bronze Age Metal Artefacts of TSBL

TSBL cemetery is the largest Bronze Age cemetery site in Xinjiang containing more than 3000 bronze objects and their study is of great significance for understanding the Bronze Age cultures of Xinjiang. The archaeological materials from TSBL have not yet been completely processed and published, there is only a small amount of the metal subject has been stylistically described. Also, no single typological study has been devoted specifically to the metalwork from Xinjiang in the Bronze Age period. The typological method of this thesis followed by essentially subdivided based on the major differences in form only, such as knives, mirrors, earrings, etc. The typology of TSBL in this thesis will not classify at functional levels, such as weapons, tools, etc. An attempt is made to avoid misleading context misgiving.

There are 14 categories of bronze artefacts discovered from the TSBL site, including knives, awls, arrowheads, short swords, socketed axes, mirrors, buttons, plaques, pao (circle dress ornament), tubes, earrings, bangles, beads, and bells. All of the drawings shown below for the bronzes from TSBL were provided by the Hami Museum.

4.3.1 Knives

Knives are single-edged blades with an, "approximately wedge-shaped section" (Catling, 1964,102). They are the most common object discovered in the cemetery during the Bronze Age throughout Xinjiang, but most sites have only yielded a small number of metal knives. There are about 62 knives found from TSBL, 19 of them so poorly preserved that their original shape is unclear. The knives of copper and bronze are classified into four main types; three of which have sub-types.

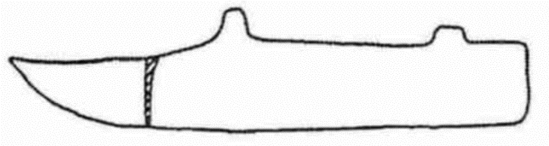
4.3.1.1 Type A

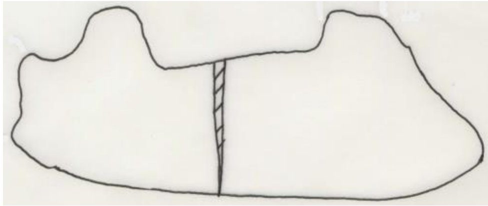
Knives with no obvious handle tang (n = 21). This type of knife divides into four sub-groups.

Type A.1 (n = 3)

Straight to slightly curved knife back (convex) with two block-shaped bulges, straight to slightly curved cutting edge. Upcurved blade tip, length 7.3-16.2 cm; width 2.9-3.1cm;

This group comprises three knives found in tombs M284, M375, and M683. While none of the members of this group is identical, they are similar in form.


M284-3

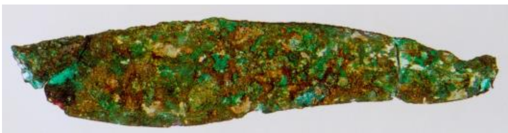

M375-9


M683-1

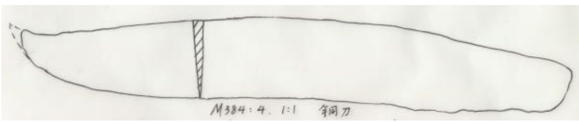
Figure 14 Knife Type A.1

Type A.2 (n = 7)

Straight to slightly curved knife back (convex), with straight to the slightly curved cutting edge. The whole knife body is rather wide, with no obvious handle tang. Length 8.3 - 17.3cm, width 2.2cm - 3.1cm. None of the groups is identical, yet they are similar in form. From tombs M59, M71, M269, M319, M384, M539 and M647. That from M647 was poorly preserved.


M59-5


M319-1


M384-4


M539—2

Figure 15 Knife Type A.2

Type A.3 (n = 4)

Relatively straight knife back, with straight to the slightly curved cutting edge. Length 7.3 - 12.9 cm., width 0.8 - 2.1 cm. From tombs M42, M342, M392, and M631.

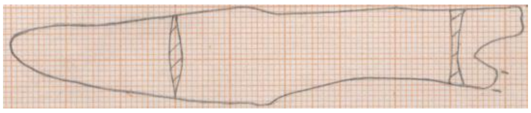
 M42-4	 M342-4
 M392-4	 M631

Figure 16 Knife Type A.3

Type A.4 (n = 9)

Straight to slightly curved knife back(convex) with upcurved blade tip, with straight to slightly curved cutting edge. Length 7.2 - 14.9 cm, width 1.8 - 2.2cm. From tombs M91. M120, M215, M220, M263, M305, M327, M471 and M694.

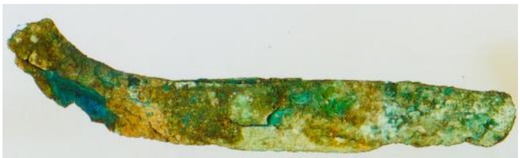
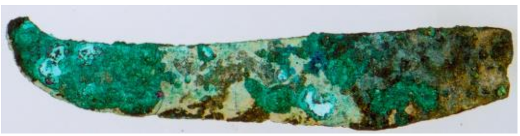
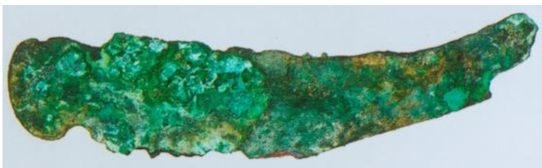
 M91-5	 M120-1
 M215-5	 M263-2
 M327-3	 M694-2

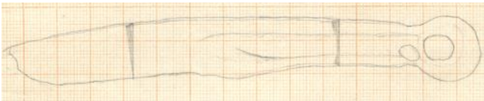
Figure 17 Knife Type A.4

4.3.1.2 Type B

Slightly curved knife back(convex), with straight to the slightly curved cutting edge. The whole knife body is rather narrow with a grooved or decorated handle. There are two types of handles defining two sub-types.

Type B.1 (n = 5)

The first sub-type is the knife with the handle ending in a ring. From Tombs M144, M148, M295, M341, and M441.


M148-7


M295-2


M341-22


M441-3

Figure 18 Knife Type B.1

Type B.2 (n = 4)

The second sub-type is the knife with a small hole in the handle end. They were found in M1, M385, M640, and M679.

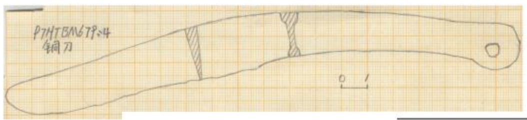
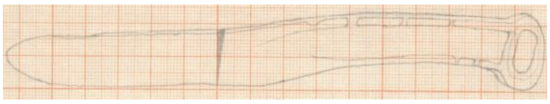
 M1-1	 M385-4
 M640-1	 M679-4

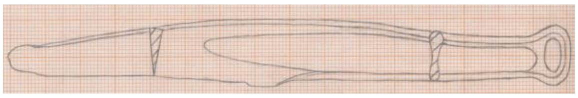
Figure 19 Knife Type B.2

4.3.2.3.Type C (n = 5)

Relatively straight knife back with the handle, straight to the slightly curved cutting edge, length 15.9 to 17.2 cm; width is 1.9 cm to 2.2 cm. They were found in M53, M72, M64, M136, M148, and M457.



M53-8



M66-4

M72-2

M136-2

M457-5

Figure 20 Knife Type C

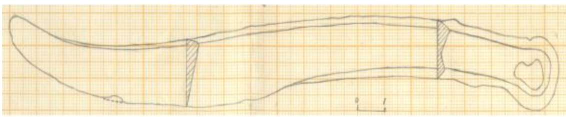
4.3.1.4 Type D

The knives with an upcurved blade tip and a curved cutting edge. This type of knife divides into two sub-groups.

Type D.1 (n = 2)

The wave knife back with an upcurved blade tip, and a curved cutting edge; The handle with a small ring or hole in the end. One was found from M85, length 14.6 cm, and width 2 cm. Another one was found from M679, length 20.5 cm, width 2.1 cm.

M85-3



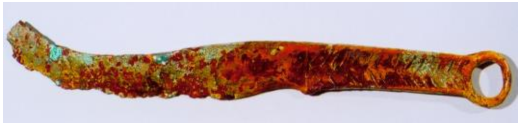
M679-4

Figure 21 Knife Type D.1

Type D.2 (n = 6)

Straight to slightly curved knife back(convex) with upcurved blade tip, and curved cutting edge. This is the knife with the handle and with or without a ring at the end, length 15.9 cm to 17.2 cm; width 1.9 cm to 2.2 cm. They were found in M131. M146, M302, M471, M649, and M701.


M131-1


M146-3


M302-2


M649-2

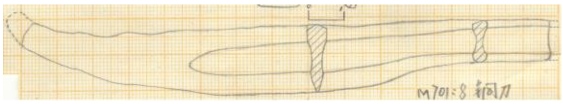

M701-8

Figure 22 Knife Type D.2

4.3.2 Awls

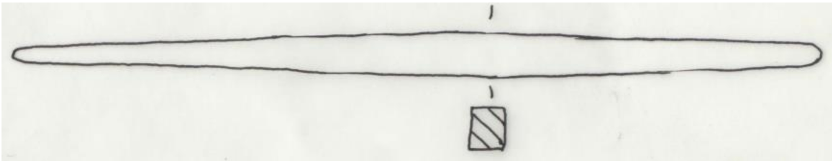
There thirty-four awls were discovered from the TSBL site over 31 tombs, most of them only contained one awl in each tomb. These awls are usually considered to be tools and used in lapidary, woodwork, and perhaps metalwork. They had bone prototypes and bone awls were persistently used alongside copper in TSBL. The awls from TSBL fall into one basic group: square-sectioned. There is little evidence available to trace the origin, development, or dissemination of this type due to their fairly close uniformity and universal distribution.

Type A (n = 34)

Square or rectangular section with thick rectangular to round butt and sharp point; often square/rectangular section smoothes to a rounded section near the point, length 11.5 cm to 3.2 cm.

M85-5

M327-2



M327-2

Figure 23 Awl Type A

The tomb that found the awl is as follows:

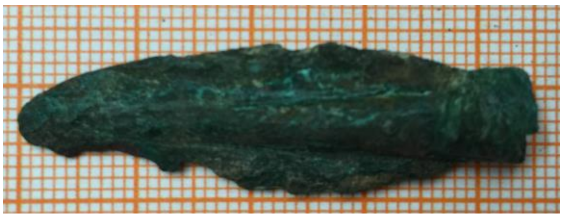
M24-3, M36-4, M41-3, M42-6, M72-2, M85-5, M92-2, M101-4, M144-4, M148-3, M150-4, M215-2, M221-2, M224-2b, M280-4, M281-8a, M305-3, M312-6, M327-2, M341-24, M384-11, M385-6, M441-4, M457-5-1, M577--7, M627-4, M631-3, M649-3, M679-5 and M695-2.

4.3.3 Arrowheads

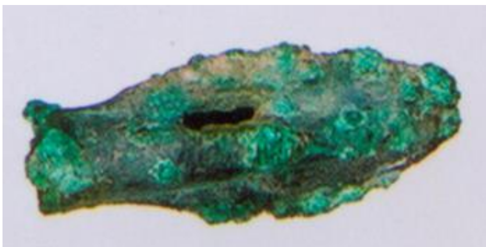
There are seven arrowheads were discovered from the TSBL site over 7 tombs, each tomb contained one object. These arrowheads are usually considered to be weapons for hunting. The arrowheads from TSBL fall into two groups: a 'leaf-shaped' blade and a long leaf-shaped blade.

Type A (n = 6)

Two-edged and leaf-shaped with a stocked, size of 3.2 cm to 5.6 cm. They were found in M127, M143, M280, M315, M320, and M632.



M127-4



M280-3

Figure 24 Arrowhead Type A

Type B (n = 1)

Two-edged and long leaf shape with a stocked, 5.7 cm long, found in M307.

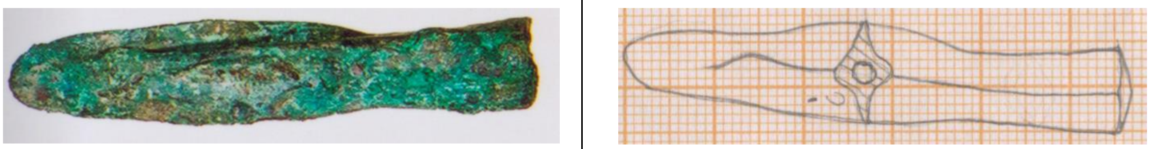


Figure 25 Arrowhead Type B (M307-15)

4.3.4 Short Sword

There is only one short sword that was discovered from the TSBL site, found in M626.

Type A (n = 1)

Two-edged and leaf-shaped with the hilt. The whole sword is 12.9 cm long, the hilt is 2.8 cm.

Figure 26 Short Swort Type A (M626-2)

4.3.5 Socketed Axes

There are two axes were discovered from the TSBL site, both found in M341. These axes are usually considered to be tools and are used in lapidary, woodwork, and perhaps metalwork.

Type A (n=2)

Straight almost parallel sides with socketed butt, straight/slightly convex cutting edge; rectangular/square section, length 3.7 cm and 5 cm; width 1 cm and 1.6 cm.


M341-13


M341-14

Figure 27 Socketed Axe type A

4.3.6 Mirrors

There are 40 mirrors were discovered from the TSBL site over 25 tombs. Most of the tombs only contained one mirror, but M15, M301, and M400 discovered more than three mirrors in each one. The mirrors are classified into two main types: Type A is the circular mirror with a knob on the back, this type has two sub-groups. Type B is the circular mirror with a handle.

Type A

This is a circular mirror with a knob on the back, two sub-groups are belonging to this group.

Type A.1 (n = 35)

With a knob on the back, and the back is plain without any decoration, size of 6.5 cm to 8.9 cm; They were M15-2, M15-11, M36-2, M43-10, M65-2, M73-4, M126-1, M226-2, M235-2, M264-1, M266-5, M281-5, M301-7, M301-12-1, M301-12-2, M315-11-1, M315-11-2, M315-13, M341-8, M400-2, M400-10, M400-13, M400-38, M437-4, M441-2, M479-9, M502-3, M605-5, M620-7, and M679-2.


M15-11 and M15-2

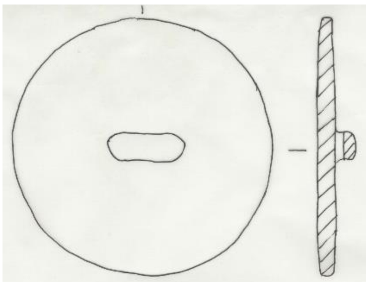

M341-8

Figure 28 Mirror Type A.1

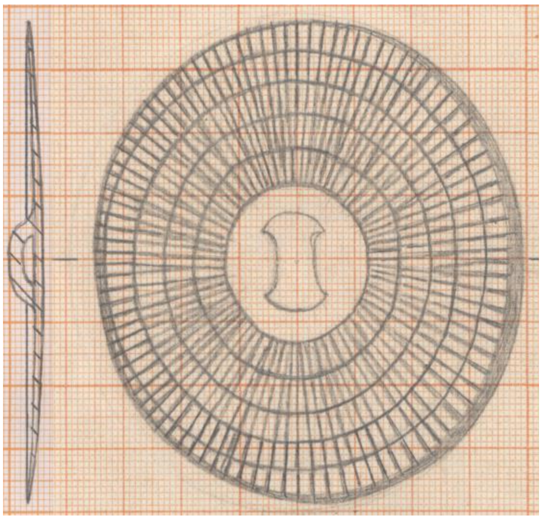
TypeA.2 (n = 4)

With a knob on the back, the back is with a decoration, size of 7.5 cm to 9.5 cm. Three of them were nearly identical, the same size, all about 7.5 cm, and the decoration pattern is also the same. The pattern is thick concentric circles filled with radiating thin bands. They were found from M15, M190, and M400. See Figure 4.15 of these mirrors.

M15-13

M190-14

M400-5



M400-5

Figure 29 Mirror Type A.2

There is another one that belongs to this type which is the largest round mirror discovered from the TSBL site, the size is 9.5 cm. The mirror was found in M483. This mirror has a different pattern from the other three circular decoration mirrors. The decorated surface represents a round human face with numerous rays emitting in all directions.

Figure 30 Mirror Type A.3 (M483-1)

Type B (n = 1)

This is a circular mirror with a handle. There is only one mirror found of this type. The mirror was found in M36. The size of the mirror is 10.9 cm, and the handle is long 2.7 cm. The mirror is plain without any decoration.

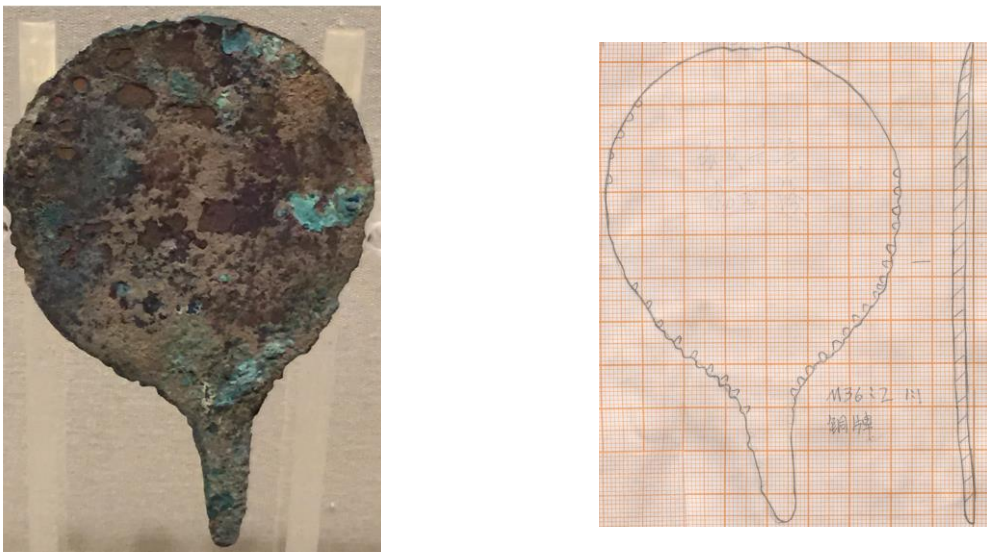


Figure 31 Mirror Type B (M36-2)

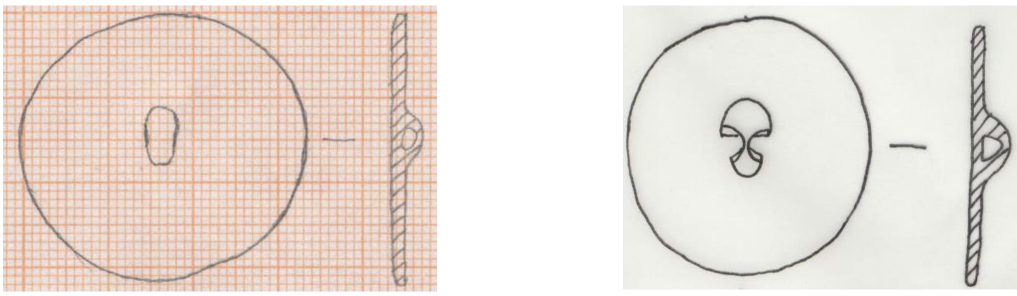
4.3.7 Buttons

Buttons are the most common object discovered from the cemetery in the Bronze Age over all of Xinjiang, and there are 317 buttons were discovered from the TSBL site over 119 tombs. Most of the tombs found more than one object, some of them like M15, M125, and M266 discovered around 20 buttons in each. The buttons from the TSBL site are classified into three main types: Type A is the round flat surface without any decoration. Type B is the curve surface; this type has two sub-groups. Type C is the double button in the shape of the figure of 8.

Type A (n = 64)

This type of button has a round flat plain surface, with a knob at the back, size of 3.5 to 4.1 cm. They were found in M29, M34, M53, M66, M68, M87, M99, M112, M125, M127, M145, M148, M154, M166, M207, M242, M254, M267, M311, M315, M316, M341, M362, M376, M397, M416, M437, M457, M487, M527, M528, M547, M554, M608, M640, M697 and M701.

M99-2 M311-32



M267-25 M640-7

Figure 32 Button type A

Type B

This is the button with the round curved surface, this type has two sub-groups.

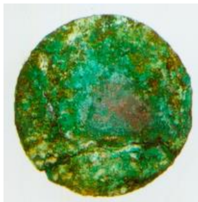
Type B.1 (n = 205)

Curved plain surface, without any decoration, with a knob at the back, size of 1.4 to 4.3 cm. The size range is rather big for this type of button. 205 buttons belong to this type. They were founded in M15, M26, M27, M29, M34, M39, M42, M43, M50, M53, M66, M68, M71, M81, M91, M99, M101, M125, M145, M148, M154. M155, M166, M190, M195, M198, M200, M203, M207, M224, M232, M233, M241, M247, M254, M257, M266, M267, M270, M275, M279, M281, M287, M301, M307, M311, M312, M316, M320, M322, M327, M328, M329 , M339, M340 , M341, M359, M361, M362, M366, M378, M384, M385, M386, M416, M437, M439, M440, M441, M443, M457, M459, M460, M462, M469, M483, M487, M496, M500， M504, M518, M526, M528, M529, M532, M547, M554, M571, M591, M608, M626, M641, M685, M687, M692, M701, M703, M705

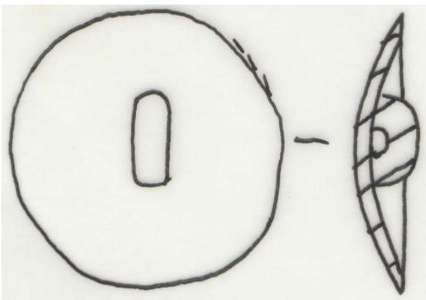
M316-7

M15-4

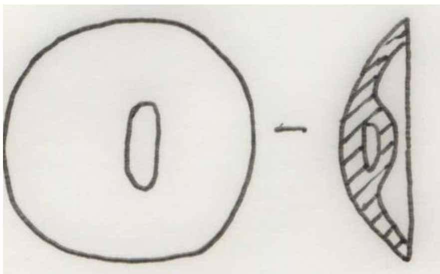
M39-2



M200-1



M327-6



M341-27

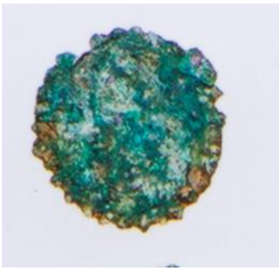
Figure 33 Button Type B.1

Type B.2 (n = 45)

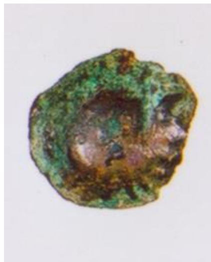
Curved surface with decoration. The surface has a circle of dotted or thin striped bumps along the edge, smooth in the middle.

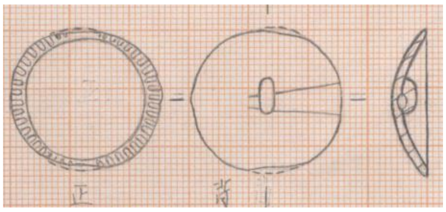
The size is from 1.7 cm to 2.8 cm. They were found in M15. M36, M43, M65, M73, M126, M226, M235, M264, M266, M281, M201, M315, M341, M400, M437, M441, M479, M502, M605, M620 and M687.


M15-9


M267-15


M270-1


M307-1


M66-3-7

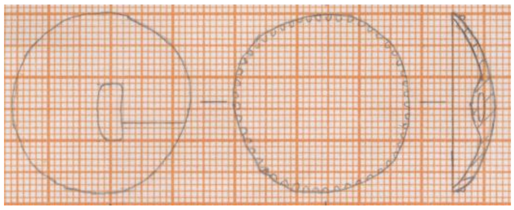
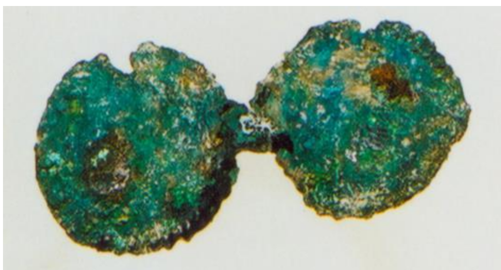
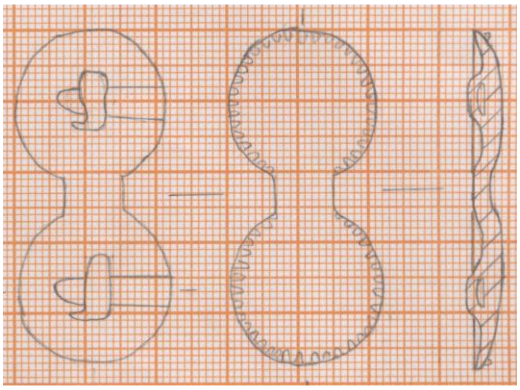

M316-16

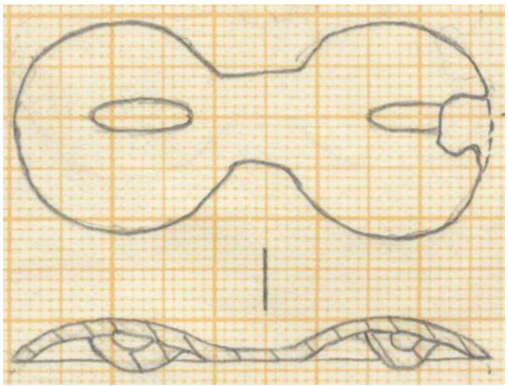
Figure 34 Button Type B.2

Type C (n = 3)

Double button in the shape of the figure of 8, curved surface, with two knobs on the back.With or Without decoration. The pattern is thin striped bumps along the edge of the surface. The size is 4.7 cm to 5.7 cm. They were found in M261, M311, and M483.


M261-9





M311-28 M483-26-2

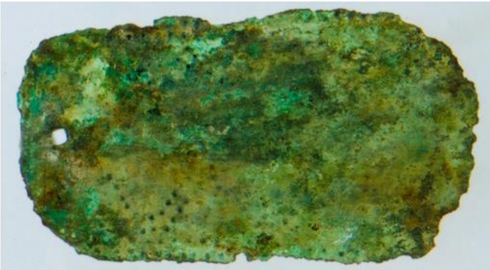
Figure 35 Button Type C

4.3.8 Plaques

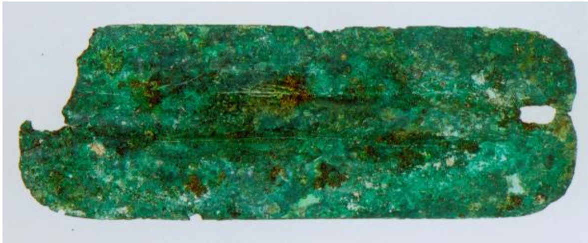
Plaques are decorative copper or bronze ornaments in different shapes. They are the common object discovered from the tomb in the TSBL site and most of the tombs only yielded one piece of the plaque. The plaques of copper and bronze are classified into three main types: Type A is Rectangular. Type B is Bow Shape and Type C is Hollow out.

Type A (n = 66)

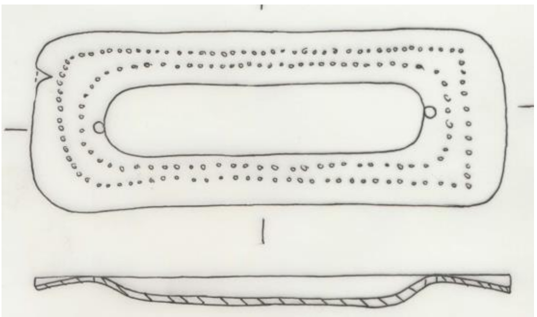
Rectangular with a round corner, a middle ridge, decoration on the surface, and with one hole at the top. None are identical, yet they are all rectangular but in different lengths and widths. The decoration of the surface is different from each other, most of them with a middle ridge. The most common pattern is the raised dot surrounding the edge. Some are significantly narrower. They were found in M15, M16, M48, M54, M65, M80, M99, M109, M110, M125, M127, M128, M130, M132, M148, M153, M179, M183, M195, M198, M200, M201, M202, M207, M226, M229, M286, M289, M301, M303, M305, M311, M316, M321, M325, M340, M342, M374, M376, M379, M384, M400, M432, M437, M447, M448, M468, M483, M506, M518, M566, M589, M597, M604, M608, M620, M641, M652, M654, M674, M676 and M685.



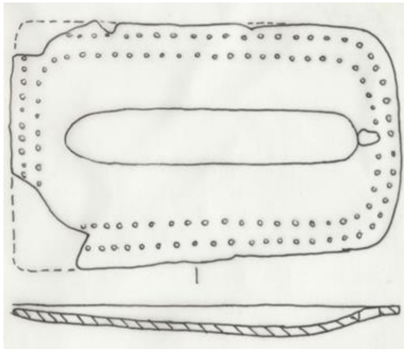
M109-1



M374-4



M200-2



M229-4

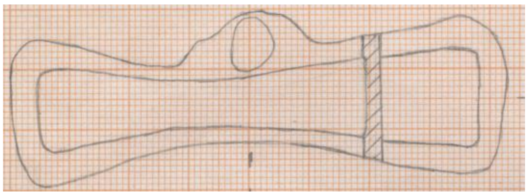
Figure 36 Plaques Type A

Type B (n = 19)

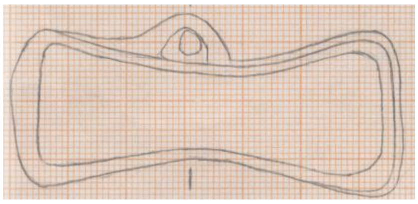
Bow shape with or without decoration on the top surface. with a small loop at the middle of the upper edge. The size is from 8 cm to 9.5 cm. The decoration of the surface is different from each other. The most common pattern is the raised thin line surrounding the edge. They were found in M130, M191, M229, M305, M304, M323, M511, M536, M582, M626, M636, M640, M675, and M683.

M130-4

M675-3



M511-2-1



M536-1

Figure 37 Plaques Type B

Type C (n = 2)

Hollow out with different shapes. One of the plaques is in a circle shape with radial decoration hollow out pattern, size of 9.5 cm. It was found in M685.

The second one is rectangular with a zigzag decoration hollow-out pattern. The length is 9.1 cm and the width is 5.1 cm. It was found in M604.

M604-1

M685-1

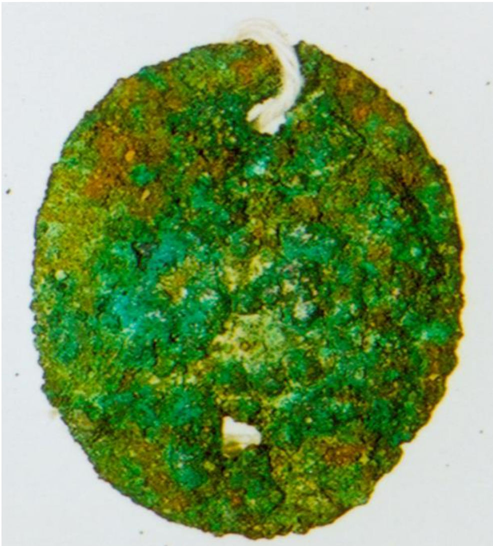
Figure 38 Plaques Type C

4.3.9 Pao (Circle Ornaments)

Pao is decorative copper or bronze round shape ornament and one of the most common objects discovered from the tomb in the TSBL. The Pao of copper and bronze are classified into two main types: Type A is a single circler. Type B is a double circler (shape like a figure of 8).

Type A (n = 292)

Single circler with a curved surface, with two holes at the top and bottom near the edge, with or without decoration on the surface. The pattern is the raised dot along the edge of the surface, size of 2.4 cm to 5.3 cm. They were found in M1, M33, M34, M40, M53, M58, M76, M81, M84, M109, M112, M123, M125, M126, M137, M139, M141, M145, M148, M150, M152, M153, M166, M190, M201, M225, M226, M235, M248, M254, M260, M265, M266, M269, M278, M289, M283, M301, M310, M311, M312, M315, M321, M328, M333, M334, M337, M341, M349, M354, M357, M365, M375, M376, M378, M385, M397, M399, M400, M411, M412, M415, M416, M443, M447, M474, M482, M483, M491, M500, M502, M511, M534, M536, M552, M571, M577, M580, M593, M605, M606, M608, M612, M618, M620, M626, M632, M633, M654, M676, M679. M691, M695, M698, and M705.



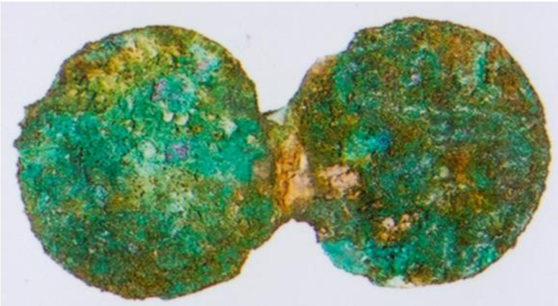
M248-4

M443-2

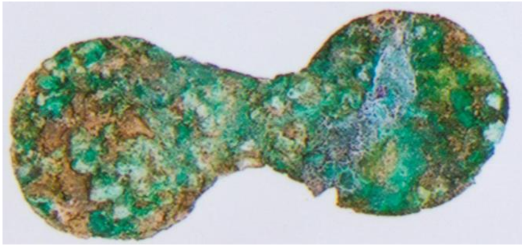
Figure 39 Pao Type A

Type B ***(n = 45)***

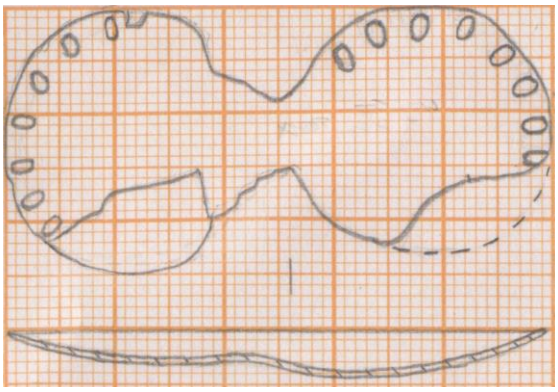
Double circler with a slightly curved surface. The shape is a figure of 8, with or without decoration on the surface. The pattern is a circle of dotted or thin striped bumps along the edge of the surface, smooth in the middle, size of 2.1 to 5.1 cm. They were founded in M15, M74, M75, M109, M112, M126, M148, M190, M266, M267, M275, M279, M301, M311, M341, M385, M490, M491, and M654.



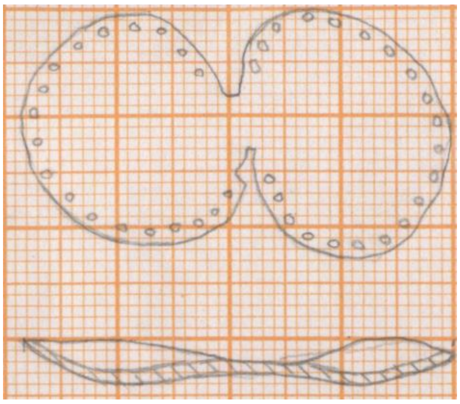
M266-37



M267-10



M341-2



M311-23

Figure 40 Pao Type B

4.3.10 Tubes

The tube is a piece of a thin sheet of copper or bronze rolled into a tube shape, consider as the decoration ornament. They are the common object discovered from the tomb at the TSBL site. There are 299 tubes found at the TSBL site. The tubes from TSBL fall into two basic groups: Type A is cylinder-shaped; Type B is spiral-shaped.

Type A (n = 252)

The tubes are cylinder-shaped with smooth surfaces. They are the same in form, used a copper or bronze thin sheet rolled into the tube, they were just different in length. The length is from 2 to 17 cm. The total number of this type of tube is 252.

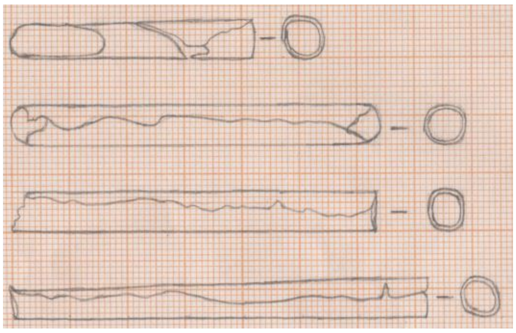
 M202	 M697=1

Figure 41 Tube Type A

Type B (n = 64)

The tubes are spiral-shaped with smooth surfaces. They are the same in form, used the copper or bronze narrow flat wire rolled into the tube, they were just different in length. The length is from 2.1 to 8.2 cm. They were found in M43, M82, M153, M200, M226, M226, M384, M440, M479, M502, M577, M579, M597, M604, M620, M674, M676, M701.

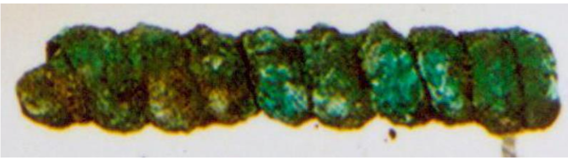
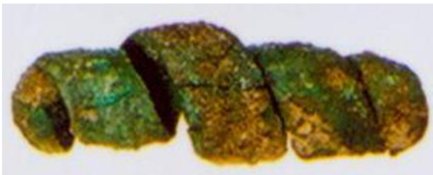
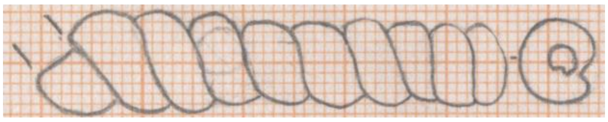
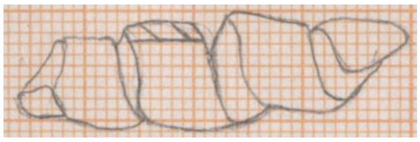
 M153-4	 M674=3
 M153-4	 M674-3

Figure 42 Tube Type B

4.3.11 Earrings

Rings for the ear, hair or finger cannot be effectively distinguished from one another. Often located in a grave setting does suggest what use the ring was put to, but the rings discovered from the TSBL site missing relevant information, and the previous research considered these rings as earrings, therefore this research will retain the same category. There 315 earrings were discovered from the TSBL site over 207 tombs. The earrings of copper and bronze are classified into two main types.

Type A ***(n = 300)***

Circular sectioned coil of copper or bronze bend into a round shape, and often overlapping terminals; One coil and no other specific feature, size of 1.7 to 3.6 cm. This is the most common type of earrings from the TSBL site.

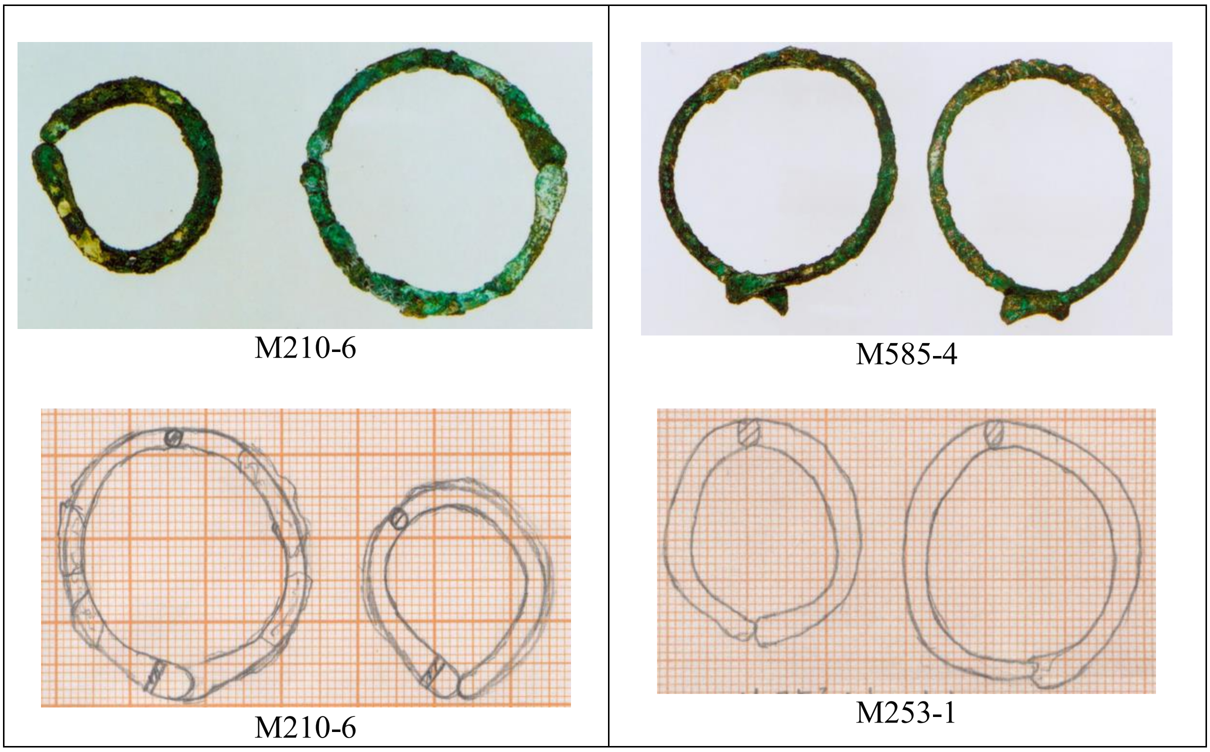


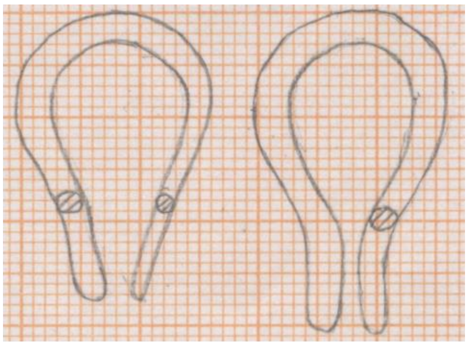
Figure 43 Earring Type A

Type B ***(n = 15)***

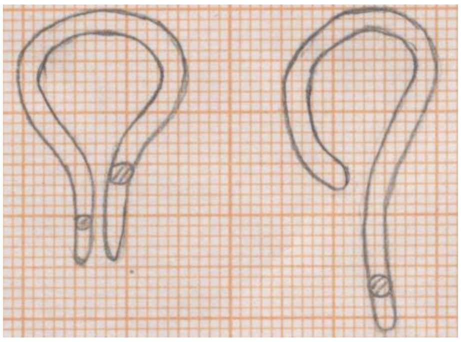
This is the Type B of earrings from the TSBL site. A Circular sectioned coil of copper or bronze bent into a spoon shape, size of 2.5 to 3.8 cm. They were found in M144, M162, M182, M280, M377, M450, M474, M513, M520, M589, M606, M670, and M679.

M162-3

M182-2



M520-2



M589-2

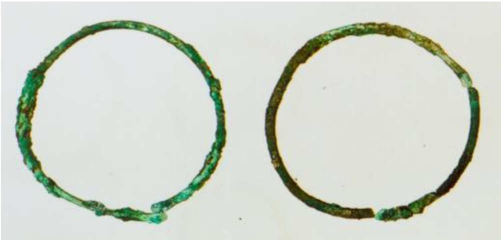
Figure 44 Earring Type B

4.3.12 Bangles

The bangle is a big copper or bronze ring, consider a decoration ornament. They are the common object discovered from the tomb at the TSBL site. There are 87 bangles found in the TSBL site. The bangles of copper and bronze are classified into two main types: Type A is the circular sectioned coil; Type B is a thin narrow flat sheet ring.

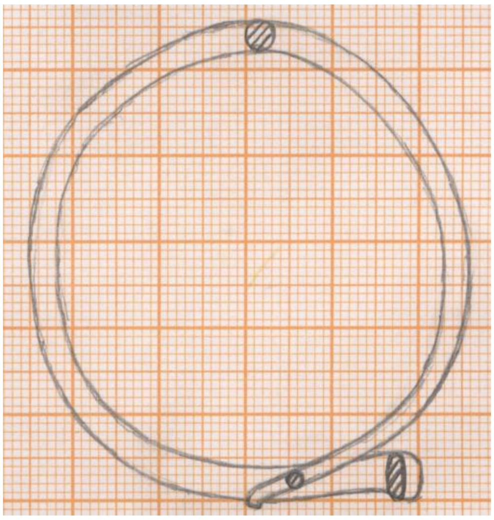
Type A *(n = 73)*

Circular sectioned coil of copper or bronze bend into a round shape, often overlapping terminals, one coil and no other specific feature, size of 5.5 to 7.2 cm. This is the most common type of earrings from the TSBL site.

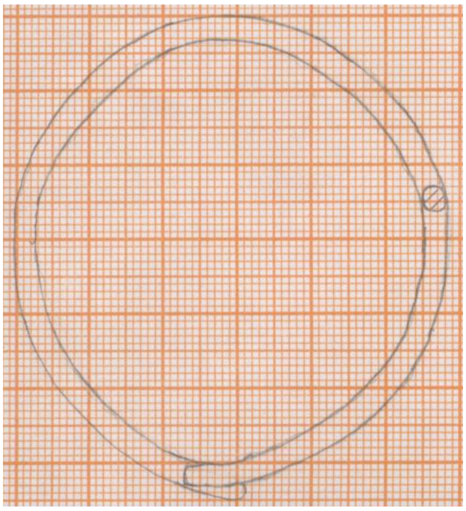


M266-1

M585-2



M246-3-2



M316-5

Figure 45 Bangle Type A

Type B *(n = 14)*

Thin flat narrow copper or bronze sheet bent into a round shape, one coil and some of them with the raised dot along the edge and size of 6.3 to 7 cm.

M399-2

M544-2

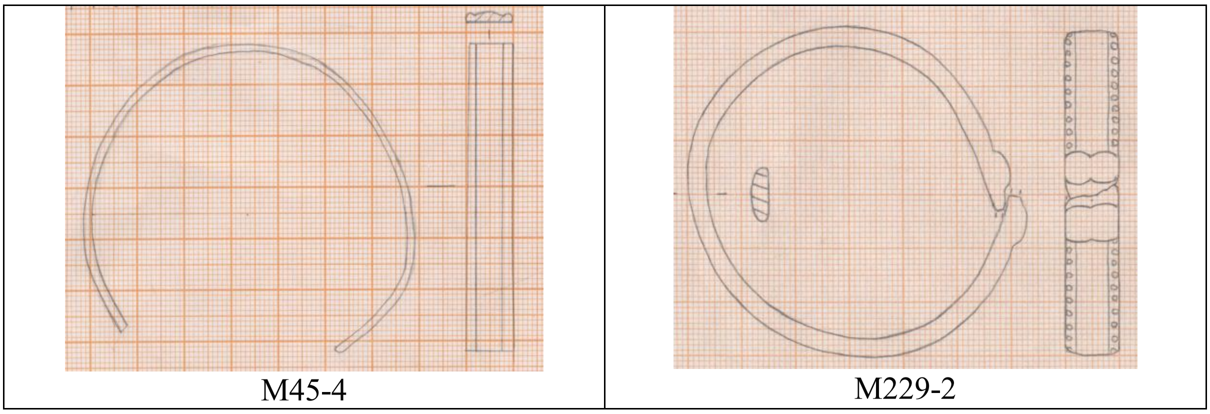


Figure 46 Bangle Type B

4.3.13 Beads

The beads are decorative copper or bronze small ornaments and one of the most common objects discovered from the tomb in the TSBL. Most beads had to be perforated to be threaded and worn -usually in sets as a necklace or bracelet. There are 775 beads found from the TSBL site. The beads of copper and bronze are classified into three main types: Type A is a solid cylinder. Type B is wire beads. Type C is joint beads.

Type A (n = 677)

Solid, perforated cylinder-like beads with a hole. The beads are of a simple, basic design that is in the same form, just different in the size, 0.6 to 0.8 cm.

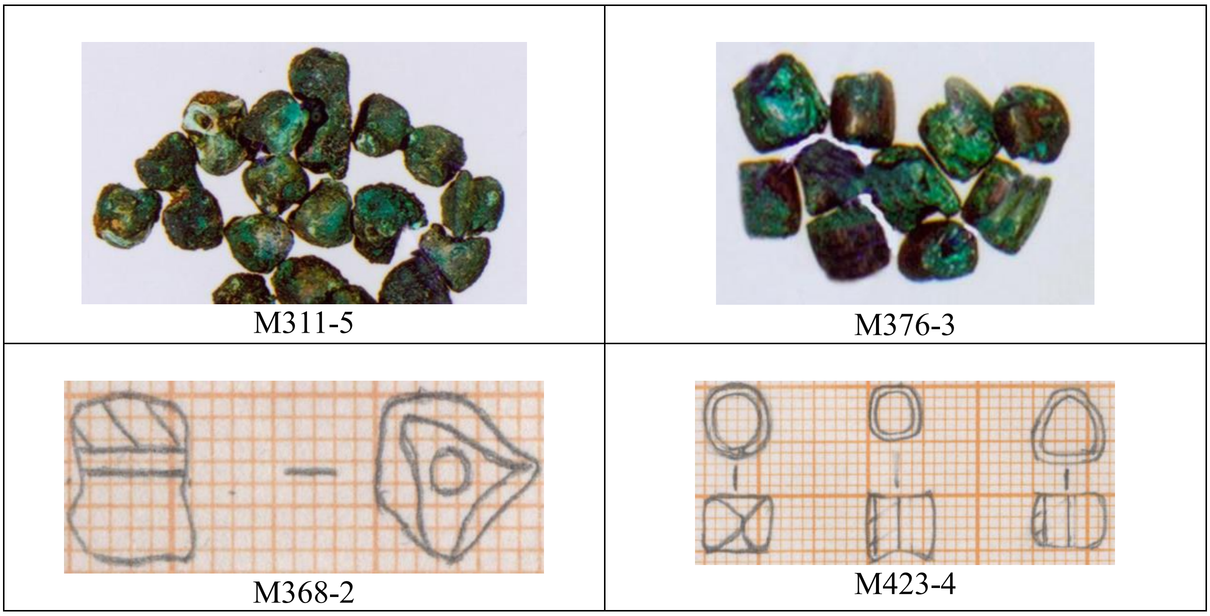


Figure 47 Bead Type A

Type B (n = 74)

Wire beads are made from a thin narrow flat wire bent into a small ring. The beads are of a simple, basic design that is in the same form, just different in the size, 0.5 to 1 cm.

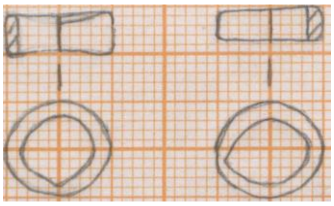
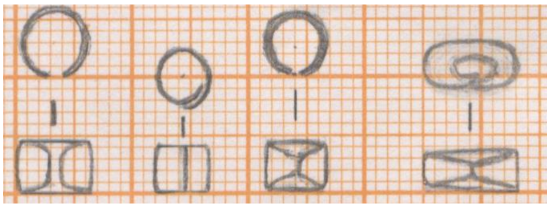
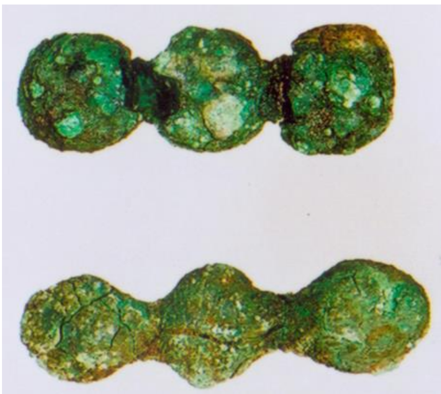
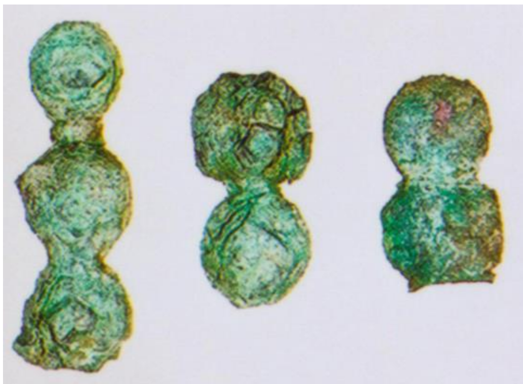
 M137-5	 M685-2
 M376-2	 M400-31

Figure 48 Bead Type B

Type C (n = 27)

Joint circular beads, perforated two or three round beads joined together as one bead.

 M680-3	 M529-3

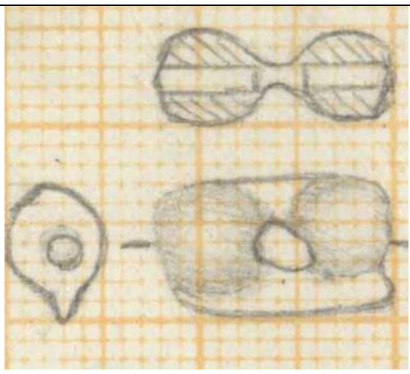
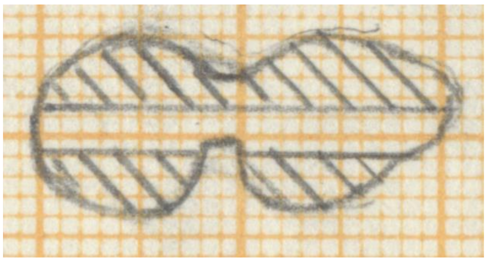
 M456-8	 M604-2

Figure 49 Bead Type C

4.3.14 Bells

Three belles were discovered from the TSBL site. There are classified into two types.

Type A is with the handle. Type B is with the perforated wall.

Type A *(n – 2)*

With the handle and the hole at the top end. A pair of bells were discovered in M502 for this type.

Type B *(n = 1)*

With a perforated wall, only one bell was discovered in M361 for this type.

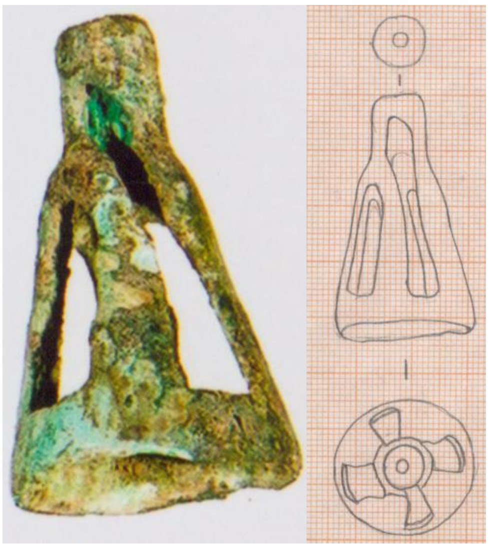
 M502-1 (Type A)	 M361-7 (Type B)

Figure The Bells

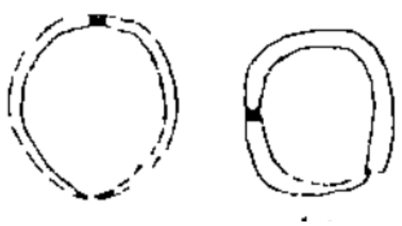
4.4 Discussion

The large number of metal objects recovered from TSBL dating back to the Bronze Age have a wide range of forms and styles. The clear variety of these artefacts indicates that the majority of them are personal ornaments, tools, mirrors as well as a limited number of weapons. Their stylistic features often coincided with those of some cultural items belonging to eastern and western prehistoric communities in Eurasia.

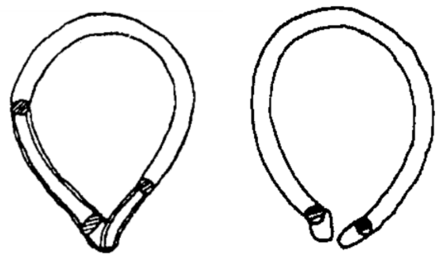
4.4.1 Personal Ornaments

The most common metalwork found at Taisnhsbanbeilu is the personal ornament, the most numerous of which are all sorts of ring-shaped ornament, including earrings and bangles. The difference between the earrings and the bangles is the size, and most of the tombs with metal artefacts contained the earrings, making it the most common metal artefact discovered at the site. A similar feature is also found in Bronze-Age cemeteries throughout the whole of Xinjiang but with different types of earrings. There are two types of earrings at TSBL.

Type A, the simple round shape earrings, are also known from the Qijia culture (2200 BC to 1800 BC) and Siba culture (1900 BC to 1500 BC) of the Hexi corridor in the Gansu region (See Figure 51). This type of earring is the most common object found in TSBL, while most earrings in other cemeteries in Xinjiang during the same period are typical Andronovo trumpet end earrings (Li 2005; Ruan 2013). These trumpet end earrings were widely throughout the whole of Xinjiang and also found in the Ganguya cemetery of Siba culture (See Figure 52). But none of this type is found in the Tiansnbeilu, which could be reflecting the design of the ring-shaped earring perhaps was adopted by (or shared with) the eastern cultural groups of Siba and the influence of Andronovo culture at that period was minimal.



Earrings found in Qijia culture



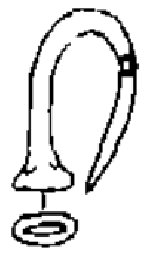
Earrings found in Siba culture

Earring from TSBL M330-2

Figure 50 The Bronze Earrings fom Siba (after Mei 2003, Fig 5), Qijia (after Li 2005) and TSBL site

a. Andronovo culture

b. Adunqiaolu SM4-1



c. Siba (Ganguya)

Figure 51 The trumpet-shaped earring from North-west Xinjiang and Siba (a from Andronovo culture, after Shao 2009; b from Adunqiaolu site date 1900-1700BC, after Cong et.al 2017; c from Siba culture Ganguya cemetery, after Yang et, al 2016).

Notably, a pair of hoop earrings unearthed at the TSBL site are made of gold (Figure 53). The use of gold for jewellery is an important indicator linking users to Western cultural groups, as pastoralist tribes in steppe regions and agricultural communities in Central Asia can cast large quantities of gold objects (Kuzmina and Mallory, 2007). The development of gold production in these regions has benefited from a large supply of raw materials from Central Asia, where large ore deposits are located in the Ural region of Kazakhstan and Fergana (Kuzmina and Mallory, 2007). In addition, large amounts of gold can be found in the Zeravshan, Vakhsh and Kafirnigan Rivers (Kuzmina and Mallory, 2007). A gold assemblage found in the Bactria-

Margiana Archaeological Complex shows that gold in Central Asia was cast as early as the late third millennium BC (Hauptmann and Stollner 2013). During the second millennium BC, the Andronovo community mined gold ores and placers, as evidenced by the various cultural artefacts discovered near the deposits. (Burker 1998). In connection with Siba culture, a set of gold earrings was also discovered in grave M79 at Huoshaogou (Figure 53). Copper and a bronze earring of this shape have also been discovered in Northwest Xinjiang, further east at Zhukaigou, in Liaoning province at Pingdishan, Fuxin, near Beijing at Fangshan, Liulihe, and in southern Inner Mongolia, Aohan qi, Dadianzi (Bunker 1994a). These earrings have a form that is similar to Andronovo examples from southern Siberia, and they may have originated there. (Bunker 1998). The gold earrings discovered at Huoshaogou are trumpet-ended and of the Andronovo type, whereas those discovered at TSBL graveyard are simple circles, implying that the origins of golden artefacts discovered in the two regions were different. It shows the complexity of the TSBL culture as it combines strong local culture with influences from different Western cultures. Not only was Andronovo culture influential during this time, but other Western cultures may have had an impact.

 TSBL	 Siba Huoshaogou

Figure 52 The Gold Earrings from TSBL and Siba

The earrings of Type B are spoon-shaped and made with copper or bronze wire. These have sometimes been considered as hairpins, but such rings for the ear, hair, or finger cannot be effectively distinguished from one another. In addition, the rings from Tianshbeilu do not have information on their location within the grave, so here they are categorized as earrings. There are no other contemporary examples of these earrings in any other Xinjiang cemeteries, and it is of interest that the same form of earrings made of different metal materials was also found at TSBL (Figure 54). Studies previously classified them as silver products (Zhang 2017; Festa 2018), but recent studies classify them as lead products (personal communication with Northwest University). The Type B earring is distinctive at TSBL and all Type B earrings in the assemblage are analysed to understand the consumption of Type B earrings at TSBL.

 Copper or Bronze earring M183	 The lead earring M182

Figure 53 The same form of earrings from TSBL in both copper and lead

The next most common personal ornament found from TSBL is the Pao and buttons. Pao is a circle or a figure of 8 shapes (double circle) ornament with one or two holes near the edge. The button is a circle or a figure of 8 shapes (double circle) ornament with a knob at the back. At present, this figure of 8 shapes of bronze ornament has only been found at Tianshanbeiou. There is yet any detailed investigation conducted in terms of its stylistic and composition in previous studies. Due to their distinctive types and high quantity in the assemblage, it is important to understand the alloy composition of Paos and buttons to reveal the relationship between production and consumption pattern. Circular ornaments of similar design have been found in the late period of the Qijia culture (1800BC to 1600BC) and Siba culture (2000BC to 1600BC) (Mei 2004; Yang et al., 2016). This is another piece of evidence to show the close connection between TSBL and their east neighboring area.

Beads are known in Xinjiang since the Bronze Age. In addition to copper or bronze examples, there are examples of bone, stone, carnelian, turquoise, and jade. Generally, beads were used in jewellery, many of them perforated so that they could be threaded and worn, usually together as a necklace or necklace arrangement. Bronze beads are plentiful at TSBL, with 875 beads in over 71 tombs. There are so many simple and basic beads that one should be careful about emphasizing typological similarities too much. There are three types: solid cylinders, wire beads, and joint beads. The solid cylinder beads and wire beads are so simple and widely distributed that little typological information can be gained from such a simple design, also it tells us little about contacts between the prehistoric communities of the TSBL. But joint beads have only been found at TSBL in Bronze Age Xinjiang. Similar examples are known from the Siba culture (2000BC-1500 BC) in Gansu (Yang 2016). Because of the large number of beads found in Tianshnabeilu, it's critical to know the alloy composition of the beads to deduce the relationship between production and consumption patterns, as well as the cultural connection.

TSBL also has a relatively large number of bronze plaques of various types, an important find among the ornaments. These objects are rather characteristic of Bronze Age Xinjiang, with marked regional differences in their design within our region of study. The plaques of copper and bronze are classified into three types at TSBL: rectangular, bow-shaped and hollowed-out. The hollowed-out plaques are unique, with no parallels elsewhere. This plaque appears to be a local development. Bow-shaped plaques unearthed in multiple TSBL tombs appear to have no analogues in Xinjiang, yet they are comparable to bronze pendants from burial M266 in the Huoshaogou cemetery in Gansu, assigned to the Siba cultural group (2000BC-1500BC) (Chen 2012). In addition, a small number of similar ornaments were discovered amid the remnants of the Kayue village in Qinghai (1600BC-600 BC). The existence of bow-shaped plaques from the TSBL site suggests that this design had a particular symbolic value among the surrounding communities, and may have been adopted (or shared) by Eastern cultural groups such as Siba and Kayue.

Three bells, rather small items of uncertain use, were recovered from TSBL and classified into two types. They do not seem to have been musical instruments and may have been used as trappings or for religious ceremonies, perhaps even carried as a symbol of authority. A similar bell with a handle found in tomb H159 in the Huoshaogou cemetery in Gansu is likewise assigned to the Siba cultural group (2000BC-1500BC) (Festa 2018). Bells with perforated walls were discovered in the Wupu site and the early stages of Turfan's Yanghai cemetery (Qi and Wang 2008). They were found attached to a pair of pants, so perhaps they had a ritual significance. Bells appear to have originated in China before moving westward; archaeological evidence suggests that western societies did not create bells before 1000 BC (Von Falkenhausen 1993). Early pottery and copper specimens have been discovered in Dahecun (Henan), of the Yangshao cultural group, dating to 3000 BC (Von Falkenhausen 1993), in the Longshan cultural site of Taosi (Shanxi), dating earlier than 2000 BC (Shanxi Working Team 2000), and among the remains of the Erlitou community in Henan (1600-1300 BC) (Shanxi Working Team 2000). (Bai 2003). These objects were basic and did not have perforated walls. There have been finds of bells that are nearly identical to those found in Eastern Xinjiang, among the remains of the later Kayue community (1600-600 BC), at Chengxi, Shanpingtai, Huangjiazhai, Dahuazhong Zhuang, Huabiliang, Luanshan, and Panjialiang (Chen 2012), this implies there are close ties between cultures in the north-western part of China. Although these artefacts are widely spread throughout the Central Plain, they do not have a known origin although their distribution reflects the outcomes of connections with eastern cultures.

4.4.2 The Tools

In addition to ornaments, a significant number of tools were recovered from TSBL, similarly to all Xinjiang Bronze Age sites, emphasizing the use of metal for the most practical of purposes (Mei 2000, 2003, 2012; Chen 2012; Liu 2016). Knives are the most common tools at Tianshabeilu and examples in bronze are the most frequently found object in other Bronze Age sites in Xinjiang, in a widespread distribution. The knives at TSBL cemetery can be divided into four main groups: knives without handle tangs, knives with a curved back, knives with a straight back, and knives with upcurved blade tips. The first group, knives without an obvious tang, comprise half the total examples and were classified into 4 sub-groups, based on shape. Similar knives were discovered in some sites attributed to the Qijia cultural group (2300BC to 1700 BC) (Yang et, al 2016). The second group comprises curved knives with a grooved or decorated handle that were comparable to that from the Rostovka cemetery in the West Siberia of the Seima-Turbino complex and a specimen from the Erlitou site in the Central Plains of China, both of which have been broadly dated to the middle of the second millennium BC (Mei 2000; Yang et.al 2016). The third group consists of a few knives with a straight back also recovered from the sites of Wupu and Lanzhouwanzi, some of which had a perforated handle. These knives were similar to specimens discovered in the Gansu-Qinghai region corresponding to the Siba and Kayue cultural sites, dating to around 1900-1500 BC and 1600-600 BC respectively. The Knives with upcurved blade tips also found in the cemeteries of Wupu, Aisikexia'er, and at Yuandong Xinshichang (Hami), shared numerous traits with specimens from the cultural sites of Siba (1900 BC to 1500BC) and Lower Xiajiadian culture (2000BC to 1400 BC) in Northeast China. The bronze knives that have been found at the TSBL site are quite numerous and varied in design. These knives may have different functions due to their different shapes and deserve further study. Such as the ring-headed knives are deemed to be ideal for carrying, whereas the ones without the ring may connect to a relatively fixed utilising habit or usage circumstance. The prehistoric bronzes of East Xinjiang are influenced by the bronze culture of Eurasia, most notably in the form of bronze knives, especially those with grooved handles, which are extremely rare elsewhere. In addition, there are strong links between the prehistoric bronze knives from TSBL and the same period knives from the Siba culture. The great diversity of bronze knives directly reflects the TSBL culture's intricacy. Both socketed axes and awls were found in TSBL, while a few specimens from Hami were collected on the surface (Hami Museum). Around the same period, socketed specimens and awls appeared in Gansu, for example in Qijiaping, where they were found as part of the remains of the Qijia community (2300BC to 1700 BC). Because these tools were discovered on the TSBL site, it shows that the TSBL population maintained long-term engagement with diverse communities in the surrounding region during the same period, a complicated cultural interaction that can be witnessed in the East Xinjiang and Hexi corridor.

4.4.3 Mirrors

In Eastern Xinjiang, two types of the mirror were discovered: handled and round. There is a similar specimen with a single handle that has been excavated from Wupu cemetery and scholars have generally agreed that they come from a western source, as the earliest handled mirrors discovered in Anatolia date from 6000-5900 BC (Albenda 1985). Several early specimens were also found in Egypt, in El Badari (around 4500 BC) (Albenda 1985), in the Tigris-Euphrates Valley (around 4000 BC), and Iraq, in Uruk and Tello (second half of the fourth millennium BC) (Albenda 1985). By the beginning of the second millennium BC, they featured among the cultural remains of the Andronovo community (Kuzmina and Mallory 2007), which may have contributed to the diffusion of these items from Western to Central Asia. There are a total of 33 round mirrors were discovered at the TSBL site. Five of the round mirrors with the decorated back surface are unique in the Bronze Age of Xinjiang. Four of the mirrors were decorated with thick concentric circles filled with radiating thin bands. There was another with multiple rays emanating from an intricately decorated surface that resembled the round face of a human. It appears at first glance as if it represents the sun or an image representing the sun. A celestial body-like decoration was discovered on a mirror from the Qijia cultural site of Gamatai, where a seven-pointed element has been recognised as a star (Liu and Chen 2012). Despite this, no human characteristics were visible in this image. Instead, as early as the third millennium BC, the Okunev steles unearthed in the Minusinsk Basin were embellished with depictions of rounded faces surrounded by sun rays, round eyes, and straight lips, and these embellishments have been interpreted as images of the Sun-headed god (Esin 2009). In view of the fact that the TSBL (1900-1400 BC) and Okunev (2500-1700 BC) communities overlapped by a few centuries, it is reasonable to assume that there likely existed some form of relationship between them (Kuzmina and Mallory, 2007).

4.4.4 Weapons

A limited number of weapons were discovered from the TSBL site, in only two categories: arrowheads and swords. Seven arrowheads are of the type most common in Xinjiang, being double-edged and leaf-shaped with a socket. This type has been recovered over a vast area in western Central Asia and continued to be in use until the Iron Age. (Kuzmina and Mallory 2007). Similar items are also found in Siba Culture (2000 -1500BC). Only one short sword was found at TSBL and it's double-edged and leaf-shaped with a hilt. Similar items were recovered from sites of the Andronovo complex in Central and North Kazakhstan (Yang et al. 2016).

4.5 Diachronic Patterns within the Typological

A more precise chronology for TSBL has recently been developed by Northwest University. According to the results, the TSBL cemetery was in use from approximately 2022 to 1802 BC and remained in use from 1093–707BC (Tong et al 2020). As considered by the typology of artefacts and stratigraphy at the site, the development of the TSBL cemetery was divided into four phases. A period of 2011-1772 BC was the first phase, a period of 1660-1408 BC was the second, a period of 1385-1256 BC was the third, and a period of 1214-1029 BC was the fourth (Tong et al 2020). This is the chronology and corresponding absolute date used within this thesis. There are 705 tombs at the TSBL site, of which 485 tombs have been given the date. Listed below are the numbers of tombs in each phase (A personal communication with Northwest University, the excavation report has not yet been published).

Phase	No of Tombs
Phase 1 (2000-1650BC)	18 tombs
Phase 2 (1650-1400 BC)	135 tombs
Phase 3 (1400-1200BC)	243 tombs
Phase 4 (1200-1000BC)	89 tombs

Table 4 Number of tombs in each phase

The following part will give details of the bronze artefacts found in each phase. Here is the table that shows the typology of the bronze objects of the TSBL site, including 14 categories.

Category	Number of objects	Type
Knives	62	Type A (no obvious handle tang) - A1 (knife back with two block-shaped bulges) - A2 (slightly curved knife back with a wide body) - A3 (straight knife back, with straight to the slightly curved cutting edge - A4 (slightly curved knife back with the upcurved blade tip) Type B (grooved handle with a slightly curved knife back and straight to the slightly curved cutting edge) - B1 (handle ending with a ring) - B2 (handle ending with a small whole) Type C (relatively straight knife back with the handle)

		Type D (handle with an upcurved blade tip and a curved cutting edge) - D1 (wave knife back) - D2 (straight to slightly curved knife back
Awls	34	Type A (Square or rectangular section with thick rectangular to round butt and sharp point)
Arrowheads	7	Type A (two-edged and leaf-shaped with a stocked) Type B (two-edged and long leaf shape with a stocked)
Short Sword	1	Type A (two-edged and leaf-shaped with the hilt)
Socketed Axes	2	Type A (Straight almost parallel sides with socketed butt, straight/slightly convex cutting edge; rectangular/square section)
Mirrors	40	Type A (circular mirror with a knob on the back) - A1 (plain back) - A2 (back is with a decoration) Type B (circular mirror with a handle)
Buttons	775	Type A (round flat plain surface) Type B (round curved surface) - B1 (plain surface) - B2 (round curved surface with decoration) Type C (in the shape of the figure of 8 with two knobs)
Plaques	85	Type A (rectangular with a round corner) Type B (bow shape) Type C (hollow out with different shapes)
Pao	351	Type A (single circler with curved surface and two holes at the top and bottom near the edge) Type B (double circle in the shape of the figure of 8)
Tubes	316	Type A (cylinder-shaped with smooth surfaces) Type B (spiral-shaped with smooth surfaces)
Earrings	315	Type A (round shape bend with circular sectioned coil) Type B (spoon shape bend with circular sectioned coil)
Bangles	87	Type A (round shape bend with circular sectioned coil) Type B (round shape bend with a thin flat narrow sheet)
Beads	775	Type A (solid, cylinder-like beads with a hole) Type B (thin narrow flat wire bent into a small ring) Type C (joint circular beads, two or three round beads joined together as one bead)
Bells	3	Type A (with the handle and the hole at the top end) Type B (with a perforated wall)

Table 5 Typology of Bronze from TSBL

4.5.1 Phase 1

In Phase 1, there were only 18 tombs. The following list shows the bronze object discovered in this phase.

Objects	Number of objects	Tomb Number	Typology type
Tubes	3	M28	Type A (cylinder-shaped)
Mirrors	1	M36	Type B (with a handle)
Beads	28	M48 M221	Type B (wire beads) Type A (cylinder-like beads)
Pao	7	M375, M411, M579	Type A (single circle)
Earrings	2	M550	Type A (round shape)
Awl	1	M221	Type A
Knives	2	M325 M375	Type A4 (no handle with upcurved blade tip) Type A1 (no handle with bulks)
Plaques	2	M36, M325	Type A (rectangle)

Table 6 Details of Phase 1

As the table shows, across 18 tombs in Phase 1 of the Tianshnabeilu site, 46 objects were discovered in 8 different kinds of bronze artefacts. Two types of bronze knives and bronze beads were found. In the first phase, the number of tombs was small, as was the number of bronze artefacts and their categories. The most common bronze object found was Pao, which was discovered in three tombs. It is the beads that are found in the greatest number in this phase, including two types. From the categories included, it is evident that most of the items are ornaments and a few tools, such as a knife and an awl. The mirror is special in this phase, this is the only handle mirror that was discovered at the TSBL site.

4.5.2 Phase 2

There were 135 tombs in this phase. The following list shows the bronze object discovered in this phase. The table shows that a total of 542 bronze objects in 12 different categories were discovered. There are two types of bronze tubes, pao, plaque and bronze mirrors, as well as three types of bronze buttons. The knives have five types in phase 2. The bronze objects of phase 2 consist of about a quarter of the total bronze objects found at the TSBL site, with the greatest number of beads and the second-highest number of tubes, although the pao is the most common. Phase 2 is still dominated by personal ornament and a smaller number of tools, including bronze knives and bronze awls. The bronze knives are more varied, containing five different types. Weapons appear in this phase, with three bronze arrowheads, accounting for nearly half of the number of bronze arrowheads in the entire TSBL site. There are three exceptional objects in Phase 2, a decorated bronze mirror and two bronze bells. This decorated bronze mirror is the largest and only round mirror with a decorated surface representing a round human face discovered at the TSBL site. These two bronze bells are a pair, appearring from a single burial, and are the only pair of bronze bells with handles from TSBL.

Objects	**Number of Objects**	**Number of Tombs**	**Typology Type**
Tubes	131	19	Type A (cylinder-shaped) Type B (spiral tube)
Mirrors	16	9	Type A (plain circular) Type B (back with pattern)
Beads	170	14	Type A (cylinder-like beads) Type B (wire beads) Type C (joint circular bead)
Buttons	50	25	Type A (round flat surface) Type B (round curved surface) Type C (shape of a figure of 8)
Pao	101	34	Type A (single circle) Type B (shape of a figure of 8)
Earrings	24	19	Type A (round shape)
Bangles	6	3	Type A (circular sectioned coil)
Plaques	21	17	Type A (rectangle) Type B (bow shape)
Awls	7	6	Type A (square-sectioned)
Knives	11	11	Type A1 (no handle with bulks) Type A2 (no handle wide body with curved back) Type A3 (no handle with a straight knife back) Type A4 (no handle with upcurved blade tip) Type D2 (handle with ring and upcurved blade tip)
Arrowheads	3	3	Type A (two-edged and leaf-shaped with a stocked)
Bells	2	1	Type A ((with the handle and the hole at the top end)

Table 7 Details of Phase 2.

4.5.3 Phase 3

This phase consisted of 243 tombs. The following list shows the bronze object discovered in this phase.

Objects	Number of Objects	Number of Tombs	Typology Type
Tubes	123	51	Type A (cylinder-shaped) Type B (spiral tube)
Mirrors	20	13	Type A (plan circular) Type B (back with pattern)
Beads	123	31	Type A (cylinder-like beads) Type B (wire beads) Type C (joint circular bead)
Buttons	215	57	Type A (round flat surface) Type B (round curved surface) Type C (shape of a figure of 8)
Pao	194	60	Type A (single circle) Type B (shape of a figure of 8)
Earrings	173	109	Type A (round shape) Type B (spoon shape)
Bangles	47	33	Type A (circular sectioned coil) Type B (round shape bend with a thin flat narrow sheet)
Plaques	40	40	Type A (rectangle) Type B (bow shape) Type C (hollow out with different shapes)
Awls	7	7	Type A (square-sectioned)
Knives	28	26	Type A2 (no handle wide body with curved back) Type A3 (no handle with a straight knife back) Type A4 (no handle with upcurved blade tip) Type B1 (grooved handle with ring) Type B2 (grooved handle with a small hole) Type C (handle with a straight knife back) Type D1 (handle with wave knife back and upcurved blade tip) Type D2 (handle with ring and upcurved blade tip)
Arrowheads	2	2	Type A (two-edged and leaf-shaped with a stocked)
Socketed Axes	2	1	Type A (Straight almost parallel sides with socketed butt, straight/slightly convex cutting edge; rectangular/square section)
Short Sword	1	1	Type A (two-edged and leaf-shaped with the hilt)

Table 8 Details of Phase 3

According to the table above, there are 243 tombs in this phase, and 981 bronze artefacts in 13 different categories were unearthed. Bronze objects in phase three covered almost all of the categories, as well as the different types of bronze objects included within each category. Phase 3 contains nearly half of the total number of bronzes from the TSBL site. This includes the largest number of bronze buttons, the second-largest number of bronze tubes, and the third-largest number of bronze earrings. In this phase, earrings are also the most popular objects. This phase is still dominated by personal ornaments and a small number of tools, such as bronze knives, bronze awls and bronze socketed axes. Bronze knives are more numerous and varied, comprising six different types. Weapons also appear in this phase, including 2 bronze arrowheads and a bronze short sword. This bronze sword is a special item in Phase 3 and is the only bronze short sword on the TSBL site.

4.4.4 Phase 4

There were 89 tombs in this phase. The following list shows the bronze object discovered in this phase.

Objects	Number of Objects	Number of Tombs	Typology Type
Tubes	16	8	Type A (cylinder-shaped) Type B (spiral tube)
Beads	44	7	Type A (cylinder-like beads) Type C (joint circular bead)
Buttons	25	16	Type A (round flat surface) Type B (round curved surface)
Pao	28	12	Type A (single circle) Type B (shape of a figure of 8)
Earrings	66	37	Type A (round shape)
Bangles	15	9	Type A (circular sectioned coil) Type B (round shape bend with a thin flat narrow sheet)
Plaques	7	6	Type A (rectangle) Type B (bow shape)
Awls	5	5	Type A (square-sectioned)
Knives	7	7	Type A2 (no handle wide body with curved back) Type A3 (no handle with a straight knife back) Type C (handle with a straight knife back)

Table 9 Details of Phase 4

The table above indicates that 89 tombs were excavated in this phase, and 215 bronze artefacts were discovered in 9 different categories. There are two types of bronze tubes, beads pao, bangle and plaque, as well as three types of bronze knives. The number of bronze objects in phase 4 decreases as the number of tombs decreases. With the largest number of earrings and the second largest number of pao, the bronze earring remains the most popular object in this phase. This phase is still dominated by personal ornaments and a small number of tools, including bronze knives, and bronze awls. The number of bronze knives decreases along with the variety, with only three types remaining. One of the unique objects in Phase 4 is a bronze bell with a perforated wall. One piece of shell-shaped flake also stands out, whose name and purpose remain unclear.

4.4.5 Discussion

TSBL site has four phases, and from the description above, it is apparent that there are obvious changes between the phases. Because of the limited number of tombs in the first phase, the number and variety of bronze objects are the least among the four phases. It is worth mentioning that the single bronze mirror with a handle found in the TSBL is believed to come from a western source and was introduced from Andronovo culture. In addition, the bronze knives are notable since they have no handles, while two of them have bulks on the back. During the second phase, the number of burials and the number of bronze objects increased significantly, as well as the variety of bronze objects, with the emergence of new categories, such as bangles, buttons, bells, and arrowheads. Bronze buttons are classified into three varieties. There have also been new types of tubes, beads, pao and plaques. Bronze knives were now available in five types, and knives with handles were introduced as well. Phase three of the TSBL site includes most tombs and bronze objects, encompassing nearly all categories, including the new category of short swords and socketed axes. Spoon-shaped earrings, banded flat sheet bangles, and hollow-out plaques are among the new styles. Three more bronze knife varieties were added, bringing the total to eight, all with handles. Type A knives with bulks on the back are no longer available. Short swords were added as another category of weapons, although the scarcity of these weapons prevented them from representing the development of weapons at that time. During phase four, the number of graves and bronze artefacts decreased dramatically, including the loss of arrowheads, bronze axes and bronze short swords. Earrings, beads, and buttons were reduced in type. Spoon-shaped earrings have vanished, making this form of earring unique in Phase 3. Bronze beads and figure-of-eight buttons have also disappeared. However, distinctive bronze bells and the shell-shaped bronze piece had not previously been discovered.

The characteristics of the bronze artefacts from the TSBL site are that they are primarily personal ornaments, along with some tools and very few weapons. Consequently, bronze objects developed primarily reflect the vigorous development of personal ornaments, with relatively little change in the development of tools, nor an increase in the category, the most prevalent types being knives and awls. There are two possible explanations: the first is that burial practices were dominated by personal ornaments and tools did not enter the process. Another possibility is that bronzes were highly valuable at the time, and most of them were used to make accessories, with only a few being made into tools. The fact that a large number of stone and bone tools were also unearthed at the TSBL site, may also be a reflection of the preciousness of bronze at the time. In the development of personal ornaments, we can see the evolution of the fashions of the TSBL people at that time. During the first phase, beads dominated the market, while during the second phase, tubes and pao, along with beads, became more popular. In the third phase, based on the second phase, earrings became the most popular ornament, appearring in almost every burial. Almost every type of ornament was updated with new styles. Personal ornament follows the trend of bronze growth at the TSBL site, with an expanding range of ornaments and forms. To sum up, the first phase of the development of bronze from the TSBL site should be viewed as being at an early stage, the second phase should be considered the development period, the third phase reached its peak, and the fourth phase had a sharp decline. Significant development and changes can be observed in the bronze artifacts during the four phases of the Tianshanbeilu site. However, in terms of the distribution and quantity of these bronze burial goods in tombs, there doesn't appear to be a particularly distinct class or wealth disparity. Bronzes in the TSBL site have some of the most interesting and unique trajectories that can be traced back to the development of local cultures and their interaction with surrounding cultures, which is a focal point of this thesis and is going to be analysed and discussed in more detail later on in the following chapters.

4.5 Summary

In summary, this chapter explores the typological classification of Bronze Age metal artefacts from TSBL, and outlines the many aspects of the major types of metal artefacts from TSBL. The metal forms in prehistoric Hami overwhelmingly reflect cultural influences from a neighbouring region. The metal objects deposited in the TSBL cemetery suggest that the local Bronze Age community was rather unique in the Bronze Age of Xinjiang, being a relatively large community group of metal consumers. More importantly, the types of material deposited at the site, their form and style are very similar to those of the Siba culture in Gansu. This testifies to an extensive interaction between the two cultures, between eastern Xinjiang and areas of the Hexi corridor in Gansu. It is vital to understand of identities and connections of TSBL need to focus on the mobilities of people, styles and technologies within this geographical area, if we are to understand the further society in Bronze Age Xinjiang. Moreover, the evidence of cultural contact with the Andronovo culture to the West can be observed, including arrowheads, a short sword and mirrors.

Beyond these regional influences in Xinjiang, the unique items at TSBL, such as spiral tubes, hollow plaques, and decorated back surface mirrors, show a strong local culture. All this evidence suggests a complex picture of the source of objects or styles and associations. Studies of the Early Bronze Age Xinjiang, have often stressed the transmission of technology, the organisation of metal production, including metal specialisation, and how people socialised and interacted in a material world. Such discussions are often framed within the context of the development of metallurgy, the emergence of extensive trade networks and social behaviour such as farming and hunting, all of which are closely related to the appearance of metal objects. It is on this basis, with an analytical approach to the metal assemblages of different phases at TSBL that this thesis will proceed, comparing compositions and alloying practice with the stylistic aspects we have discussed here.

Chapter 5 Bronzes Analysis and Results

5.1 Introduction

The purpose of this chapter is to present the results of an integrated investigation of the metal assemblage at the TSBL site. It describes and discusses the contextual perspective and chemical characterization of bronze artefacts, as well as their interpretation in terms of distribution, alloy grouping, technology, and circulation. The results are divided into two parts: The first part is the integration of the conceptual approach, which is to integrate all finds from tombs throughout the TSBL site so that they can be subjected to a general investigation of metal consumption in TSBL cultural processes while contextualising the artefacts' style and distribution with some details of their manufacture. The goal is to emphasise the strong relationship between metal, other materials, artefacts, and burial activity, as well as human remains. The second part concerns alloying composition analysis, to identify and characterise changes in metal technology and thus discuss transformation in production and organisation. The alloy group forms the core of the second part and it is on the ground of chemical composition that pXRF was applied. The integrated results aim to 1) understand the relationship between the metal object and the other grave goods in the tomb of the TSBL site and the role of a metal object in the burial practice, 2) identifiable aspects of production technology of metal objects, especially their allow composition 3) changes in metallurgical tradition over the time and the characteristics of the metal object of each phase, 4) the relation between different elemental compositions, alloys in the development and the choice of the raw material.

5.2 Part One - Contextual Study

Here the primary presence of metal assemblage in funerary contexts of TSBL is summarised. TSBL over 3000 bronze objects were recovered from TSBL, with 409 of the 706 tombs (58%) containing bronze objects. Many of the bronze artefacts from TSBL are highly corroded, and approximately 500 of them are fragments that are difficult to distinguish from their original shapes, making it impossible to classify them. In this thesis, only bronze artefacts that can be distinguished by their specific shapes are counted, totalling 2,503 pieces, of which 14 categories are included. Table 55 shows the kind of bronze artefacts that are found in tombs across all periods. There is a wide range of objects that include ornaments, tools and also a few weapons.

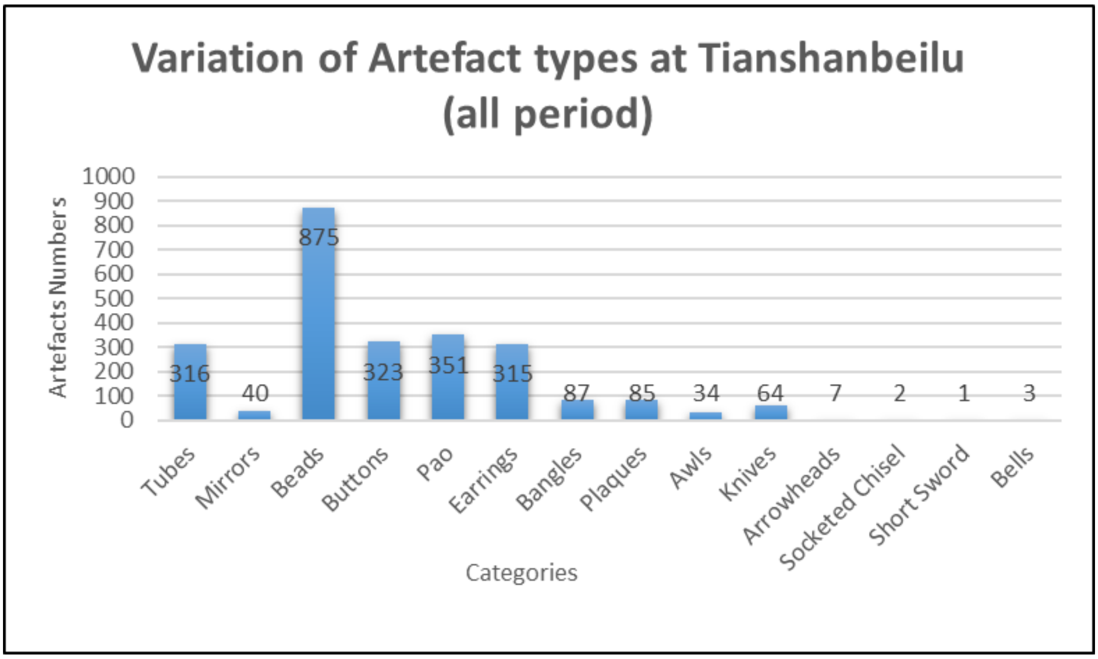


Figure 54 Amounts of different artefacts at TSBL

As the table shows, there are 14 categories of bronze artefacts found at TSBL. Bronze beads were the most numerous and they were typically threaded into necklaces or bracelets, thus a single burial might include a reasonably large number of them, increasing the overall amount.

Bronze earrings are the most popular and widely distributed, followed by pao and plaques (See Table 10 for detailed figures)

Category	Number of items	Number of tombs
Tubes	315	96
Mirrors	40	26
Beads	875	71
Buttons	323	116
Pao	351	119
Earrings	315	202
Bangles	87	56
Plaques	86	121
Awl	34	33
Knives	64	62
Arrowheads	8	8
Socketed Chisels	2	1
Short Sword	1	1
Bells	3	2
Unknown	1	1
Total Number	*2505*	

Table 10 The number and distribution of each category of bronze artefacts at TSBL

The number of objects varies across TSBL's four phases. The bronzes excavated in each phase have been described in detail in the previous chapter and will not be repeated here. The following illustrates the bronze artefacts found in each phase (Fig 56-59) .

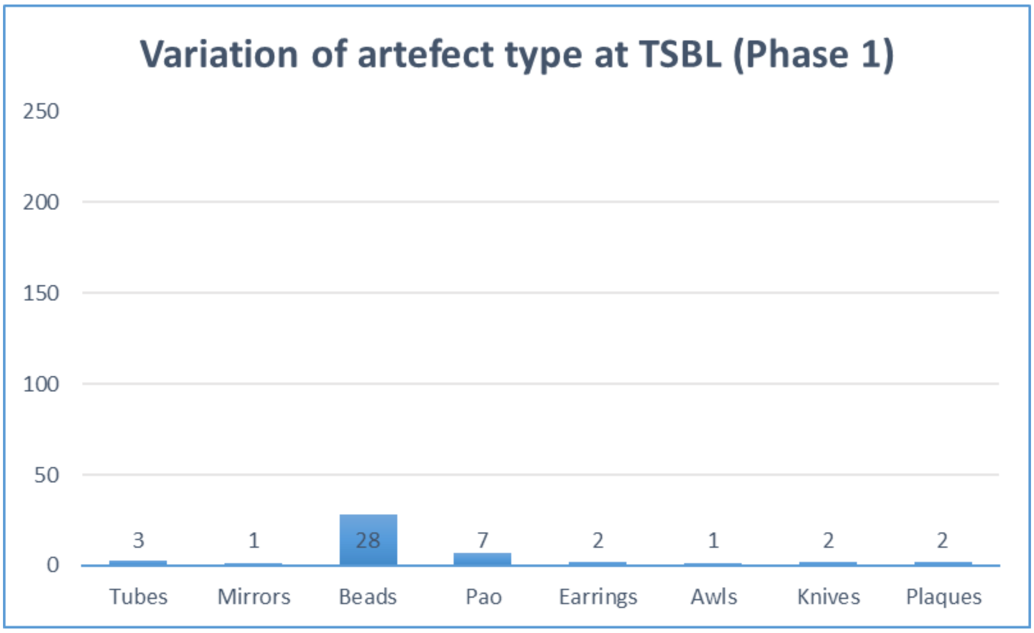


Figure 55 The bronze artefacts found in Phase 3

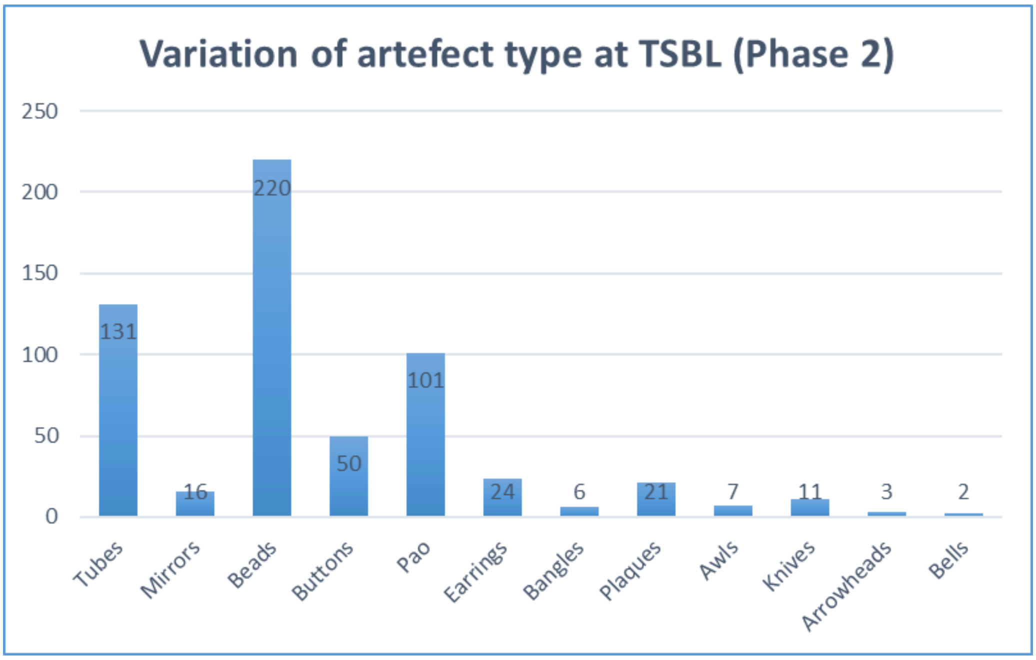


Figure 56 The bronze artefacts found in Phase 2

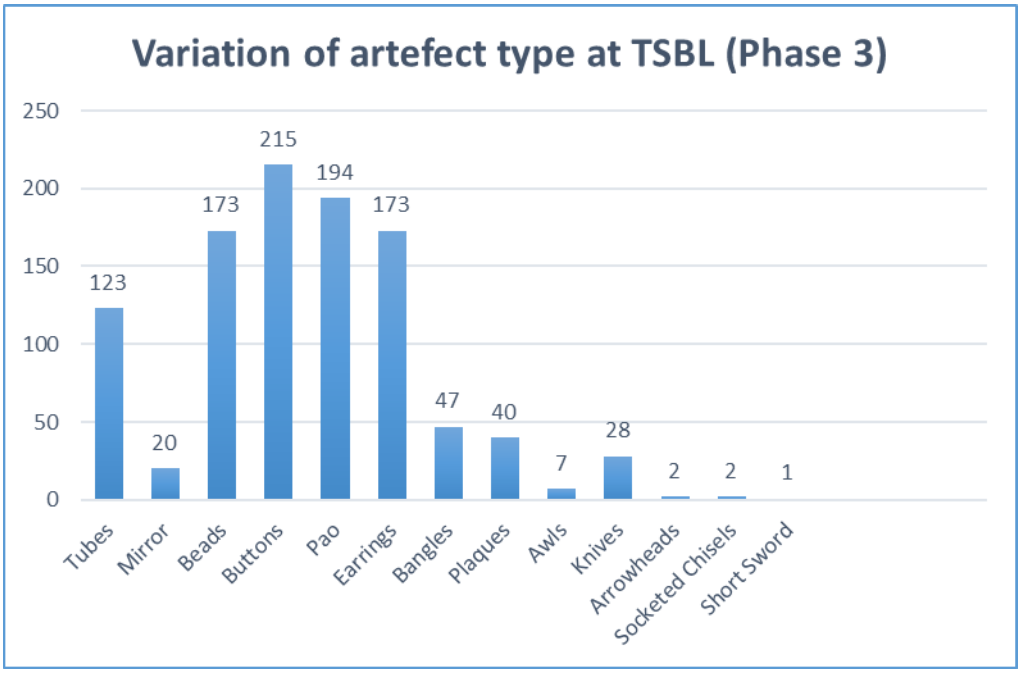


Figure 57 The bronze artefacts found in Phase

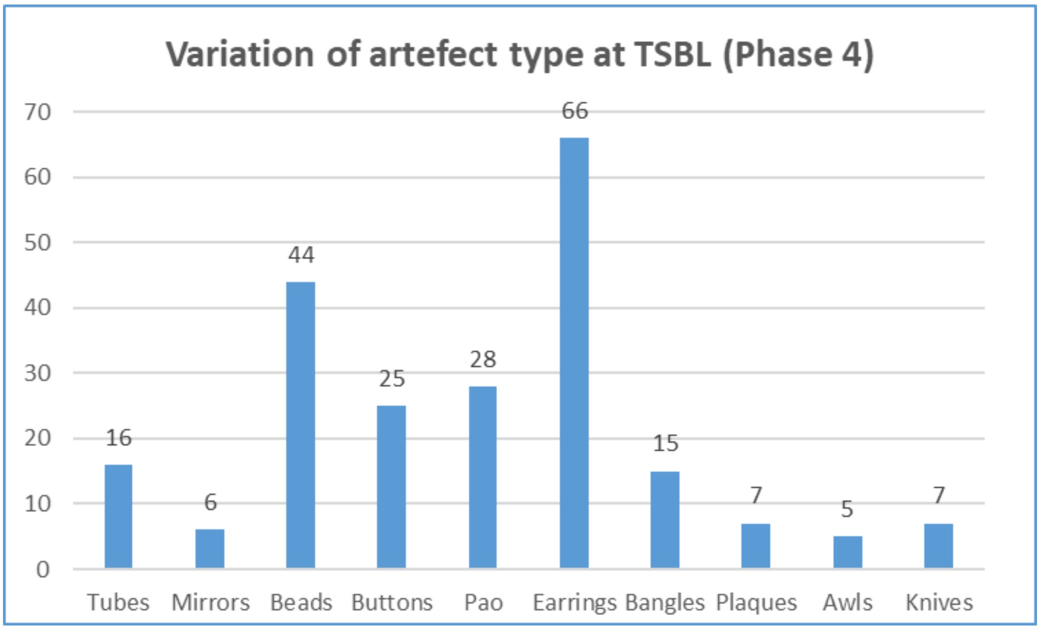


Figure 58 The bronze artefacts found in Phase 4

Collectively, the unifying feature of all four phases is that they are all largely personal ornaments, complemented by tools, with just a few weapons emerging in phases 2 and 3. According to the number of bronze artefacts and their category, the first phase is the earlier stage of TSBL, and the number of graves is the lowest. The second phase, which may be regarded as an active period of development in the Bronze Age of TSBL, has a large increase in the number of graves as well as the number and type of bronze objects. The third phase of bronze development reaches its climax at the TSBL, where the greatest amount and variety of bronze objects can be found. A precipitous decline can be observed in the fourth phase, clearly a consequence of a decline in burials. The changes in the fourth phase of TSBL are of great interest, and the causes behind this phenomenon are well worth investigating, as explained in the next chapter. Despite this, only 409 burials have been dated, and the rest are inconclusive, thus the above conclusions are based solely on the data available at present.

Metal artefacts other than copper or bronze were also discovered at TSBL, including eight gold and nineteen lead earrings. The gold earrings, which have rounded shapes, are only found in Phase 1, in graves M325, M375 and M468 and five have been analyzed by pXRF. The appearance of gold earrings is assumed to be the consequence of interaction and influence from western steppe culture, which is one of the phenomena of interest in this study and will be discussed in the next chapter. The lead earrings initially appear in Phase 2 and may also be seen in Phases 3 and 4, (2, 11 and 3 in the respective phases). As with bronze earrings, lead earrings can be divided into two types: round and spoon-shaped. As a result of pXRF testing, these earrings, which were previously thought to be silver, were identified as lead, and seven of them were confirmed to be 92-99% pure lead products, not alloys. The earrings were among the most popular ornaments since the second phase of the TSBL, and their composition most likely reflects a demand for different coloured jewellery. As one of the key alloying elements in bronze technology, lead is of interest and will be discussed in more detail in the following chapter.

According to an analysis of all the grave goods discovered in the TSBL cemetery, bronze and pottery were the most frequent burial artefacts, with pottery being the most common type of object. 521 burials out of 706 yielded pottery (604 pieces). There were also a few stone objects and bone objects found in the cemetery, including tools and weapons. Furthermore, there was a wide range of personal ornaments, such as beads in stone, bone, carnelian and turquoise, indicating that the inhabitants of the TSBL area put a high value on personal and dress ornamentation. It is common to find sheep and cattle bones buried in the graves of the TSBL site, with sheep bones predominating. It is crucial to note that this vital burial information, coupled with the bronzes, gives a contextual context as well as a useful evaluation of the economic and social patterns of the TSBL's inhabitants. One of the major goals of this thesis, in addition to studying the bronzes, is to investigate the period's social patterns and cultural context.

5.3 Part Two – Analytical Result

This research analyses 1352 metal objects, derived from 406 graves from the TSBL site, representing an almost complete coverage of the graves with metal objects. The data results are generated from pXRF testing, with careful data analysis and selection. The data result is based on the previous research by the Oxford team used a cut-off of 1% for deliberate alloying (Liu et al. 2020). When the content of Sn, Pb, and As in copper exceeds or equals 1%, the element is regarded to be the appropriate copper alloy type, whereas elements less than 1% are considered trace elements. Elements such as Fe, S and O are not involved in the classification of materials. As a consequence of heavy corrosion, the results of this analysis are not able to determine the original alloying ratios of the samples, e.g. partial corrosion will lead to high measurements of tin and lead content, but if other alloying elements, such as tin and arsenic, are present in the rusted composition, they will still be marked as tin bronze or arsenic tin bronze (Liu et al. 2020). As such, when viewing and using the data, samples with of particularly unusual compositions will not be included, such as those with very high Sn content (above 20%) and other similar cases.

5.3.1 Alloy Types

There are eight alloy groups for the copper or bronze objects found in TSBL, which involve tin bronze (Cu-Sn), arsenic copper (Cu-As), pure copper (Cu), arsenic bronze (Cu-Sn-As), leaded bronze (Cu-Sn-Pb), leaded arsenic copper (Cu-As-Pb), leaded arsenic bronze (Cu-SB-Pb-As) and arsenic antimony copper (Cu-As-Sb), as illustrated in Fig 60.

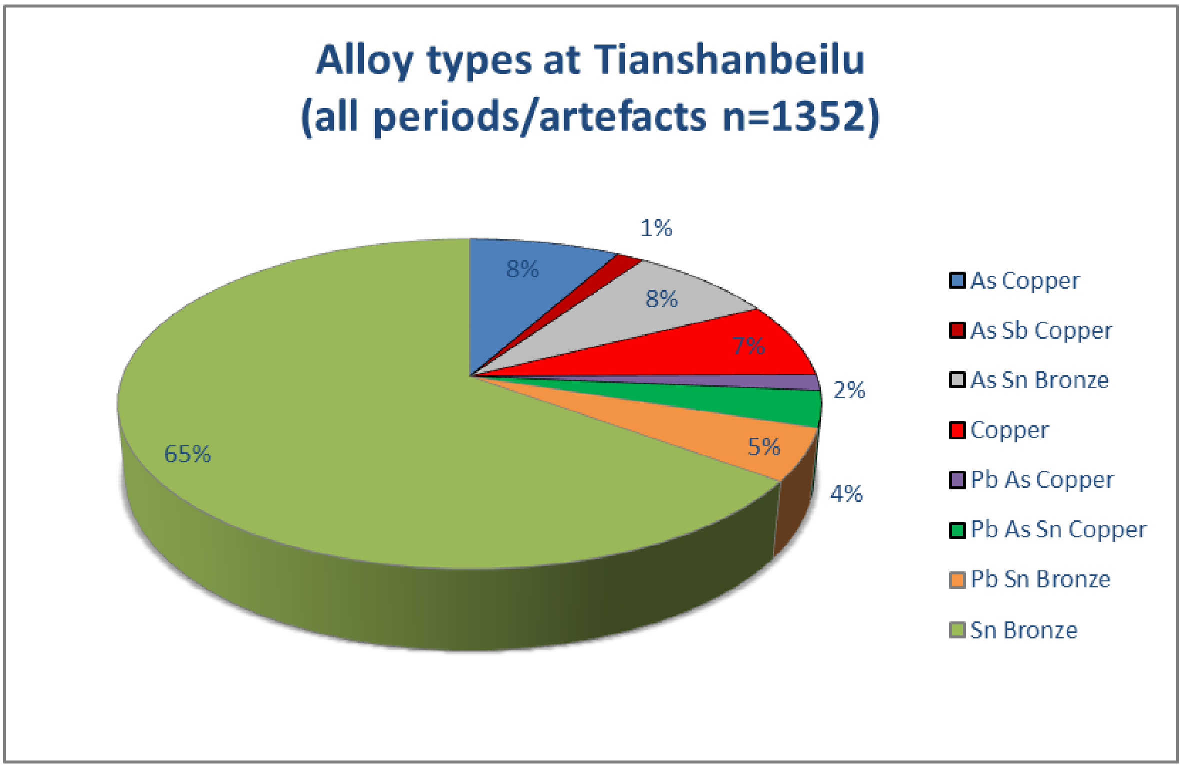


Figure 59 Alloy types at TSBL

The most common alloy type is tin bronze (Cu-Sn) but there are also significant amounts of arsenic copper (Cu-As), arsenic bronze (Cu-Sn-As) and pure copper (Cu). The presence of arsenic bronze (Cu-Sn-As) and leaded arsenic bronze (Cu-Sn-Pb-As) as significant groups suggest that intermixing was common. There are very few examples of arsenic and antimony copper (Cu-As-Sb) and leaded arsenic copper (Cu-As-Pb). The latter three-element alloy is common in steppe-style bronze objects. According to the previous analysis, the 'arsenic-antimony' (Cu-As-Sb) appears only in the steppe (Hsu et.al 2016) and is particularly typical of metal production in the Bronze Age of the northern Sayan (Bobrov et al., 1997; Borodovsky 2013). Arsenic and antimony are frequently found together in minerals of the tennantite-tetrahedrite family, in which these two elements form a full solid substitution series from the end members of tennantite ($Cu_{12}As_4S_{13}$) and tetrahedrite ($Cu_{12}Sb_4S_{13}$). As a result, the composition can be suggested to be the result of the use of tennantite-tetrahedrite or tennantite as part of the ore charge (Krismer et al., 2011). In fact, a varied range of alloy types can be observed in TSBL, which is characteristic of steppe metal assemblages (Chernykh 1992; Hsu 2016; Liu et.al 2020). It might be suggested that the mobility of pastoralist societies will likely lead to a more diversified and fluctuating metal supply, resulting in more varied alloy compositions.

According to the analysis, tin bronze accounts for 65% of the alloy types, with Sn content between 1% to 21.4%. Tin is also contained in three ternary alloys, including arsenic tin bronze, leaded tin bronze and leaded arsenic tin bronze. The most frequent concentration range of the tin is 3.5% to 6%, the next common use range is 8.5%-11% at TSBL. There will be different content of tin to meet the demands of the particular object, as weapons will often need hardness, while mirrors require a higher content to produce the silver and white colour, and ornaments will need toughness and workability. With a tin content of 7% to 10%, the elongation of copper falls directly from 40% to 20%, a range which is detrimental to the processing of bronze (Jin 1987). The histogram (Figure 61) illustrates that nearly half of the alloys have a tin level of 7% or more. This suggests that a large proportion of the bronzes were made without the best techniques of tin bronze working on ornaments.

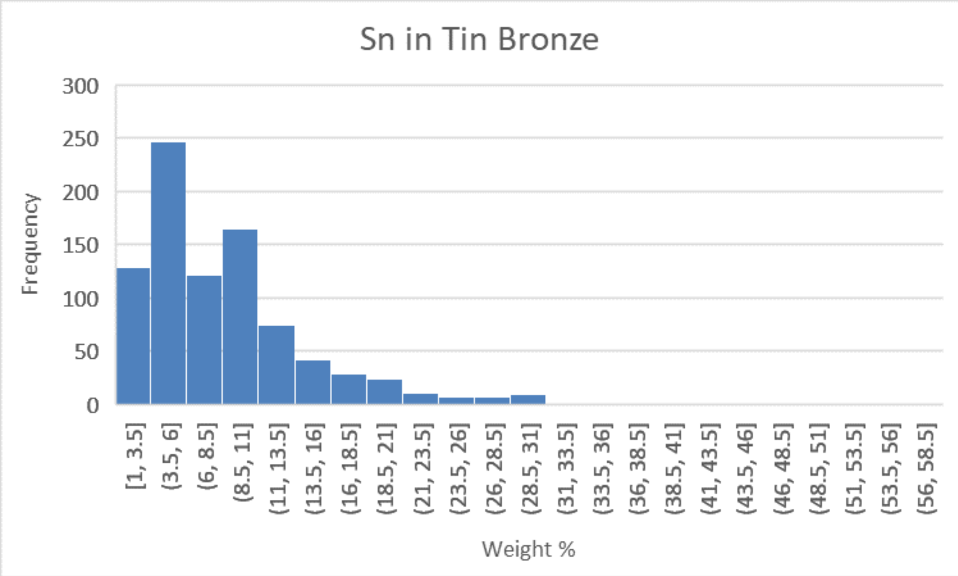


Figure 60 Tin Level in Tin Bronze objects at TSBL

The other two relatively common alloys are arsenic copper (Cu-As) and arsenic bronze (Cu-Sn-As), both at 8%. The arsenic content can reach 7.5% in arsenic copper, but the majority of the level is between 1% to 3% (see Figure 62). In human history, the first alloy to be used was arsenic copper, a copper alloy with arsenic as a major alloying element. In almost all regions of the world, arsenic was introduced as an alloying component earlier than tin. Initially, arsenic-copper was the result of smelting red copper, rather than conscious alloying. Accordingly, the origin of copper follows a sequential sequence of red copper, arsenical copper, and bronze, determined by the structure and nature of copper deposits (Jin 1987). Arsenic oxides have a low boiling point and are volatile, therefore when arsenic-bearring copper oxide ores are smelted under reducing circumstances, some arsenic is retained in the result, although usually less than 2%. The peak range of the arsenic level is less than 2% at TSBL. Previous studies have suggested that smelting arsenic-bearring copper oxide ores can retain up to 7% arsenic in the copper (Chase and Ziebold 1978), whereas very little tin content was above 7% at TSBL, possibly from smelting arsenical-copper ores. As mentioned before the use of distinctive ores from the tennantite-tetrahedrite series shown in the data, is different from the ore concentrations of arsenic but not antimony. This may reflect a variety of exploited raw material sources. One such potential resource is Nulasai, the most well-known Bronze Age mining and smelting site (Mei 2000; Li 2001).

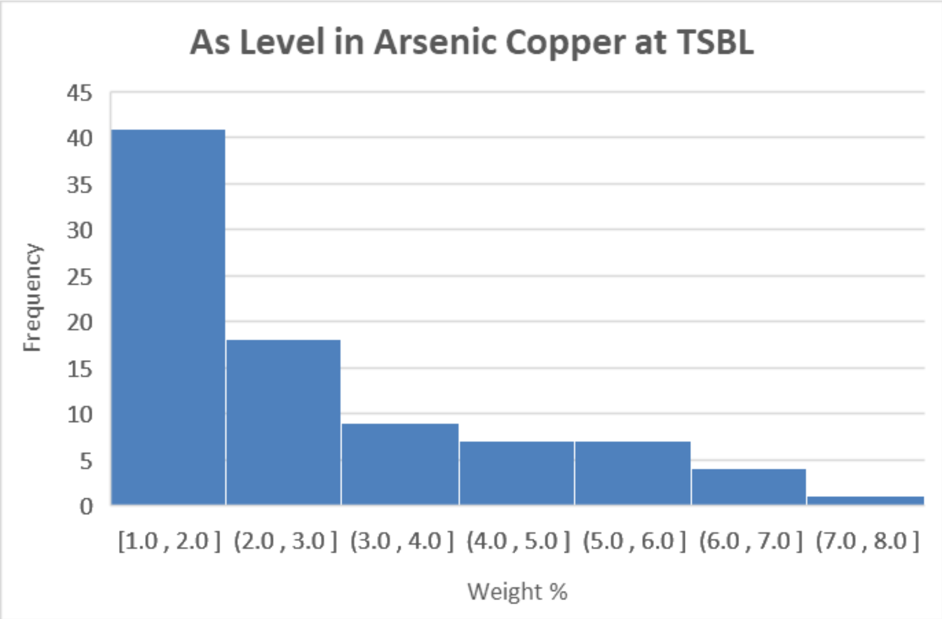


Figure 61 As Level in Arsenic Copper objects at TSBL

In arsenic bronze, a ternary alloy, the arsenic level is between 1% to 4.8% (see Figure 63), and the tin content fluctuates over a wide range from 1%-21%. The inclusion of both As and Sn in the alloys might be due to recycling, but it could also be owing to a desire to capitalise on the benefits of both elements. In this regard, it is worth noting that the remnants of an arsenic tin ingot have been found at the Nulasai copper mine site dated around 1000BC. It is the only tin ingot discovered in Bronze Xinjiang (Mei 2012).

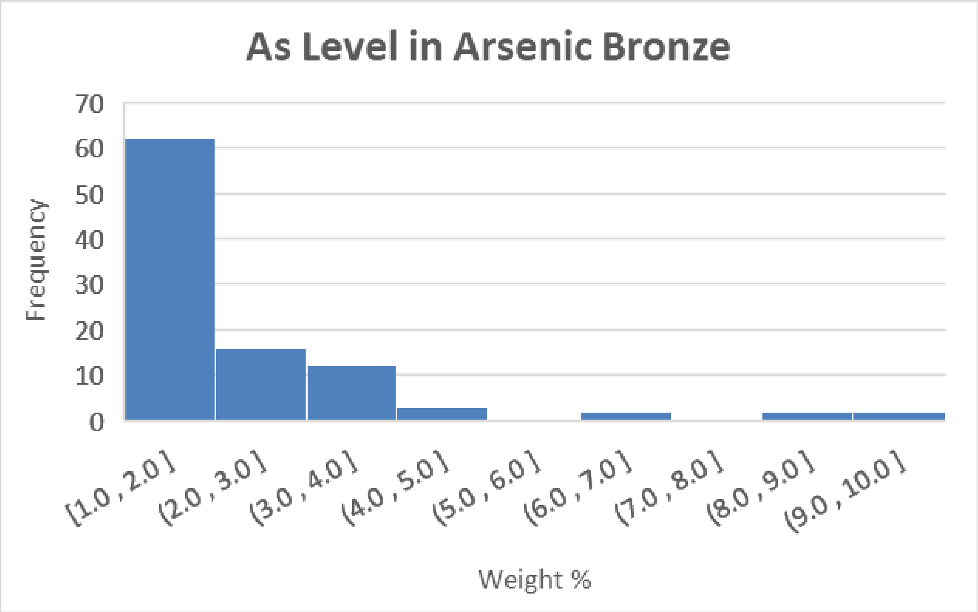


Figure 62 As Level in Arsenic Bronze

There are also a few leaded alloy groups present, including leaded bronze (Cu-Sn-Pb), leaded arsenic copper (Cu-As-Pb), and leaded arsenic bronze (Cu-SB-Pb-As). As the three histograms demonstrate below, the lead content in leaded arsenic copper is 1.0% to 5.8%, with the majority of the level is below 3.6%, and only two samples with 4.2% and 5.8% lead. The examples of leaded arsenic bronze contain lead levels up to 16.3%, but most of them were in the range of 0.3% to 4.8%, with 8 figures above 4.8%. The lead level is from 0.4% to 15.4% in leaded bronze, but the main level range is 0.4% to 5.4%, with three high values at 6.9%, 12.2% and 15.4%.

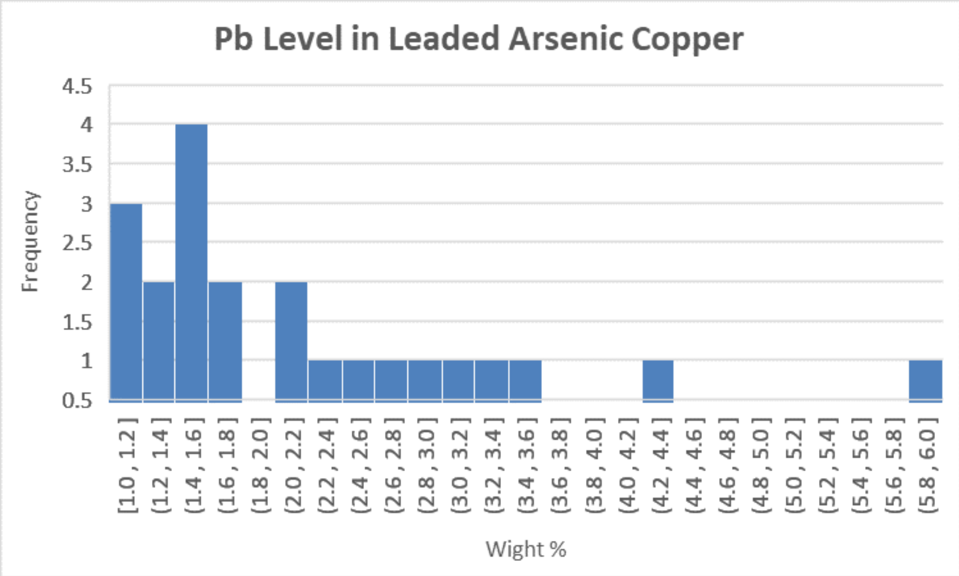


Figure 63 Pb Level in Leaded Arsenic Copper at TSBL

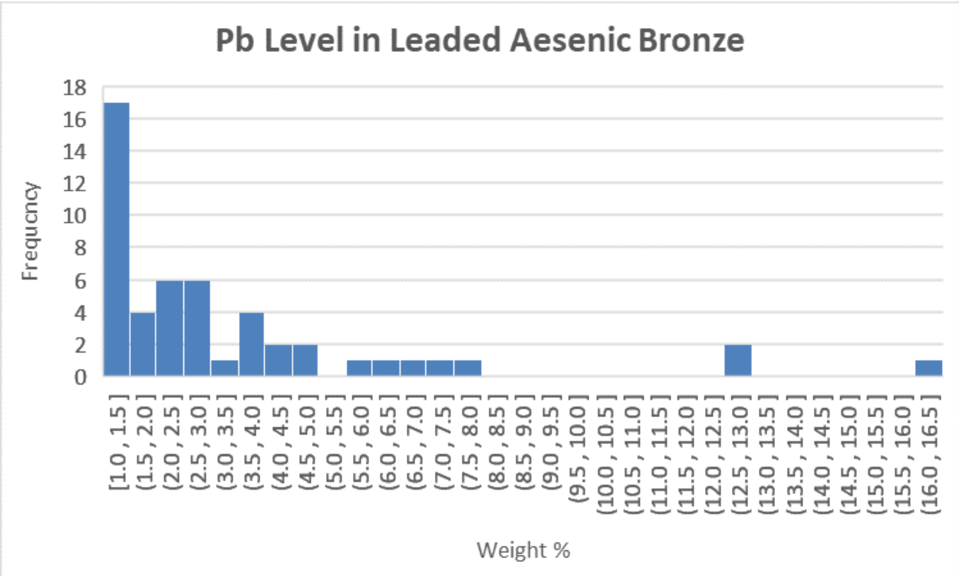


Figure 64 Pb Level in Leaded Arsenic Bronze at TSBL

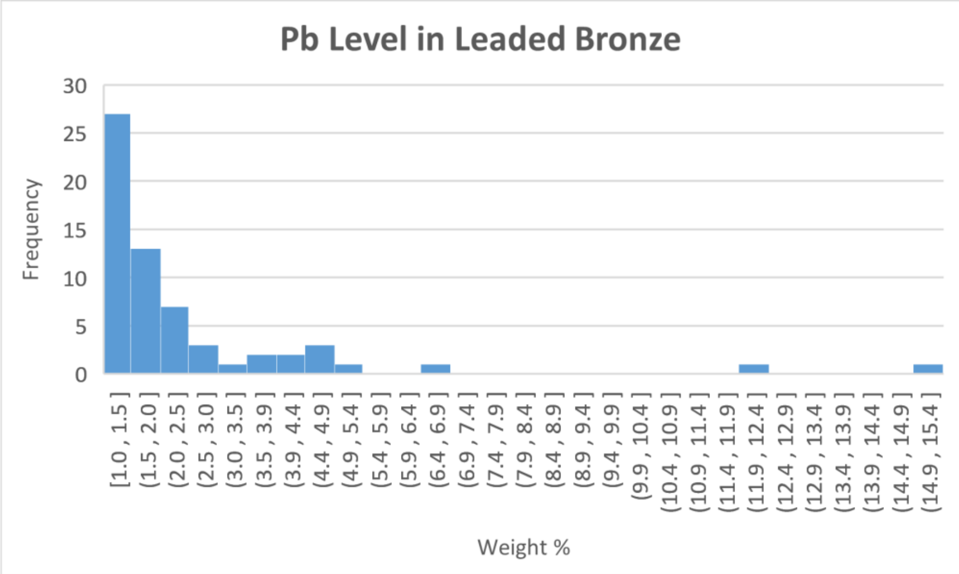
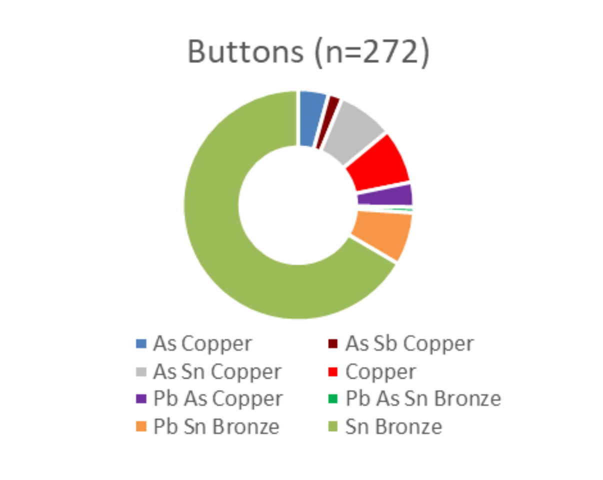


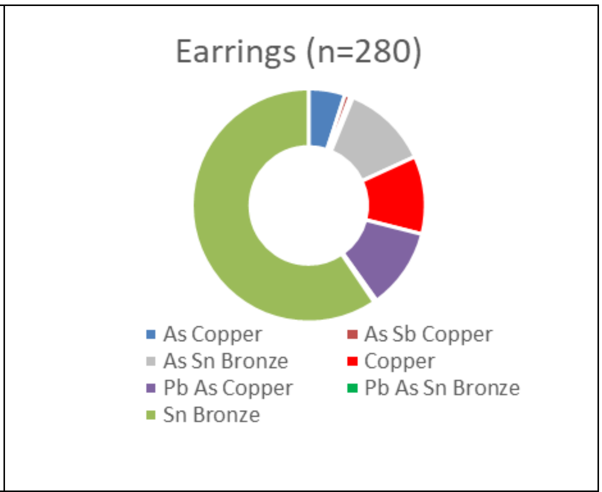
Figure 65 Pb Level in Leaded Bronze at TSBL

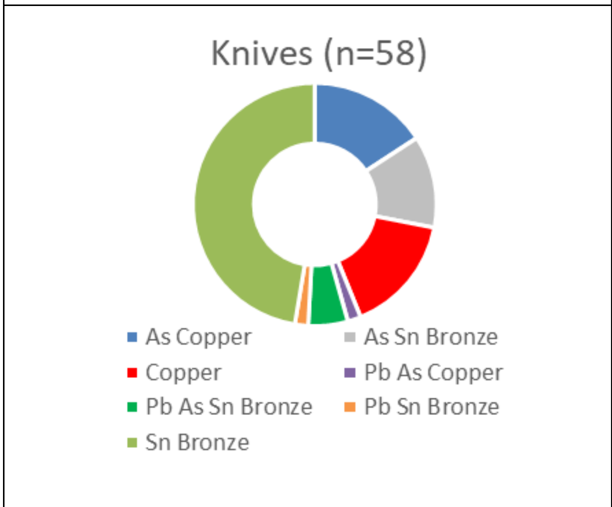
The alloy groups containing lead accounted for 12% of the total, so it is clear that lead was also an invaluable raw material in local metal production. By adding lead to copper-based making processes, the melting point will be lowered and fluidity will be increased, making it easier to pour and cast. The unevenness of the lead concentration in the leaded bronze or copper alloy groups, as well as the large fluctuation in values, may be due to recycling, but it may also be due to a desire to capitalise on the element's benefits. The understanding and usage of lead are partially symptomatic of the mastery of technology and production capabilities at the time. Earrings made of pure lead were also discovered in the TSBL, indicating that lead was a significant metal utilised by the populace at the time, and the source and circulation of lead is an important subject that deserves to be addressed and will be described in the next chapter.

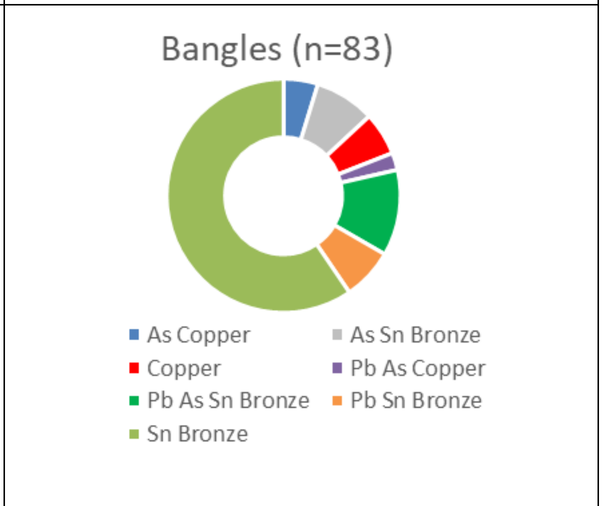
5.3.2 Categories of bronze alloy types

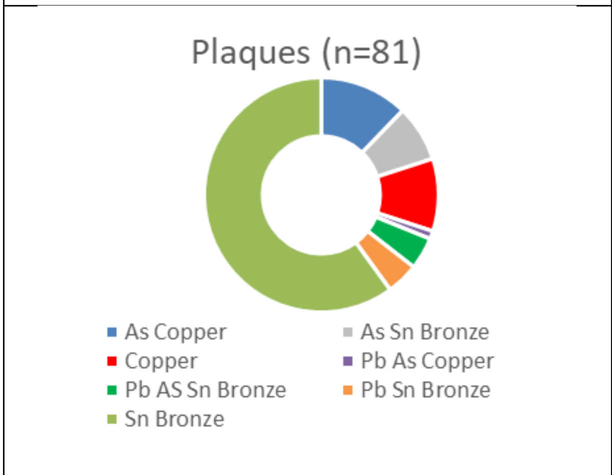
The relative frequency of bronze alloys, in association with their typological and technological association are represented below (Fig 67), showing that the eight major alloy types are used in 14 categories of bronze artefacts from TSBL.

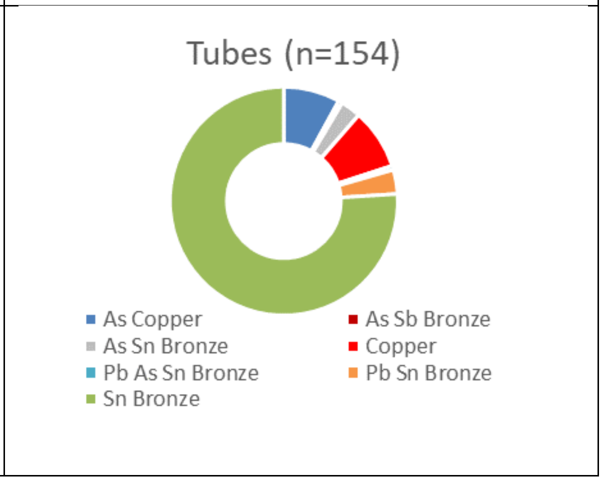

Buttons (n=272)
As Copper
As Sb Copper
As Sn Copper
Copper
Pb As Copper
Pb As Sn Bronze
Pb Sn Bronze
Sn Bronze


Earrings (n=280)
As Copper
As Sb Copper
As Sn Bronze
Copper
Pb As Copper
Pb As Sn Bronze
Sn Bronze


Knives (n=58)
As Copper
As Sn Bronze
Copper
Pb As Copper
Pb As Sn Bronze
Pb Sn Bronze
Sn Bronze


Bangles (n=83)
As Copper
As Sn Bronze
Copper
Pb As Copper
Pb As Sn Bronze
Pb Sn Bronze
Sn Bronze


Plaques (n=81)
As Copper
As Sn Bronze
Copper
Pb As Copper
Pb AS Sn Bronze
Pb Sn Bronze
Sn Bronze


Tubes (n=154)
As Copper
As Sb Bronze
As Sn Bronze
Copper
Pb As Sn Bronze
Pb Sn Bronze
Sn Bronze

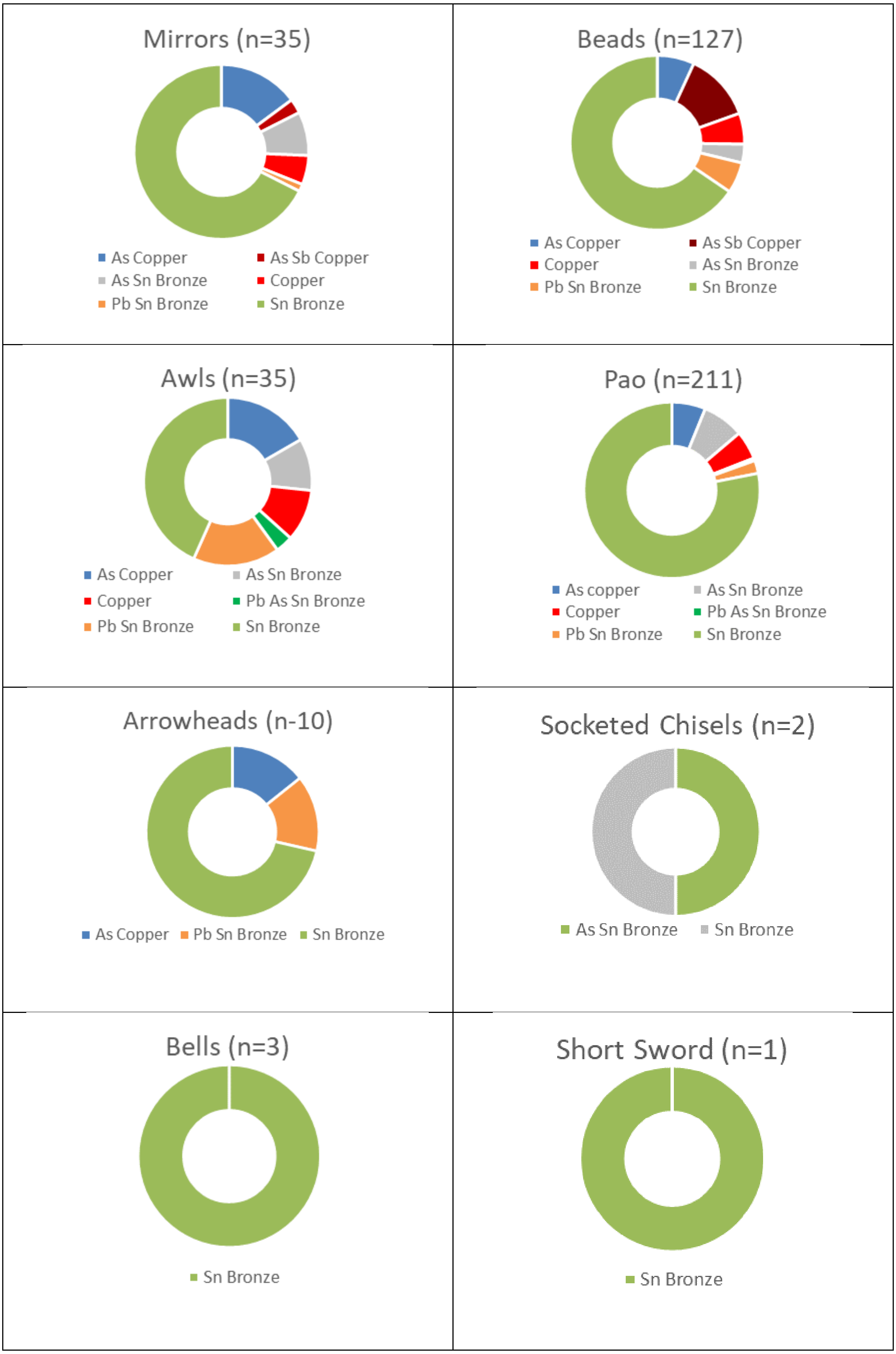


Figure 66 The Distribution of the Alloy Types by Category.

Earrings and buttons are represented in all alloy groups at TSBL, probably as they are the most common objects in the graves. The distribution of knives, bangles, and plaques is very consistent, as all of them occur in the same alloy types. Pao and awls are also similarly varied, sharing the same six alloy types. There are also mirrors and beads involved with the six alloy types, and with the distinctive feature of the co-occurrence of arsenic and antimony copper alloy. The arsenic antimony copper alloy is also contained in the tubes, beads, mirrors, earrings, and buttons. As arsenic antimony is associated with ores from the tennantite-tetrahedrite series, this suggests that the production may share the same raw material resources. There are very few awls, chisels, short swords and bells found in the graves, so there is less variability in the alloy composition. The awls contain three alloys, including tin bronze, arsenic copper and leaded tin bronze. Chisels were identified in two alloy groups: tin bronze and arsenic tin bronze. Notably, both chisels were found in the same burial, so they may have come from a different production centre or a different choice of alloy by the maker. The bronze bell and the short sword are both of tin bronze. A particular object type using the same alloy group could indicate either a similar origin or different production units using a shared alloy technology.

There is a wide range of alloy combinations available in most categories of bronze artefacts from TSBL. Additionally, arsenic copper occupies an important position alongside tin bronze as the most prevalent alloy. Ternary alloys occur in most categories, which indicates that recycling may be widespread.

Tin is the most essential element in bronze alloys, and its amount in different bronzes may be considered to investigate variations in alloy choices over space and time. The tin content in the copper-based artefacts at TSBL, is similar in almost every object category, except for a limited number of particular classes with only a small quantity. The earrings, buttons, bangles, beads, plaques, knives, mirrors, and tubes all follow the same pattern, as shown in the bar charts below (Figs 68 – 75). The data indicate that the bulk of the tin levels in the alloys were less than

12.5%, with the most common range being 3.5% to 6%, followed by 8.5% to 11%. Returning to Figure 5.6, the distributions for the individual categories are comparable to the tin concentration in bronze artefacts across the entire assemblage at TSBL. The exceptions include 8 arrowheads, 2 socketed chisels, 3 bells and 1 short sword. The tin level in arrowheads ranges from 1.2% to 12.5%, an uneven and wide disparity. Three bells, one pair with handles and one cut hollowed-out, the pair composed of leaded arsenic tin bronze with tin concentrations of 33.3% and 27.6%, respectively. These very high tin contents may be caused by the corrosion on the surface. The carved hollowed-out bell is made of tin bronze, which contains 4.5% tin. Two chisels were found in the same grave made of tin bronze and arsenic tin bronze, with tin levels of 11.2% and 10.1%, respectively. The short sword is made of tin bronze, tin content of 17%. Both chisels and short swords contained a rather high amount of tin, demonstrating the possibility of the maker adding more tin to produce greater hardness.

These findings show that bronze workers chose to utilise similar tin content in the alloys during the period, which might imply that bronze-making processes features shared choices and practices and that communities shared technological knowledge. A substantial discussion of this topic will take place in the following chapter, which involves technology transmission or exchange, as well as trade or exchange between the TSBL community and other neighbouring cultures.

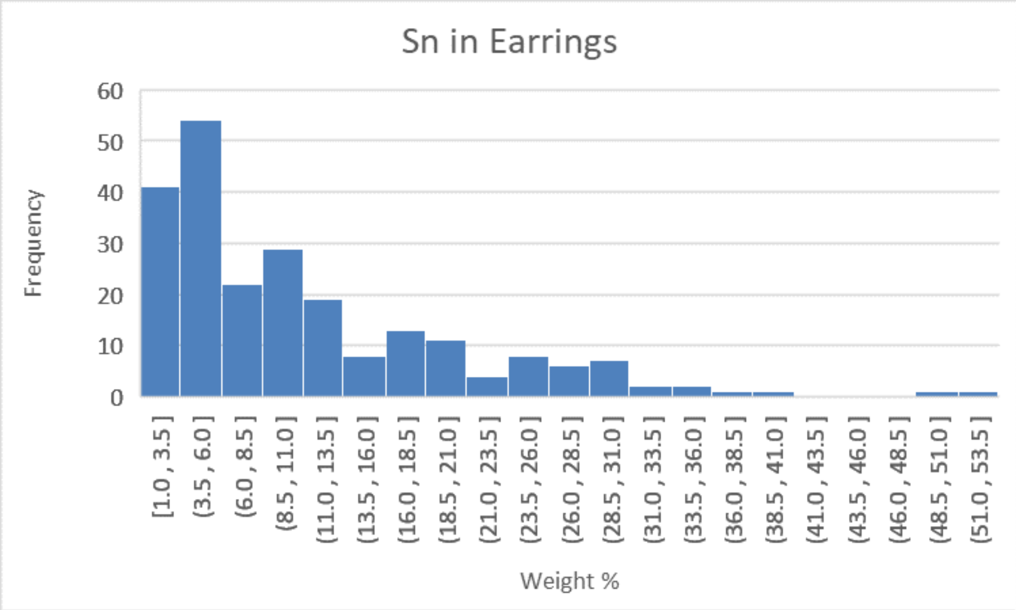


Figure 67 Sn Content in Earrings

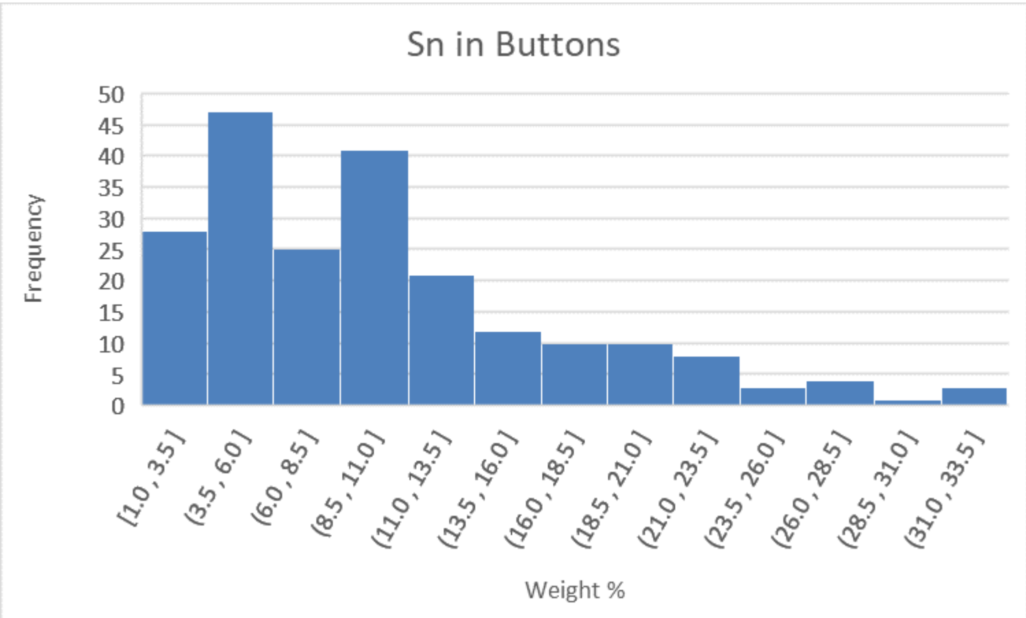


Figure 68 Sn Content in Buttons

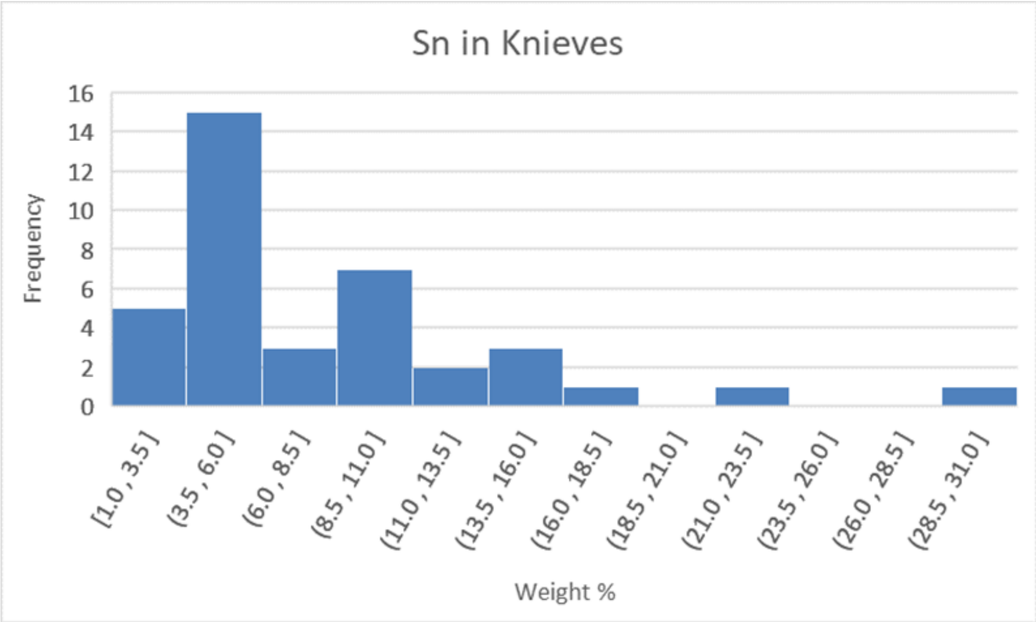


Figure 69 Sn content in Knives

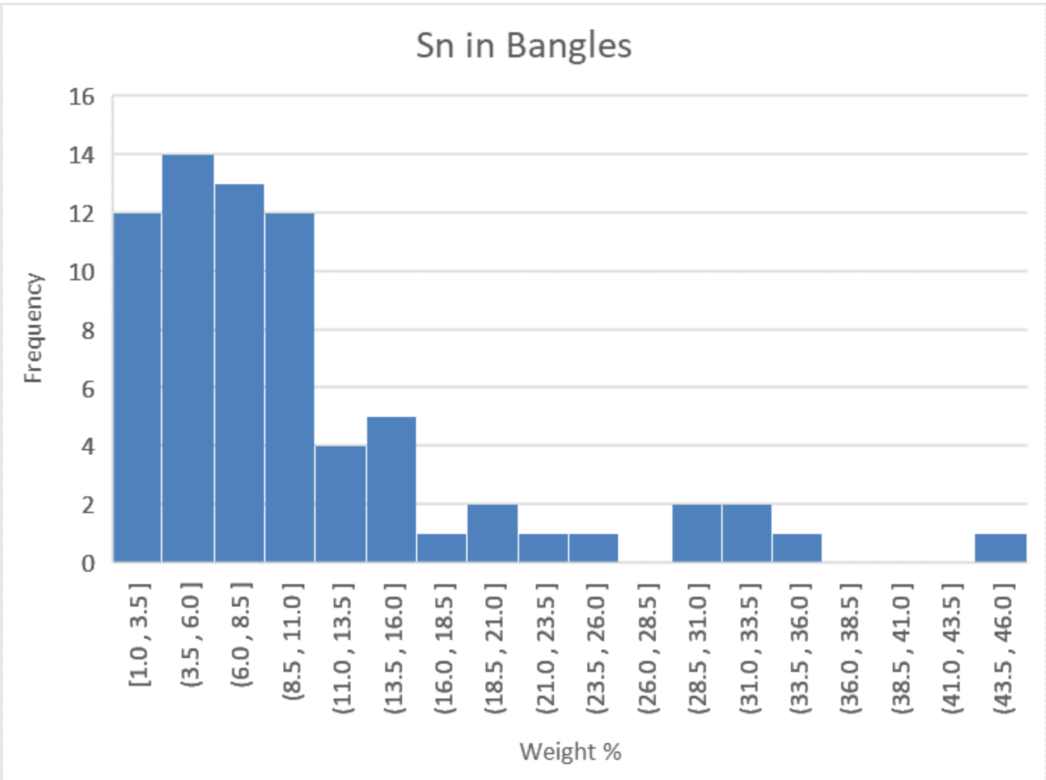


Figure 70 Sn content in Bangles

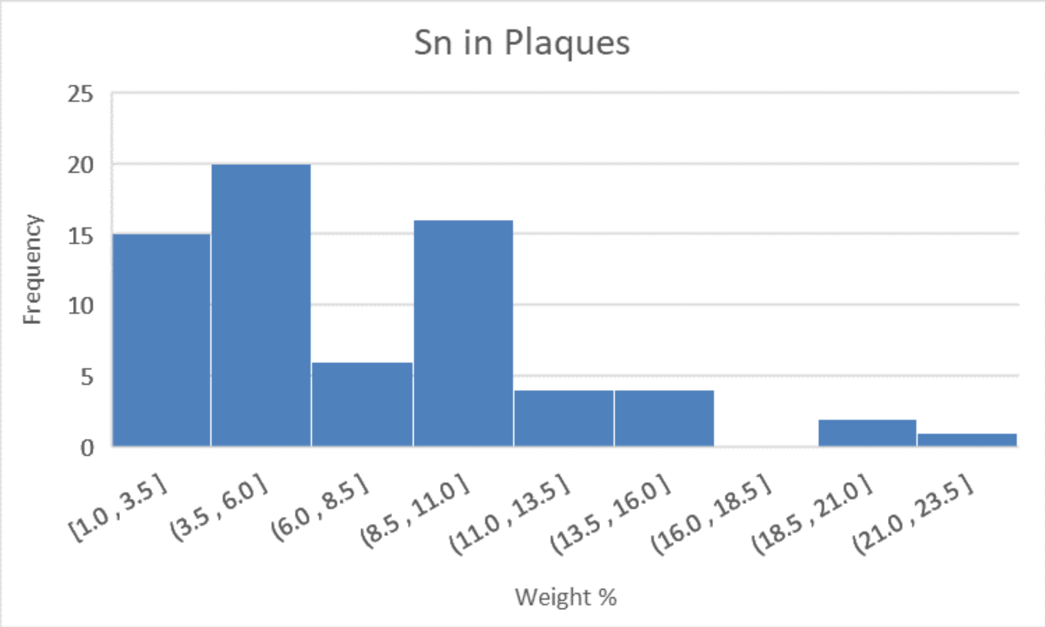


Figure 71 Sn cotent in Plaques

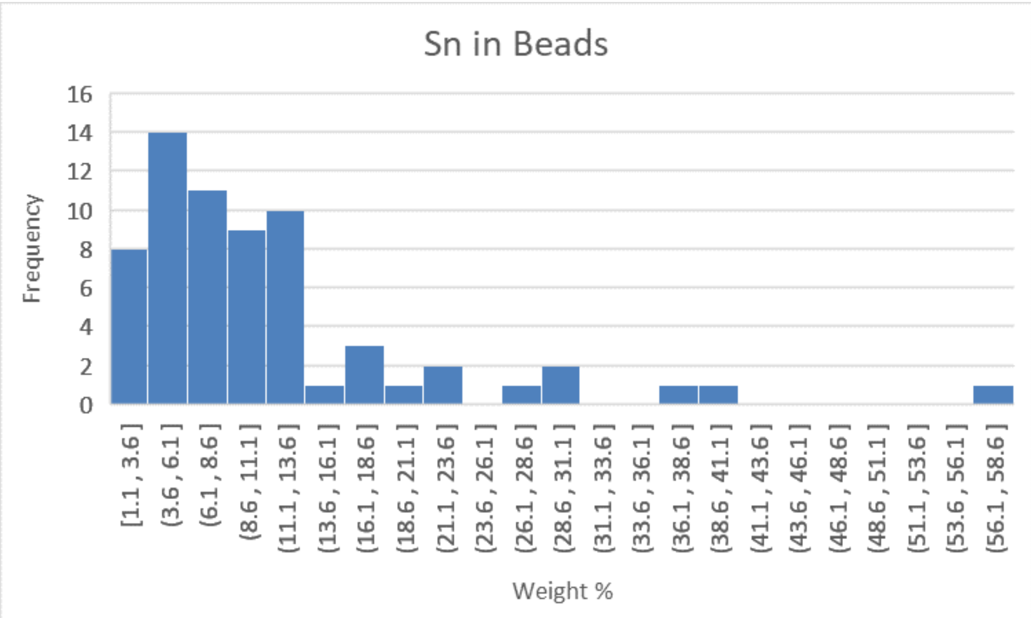


Figure 72 Sn content in Beads

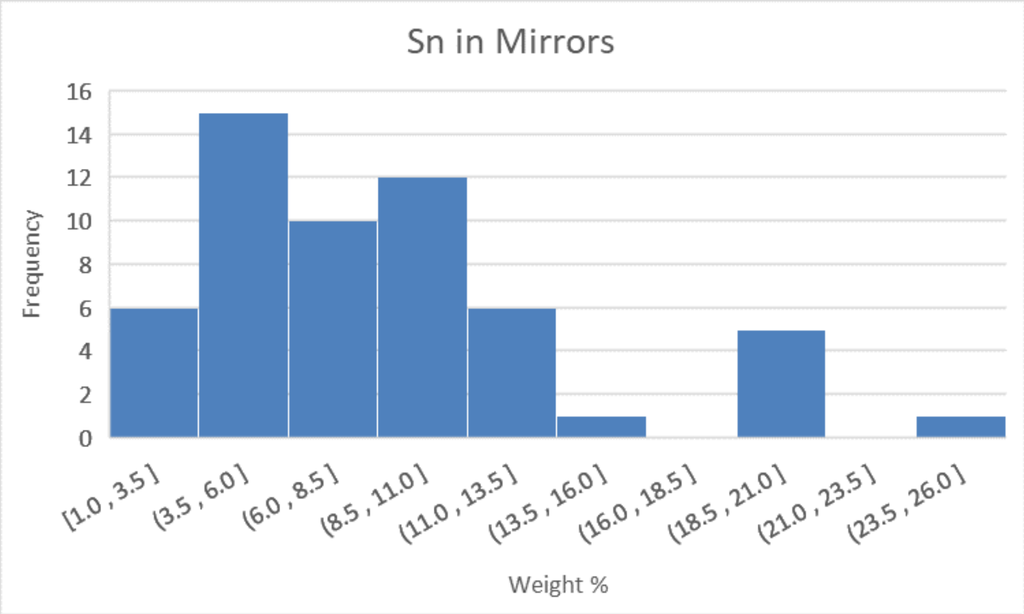


Figure 73 Sn comtent in Mirrors

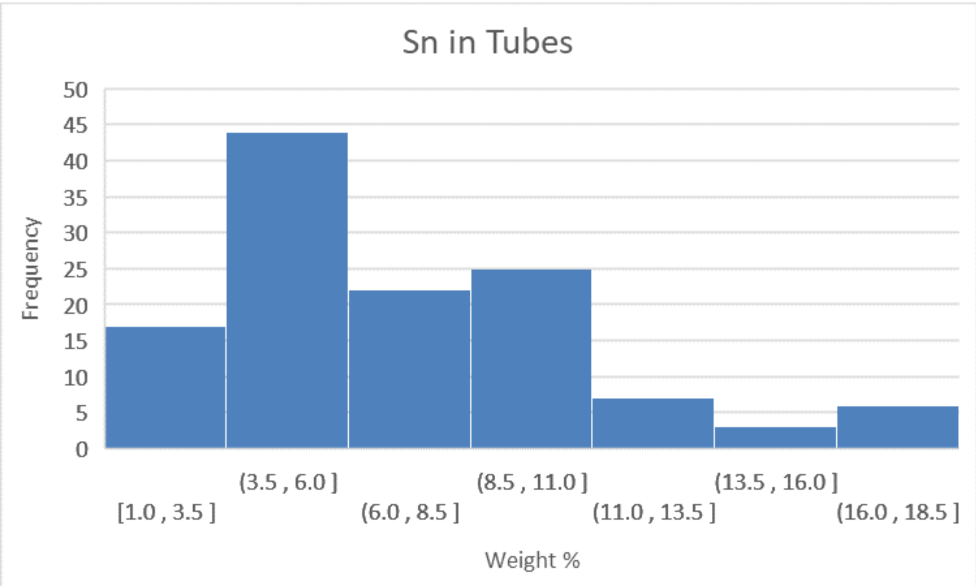


Figure 74 Sn content in Tubes

5.3.3 Diachronic variability in alloy composition

The appearance of alloy types in each period at TSBL is outlined to represent their diachronic pattern and alloy technological association. There are four phases in the TSBL, Phase 1 features fewer graves and bronze objects, and only contains objects in tin bronze (Figure 76). The alloy compositions of Phase 2 (Figure 77) include tin bronze, arsenic copper, arsenic antimony copper, arsenic bronze, pure copper, leaded tin bronze and leaded arsenic tin bronze. Phase 3 (Figure 78) is composed of all the alloy groups that appeared in Phase 2, but also leaded arsenic bronze, which is contained in all the object groups of TSBL. Phase 4 (Figure 79) remains the same as Phase 3, which includes all of the alloy types in TSBL. |As the figures demonstrate, the main changes in the occurrence of the alloy groups are between Phases 1 and 2. The striking change in Phase 2, sees the presence of nearly all of the TSBL bronze alloy groups; only one new group was added in Phase 3, that being leaded arsenic copper. There was no change in Phase 4, even though the number of burials and bronzes decreased significantly.

Taking all of this information into consideration, the following conclusions may be reached:

- Phase 1 corresponds to the early phases of TSBL's development when tin bronze already exists and is the only alloy type. Although the number of bronzes in the first phase is small, they cover five types of personal ornament, bronze mirrors and knives, all of which are made of tin bronze. The presence of tin bronze should not be a surprise in Phase 1, the date of ~2000-1900BC is about the time that tin appears across the Eurasian steppe (especially among the Sintashta) as it seems to derive from sources in Northern Kazakstan (Hanks & Doonan 2009; Garner 2013).
- The second phase witnessed the introduction of a large number of novel alloy combinations, including the development of arsenical copper and a high proportion of ternary alloys, indicating there may have been more widespread recycling.
- The alloy combinations in Phases 3 and 4 do not alter considerably, and it is conceivable that the relevant alloying techniques were developed during Phase 2, and have been followed for a long time into Phases 3 and 4. Over time, the local people probably followed a more stable supply of bronze-related raw materials or finished products with comparable distribution patterns and no notable changes. The primary changes were simply an increase in the diversity and amount of bronze categories.

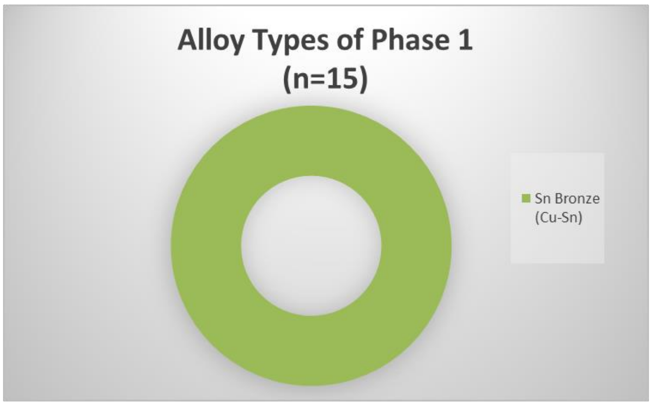


Figure 75 Alloy Groups in Phase 1

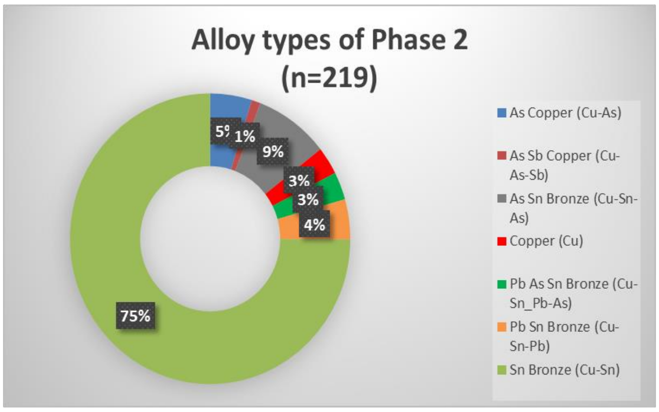


Figure 76 Alloy Groups in Phase 2

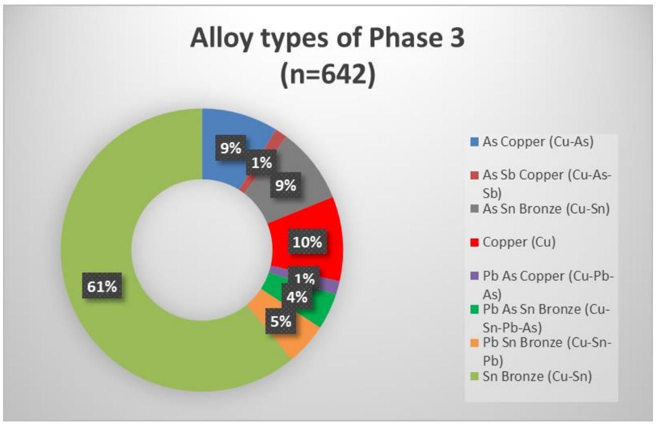


Figure 77 Alloy Groups in Phase 3

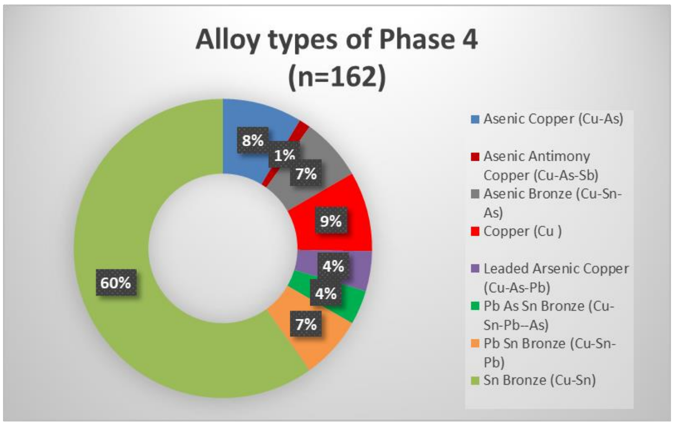


Figure 78 Alloy Groups in Phase 4

The diachronic pattern in alloy groups of different bronze artefacts is summarised in Table 5.2. After the dominance of tin bronze in Phase 1, the six new alloy types introduced in Phase 2 are not represented in every object type. While the overall range of alloy combinations changed little in the third phase, with only one addition, the spread across object types was extended, with four new alloy combinations for awls, three for tubes, two for each bangle, buttons, earrings, knives, mirrors, and plaques, and a reduction of one alloy combination for both arrowheads and pao. In Phase 4, although the general alloy groups remained the same as in Phase 3, their distribution across object categories changed significantly. The arrowheads, bangles, and earrings were all combined with a new alloy. Awls and beads had five fewer alloy types, leaving just tin bronze; the pao, knives, tubes, mirrors, and plaques all occurred in three or four fewer alloy types. Both the mirrors and the pao are made of the same alloy, tin bronze. The buttons are still made of seven different alloys.

In phase 2, the alloy composition for awls and bangles was the same; both comprised arsenic copper, arsenic tin bronze and tin bronze. Beads and buttons are made from the same alloy groups: arsenic copper, arsenic antimony copper, arsenic tin bronze, leaded tin bronze, and tin bronze. Another pair may consider the same group including plaques and tubes, the alloys presented by arsenic tin bronze, pure copper, leaded arsenic tin bronze and tin bronze. The reasons for this might include a different production centre or a different choice of alloy by the maker. The presence of mixed ternary alloys, i.e., Sn Bronze with As and to some degree Pb Sn Bronze or Pb As copper and with antimony might indicate a tradition of recycling. All categories of objects in Phases 2 and 3 contain this feature, suggesting widespread recycling is dominating bronze production at that time. This tradition was carried through until Phase 4 for arrowheads, awls, bangles, beads, buttons, earrings, and tubes, but there was a significant shift for mirrors, pao, and plaques. For some reason, these three categories are solely formed of tin bronze and arsenic copper and are not made from recycled metal. This different alloy choice might be due to a different production process specific to these objects, or changing raw material supplies. It should be noted that arsenical copper produces a finish that resembles silver and that this colour difference might be the reason for the careful choice of primary metal materials for alloying and the avoidance of recycled material that would have introduced a variety of alloying elements (Lechtmen 1996; Doonan and Day 2007).

The most common alloy types have no discernable correlation with particular categories of bronze objects at TSBL. The figure of eight-shaped pao and buttons found exclusively at TSBL and their manufacture exclusively from pure copper, tin bronze, and arsenic copper, rather than recycled metal may indicate some aspect of ethnic identity or perhaps that they were crafted specifically as funerary objects and deposited as soon as they were made.

	Phase 1	Phase 2	Phase 3	Phase 4
Arrowhead		Cu-As 25% Cu-Sn-Pb 25% Cu-Sn 50%	Cu-As 25% Cu-Sn 75%	
Awls	No sample test	Cu-As 14% Cu-Sn-As 29% Cu-Sn-Pb 14% Cu-Sn 43%	Cu-As 7% Cu-Sn-As 7% Cu 13% Cu-Sn-Pb-As 7% Cu-Sn-Pb 20% Cu-Sn 47%	Cu 33% Cu-Sn-Pb 50% Cu-Sn 17%
Bangles		Cu-Sn-As 25% Cu-Sn-Pb-As 25% Cu-Sn 50%	Cu-As 2% Cu-Sn-As 8% Cu 8% Cu-Sn-Pb-As 6% Cu-Sn-Pb 2% Cu-Sn 73%	Cu-As 7% Cu-As-Sb 7% Cu-As 14% Cu-Pb-As 7% Cu-Sn-Pb-As 36% Cu-Sn 29%
Beads	Cu-Sn 100%	Cu-As 6% Cu-As-Sb 13% Cu-Sn-As 6% Cu-Sn-Pb 6% Cu-Sn 69%	Cu-As 5% Cu-As-Sb 15% Cu-Sn-As 3% Cu 8% Cu-Sn-Pb 3% Cu-Sn 67%	Cu-As-Sb 11% Cu 22% Cu-Sn 67%
Buttons		Cu-As 7% Cu-As-Sb 2% Cu-Sn-As 9% Cu 2% Cu-Sn-Pb 7% Cu-Sn 73%	Cu-As 3% Cu-As-Sb 8% Cu-Sn-As 8% Cu 5% Cu-Sn-Pb-As 3% Cu-Pb-As 9% Cu-Sn 65%	Cu-As 5% Cu-As-Sb 5% Cu-Sn-As 5% Cu 15% Cu-Pb-As 5% Cu-Sn-Pb 20% Cu-Sn 55%
Earrings	Cu-Sn 100%	Cu-Sn-As 8% Cu 4% Cu-Sn-Pb 16% Cu-Sn 72%	Cu-As 4% Cu-As-Sb 1% Cu-Sn-As 14% Cu 8% Cu-Sn-Pb-As 11% Cu-Sn-Pb 6% Cu-Sn 54%	Cu-As 7% Cu-Sn-As 8% Cu 11% Cu-Sn-Pb-As 7% Cu-Pb-As, 8% Cu-Sn-Pb 7% Cu-Sn 52%
Knives	Cu-Sn 100%	Cu-As 8% Cu-Sn-As 31% Cu 8% Cu-Sn 54%	Cu-As 28% Cu-As-Sb 9% Cu-Sn-As 16% Cu 3% Cu-Sn-Pb-As 3% Cu-Sn 47%	Cu-Sn-As 33% Cu 33% Cu-Sn 33%
Mirror	Cu-Sn 100%	Cu-As 21% Cu-As-Sb 4% Cu-Sn-As 4% Cu-Sn 71%	Cu-As 17% Cu-As-Sb 3% Cu-Sn-As 11% Cu 11% Cu-Sn-Pb 9% Cu-Sn 49%	Cu-Sn
Pao	Cu-Sn 100%	Cu-As 1% Cu-Sn-As 12% Cu 1% Cu-Sn-Pb 1% Cu-Sn-Pb-As 2% Cu-Sn 82%	Cu-As 12% Cu-Sn-As 8% Cu 10% Cu-Sn-Pb 3% Cu-Sn 67%	Cu-Sn
Plaque	Cu-Sn 100%	Cu-Sn-As 14% Cu 5% Cu-Sn-Pb-As 9% CuSn 73%	Cu-As 21% Cu-Sn-As 10% Cu 10% Cu-Sn-Pb-As 5% CuSnPb 5% CuSn 43%	Cu-As 40% Cu-Sn 60%
Tube	Cu-Sn 100%	Cu-Sn-As 5% Cu 11% Cu-Sn-Pb-As 3% Cu-Sn 82%	Cu-As 10% Cu-As-Sb 1% Cu-Sn-As 4% Cu 10% Cu-Sn-Pb-As 1% Cu-Sn-Pb 1% Cu-Sn 71%	Cu-Sn-As 22% Cu-Sn 88%
Bell		Cu-Sn-Pb-As		Cu-Sn
Socketed Chisel			Cu-Sn-As Cu-Sn	
Short Sword			Cu-Sn	

Table 11 The Diachronic Pattern in Alloy Groups in Different Bronze Artefacts

5.4 Summary

This chapter presents technical studies that have been carried out on the early metal artefacts recovered in TSBL. The integrated analytical programme has produced a rich set of insights into the chemical composition of the bronze assemblages of Phases 1 to 4 at TSBL. Bronze artefacts were one of the most prominent burial objects in the TSBL burials, accompanied by a characteristic combination of pottery and personal ornaments, a small number of stone and bone tools, and sometimes accompanied by animal bones found in the TSBL. The bronze objects are mainly personal ornaments, accompanied by some tools and a few weapons, of which there are 14 different categories. A wide variety of ornaments demonstrates the high demand for decorations by the sections of the TSBL population in society at the time. The fact that personal ornaments were the mainstay of bronze may indicate that bronze was still a relatively precious material at the time and was not widely employed in many parts of people's life.

The number and variety of bronzes on the TSBLshowed notable changes from Phase 1 to Phase 4. Phase 1 represented the early stage, when the number of bronzes was small, containing eight categories and mainly personal ornaments. Phase 2 witnessed an increase in both the number and variety of bronzes increased, Phase 3 hosts the all object types, while Phase 4 perhaps reveals a period of decline, with a decrease in both the number and variety.

Bronze alloys vary over the four periods differently from the changes in bronze types and numbers listed above. The first phase falls into the early stages and contains only tin-bronze. The second period increases the number of alloys to seven, still predominantly tin-bronze, with arsenic-bronze and five ternary alloys (elements including arsenic, lead and antimony). The third and fourth phases continue to use the same alloys as the second phase, but add a small amount of one type of alloy (leaded arsenic bronze). In general, it can be concluded that the major metallurgical tradition of the TSBL is characterised by a wide range of alloys, containing eight alloy types, mainly tin bronze, accompanied by arsenic bronze and the other six ternary alloys. The main alloy technology was developed in Phase 2 and has been utilised for a long period, with no significant modifications in alloy technology from Phase 3 to Phase 4.

When it comes to alloy technology, tin is the most prevalent alloying element. Based on the analysis of the data, it has been identified that the majority of tin concentrations in alloys ranged from 1% to 12.5% at TSBL, with the highest frequencies occurring between 3.5% and 6%, followed by 8.5% to 11%. In addition to this distribution, most of the different classes of bronze are consistent with it. Accordingly, a similar alloying technique was widely used in the production of bronzes from TSBL, beginning in Phase 2 and continuing throughout Phases 3 and 4. The arsenic content of the alloys is generally low, mostly below 2% and less than 7% in general, pointing out the possibility of smelting arsenical copper ores. In addition, the lead content of the alloys was very low, mostly below 1.8% and largely below 4.8 overall. This may have been due to the alloy choice at the time or to the recycling process. There was a relatively high proportion of ternary alloys in the TSBL, which appears in almost every category of bronze, indicating that recycling was more common at the time and was an integral part of raw material sourcing. The same alloy combinations in bronze categories, such as awls and bangles in Phase 2, point to the same production centre. The presence of antimony in various bronze types shows the usage of tennantite-tetrahedrite series ores, which suggests the likelihood of the same raw material supply and differs from alloys employing arsenic copper ores. The absence of any pattern in the alloys associated with typology suggests that the composition of the alloys is not carefully controlled during the production process, or the manufacturers are not skilled at selecting their alloys based on the properties of the objects they are constructing. The unique artefacts from TSBL, the figure-of-eight shaped buttons and pao, reveal a significantly distinct outcome, and ternary alloys are absent in these objects, indicating specialised burial artefacts or specialised supply sources. Their compositional consistency perhaps suggest that they were locally made.

Ultimately, the radical diachronic changes in terms of bronze context, alloy tradition, and raw material resources within the material examined in this assemblage reflect transformations in the technology of bronze production and the place of bronzes in society, and it is the implications of these results that we turn in the next chapter.

Chapter 6

The Bronze Age of TSBL - discussion

6.1 Introduction

As discussed in the previous chapter, the widespread use of alloy technology in the study of bronzes has allowed us to gain a good understanding of the character of bronze assemblages at the TSBL site. The radical changes in metals – the introduction of technological and stylistic characteristics into the existing local tradition – in TSBL involved a series of changes in the selection of raw materials, alloy choice and object types. These transformational improvements introduce a new way of producing bronze and broaden the scope of the bronze repertory. Comparing manufacturing techniques in specific alloy recipes aids an understanding of the technological and stylistic development in bronze production from TSBL Phase 1 to Phase 4. Regarding this element of bronze fabrication, it allows the transmission and modifications of knowledge and technology in bronze production to be examined from an analytical standpoint using chemical studies applied in this study. At the same time, technological choices and practices are strongly related to the typological and stylistic characteristics, as well as the origins of bronzes, which offer a more complete image of bronze consumption at TSBL.

It is argued here that these transformations in the production of bronze have much to tell us about the wider changes in society and economy during the Bronze Age of TSBL, around which much discussion of culture change and interaction with the surrounding area has centred.

The following section integrates the analytical work to demonstrate the different technological traditions for the major shape categories in each phase at TSBL, from alloy recipes in metal manufacture and potentially how these bronzes are linked to the other cultures and consumed at this site.

6.2 Phase One (2000-1650 BC)

The results of the first phase reveal the importance of ornaments at the time, with tin bronze being the main alloy type. Two knives and a bronze mirror also appear. One of the knives is of Type A1, with no handle and two block-shaped bulges on the knife's back, and a very similar knife was discovered at Huangniangtai's tomb in the Early Qijiayuan culture (2000-1700BC) (Chen 2017). Type A1 knives are only found in the TSBL and Qijia cultures at this time. The other knife is of Type A4, and a comparable knife was discovered at the Late Qijia culture's Qin Weijia burial site (1700-1500BC) (Yang et.al 2016; Chen 2017). The two bronze knives from the TSBL are both tin-bronze, but the bronze knives from the Qijia culture are red copper, yet the pao and earrings found at the Qijia culture's Ga Matai cemetery are both tin-bronze and of the same form and style as those from the Phase 1 (Yang et.al 2016). All of this may suggest that the early phase of the TSBL and Qijia cultures were more closely associated and that these bronzes may come from them directly. Another notable piece is the bronze mirror with handle, which is the sole one with a handle discovered from TSBL; a similar object found by Andronovo culture in the Semirechiye district of Kirghizia (Mei 2000). As shown above, the cultural aspects of the first phase of the TSBL are complicated, with the degree of interaction with both the Qijia culture and the Andronovo culture in terms of bronze types and forms being the most visible at the moment. The Andronovo culture (ca. 2000-1200 BC) has been documented to have had a high level of skill in the manufacture of tin bronze during the Bronze Age (Chernykh 1992). Tin bronze is indeed associated with the Andronovans, whose tin reserves were reportedly exploited in Kazakhstan and Uzbekistan, respectively (Garner 2015). The discovery of a tin-bronze knife in Linjia (Dongxiang County in Gansu) belonging to the Majiayao cultural group and dating back to 3300-2740 BC has called into doubt the assumption that tin bronze was a western import, and may be introduced by the Andronovo people (Li and Shui 2002). While this issue has been the subject of intense debate among international scholars, it remains unresolved. Nonetheless, the discovery of some tin-bronze items in late Qijia cultural sites may suggest that early interaction with TSBL might have been the source of the Qijia Culture's tin bronze technology, or it could have advanced the alloy technology development of Qijia culture. In addition to the bronze earrings, eight gold earrings were discovered in Phase I. These are exclusively found in the early phase, with no gold artefacts discovered in the following three phases. Their origin is unknown, however, they are more likely to have been influenced by western nomadic culture, such as Andronovo (Bunker 1998). Furthermore, shells and shell ornaments were found in three graves in Phase 1 that originated in either the Indian or Pacific Oceans and highlight the complexity and diversity of TSBL's exchange or trade and communication networks (Bin 2001; Liu et al. 2020).

6.3 Phase Two (1650 – 1400 BC)

Although Tin bronze remains the dominant alloy in the second phase, there are some major shifts, such as the development of arsenic copper and a variety of distinct ternary alloys. The number and variety of bronzes from the TSBL increased in the second phase, reflecting a change in population and the possible expansion of the group. The majority of bronze demand continues for ornaments, with a preference for bronze alloys of higher hardness and colour in the decorative category and a significantly smaller proportion of tools than ornaments utilising tin bronze, reflecting the prominence of ornaments at the time. It is noticeable that the more numerous or more popular categories have more combinations of alloys. The high number of bronze beads and tubes in this phase, as well as the fluctuating content of tin as the main alloying element and the unstable proportions of lead and arsenic, which were generally less than 6%, indicated that TSBL bronze production was fairly basic at the time, but there was some preliminary understanding of the material properties of different types of copper alloys. The features of these alloys are the same as those of the Siba culture's Huoshaogou site, particularly the high degree of agreement between antimony, arsenic, and lead alloys (Chen et.al 2018), reinforcing the direct link between TSBL bronzes and the Huoshaogou of Siba culture. There is direct evidence that the bronzes were created locally in Huoshaogou (Chen et, al. 2018), and it is conceivable that the bronzes were consumed by TSBL. However, only half of the bronzes at Huoshaogou are tin-bronzes; the other half are arsenic-copper and pure copper, while 75% of the second phase are tin bronzes from TSBL. This is probably because the majority of the tools in the Huoshaogou were made of pure copper and arsenic copper, and the ornaments were deliberately made in tin bronze. There is also the potential that TSBL bronzes were made by other suppliers than Huoshaogou, and from the first phase, it is evident that TSBL cultural links are already quite complex, with some links to different surrounding cultures, and that the bronzes originated from a range of sources. Phase 2 produced another two type A1 knives, which may suggest a continuing link with the Qijia culture. Carnelian beads appear from Phase 2 and may indicate a connection to Central or even Western Asia (Rawson 2010; Ye 2018). A few unique faience beads in the shape of long or segmented tubes were discovered in tomb M200, which might be the consequence of exchange with the steppe population in the North Caucasus region and the Eurasian steppe (Lin et al. 2019). There is a unique round mirror in tomb M483 with a decorated surface resembling a human's round face, suggesting that there likely existed some form of relationship with Okunev communities (2500 -1700BC) in Southern Siberia (Kuzmina and Mallory 2007). There is sufficient evidence to suggest that the cultural features of TSBL are more complicated, in this phase, with multiple forms of exchange and trading behaviour in social groups.

The development of bronzes in the Early Bronze Age, both in the Middle East and in Europe, followed a progression from pure copper, arsenic copper to tin bronze (Tylecote 1976; Bar-Adon 1980; Muhly 1988; Shalev and Northover 1993). In general, the Hexi Corridor, including the Qijia and Siba cultures, exhibited the same pattern with pure copper dominating first, followed by arsenical copper and, finally, Tin bronze dominating gradually. The bronzes of TSBL, on the other hand, exhibit a rather different sequence, with tin bronze appearring in the first phase and arsenic bronze gradually appearring in the second phase, as a result of direct influence from neighbouring cultures, particularly the Siba culture from the Hexi corridor to the east, where migration cannot be ruled out. The second phase demonstrates a direct increase in the community in terms of burial numbers, perhaps through an influx of population from the surrounding region, bringing with them new cultural values and metallurgical technologies, as well as new habits of consumption (Shao 2018). It can be tentatively concluded that Phase 2 is considered to be the beginning of the interaction between TSBL and Siba cultures. The small number of ternary alloys that emerged are most likely the result of recycling, which was one of the different raw material sources discovered in Phase 2. Recycling saves effort compared to the traditional mining to smelting procedure and would have been easily adopted and accommodated during the rising demand for copper raw materials. Unfortunately, it is difficult to determine the exact manner and system of recycling at this time, in the absence of detailed compositional trace element data or the study of lead isotopes (Liu et al., 2020).

6.4 Phase 3 (1400-1200 BC)

There were no substantial changes in alloy technology between the third and second periods, with tin bronze being the dominant alloy. Tin bronze was utilised slightly less during the third phase than it was during the second, dropping from 70% to roughly 60%. This is one of the unique elements of the TSBL bronze evolution, with the amount of pure copper rising by around 10% in Phase 3 compared to Phase 2, while the proportion of tin bronze decreased. Each bronze type contains small amounts of various ternary alloys, primarily containing lead, arsenic, and antimony, and the increasingly complicated alloy combinations of each bronze type may suggest that recycling was prevalent. Furthermore, it might point to a more consistent pattern of alloying practice employed in manufacturing during the period, when skills and associated technologies were shared among socioeconomic groups. In addition, different alloy ratios may also reflect ongoing experimentation and exploration of production techniques at the time, demonstrating that alloy technology had not yet reached a mature and stable state. Considering bronzes from the Siba culture contain traces of antimony, it is possible that the antimony-containing bronze alloys from the TSBL originated in Siba, or came from the same source.

The absence of Type I knives in Phase 3 corresponds to the gradual replacement of influence from the Qijia culture by the Siba culture. As evidenced by the increased amount of carnelian, shell, and shell jewellery, the people of TSBL continued to exchange or trade with various cultural groups. Phase 3 has spoon-shaped earrings made of tin bronze or arsenical copper, not the products of recycling. These are unique to Phase 3 and have not been found elsewhere, most likely being from the same production centre. The hollowed plaque found in M626 is also an object unique to TSBL, and it is highly likely that all of these bronzes, which are strongly local in style, were made locally. Subei (2019) noted that the discovery of a stone model from the Liushugou cemetery could provide evidence of the local production of bronze in Hami. She/he analysed 20 bronze objects from the early phase of the Liushugou Cemetery in Hami, which was excavated in 2013. The early phase of Liushugou dates from around 1400-1100BC, the same period as TSBL Phases 3 to 4. The bronzes from Liushugou are very similar to those from TSBL in terms of type, shape and alloy composition. The discovery of evidence of local production in Liushugou proves that some of the bronze from TSBL from Phase III onwards may share the same supplier and the same techniques as those from the Liushugou Cemetery, and could have been made locally in the Hami region.

6.5 Phase 4 (1200 -1000 BC)

Phase 4 at TSBL reveals no significant change in alloy types overall, but the several bronze categories demonstrate their differences. The number of pao and mirrors has been reduced to only tin bronze, and the number of awls, beads, knives, plaques and tubes has also been significantly reduced to a predominance of tin alloys. Only the earrings and buttons retain a small number of multiple alloys, while the overall quantity of alloys containing tin components increases. The decrease in the number of graves and bronzes in the fourth phase of the TSBL is probably due to the migration of the population and the abandonment of the original site. The decline of the TSBL culture is probably the result of the diachronic and gradual development of a new cultural identity. The other sites in the Bronze Age of the Hami region around TSBL, such as Liushugou, Wubao, and Nanwan cemeteries, as well as the early Yanbulak culture, have a similar type and alloy composition of the bronze as the TSBL. They seem to have all been involved in the transmission of TSBL's bronze culture, including the transmission of technology and styles, or to have been part of the same exchange networks as TSBL. With the emergence of these cultures, the characteristic features of TSBL culture gradually disappeared, and one of the reasons for this phenomenon is likely to be related to environmental change. Studies have shown that around 1200 BC, the Eurasian steppe zone began to dry out due to climate change and become more populated and that the economic model was changing from mainly agricultural to the pastoralist, with the emergence of a nomadic economy and lifestyle and new cultures (Wang et al. 2017; Festa 2018). This also coincides with the fourth phase of the TSBL. It is possible that the TSBL people gradually migrated and merged with new populations and that the TSBL culture is representative of the Early Bronze Age in the Hami region, with subsequent developments in the Late Bronze Age and Early Iron Age cultures being profoundly influenced by it.

6.6 Technology and Practice in the Bronzes from TSBL

This section aims to integrate the stylistic and typological features of the metal assemblage with the different technological practices evident in the bronzes of major categories, as revealed by fabrication strategies in bronze manufacture.

6.6.1 Beads

Beads were the largest number of bronze objects discovered from the TSBL site. Three types of beads were found: cylinder-like beads, wire beads and joint circular beads. There are clear differents between them, cylinder-like beads and joint circular beads are solid with a very small hole, very likely made by casting, according to previous analysis by SEM (Qian 2006). The wire beads are made of banded thin flat and narrow copper sheets and the hole is very large and was most likely shaped by a forging process to obtain the thin sheet. Therefore, there are possibly two methods of making the beads, including casting and forging applied to the varied shape of the beads.

6.6.2 Earrings and Bangles

Bronze earrings were the most common bronze objects across the tombs of TSBL and have two types, both made by a circular sectioned coil of copper or bronze. One type is bent into a round shape and the other type into a spoon shape. Such a thin copper coil could be forged. Previous analysis using SEM has indicated that the same type of earrings was made by casting and hot forging (Qian 2006). The same coil is also made into bangles, larger in size, and again previous analysis results from SEM suggest that this bangle type is made by casting and cold forging. Another type of bangle is made of thin copper sheets bent into a round shape, some of them with dot or line decorations along the edge, very likely processed through forging and carving, or the decoration could be made by casting from the mould. Thus, the earrings and bangles are possibly made by casting and hot or cold forging.

6.6.3 Tubes

Two types of bronze tubes were discovered at TSBL, the first one is cylinder-shaped with smooth surfaces, and the second one is spiral-shaped. Both of them are made from thin flat copper sheets: the cylinder-shaped example with sheet copper rolled into the tube and a spiral-shaped one that uses very narrow strips to roll into the tube. The thin flat sheets are very likely made by forging (Qian 2006) and some of them may have been annealed (Mei 2000).

6.6.4 Plaques

The bronze plaques are classified into three types at TSBL: rectangular, bow shape and hollowed-out. The majority of the plaques are rectangular, with a round corner, a middle ridge, one hole at the top and the decoration on the surface, the decoration other dots or lines around the edge. They are made of copper sheets, very likely processed through forging, the decoration could be made by carving or casting from the mould. According to previous SEM results, some of the rectangular plaques were made by casting, and some of them were made by hot forging (Qian 2006). The bow shape plaques are much thicker than the rectangular ones and the surface is slightly dented with the raised ridges along the edge, this type of shape is very likely made by mould casting. The hollowed plaques are more likely to use mould casting to get the delicate hollow pattern. Hence, the plaques made by both forging, casting and mould casting are applied to the different types of them.

6.6.5 Buttons and Pao

Bronze or copper buttons and pao are similar in shape to TSBL, both circular, the difference between them is the button has a knob at the back and the pao has two holes near the edge, also the pao is thinner than the buttons. There are three types of buttons, including ones with a round plan flat surface, a round curved surface and a double circle in the shape of a figure of 8. Some of the round curved surface buttons have decoration, with a dot or line around the edge. All of the buttons were very likely made by casting (Mei 2000; Qian 2008). The pao are classified into two types, single and double circular types, both with slightly curved surfaces, with or without decoration. Although they are similar in shape to buttons, they are much thinner and lack the knob, Therefore it is possible that they were made by forging or forging after casting.

6.6.6 Mirrors

The bronze mirrors are classified into two types at TSBL, one is the circular mirror with a knob on the back and with or without decoration, and another is the circular mirror with a handle. Both types of mirrors are very likely made by mould casting, especially the one with the delicate pattern on the surface, as suggested for similar material elsewhere (Mei 2000).

6.6.7 Knives

The copper or bronze knives discovered from TSBL are classified into four types. All of the knives have a similar shape, the main difference being the presence or absence of a handle, with other variations in the shape of the back or blade. Some have a grooved or decorated handle and have a ring at the end. They are very likely made by forging after mould casting, especially since the blade section should sharpen by forging. The previous SEM results from two knives indicate that they were made by casting, followed by hot forging and cold working.

6.6.8 Awls and Socketed Axes

There are not many bronze tools discovered from TSBL compare with the ornaments, except for the 34 knives and two socketed axes. The awls from TSBL fall into one basic group: square or rectangular sections with thick rectangular to round butts and sharp points. The awls with the sharp point are very likely processed through forging, previous SEM results from two awls analysed indicate that they were made by hot forging followed by cold working (Qian 2006). Two socketed axes were found in the same tomb, in a similar shape. There is a distinctive seam in the middle of the axe body, which seems to bisect the copper axe, and this kind of seam is very likely left by mould casting (Shui pers. comm.).

6.6.9 Arrowheads and Short Sword

There are very few weapons discovered from TSBL, a few arrowheads and one short sword. The arrowheads fall into two groups: a 'leaf-shaped' blade and a long leaf-shaped blade. Both of them are very likely made by mould casting, the previous SEM result for one arrowhead indicates that it was made by casting (Qian 2006), there are also two moulds of arrowheads found in the Huoshaogou site of the Siba culture, therefore, the arrowheads possibly made by mould casting at the same period from TSBL. The short sword is also very likely made by mould casting, and a similar type of short sword from sites of the Andronovo complex in Central and North Kazakhstan was made by mould casting and followed by forging (Yang et al. 2016).

6.6.10 Bells

Three bells were recovered from TSBL and classified into two types, contained with the handle one and the other one with the perforated wall. The handle bell is in a pair from the same tomb. All of them have a distinctive seam in the middle of the body, this sort of mark is very likely left by mould casting (Shui pers. comm.).

6.6.11 Summary

To summarise, the above examination provides a part of the detailed manufacturing technologies of bronzes in TSBL. The TSBL employs two primary bronze forming techniques: casting and forging, specifically contained casting followed by hot forging, mould casting, cold working after casting, and cold working after hot forging. Forging and casting have comparable proportions in the TSBL, bronze beads and buttons may all be made by casting. Bronze knives, plaques, mirrors, bells, swords and arrowheads all use the mould casting process, and there is a subsequent part of the forging process, including hot and cold forging. Bronze tubes were made by hot forging, and earrings and bangles were probably made by casting followed by hot or cold forging. The bronze tubes, bangles and pao were all made from thin flat copper sheets, which was an important part of the TSBL bronze production, as its frequent use would probably have determined the style of many of the subsequent objects. The absence of any patterns between the alloy technology and manufacturing technology suggests that the alloy was not strictly regulated when the production process was established and that the best techniques for alloying were not fully applied at the time, especially concerning the use of tin and lead, which may still be in the exploratory stage. This study argues that the majority of bronze objects from TSBL are considered to be consumer products based on the current archaeological evidence, with only a small number being attributable to locally made in the Hami region, possibly limited to items unique to TSBL such as spoon-shaped earrings and a figure of 8 buttons and pao. The manufactured craftsmanship exhibited in the bronzes of TSBL as the consumer reflects that these crafts were quite widespread in a certain surrounding area at the time and that there was a technological transmission between communities, sharing related technology practices. The fact that different manufacturing techniques were used for the same category but different types of bronze, may be due to a different production centre, although it cannot be ruled out that the same production centre uses a different technique, and that these different techniques were probably the result of social or technological factors.

6.7 Organisation of bronze production

In assessing the structure of the metallurgical production chain, we consider mining, mineral separation, smelting, and fabricating (casting and forging), as well as the evident relationship between these activities and hypothesised increases in social complexity at TSBL, unfortunately, there is no direct production evidence, so the metal objects were a consumption assemblage and that material came from a variety of sources. However. TSBL is located in the Hami Basin, a meeting point surrounded by three metallurgical centres at the time. The discovery of the Xichengyi site in the Hexi Corridor to the east of Hami and the Jirentai Goukou site in the Ili region to the west has provided knowledge of a complete metallurgical chain of evidence dating back to the early second millennium BCE (Chen, 2017; Wang et al., 2019), while the Altai region to the north saw the establishment of an independent metallurgical centre in the third millennium BCE (Chernykh 2014; Mu 2018). The previous part of the results has shown that the TSBL Phase I and Qijia cultures were closely connected, and a recent study suggests that the Xichengyi and Qijia cultures formed a metallurgical community in the Hexi Corridor between 2100 and 1700 BC. The Xichengyi and Qijia cultures each performed a unique contribution to the early development of metallurgy (Chen et al., 2015; Chen 2017). Because the Qijia culture, like that of TSBL, has no direct evidence of metallurgical production, it is proposed that the Qijia culture did not control metallurgical technology but rather acquired and widely disseminated metallurgical products or technology through contact and exchange with the Xichengyi people (Chen 2017). Therefore, part of the TSBL bronzes might have been made by the Xichengyi people, acquired through contact with the Qijia culture, or both. From 1700BC onwards, the Qijia culture was progressively superseded by the Siba culture in the Hexi Corridor area. The Siba culture is thought to be the successor to the Xichengyi metallurgical culture, which achieved metalworking technology, and a significant number of the TSBL's bronze items came from the Siba culture, particularly the finding of arsenic bronze, which highlights this occurrence.

The role of arsenic in copper in TSBL and Siba is more likely to have come from the ore itself, as the study results demonstrate that in the majority of cases the arsenic concentration is relatively low in these alloys, suggesting that it may not be intentionally introduced, or may be due to the recycling. The presence of copper ores with high arsenic content in both Hami and the Hexi Corridor (Yang 2018) suggests that there is a high probability that both TSBL and Siba use local ore materials. This study suggests that the use of arsenic-copper for the TSBL and Siba populations is more likely to have originated from the use of local resources for production and is not the result of acceptance of arsenic-copper technology. The results of the study show that a higher proportion of arsenic bronze was used for tools, while tin bronze was used for the majority of the ornaments. Arsenic in alloys can alter the colour of the bronze, giving it a silver-like effect, with a more pronounced colour difference to tin bronze. Thus, the people at the time may seek a silver-like effect for tools. Moreover, the TSBL population has been using tin bronze ornaments since the first period and may have had certain requirements regarding the colour of the ornaments, so it is likely that this aesthetic habit has continued and that there is a certain choice and requirement regarding the source of the bronze ornaments. The Siba group may have offered these ornaments made of tin bronze specifically to TSBL as a 'consumer' group. The bronze objects from Tianshanbeilu showed a close connection with the Hexi Corridor from the first period, and this connection lasted for nearly 1,000 years. Long-term contact and interaction will form a relatively fixed exchange or trade behaviour and channel, which will also affect the style and technical development of bronze, which why call people from Tianshanbeilu a 'consumers'.

The widespread use of arsenical copper throughout Xinjiang and in the Siba culture suggests that it played an important role in the metallurgical development of the Bronze Age across Xinjiang. The current archaeological evidence points to the use of arsenical copper being more common in the Hami region, possibly because the largest number of bronzes have been excavated in the region. Arsenical bronze also includes the ternary alloy lead-arsenical copper and the quaternary alloy leaded arsenic bronze. Yang (2018) collated 65 arsenical-copper alloys from seven cemeteries in Hami, excluding TSBL, and most of them have arsenic concentrations of between 1% and 3%, with individual pieces approaching 5%, while TSBL, Nanwan, Yanbulak, and Fushishuancang all show small quantities of high-level arsenical copper alloys with arsenic contents above 10%, with 16 such items found in TSBL. This high level of arsenic would have been deliberately added and may be from a different production centre to the low-level arsenical copper alloys, or from a very different source of ore. It is likely that most of the low-level arsenic copper alloys were made at Siba, and that the ore may also have come from Siba or local sources within Hami. In contrast, the high level of arsenic copper could have originated from the Nulasai copper mine site in the Yili area, and Mei (2001) mentioned the discovery of three ingots with an arsenic content above 10% of leaded arsenic copper alloys, suggesting that the copper resource produced at the Nulasai site could have been used in the Hami area. Unfortunately, no remains have been found at the Nurasaai copper mine before 1000BC, but evidence for earlier exploration may await discovery. The widespread and continuous use of arsenical copper in the Hami region for approximately a thousand years illustrates the alloy's importance in the development of metallurgy in the Hami region of Xinjiang. The present study argues that the use of arsenical copper in the Hami region was influenced by the TSBL, and subsequently spread to the entire Xinjiang region, where the TSBL population began to accept and use arsenical copper from the Siba around 1700BC, and spread the tradition of arsenic copper use and related technology throughout Xinjiang. Although no evidence of metallurgy production has been found from the third period of the TSBL, the discovery of the Liushugou stone model proves that local production existed in the Hami region from around 1600 BC. The reason for the continued use of arsenic copper in Hami is probably also due to the convenience of local access to the material, as arsenic copper ores existed in Hami.

The use of tin-bronze, the source of the ore, and the associated technological transmission are thus of greater concern, as the use of tin-bronze from Phase I of TSBL onwards is extensive, and the results of this study show that the tin content is largely dispersed in the medium to high range, implying that tin element was mostly intentionally added, but without a stable formula. Although the two knives and the buttons are perhaps from the Qijia culture, the related more sophisticated tin bronze technology may have originated in western Siberia, where tin bronze was already widely used in the late Early Bronze Age. According to this study, TSBL may have played a crucial role in the transmission of tin-bronze technology by acting as a technological conduit for the subsequent development of bronze-related technology in the Hexi Corridor. The Qiemuerqieke culture in the Altay area to the north, which is thought to have been the first place in Xinjiang to initiate bronze usage and production, is the most likely impact on the first phase of TSBL during the same period (Shui, personal communication). Shui proposed the concept of the Altai phase interaction sphere, and the latest research sets out a new chronology in the Altai region of Xinjiang as follows: Afanasevo culture (c. BC2900-BC2500) - Qiemuerqieke culture (c. BC2600-BC1800) - Andronovo culture (c. BC1800-BC1300) - Bekazen-Dandenbeyev culture (c. BC1300-BC900) - Eastern Tallad type remains (c. BC800) - Pazyryk culture (mid BC6th century) (Mu 2019). The Qiemuerqieke culture of the second phase is closely related to the Okunev culture (Mu 2019), and the bronze mirror with a human face from the second phase of TSBL shows a connection with the Okunev culture, probably indirectly through exchanges with the Altai region. This study agrees with Shui that the Qiemuerqieke culture of the Altay region played an important role in the early Xinjiang Bronze Age. It was one of the key routes for the eastward transfer of tin bronze technology. The TSBL population served as an intermediary in these trades as the western steppe metallurgical culture moved eastward toward the Gansu region of China through the Hami region. The mode of access to tin resources is also an issue of address; the entire Xinjiang region was rich in tin ore, with the Altai region in the north, the Yanqi basin in the south and Hami basin in the east (Yang 2018; Lan 2021). Both TSBL and Siba had convenient access to local resources, which greatly facilitated the production of bronzes. The discovery of a pure tin object from the Xiaohe cemetery (Mei et al. 2013) suggests that the tin could have been circulated as a precious resource. The interesting phenomenon is the absolute convenience of the Hexi Corridor region in terms of objective resource conditions, and the insistence on the use of arsenical copper from the Xichengyi to the Siba cultures. In addition to the adoption of arsenical copper ore, it is speculated here that there may well have been an insistence on a certain traditional technique as well. Additionally, since the second phase of TSBL, the whole of Xinjiang persisted in the use of arsenic copper for 1000 years. The case study of Poros-Katsambas in the early third millennium Aegean argued that the adoption of tin bronze is about enabling the scale of production, not any inherent advantages, and should be seen as a material that allowed existing skills to be applied to new material to permit intensification of production (Doonan and Day 2007). Sometimes the general adoption and acceptance of technology are likely to have taken a long time and have been influenced by variables that are highly complex and challenging to describe, rather than by what we can now easily grasp as technological developments along functionalist lines.

Another significant alloy component is lead, which makes up 12% of TSBL alloys and is present in ternary and quaternary alloys in quantities that can range from low to high values. Therefore, both purposeful addition and recycling are possible. The intentional addition of Pb elements for alloying and the widespread use of materials such as lead-tin bronze and lead bronze are typical features of the technology in the Bronze Age of the central plain of China, which increases fluidity and facilitates the casting of various types of vessels with ornamentation (Liu 2016; Yang 2018). The Bronze Age of the central plain in China was the area with the highest concentration of lead-containing alloys, with leaded bronze dominating (48%) and TSBL and Siba not using lead-containing alloys as their main material, it is also possible that the associated technology received influence from the Erlitou (Hus et al. 2016; Pollard et al. 2018). The presence of lead earrings at TSBL also suggests that lead could have been circulated and used as a resource. Qian Wei's research (2006) revealed that a significant proportion of bronzes from the TSBL use casting, particularly beads and that adding lead to the alloy was known to increase fluidity. This shows that the bronze objects from TSBL reflect craftspersons exploring and experimenting with alloying techniques. Lead and zinc mines in Xinjiang are found in the Tarim Basin and Fuyun County in the Altay region, and there are also lead and zinc mines in Subei County in north-western Gansu, which is adjacent to Hami, and also in the east of Gansu (Mei 2000; Yang 2018). The population of Siba had ample local resources to draw upon and TSBL had access to relevant mineral resources through exchange or trade with the Siba and Altai people.

To conclude, the TSBL alloys are diverse in composition and come from a wide range of sources. From the first phase onwards tin bronze dominated under the influence of the Eurasian steppe bronze cultures, as well as that of the Qiemuerqieke culture in the northern Altay region and the Andronovo culture which extended eastwards. There are also close links with the Qijia and Xichengyi cultural communities in the Hexi Corridor to the east, which may have been one of the main sources of bronzes. No signs of mining or smelting activity have been found in the entire Xinjiang region until 2000 BC. The discovery of the stone model in M17 of the Qiemuerqieke culture (around 1800 BC) indicates metal production in the Altay region. The more systematic local production of metals in the Xinjiang region began around 1600 BC, a related metallurgical production centre lies at the Jirentaigoukou site at the Ili Valley in West Xinjiang. Given the available archaeological evidence, it is more conceivable that the bronzes from Phases 1 and 2 of TSBL were brought to the Xinjiang region either directly by migrating populations or through trade or exchange, and the TSBL populations may have played a significant role in the transmission of finished products and technologies in the region, particularly tin-bronze technology, which may have accelerated the development of tin bronze in Bronze Age of Gansu in the east. As the TSBL enters its third phase, we argue that the local production of metal in the Hami region began around 1400BC due to the stone model found in Liushugou, but the scale of production was perhaps small, and it possible that the unique bronze objects were produced locally, while most of the bronze objects were probably introduced through trade or exchange with neighbouring cultures. Due to the high degree of similarity in alloy types and categories the most important source is, therefore, the Siba culture. The natural resources of Hami are compatible with autonomous local production, including the source of ore and access to technology. However, as it stands, TSBL did not develop into an influential centre of metallurgical production like Siba and Jirendaigoukou, and its greatest role remains as a conduit for absorption and transmission. But whether social factors such as the size of the population or natural factors such as the condition of the metal resources were to blame requires further study.

6.8 Exchange and consumption of bronzes

Research is still in its infancy regarding the patterns and distribution of communities, along with social structure and economic patterns in TSBL and East Xinjiang, and this study will attempt to discuss these issues. The significant variations in copper or bronze output in TSBL undeniably represent the transformation of consumer patterns and consequently the social structure of East Xinjiang throughout the Bronze Age. Based on the results of the analyses and comparisons with previously studied metal assemblages in other contemporary sites, it is possible to assess the interaction between the population at TSBL in East Xinjiang and its external environment in terms of consumption habits and the exchange of copper or bronze objects. From the discussion above, it is argued that the majority of the bronzes from the TSBL were obtained through trade or exchange. Even if there was a chance for independent local production to begin in the third period, it was probably on a small scale, which must have been tied to the social circumstances at the TSBL at the time. TSBL is a large cemetery site with over 1000 burials, closer examination reveals that there is some variation in density within the cemetery, which can be divided into several different sections. This huge cemetery formed by the merger of various cemeteries may represent how the local population was originally organised into clans or families as the fundamental unit of social structure. The lack of evident hierarchical disparities in the magnitude of the tombs and burial artefacts implies that the social divide between the wealthy and poor had not yet become substantial. The stone pestle, stone grinder, stone scythes, and a lot of stone implements discovered in the burials suggest that farming was common and fairly sophisticated at the time. Sheep and cattle bones are commonly buried in the cemetery, with sheep bones predominating, reflecting the widespread consumption of meat in the daily lives of the inhabitants of TSBL. The nitrogen isotope ratios of bone collagen show that TSBL inhabitants primarily ate animal products including mutton and beef (Zhang et al. 2010). The carbon isotope ratios of bone collagen show that most plant products came from C3 plants, of which most were wheat and with a small number of plant products came from C4 plants, which could be millet, etc (Zhang et al. 2010). Wheat and millet co-occurred in the diet of the TSBL people, demonstrating the interaction and exchange of Eastern and Western communities. Wheat was first cultivated in Western Asia in the ninth millennium BC and later spread eastward to Central and Southern Asia (Donson et al. 2013; Betts et al. 2014). Millet was a key component of Chinese agriculture and eventually spread westward around the third to second millennium BC (Franchetti et al. 2010). The discovery that wheat and millet were cultivated and consumed in eastern Xinjiang by 2100 BC or earlier adds to the importance of eastern Xinjiang in the early cultural exchange between East and West, as well as the subsequent migration of people, trade, and technological exchange over long distances and probably far beyond our comprehension. The discovery of arrowheads shows that the inhabitants were also engaged in some hunting activities and the cemetery has also turned up leather products and other articles of clothing. As seen above, the TSBL inhabitants produced crops like wheat, corn, and millet, grazed animals such as sheep and cattle, and engaged in certain hunting activities. They lived a stable sedentary existence supported by a semi-agricultural and semi-pastoral economy. The agricultural community's land served as the primary means of production, and the food and animal products generated served as a source of sustenance as well as an essential resource for trade and exchange. Animal husbandry growth not only supplemented food supplies, but also provided raw goods such as wool and skins, woollen textiles, and leather items, which might have been valuable resources for the TSBL people to barter for bronze and other things that they don't produce at the time. The trade of the TSBL people was probably more developed and frequent at the time, and they were in a kind of commercial centre; a large number of flat, round red carnelian beads have been excavated from the TSBL, and small quantities of carnelian beads with the same form occur in both the Qijia and Siba cultures, probably through exchange with the TSBL. Shells and shell ornaments have also been discovered at TSBL, demonstrating the extent and complexity of the trading network of the period, which may have involved long-distance trading. The TSBL people traded frequently with different cultures to obtain different goods and commodities, and then exchanged them again to obtain what they needed, forming a well-developed trade network that was mature enough to support the demand for the exchange of bronze products. This is probably the reason why the TSBL did not develop a metallurgical industry, as both demand and supply could be met without the need to spend huge amounts of manpower and material resources on metallurgical production-related activities. With no desire for additional categories and a paucity of weapons, in particular, the TSBL bronze consumption categories are concentrated, consistent, and dominated by ornaments. As evidence that the aesthetic was largely consistent from the early to the late period, the range of ornaments is rather full but there is not much development of other styles or patterns, etc. The TSBL population did not at this time fully benefit from the use of bronze in all facets of life since ornaments would have been among the more luxurious materials in life. The TSBL gender analysis revealed a disproportionate sex ratio among the inhabitants of the TSBL, with significantly more female individuals than male ones. The reasons for this are unclear, as the sex ratio has implications for the social status and social division of roles of both sexes (Wei and Shao 2012). This study argues that it is challenging to carry out pertinent metallurgical activities in the absence and restricted availability of a labour force and speculates that this may also be one of the reasons for the underdevelopment of metallurgical production in the TSBL population. In addition to the bronzes, most of which are ornaments, there are upwards of 5,600 various types of beads, including carnelian, malachite, talc, marble, and white jade. Though it cannot be excluded that men were also in the practice of wearing jewellery during the period, women may have had a stronger demand for jewellery.

6.9 Tianshanbeilu in its Bronze Age Xinjiang context

This detailed study of bronze production and consumption in TSBL provides insight into the transmission of various aspects of technological practice, and sociocultural traits. The specifics of the use and consumption of TSBL bronzes are indicative of the social and economic patterns of the time, and the acceptance and consumption of bronzes from neighbouring cultures by the TSBL would have influenced bronze traditions, including technological practices and transformation across Xinjiang during 2000BC to 1000BC.

It appears that the major developments in alloys happened around the second phase of the TSBL when arsenic copper was introduced. This common phenomenon of alloy choice in the Bronze Age of Xinjiang suggests we rethink the level of connectivity and the flow of information and techniques both within and outside communities of practice. TSBL had long traditional contact with the Hexi corridor for bronze consumption, new technologies based on pre-existing trade routes may be embraced more readily. As far as current archaeological data is concerned, arsenic copper was first used in Xinjiang in the Hami region, with its remains appearring in the later Wupu, Liushugou and Nanwan cemeteries, as well as the early period of Yanbulak's remains until tin bronze gradually replaced it around 1000 BC. Not only was the technology of arsenic copper relayed, but the TSBL consumption channel was also adopted, and the radiation of the Siba copper products reached the entire Hami region. TSBL, on the other hand, adhered to its original consumption habits, which were still dominated by tin bronze, and this perhaps would have directly influenced the choice of alloys for the production sites ranging from Xichengyi to Siba, to promote the development and expansion of tin bronze. Similarly, there is an impact on the production centre in terms of the type and style of bronzes and aesthetics, which in turn is likely to radiate these aspects to various customers from different regions. The Bronze Age cultures in the Hexi Corridor encompass nearly every facet of the Hami region. This is also demonstrated by the painted pottery culture's rapid eastward expansion (Han 2007; Shao 2012). The fusion of foreign and indigenous cultures has resulted in distinct cultures peculiar to the Hami region. These cultural impacts are expected to be accompanied by population migration (Shao 2012; Xi 2018), particularly as the metallurgical industry develops, which needs skilled relevant professionals rather than just technical influences. According to the archaeological evidence, the entire Eastern Tianshan region was a radiating location for the Siba culture, with TSBL at the forefront of this radiation (Li 2005; Qian 2006; Shao 2012; Xi 2018; Liu et al. 2020). Other areas of Xinjiang throughout the Bronze Age, except for the Altay region in northern Xinjiang, used and developed bronze products later than the TSBL, and they were influenced by various cultures (Han 2007; Shao 2012; Wang et al. 2019). The previous data show that arsenic-copper usage is roughly 4% in the western region of the Xinjiang, centred on the metallurgical site of Jirentai Goukou in Ili, nearly 20% in the central region, and approximately 8% in the south; no arsenic-copper use was discovered in the north Xinjiang (Liu et al. 2022). It seems that the farther away from the Hami area, the lower the proportion of arsenic-copper use, which proves that spread and application of arsenic-copper-related technologies in the Hami area are more likely to occur in the region and adjacent areas. The use of tin-bronze is dominant throughout Xinjiang, with tin-bronze as the main alloy in every region, with pure copper coming second in the Yili, northern and southern regions, and the Hami region having the greatest amount of arsenic copper in the bronze age of Xinjiang. From 2200 to 1800 BC, the Afanasevo and Okunev cultures affected the Aletay area in the north. The whole of Xinjiang was influenced by the Andronovo culture from around 1600BC onwards, from Altai in the north, Tacheng and Yili in the west, Urumqi and the surrounding areas in the centre, and the Tajik neighbourhood in the south-west (Mei 2000; Ruan 2013; Shao 2018; Shao and Zhang 2019), with the latest data showing that it radiated as far as the Balikun region in the east (Zhu et al. 2021). The Hami region was less impacted by Andronovo culture and is part of the Hexi Corridor culture's sphere of influence. The Seima-Turbino-related culture also had a cultural impact on Xinjiang. However the specific path has not been explored, the latest suggestion is that it may have reached Xinjiang through the northern Mongolian area, southwards from the Altai region, although this information has not been published and requires additional refinement (Fessta 2018; Shui pers. comm.). This is also the path hypothesised for the transmission of bronze technology to Gansu and Qinghai before 2000BC, from Mongolia via Altay and eventually to the northwest of China (Festa 2017; Chen et al. 2018; Dong and Li 2021). The traditional Andronovo-type trumpet end earrings made of gold and bronze unearthed in Siba, which were not found in the TSBL, demonstrated that Eurasian steppe cultures had an impact on the Gansu region without passing through east Xinjiang.

To conclude, the Xinjiang area was still primarily peripheral during the Bronze Age from 2200BC to 1800BC and exchanges between local inhabitants and adjacent communities were still in their early stages. As a consequence of impacts from their neighbours, the Andronovo and the Siba, Xinjiang was gradually occupied by two metal-using cultures in the west and east during the second millennium BC. Contributions from cultural groups from Central Asia, South-western Siberia and the Gansu and Qinghai region are evident also from metal evidence, which suggests that Eastern Xinjiang was already a centre for east-west and north-south exchanges as early as the beginning of the second millennium BC, and TSBL is the main force of this centre.

6.10 Summary

This chapter brings together the stylistic, contextual, provenance and technological information produced in the thesis research. In the context of the movement of bronzes, ideas and people in the bronze age, TSBL offers an opportunity to examine the development of specialised metallurgy production and the variable responses to the technological innovation and technical identity in the network of contact and exchange between TSBL and metallurgy communities in the transition between 2000BC to 1000BC, a time of great change in the east Xinjiang. Metallurgy production, consumption and exchange at TSBL indicate the connectivity of east Xinjiang. The new alloys at TSBL and across Xinjiang reflects their intimate connection to social circumstances and the transmission of knowledge and technical practices during the second millennium BC. The local development through the acceptance and adoption of cultural and social norms as well as technology during the interactions outline the connectivity and conformity between regions and the neighbouring region in general. As a consequence, through large-scale trade and exchange on site and widely distributed specialised bronze objects and other many types of goods involved in short-distance and more distant trading activities across Xinjiang, it is possible to think of TSBL as a trade and exchange centre with associated goods bearring social value. The mobility of bronzes and, presumably, the migration of craft producers may represent diverse perspectives about social and technical activities in local crafters and consumer groups. During the second millennium BC, tin bronzes are widespread across Xinjiang, most are made into personal ornaments. The alloy differences that may show regional variances in a distinct production centre, the categorise and technological change of the bronzes witness the existence of cultural transmission and acceptability over a broader geographical area. Moreover, the ternary and quaternary alloys show that recycling may occur and this is the multiple resources for raw materials and commonly happened across Xinjiang. Concerning the study of the circulation of bronze, it shows that the socioeconomic interconnections extend to a broader network, from Central Asia, South-western Siberia and the Gansu region. It is worth emphasising that the flow of metal may only be one way to imagine this network. Many other commodities and exotics must also flow as packages within it. For instance, the TSBL is known as the food-producing region in Xinjiang. It is reasonable to propose that the most effective tool in the negotiation with other local powers might be wheat. The stable source of food for the survival of the steppe was quite important for the surrounding population. The agricultural economic model allowed for a more elaborate development of food cultivation, together with settled livestock farming, stable production and a relatively advanced economic form that made it beneficial to develop trade and exchange. Until the end of the second millennium BC, new climatic conditions led to a more intense occupation of the Xinjiang territory, prompting the establishment of actual routes connecting TSBL populations with the other people groups which developed in the first millennium BC, at the beginning of the Iron Age.

Chapter 7 Conclusion

This chapter reviews the important understandings and implications produced by the research, and offers an account of technological traditions and the change of technological choices and practices in metal production, as well as consumption trends in the TSBL bronze assemblage. The end of this chapter also highlights the prospects for future research in light of the main conclusions of the study.

This thesis has aimed to provide a detailed understanding of typology, alloy technology, consumption and circulation of bronze at Tianshanbeilu cemetery in Xinjiang from 2000BC to 1000 BC. Through the typological study of the assemblage and the chemical analysis of a large number of samples, it has established the typology of the bronze objects, characterised change in alloy technology and practise, notably those involving alloy choice and raw materials at TSBL and its environs. It has also investigated consumption patterns at TSBL to situate eastern Xinjiang in its economic and social contexts, both on the Hexi corridor in west Gansu and the range of Xinjiang networks in which it was involved.

These objectives were attained by an integrated analytical process that included typology, contextual study and chemical analyses. The typology study allowed the full understanding of the bronzes of TSBL in terms of different categories and provided information on certain aspects of style trends at the time. Despite being the first stage in the methodological framework, it was the very important part, but more specifically, this approach serves as the foundation for later chemical composition analyses. While the scope, logistics and timeline of the thesis allowed the study of a small range of contexts, compared to the wealth of material excavated from the site, it is considered representative. Certainly, the contrasts between the four phases reflect changes in the technological tradition and practice of the bronze discovered from TSBL at the time. The contextual study identifies the presence of metal together with other materials in funerary contexts, whilst integrating an extensive study of the metal objects to extend our understanding of the material culture of TSBL.

The next analytical step was based on the chemical composition to examine alloy choices which have given clear indications of technological changes employed in the bronzes of TSBL. When compared to cognate practices over space and time, these were related to social identity and the level of interaction between different communities.

For the study of chemical composition, pXRF was used, which has great potential for exploring the selection of prehistoric alloys for bronze production as well as the evolution of alloy techniques due to its ability the provide compositional information non-destructively on a large number of objects in their storage context. Thus 1352 metal objects, derived from 406 graves from the Tianshanbeilu site were analysed, representing an almost complete coverage of the graves with metal. With such an extensive dataset, it is possible to determine raw materials, techniques, and their proportions during mixing, components which affect the final performance and appearance of the objects.

In terms of methodology, whilst the data quality of portable XRF is often questioned, this research demonstrates the great potential of using a large set of pXRF data in order to generate archaeologically meaningful results. Without such a number of data, it is by no means possible to be certain about the archaeological conclusions above mentioned. This study's cautious interpretation of the data is another strength of the project. Bearing in mind that almost all the Tianshanbeilu (and the entire Xinjiang) metal objects are small and heavily corroded, the current analysis and discussion are primarily based on the presence and absence of various alloying elements in the extremely large database, with reference to the semi-quantitative skyline of the alloying distributions. This is the first time that the methodology has been used, and the results have proven to be successful.

The identification of technological tradition and the change of technological choices and practices in metal production as well as consumption trends with TSBL bronze assemblage can be summarised as follows:

1) The bronze objects are mainly personal ornaments at TSBL, accompanied by some tools and a few weapons, of which there are 14 different categories, including beads, earrings, pao, buttons, bangles, tubes, plaques, mirrors, knives, awls, socked axes, arrowheads, short sword, and bells. Bronze beads were the most numerous; bronze earrings are the most popular and widely distributed, followed by Pao and plaques.

2) There are eight alloy groups for the copper or bronze objects found in TSBL, which involve tin bronze (Cu-Sn), arsenic copper (Cu-As), pure copper (Cu), arsenic bronze (Cu-Sn-As), leaded bronze (Cu-Sn-Pb), leaded arsenic copper (Cu-As-Pb), leaded arsenic bronze (Cu-SB-Pb-As) and arsenic antimony copper (Cu-As-Sb).

3) Tin bronze is the predominant alloy at TSBL, and has medium to high tin content, implying that tin was mostly intentionally added, but without a stable formula.

4) Arsenic copper or bronze is another important alloy type and generally has a low arsenic content, from Phase 2 onwards. The low arsenic content suggests that it may not be intentionally introduced, and may be more likely to have come from the ore itself, or may be due to recycling.

5) Pure copper, leaded arsenic copper ternary and leaded arsenic bronze quaternary alloys are also common at TSBL, indicating that recycling may be widespread. Arsenic antimony copper indicates the use of ores from the tennantite-tetrahedrite series.

6) The type of alloy varies between bronze categories, suggesting that different alloys were chosen at the time depending on the type of bronze or supplied by different production centres. Tin bronze was used for the majority of the ornaments, and a higher proportion of arsenic copper was used for tools.

7) In phases 1 and 2. The finding of a Type A1 knife shows the link between TSBL and the Qijia culture in the Hexi corridor; similarly, a Type 2 mirror with a handle can be associated with the Andronovo culture in the Semirechiye district of Kirghizia.

8) In phases 2, 3 and 4, in terms of category and the features of alloys indicate the direct link between TSBL bronzes and Siba culture in the Hexi corridor, particularly the low-level arsenical copper alloys and arsenic antimony copper alloys, which also indicates the possibility of the same raw material source. A high level of arsenic would have been deliberately added and may be from a different production centre to the low-level arsenical copper alloys, or from a very different source of ore.

9) Lead is another significant alloy component, which makes up 12% of TSBL alloys and is present in ternary and quaternary alloys in quantities that can range from low to high values, thus both purposeful addition and recycling are possible.

10) The use of different elements such as tin, arsenic and lead in alloys for bronze objects from TSBL reflects craftspersons exploring and experimenting with alloying techniques.

These shifts in production and consumption result in the following conclusions:

1) TSBL alloys are diverse in composition and come from a wide range of sources. TSBL bronzes from Phases 1 and 2 were brought directly to Xinjiang by migrating populations or through trade. In addition, TSBL populations likely played a key role in the transmission of tin-bronze technology, which may have accelerated the development of tin bronze in the Hexi Corridor of Gansu and the Hami region.

2) There is no direct evidence of bronze production at TSBL While this study argues that the production of metal in Hami began around 1600BC, due to the discovery of the stone model in Liushuigou, contemporary with Phase 2 at TSBL, the scale of production was small, and possibly only unique bronze objects were produced locally in the Hami region, while most of the bronze objects were probably introduced through trade and exchange with neighbouring cultures.

3) Through contextural study, considering spatial distribution in the cemetery, burial practice and burial goods, this study suggests that the population of TSBL lived a stable sedentary existence supported by a semi-agricultural and semi-pastoral economy. The inhabitants produced crops like wheat, corn, and millet, also grazed animals such as sheep and cattle, as well as engaged in certain hunting activities. The food and animal products generated served as a source of sustenance as well as an essential resource for trade and exchange.

4) The TSBL inhabitants did not fully benefit from the use of bronze in all facets of life, as personal ornaments dominate bronze objects and would have been among the more luxurious materials in life. While the natural resources of the Hami region are compatible with autonomous local production, including sources of ore and access to

technology, TSBL did not develop into an influential centre of metallurgical production and its role remains as a conduit for absorption and transmission.

5) Through large-scale trade and exchange on TSBL and widely distributed specialised bronze objects and other many types of goods involved in short-distance and more distant trading activities across Xinjiang, it is possible to think of TSBL as a trade and exchange centre with associated goods bearring social value.

6) In East Xinjiang, a socio-cultural region with local variation - similar bronze technology traditions and choice of alloys combine with comparable tomb structure and burial practises, displaying a similar cultural identity at a broader regional level. The different characteristics of the bronze repertoire and varying degrees of sophistication on specific objects, on the other hand, reflect the different production and consumption choices between the western, central, and northern zones of Xinjiang. The strong connection between dispersed site regions and intercommunal contact with Xinjiang, large-scale trade or exchange, and the use of metals may lead to a reassessment of social identity within and between Xinjiang communities.

7) Through interactions between communities of East Xinjiang and with the nearby Siba culture in the Hexi corridor, and also the other zones of Xinjiang - TSBL consumed distinctive products (i.e. painted pottery, shells, shell ornaments, carnelian beads, etc.) from multiple suppliers. It may also have exchanged its traded products to neighbouring areas. This may prompt ideas about the motivations behind the development of arsenic copper, as both technological and stylistic innovations were simultaneously taken advantage of in a demand-driven exchange mechanism, suggesting organised craft specialist skills and technological knowledge transmission through the expansion of

exchange networks. The common use of arsenic copper reflects the interactions between communities. Technological transfer through shared emulated practices and emulation in a socio-cultural sphere where diversity and variability were incorporated.

According to the previous discussion in this chapter, the interpretation of the lifestyle of TSBL in the Bronze Age provides a material discourse in socio-cultural contexts: the flow of commodities, the migration of populations, the use of metal and rare resources, and the demand for high-value objects. More specifically, in terms of bronze or copper, the consumption choice of bronze at TSBL shows strong demand for personal adornment and body ornamentation. This was an important economic and cultural feature of the time and demonstrates how social value was displayed and understood and its relation to individual and/or group identity. Furthermore, there are a range of changes witnessed in TSBL bronzes: the changing technical choices and traditions; increasing alloy types indicating a general trend of an increase in strength; the more complex pattern of consumption and organization; the broader range of products exchanged, and the commodities exchanged from diverse production centres. As part of the overall phenomenon of Bronze Age Xinjiang, they are all part of the new social strategy that has been developed as a response to broader transformations and instabilities in the environment they inhabited. There was a significant increase in the scale of economic activities during the period studied in this thesis, with a series of fundamental changes in both social and technological aspects. In TSBL we seem to be witnessing a greater transformation in metals. The shifts in metal use are tied to social changes in consumption, movement, and sharing practices. As new technologies and innovations were introduced, the repertoire of commodities and goods consumed changed; it adapted to the conditions prevailing in a particular social setting, which entered circulation and were further diversified as a result of technological shifts.

Future research prospects

The purpose of this thesis is to provide a detailed investigation of the bronze assemblage at TSBL to reconstruct the nature of the site and the human activities associated with it. This research demonstrates a new way of using pXRFgenerated alloying data that enables us to reveal crucial changes in prehistoric Xinjiang and bring new light to future research.

Further research of the site needs undertaking to enable a detailed reconstruction of the full process of bronze production of objects recovered from TSBL: smelting, alloying, manufacturing, and the raw materials used in the production of the bronze, as well as the provenance of non-local products. Therefore, it would be fruitful to carry out further analysis of selected objects, especially those that exploit trace elements and lead isotopes, offering the prospect of more detail in the grouping of objects and especially evidence for re-cycling the provenance of objects.

The extensive corrosion of the bronzes examined in this study produced challenges for the detailed reconstruction of alloy compositions. This is not a problem unique to TSBL but applies more widely to objects recovered from sites throughout Xinjiang. In an attempt to mitigate these issues, the selection of objects and the areas of analysis on the objects were chosen very carefully in this study, but more accurate results are likely to be obtained in the future examination if surfaces changed by corrosion were able to be removed.

Future analyses of material from prospected ore sources are expected to provide additional evidence that will reveal the variability of ore deposit(s) in the local and broader area and may shed light on the provenance of the raw materials.

As is often the case in the early stages of material analysis in any region, the increased availability of comparative analyses of contemporary bronze assemblages in Hami and throughout Xinjiang is needed to provide additional insight into the character of the sites and place them in an active role within the flourishing Xinjiang context. A lack of such comparative data is the main issue in the chemical analysis of bronze objects of Xinjiang and the Northwest China zone. Therefore, this study attempts to use the pXRF's non-destructive and non-invasive nature to collect as much data as possible from TSBL and aims to create an open database as well as some useful discussions and references for future studies. More chemical analyses and archaeological information will hopefully be released in the future. Finally, our understanding of TSBL and surrounding areas in terms of other types of finds (pottery remains, other materials of beads and stone tools, etc.) is limited The release of more excavation reports would be very beneficial for the detailed contextural studies required to take our understanding forward. It is hoped that this study provides useful information as a basis for future work in the investigation of human activity in Xinjiang during the Bronze Age.

Bibliography

Abuduresule, Y., Li, W., Hu, X., 2007. The Xiaohe Graveyard in Luobupo, Xinjiang. Wenwu (Cultural Relics) 10, 4–42 (In Chinese).

Abuduresule, Y., Li, W., Hu, X., 2018. Preliminary study of the Xiaohe cemetery, Xinjiang, China. In: Betts, A., Jia, P., Vicziany, M. (Eds.), From Cattle toCamel Trains. The Development of the Silk Roads. Sydney University Press.

Albenda, Pauline., 1985 Mirrors in the ancient Near East, in Notes on the History of Science, 1985, no. 4, pp. 2-9.

An, Zhimin, 2000. On early copper and bronze objects in ancient China, in K. M. Linduff et al.,(eds.) The beginnings of metallurgy in China, 29–46. Lewiston, N.Y., 2000.

Anthony, D., 1998. The opening of the Eurasian steppe at 2000 BCE. Victor H. Mair, (eds) In The Bronze Age and early Iron Age peoples of eastern central Asia. Pp. 94–113. Philadelphia: University of Pennsylvania Museum.

Anthony, D., 2007 The horse, the wheel, and language: how Bronze-Age riders from the Eurasian steppes shaped the modern world. Princeton, NJ: Princeton University Press.

Anthony, D., 2009. The Sintashta genesis: the roles of climate change, warfare, and long-distance trade. In Social complexity in prehistoric Eurasia: monuments, metals, and mobility. Bryan K. Hanks and Katheryn M. Linduff, eds. pp. 47–73. Cambridge: Cambridge University Press.

Bagley, R.W., 1987. Shang Ritual Bronzes in the Arthur M. Sackler Collections. Arthur M. Sackler Foundation, Washington D. C.

Bergman, F., 1939. Archaeological Researches in Sinkiang. Especially in the Lop-Nor Region. Reports from the Scientific Expedition to the Northwestern Provinces of China under the Leadership of Dr. Sven Hedin / Scientific Expedition to the North-Western Provinces of China: Publication 7. Thule, Stockholm 1939

Betts, A; Jia, Peter; Abuduresule, I., 2019 A new hypothesis for early Bronze Age cultural diversity in Xinjiang, China, in Archaeological Research in Asia 17 (2019) 204–213

Bin, Yang., 2001 The rise and fall of cowry shells: the Asian story, in Journal of World History, 2001, vol. 22, no. 1, pp. 1-25.

Bobrov, V.V., Kuzminykh, S.V., and Teneyshvili, T.O., 1997. Drevnyaya metallurgiya srednego Yeniseya (Lugavskaya Kul'tura). Kemerovo: Kuzbassvuzizdat, 1–12.

Borodovsky, P. Andrey., 2013 "Prestigious Afanasyevo wooden metal-bound ware from Sayan-Altai", in Archaeology Ethnology and Anthropology of Eurasia, 2013, vol. 41, no. 4, pp. 119-122.

Bray, P., Cuénod, A., Gosden, C., Hommel, P., Liu, R., Pollard, A.M., 2015. Form and flow: the 'karmic cycle' of copper. J. Archaeol. Sci. xxx, 1–8 (available online).

Bray, P., Pollard, A.M., 2012. A new interpretative approach to the chemistry of copper–alloy objects: source, recycling and technology. Antiquity 86, 853–867.

Brill, R.H., Wampler, J.M., 1967. Isotope studies of ancient lead. Am. J. Archaeol. 71, 63–77.
Carpenter, H.C.H., 1933. Preliminary report on Chinese bronzes. Guoli Zhongyang Yanjiuyuan Lishi Yuyan Yanjiusuo. An yang fa que bao gao di si qi .(Excavation report of Anyang, IV, Taiwan). pp. 677–680.

Bronk Ramsey, C., 1998. Probability and dating. Radiocarbon, 40: 461–474.

Bronk Ramsey, C., 2018. Methods for summarizing radiocarbon datasets. Radiocarbon, 59: 1809–1833.

Budd, P., R. Haggerty, A. Pollard, B. Scaife, and R. Thomas, 1996, Rethinking the quest for provenance, Antiquity, 70(267), 168-174

Bunker, C. Emma., 1998 Cultural diversity in the Tarim Basin vicinity and its impact on ancient Chinese culture, in Mair, H. Victor (ed.), The Bronze Age and Iron Age people of Eastern Central Asia, Monograph 26, vol. 1, Washington: Institute for the Study of Man, 1998, pp. 604-618.

Bunker, E., 2009. First millennium BCE Beifang artifacts as historical documents, in B. K. Hanks and K. M. Linduff, (eds.), Social complexity in prehistoric Eurasia, 272–95. New York, 2009.

Catling, H. W., 1964 Cypriot Bronzework in the Mycenean World. (Oxford).

Chase, W.T., Ziebold, T.O., 1978 Ternary representation of ancient Chinese bronze compositions. Archaeological Chemistry, Advances in chemistry Series 171. Washington D.C.: American Chemical Society, 1978, 302-305.

Chen G, Cui Y, Liu R, Wang, H., Yang, Y., Pollard, M., 2020 Lead Isotopic Analyses of Copper Ores in the Early Bronze Age Central Hexi Corridor, Northwest China. Archaeometry. 2020, 62(05).

Chen, Xiaosan., 2012. Hexi zoulang ji qi linjin diqu zaoqi qingtong shidai yicun yanjiu (Study on early Bronze Age remains in the Hexi Corridor and its adjacent areas), PhD Thesis. Jilin University, 2012

Chen, Ge 1982. A discussion of painted pottery. Xinjiang She Hui Ke Xue. Vol 2. pp77-103

Chen, Ge 1991 A discussion of Yanbukela culture. Xi Yu Yan Jiu. Vol 1. pp81-96

Chen, Ge 1995. A preliminary research on early cultures in Xinjiang. Xi Yu Wen Wu. Vol 4, 5-72

Chen, Guoke., 2017. Xi changyi – Qijia ye jin gong tong ti= He xi zou lang di qu zao qi ye jin ren quan ji xiang guan wen ti chu tan (Xichengye - Qijia Metallurgical Community--A preliminary study of early metallurgical populations and related issues in the Hexi Corridor region). Kao Gu Yu Wen Wu 2017 vol 5 pp 37-44.

Chen, Guoke., Li, Yanxiang., Qian, Wei., Wang, Hui., 2015 A Preliminary Study on the Unearthed Bronze from the Xichengyi Site in Zhangye. Kao Gu Yu Wen Wu 2015 vol 2, pp 105-118.

Chen, Kunlong., Wang Lu, Wang Yinsheng, Mei Jianjun, Wang Kun. 2018 Scientific Analysis and Related Issues of the Bronze of the Siba Culture in Huoshaogou, Yumen, Gansu. Wen Wu Bao Hu Yu Ke Ji 2018 vol 2.

Chen, Kwang-tzuu., and Hiebert, Fredrik T., 1995. The Late Prehistory of Xinjiang in Relation to Its Neighbors in Journal of World Prehistory, June, Vol. 9, No. 2 (June 1995), pp. 243-300

Chen, Xingcan, 1997. The History of Prehistorical Archaeology in China 1895-1949. Beijing. Shanlian Shudian.

Cheng, W., Zhou C., Zhu A., Li X., 2003 Landscape pattern characteristics of northern foothill belts along Tianshan mountains., Ecosystems Dynamics, Ecosystem-Society Interactions, and Remote Sensing Applications for Semi-Arid and Arid Land, 90.

Chernykh, E.N., 2014. Metallurgical Provinces of Eurasia in the Early Metal Age: problems of interrelation. ISIJ Int. 54 (5), 1002–1009.

Chernykh, N. Evgenil., 1992. Ancient metallurgy in the USSR: the early Metal Age, Cambridg Cambridge University Press, 1992

Cong, Dexin., Jia, Weiming., Alison Betts., Jia Xiaobing., Paula N Doumani Dupuy 2017. Adonqolo: New Type of Bronze Age Remains in the Western Tianshan Mountains

Cuénod, A., P. Bray, and A. M. Pollard, 2015, The 'tin problem' in the near east -- further insights from a study of chemical datasets on copper alloys from Iran and Mesopotamia, Iran, 53, 29-48.

Debaine-Francfort, C., 1988. Archéologie du Xinjiang des Origins aux Han. Paléorient 14 (1), 5–29.

Dong, Xiaoshuai., Li, Xiuhui. 2021. Gan su di qu xian qin shi qi tong qi jian ze fen xi zi liao de zheng li yu yan jiu(An Analysis of the Detection of Bronze Artefacts from the Pre-Qin Period in Gansu Compilation and study of data). Nan Fang Wen Wu 2021 vol 3 pp 210=229

Doonan, Roger C.P., Day, Peter.M., Dimopouloi-rethemiotaki, Nota., 2007. Lame Excuses for Emerging Complexity in Early Bronze Age Crete: the Metallurgical Finds from Poros Katsambas and their Context (eds) Day, Peter.M., Doonan, Roger C.P. Metallurgy in the Early Bronze Age Aegean. Oxbow Books. pp 98-122

Doonan. R, Pitman. D., Hanks. B., Zdanovic. D. & Kupriyanova. E., 2013, Die Organisation der Metallurgie der Sintašta-Kultur in Stöllner T and Eisenach P (eds) Unbekanntes Kasachstan Archäologie im Herzen Asiens: Führer zur Ausstellung des Deutschen Bergbau-Museums Bochum. pp 211-218

Eaton, R. Ethel., Mckerre, Hugh, 1976. Near Eastern alloying and some textual evidence for the early use of arsenical copper, in World Archaeology, 1976, vol. 8, no. 2, pp. 169-191.

Festa, Marcella., 2018 Bronze Age communities and bronze metallurgy in Xinjiang. PhD Thesis

Frachetti, M., 2012. Multiregional emergence of mobile pastoralism and Non-uniform institutional complexity across Eurasia. Current Anthropology, Vol. 53(1): 1-18.

Frachetti., Michael D., Robert N. Spengler., Gayle J. Fritz1 & Alexei N. Mar'yashev (2010) "Earliest direct evidence for broomcorn millet and wheat in the central Eurasian steppe region", in Antiquity, 2010, vol. 84, no 326, pp. 993-1010

Frahm, Ellery., Doonan, Roger C.P. 2013 The technological versus methodological revolution of portable XRF in archaeology. Journal of Archaeological Science 40 (2013) 1425-1434

Francfort, Henri-Paul., Fouilles de Shortugaï: recherches sur l'Asie Centrale protohistorique (Excavations at Shortugai: research on Central Asia protohistory), Paris: Diffusion De Boccard, 1989, vols. 1-2.

Gao, Jun., Jin Zhengyao., Wang Binghua., Chang Xi'en., Wang Yongqiang Wang Bo , Lv Enguo., Fan Anchuan., Huang Fang., 2021. A provenience study of Bronze Age metal objects from the Hami Basin, Xinjiang, China. Journal of Archaeological Science: Reports 39 (2021)

Garner, Jennifer., 2015. Bronze Age tin mines in Central Asia", in Haupymann, Andreas., Moderessi-tehrani. Diana. (eds.), Archaeometallurgy in Europe III. Proceedings of the 3rd International Conference Deutsches Bergbau-Museum, Bochum 2011, Bochum: Deutsches Bergbau-Museum, 2015, pp. 135-144.

Gong, Guoqiang, 1997 "Xinjiang diqu zaoqi tongqi lüelun" (On the early bronzes in Xinjiang), in Kaogu (Archaeology), 1997.9, pp. 7-20.

Han Kangxin 1998. The Physical Anthropology of the Ancient Populations of the Tarim Basin and Surrounding Areas, In: The Bronze Age and Early Iron Age Peoples of Eastern Central Asia, edited by Victor H.Mair,1998,558-570

Han, Jianye. 2005. Xinjiangqing tong shi dai-zao qi tie qi shi dai wen hua de fen qi he pu xi (The chnology and culture of Xinjiang – from Bronze Age to Early Iron Age), in Xinjiang Wen Wu 2005.vol 3, pp57-99.

Han, Jianye. 2007. Cultures in Xinjiang from the Bronze Age to the Early Iron Age. Wen Wu Chu Bam She Press, 2006.

Han, Kangxin., 1986. Study on the skeletons found at Gumugou cemetery in Xinjiang Konghe. J. Archaeol. Stud. 3

Hanks, B. and Doonan, R., 2009. From Scale to Practice: A New Agenda for the Study of Early Metallurgy on the Eurasian Steppe. Journal of World Prehistory 22: 329-356

Hanks, B., and Doonan, R., 2012. Comments on, M. Frachetti 2012, Multiregional Emergence of Mobile Pastoralism and Non-uniform Institutional Complexity across Eurasia. Current Anthropology, Vol. 53 (1): 23-24

Hong, Lideng, 1981. Summary of Geological Quaternary period in Xinjiang. An anthology of geological Quaternary period and glacial age in Xinjiang. Xinjiang Ren Ming Chu Ban She. pp36-58

Hopkirk, P., 1980 Foreign Devils on the Silk Road: The Search for the Lost Cities and Treasures of Chinese Central Asia. John Murray Publishers Ltd

Hsu, Y.-K., P. J. Bray, P. Hommel, A. M. Pollard, and J. Rawson, 2016, Tracing the flows of copper and copper alloys in the Early Iron Age societies of the eastern Eurasian steppe, Antiquity, 90(350),357-375

Hsu, Y-K., 2016, The dynamic flow of copper and copper alloys across the prehistoric Eurasian steppe from 2000 to 300 BCE, University of Oxford

Huang, Wenbi, 1983. Xinjiang Archaeological Reports (1957-1958). Wen Wu Chu Ban She

IXER, R.A. 1999. The role of ore geology and ores in the archaeological provenancing of metals, in S.M. Young, A.M. Pollard, P. Budd & R.A. Ixer (ed.) Metals in antiquity: 43–52. Oxford: Archaeopress.

Jia Peter Wei Ming and Betts, A., 2010. A re-analysis of the Qiemu’erqieke (Shamirshak) cemeteries, Xinjiang, China. The Journal of Indo European Studies, 38.3–4 (Fall/Winter, 2010): 275–317.

Jia, P.W., Betts, A., Wu, X., 2011. New evidence for Bronze Age agricultural settlements in the Zhunge'er (Junggar) Basin, China. J. Field Archaeol. 36 (4), 269–280.

Jia, Peter Wei Ming and Betts, Alison V. G. 2010 A re-analysis of the Qiemu’erqieke (Shamirshak) cemeteries, Xinjiang, China in The Journal of Indo-European Studies, Volume 38, Number 3 & 4, Fall/Winter 2010

Jiang, Fengqing, Hu Ruji, Ma Hong, 1998. "Xinjiang qi hou yu huan jing de guo qu, xian zai ji wei lai qing jing (The past, present and future climate and environment in Xinjiang), in Ganhan Qu Dili (Arid Lands Geography), 1998, vol. 21, no. 1, pp. 1-9

Jin, Zhengyao., 1987. Wan shang zhong yuan qing tong de kuang liao lian yuan yan jiu (A study of the ore sources of bronze in the Late Shang of central plain). Ke ji shi lun wen ji(A collection of essays on the history of science and technology), 1987, 373-375.

Kohl, P. L. 2007. The making of Bronze Age Eurasia. Cambridge: Cambridge University Press.

Kohl, P. L., 1987. The use and abuse of world systems theory: the case of the pristine west Asian state. Advances in Archaeological Method and Theory 11:1–35.

Kohl, P. L., 2008. Shared social fields: evolutionary convergence in prehistory and contemporary practice. American Anthropologist 110(4):495–506.

Kohl, P. L., 2009a. The Maikop singularity: the unequal accumulation of wealth on the Bronze Age Eurasian steppe. Bryan K. Hanks and Katheryn M. Linduff (eds). Social complexity in prehistoric Eurasia: monuments, metals, and mobility. pp. 91–104. Cambridge: Cambridge University Press.

Kohl, P. L., 2009b. Perils of carts before horses: linguistic models and the underdetermined archaeological record. American Anthropologist 111(1):109–111.

Kovalev, Alexei., Erdenebaatar Diimaazhav, "Menggu qingtong shidai wenhua de xin faxian" (New discoveries of Bronze Age cultural remains in Mongolia), in Bianjiang kaogu yanjiu (Archaeological Research at the Frontiers), 2008, vol. 9, pp. 246-279

Krismer, M., Vavtar, F., Tropper, P., Kaindl, R., and Sartory, B., 2011. The chemical composition of tetrahedrite-tennantite ores from the prehistoric and historic Schwaz and Brixlegg mining areas (North Tyrol, Austria). European Journal of Mineralogy, 23: 925–936.

Kuijpers, M., 2008. Bronze Age metalworking in the Netherlands. Leiden, 2008.

Kuzmina, E. Elena and Mallory, P. James., 2007. The origin of the Indo-Iranians, Leiden: Brill,

Kuzmina, E., 1998. Cultural connections of the Tarim Basin people and pastoralists of the Asian steppe at 2000 BCE, in V. H. Mair, ed.,The Bronze Age and early Iron Age peoples of Eastern Central Asia, vol. 1: 63–93. Washington, D.C., 1998.

Kuzmina, E., 2004. Historical perspectives on the Andronovo and early metal use in Eastern Asia, in K. M. Linduff, (eds), Metallurgy in ancient Eastern Eurasia from the Urals to the Yellow River, 37–84. Lewiston, N.Y.

Lan, Shirui., 2021. Xi bei di qu qing tong shi dai zao qi de jin shu shi yong – Cong ji shu yu zi yuan jiao du tan tao (Metal use in the Early Bronze Age in the Northwest - a technological and resource perspective). Wen Bo 2021 vol 5 pp 59-72.

Lechtman, H. 1996 Arsenic Bronze: Dirty Copper or Chosen Alloy? Journal of Field Archaeology 23: 477–514.

Li, Qinling., 2010. Studies on metal sources in antiquity. PhD Thesis. University of Science and Technology China. 2010

Li, Shuicheng , Shui, Tao, 2000 "Siba wen hua tong qi yan jiu, Wenwu (Cultural Relics), 2000.2, pp 36-44

Li, Shuicheng, 1993 "Siba wenhua yanjiu " (Research on the Siba culture), in Su Bingqi (ed.), Kaoguxue wenhua lunji (Collection of studies on archaeological cultures), Wen Wu Chu Ban She 1993, pp. 80-121.

Li, Shuicheng, 1999 Cong kaogu faxian gongyuan qian erqian nian dongxi wenhua de pengzhuang he jiaoliu (Encounter and exchange between east and west during the second millennium BC, from an archaeological perspective), in Xinjiang Wen Wu (Xinjiang Cultural Relics). 1999.1, pp 53-65.

Li, Shuicheng, 2001. Hexi diqu xinjian Majiayao wenhua yicun ji xiangguan wenti (Remains of the Majiayao cultures newly seen in the Hexi region and related questions), in Su Bingqi (ed.), Su Bingqi yu dangdai zhongguo kaoguxue (Su Bingqi and archaeology in contemporary China), Beijing: Ke Xue Chu Ban She, 2001.

Li, Shuicheng, 2005. Xi bei yu zhong yuan zao qi ye tong ye de qu yu te zhen he jiao hu zuo yong (Regional characteristics and interactions between early copper metallurgy in the Northwest and Central Plains) Kao Gu Xue Bao. 2005 vol 3
Li, Shuicheng, 2006. "The regional characteristics and interactions between the early bronze metallurgies of the North-west and Central Plains", in Chinese Archaeology, 2006, vol. 6, no. 1, pp. 132-139

Li, Shuicheng., 2009. Study on the First Phase in Tianshanbeilu Cemetery, Collection in Memorial of Mr. Yu Weichao. Relics Press, Beijing.

Li, Shuicheng., 2017. The dawn of the former Silk Road. Discussion on migration and interaction between the early north-west population and the Eurasian steppe. Silk Road Archaeol. (1), 76–81.

Li, Yuchun, 1959 Painted pottery found in Xinjiang. Kao Gu, Vol 3, 153-154

Lin, Meicun 2002. 林梅村, "Tuhuoluoren de qiyuan yu qianxi (Origins and migrations of the Tocharians), in Xinjiang Wenwu (Xinjiang Cultural Relics), 2002, vol. 3-4, pp. 69-80.

Lindruff, K., 2000. The Emergence of Metallurgy in China: Lewiston, Queenston, Lampeter: Edwin Mellen Press

Lindruff, K., 2004. The Beginnings of Metallurgy from the Yenesei to the Yellow Rivers, Katheryn M. Linduff (ed.), Lewiston, Queenston, Lampeter: Edwin Mellen Press.

Ling, Yong, 2008. Research on prehistoric metal technology in Xinjiang, China. Journal of Guangxi University for Nationalities (Natural science Edition), Vol 14, 3. 8-46

Liu, Cheng, Liu Ruiliang, Zhou Pengcheng, Lu Chun, Yang Zengxin, Pollard A. Mark., Hommel, Peter., Ma Jian, Cui Jianfeng, Bary., Peter., Tong Jianyi1 and Rawson, Jessica., 2020. Metallurgy at the Crossroads: New Analyses of Copper-based Objects at Tianshanbeilu, Eastern Xinjiang, China in Acta Geologica Sinica (English Edition), 2020, 94(3): 594–602

Liu, Cheng., Liu, Ruiliang., Zhu, Siying., Wu, Jie., Pollard, A. Mark., Cui, Jiangfeng., Tong, Jianyi., Huan, Limin., Hui, Yiu-Kang., 2022 New scientific analyses reveal mixing of copper sources in the early Iron Age metal production at Ili, western China. Archaeometry. 2022;64(S1):98–115.

Liu, Li., Chen, Xingcan., 2012 The Archaeology of China, from the late Palaeolithic to the early Bronze Age, New York: Cambridge University Press, 2012.

Liu, Ruiliang., 2016. Capturing changes: applying the Oxford system to further understand the movement of metal in Shang China. PhD Thesis, University of Oxford.

Liu, Ruiliang., Bary Peter., Pollard, A.M., Hommel,. Peter., 2015 Chemical analysis of ancient Chinese copper-based objects: Past, present and future. Archaeological Research in Asia 3 (2015) 1–8

Ma, Yingxian., 1995. A Study of Xinjiang Geograpgy. Urimchi: Xinjiang Renmin Chubanshu.

Mallory, JP and Mair, VH., 2000: The Tarim Mummies. Thames and Hudson.

Mei Jianjun, Xu Jianwei, and Chen Kunlong, et al. 2012. Recent Research on Early Bronze

Metallurgy in Northwest China. In Paul Jett (ed.), Scientific Research on Ancient Asian Metallurgy. Washington: Freer Gallery of Arts, pp. 37-46.

Mei, Jiangjun and Li Yanxiang, 2003b. Early copper technology in Xinjiang, China: The evidence so far. Paul Craddock and Janet Lang (eds.), Mining and metal production through the ages. London: British Museum Press. 111-21.

Mei, Jiangjun, 2003a. Cultural interaction between China and Central Asia during the Bronze Age. Proceedings of the British Academy, 121, 1-39

Mei, Jiangjun, 2004. Metallurgy in Bronze age Xinjiang and its cultural context. Katheryn M. Lindff (eds), Metallurgy in Eastern Eurasia from the Urals to the Yellow River. Lewiston: The Edwin Mellen press. 173-188.

Mei, Jiangjun, Liu Guori and Chang Xi'en, 2003c. A metallurgical study of early metal objects from eastern Xinjiang, China. Bulletin of the Metals Museum, Vol 36, 45-62

Mei, Jianjun, Ling, Yong, Chen Kunlong, Idriss Abduressul, Li Wenying, Hu Xingjun, 2013. "Xinjiang Xiaohe mudi chutu bufen jinshuqi de chubu fenxi" (A preliminary analysis of some metal objects unearthed from Xiaohe cemetery, Xinjiang), in Xiyu Yanjiu (Western Regions Studies), 2013.1, pp. 39-49.

Mei, Jianjun. & Shell, C. 1999. The existence of Andronovo cultural influence in Xinjiang during the 2nd millennium BC. Antiquity, 73(281), 570-578.

Mei, Jinagjun, 2000. Copper and bronze metallurgy in late prehistoric Xinjiang: Its cultural context and relationship with Neighbouring Regions. BAR International Series 865, Oxford: Archaeopress.

Mu, Jingshan., 2019. The Altai Mountain interactive zone from Bronze Age to Early Iron Age. PhD Thesis, Nanjing University, China.

Muhly, D. James., 1988. The beginnings of metallurgy in the Old World in Maddin Robert (ed.), The Beginning of the Use of Metals and Alloys, Cambridge: MIT Press, 1988, pp. 2-20.

Needham, J., 2001. Chemistry and Chemical Technology, Part XIII: Ming, Golas, P. (eds), Science and Civilisation in China, Vol 5. Cambridge University press.

Pan, Xiaolin., Ma Yinjun, Gao Wei, Qi Jiaguo, Shi Dong Qing and Lu Haiyan, 2004 Evolution of ecological environment in the arid area of Western China. Zhong Guo Sha Mo. Vol 6.

Pei, Wenzhong., 1942. Prehistoric Archaeological History of Xinjiang. Central Asia. Vol 1. Beijing

Perucchetti, L., P. Bray, A. Dolfini, and A. M. Pollard, 2015, Physical Barriers, Cultural Connections: Prehistoric Metallurgy across the Alpine Region, European Journal of Archaeology, 18(4), 599–632

Pollard AM, Bray P, Hommel P, Hsu Y, Liu R, Rawson J. 2017 Applying the Oxford System to further understand bronzes in China. Kao Gu 2017 issue 1, pp 95-106

Pollard, A. M., P. Bray, C. Gosden, A. Wilson, and H. Hamerow, 2015, Characterising copper-based metals in Britain in the first millennium AD: a preliminary quantification of metal flow and recycling, Antiquity, 89(345), 697-713

Pollard, A. Mark., 2009, What a long, strange Trip it's been: lead Isotopes and Archaeology, in From mine to microscope: advances in the study of ancient technology, 181-189, A. J. Shortland, I. Freestone, T. Rehren, and M. S. Tite, eds., Oxbow Books, Oxford

Pollard, A.M., Bray, P., Hommel, P., Hsu, Y.-K., Liu, R., and Rawson, J., 2017. Bronze age metal circulation in China. Antiquity, 91: 674–687.

Pollard, A.M., Bray, P., Hommel, P., Liu, R., Pouncett, J., Saunders, M., Howarth, P., Cuénod, A., Hsu, Y. -K., and Perucchetti, L., 2018. Beyond Provenance: New Approaches to Interpreting the Chemistry of Archaeological Copper Alloys. Leuven: Leuven University Press, 115–144.

Pollard, M., Liu, Ruiliang., Rawson, J., Tang, Xiaojia., 2018. From Alloy Composition to Alloying Practice: Chinese Bronzes: From alloy composition to practice: Chinese bronzes. Archaeometry 2018 61 (306),

Pollard, Mark., 2007. Analytical chemistry in archaeology. Cambridge University Press, Cambridge.

Pope, J.A., Gettens, R.J., Cahill, J., Barnard, N., 1967. The Freer Chinese Bronzes. Freer Gallery of Art, Smithsonian Institution, Washington, D. C

Qi, Xiaoshan., WANG, Bo., 2008 Sichou zhi lu Xinjiang gudai wenhua (The ancient culture in Xinjiang along the Silk Road), Urumqi: Xinjiang Renmin chubanshe.

Qian, Wei, Sui Shuiyun, Han Ruifeng, Chang Xien, Yahepujiang. Studies on the bronzes unearthed from a graveyard in the northern branch of the Tianshan Mountains in Hami, Xinjiang, 2001. in Wen Wu 2001, pp. 79-89.

Qian, Wei., 2006. The prehistorical copper and bronze of Hami region in Xinjiang and their contexts of neighbouring cultures. Ke Xue Chu Ban She Press, 2006

Qin , Y., Wang, C., Yang, L., Wang, J., Zhang, G., 2004. Wan nan yan jiang di qu bu fen chu tu qing tong qi de tong kuang lai yuan chu bu yan jiu (Preliminary research on the metal source of bronzes found in Wannan). Wenwu Baohu Yu Kaogu Kexue 2004 16, pp 9-12

Qin, Y., Wei, G., Luo, W., Yang, L., Zhang, G., Gong, C., Qu, Y., Wang, C., 2006. Chang jiang zhong xia you gu tong kuang ji yan lian chan wu shu chu fang xiang pan bie biao zhi chu bu yan jiu (Preliminary studies on indicators of metal flow in the middle and lower Yangzi river). Jiang Han Kao Gu 65-69.

Ravich, Irina., Ryndina, V. Natalia, “Early copper-arsenic alloys and the problems of their use in the Bronze Age of the North Caucasus”, in Bulletin of the Metals Museum, 1995, no. 23, pp. 1-18.

Rawson, J., 1990, Western Zhou ritual bronzes from the Arthur M. Sackler Collections: Ancient Chinese bronzes in the Arthur M. Sackler collections: Washington, D.C, Arthur M. Sackler Foundation

Rawson, J., 2010. Carnelian beads, animal figures and exotic vessels: traces of contact between Chinese states and Inner Asia, ca 1000-650 BC. In: Wagner, M., and Wang, W. (eds.), Bridging Eurasia. Mainz: Von Zabern, 5–12.

Ren Meier, 1999. Outline of Chinese Natural Geography (Third Edition). Shang Wu Yin Shu Guan.

Roberts, W., Thornton C, and Piggott V. 2009. Development of metallurgy in Eurasia. Antiquity 83(322):1012–1022.

Ruan, Qiurong., 2014. Research on Andronovo cultural remains founded in Xinjiang. Xi Bu Kao Gu Vol 7, pp 125-154.

Sackett, J.R., 1990 Style and ethnicity in archaeology: the case for isochrestism, in The Uses of Style in Archaeology, eds. Conkey, M.W. & Hastorf, C.A.. Cambridge: Cambridge University Press, 32–43.

Shao HQ and Zhang WS (2019) Review of the research of Andronovo cultures in Xinjiang. Xi Yu Yan Jiu 2019 vol 2 pp113–121.

Shao, Huiqiu, 2007. The development of the pre-historical cultures in Xinjiang and the interaction with neighbor cultures, Phd Thesis, Jilin University, China

Shao, Huiqiu, 2008. A discussion on bronze culture in Aletai area of Xinjiang, China. The Western Regions Studies, Vol 4, 59-65

Shao, Huiqiu., 2009 An analysis of the Related Remains of Andronovo Culture in Xinjiang. Bian jiang Kao Gu. 2009 00

Shao, Huiqiu., 2018. Xinjiang shi qian shi qi wen hua ge ju de yan jin ji qi yu zhou lin wen hua de guan xi (The evolution of cultural patterns in prehistoric Xinjiang and their relationship with neighbouring cultures). Science Press 2018

Sherratt, A., 2006. The trans-Eurasian exchange: the prehistory of Chinese relations with the West, in V. H. Mair, (eds.), Contact and exchange in the ancient world, 30–61. Honolulu, 2006.

Shui, Tao, 2001. A Comparative study of bronze cultures in Xinjiang - with a discussion of the process of early cultures exchange between the East and West. Shui Tao (eds), Symposium of Chinese Bronze Age Archaeology in Northwest China, p.6-47, Nanjing University press (in Chinese).

Shui, Tao., 1993. Comparison of Bronze Age cultures in Xinjiang and the historic progress in early cultural interaction between East and West. Guoxue yanjiu 1993 (1), 447–490

Shui, Tao., 2017. Comparative studies on Xinjiang Bronze Age cultures and the historical progress in east and west interaction. Silk Road Archaeol. 1, 45–75

So, J.F., 1995. Eastern Zhou Ritual Bronzes from the Arthur M. Sackler Collections. Arthur M. Sackler Foundation, Washington, D. C

Spengler, R., Frachetti, M., Doumani, P., Rouse, L., Cerasetti, B., Bullion, E., & Mar'yashev, A. (2014). Early agriculture and crop transmission among Bronze Age mobile pastoralists of Central Eurasia. Proceedings: Biological Sciences, 281(1783), 1-7.

Subei, Naibi., Wang, Y., Zhang, Jie, Song, G., Luo, W., 2019. Scientific Analysis on the Bronzes Unearthed at the Liushugou Cemetery in Hami. Xi Yu Yan Jiu 4, 73-82

Svyatko. Svetlana, Schultings, J. Rick, Mallory, P. James, Murphm, Y. Eileen, Rermer J. Paula, Khartanovich I. Valery, Chistov K. Yuri, Sablin, V. Mikhail, 2013. “Stable isotope dietary analysis of prehistoric populations from the Minusinsk Basin, Southern Siberia, Russia: A new chronological framework for the introduction of millet to the eastern Eurasian steppe”, in Journal of Archaeological Science, 2013, no. 40, pp. 3936-3945

Tong, Jianyi., Ma Jian, Li Wenying Li, Chdng Xi’en, Yu Jianjun, Wang Jianxin, Ma Yingxia, Tian Yiliang, Kuerban Reheman, Mulati Simayi, Liu Ruiliang, 2020. Chronology of the Tianshanbeilu ceretery in Xinjiang, Northwestern China. Radiocarbon, Vol 00, Nr 00, 2020, p 1–14

Tylecote, Ronald, 1976. A history of metallurgy, London: The Metals Society, 1976

Von Falkenhausen, Lothar., 1993 Suspended Music: Chime-Bells in the Culture of Bronze Age China, Berkeley and Los Angeles: University of California Press.

Wang Penghui, 2005. Research status of Prehistoric Archaeology in Xinjiang. Huaxia Archaeology, Vol 2, 51-61.

Wang, T., Wei, D., Chang, X., Yu, Z., Zhang, X., Wang, C., Hu, Y., and Fuller, B.T., 2017. Tianshanbeilu and the Isotopic Millet Road: reviewing the late Neolithic/Bronze Age radiation of human millet consumption from north China to Europe. National Science Review, 00: 1–16.

Wang, Yongjiang., Yuan, Xiao., Ruan, Qiurong., 2019 Xinjiang nelike xian Jirentaigoukou yi zhi 2015-2018 nian kao gu shou huo ji chu bu ren shi (The brief excavation infomation for Jiretaigoukou from 2015-2018). Xi Yu Yan Jiu 2019 vol 1, pp 133-138.

Wei, Fong., Shao, Huiqiu. 2012. Hami tian shan bei lu mu di gu dai ju ming ren kou xue yan qiu (Ancient demography study of Tianshanbeilu cemetery). Bian Jiang Kao Gu Yan Jiu, vol 11 pp 465-470.

Wei, Guofeng., 2007. Gu dai qing tong qi kuang liao lai yuan yu chan di yan jiu de xin jin zhan (New progress of provenance study on ancient metal source). PhD Thesis. University of Science and Technology China.

White, J. C. and Hamilton, E. G., 2009. The transmission of early bronze technology to Thailand: new perspectives. In Journal of World Prehistory 22:357-397

Wright, J, W Honeychurch, and C Amartuvshin., 2009. The Xiongnu settlements of Egiin Gol, Mongolia. Antiquity 83(320):372–387.

XASS (Xinjiang Academy of Social Sciences), 1972 The main gains of archaeology in

Xinjiang since the founding of new China Thirty Years of Archaeological Work. 169-183

XGA (Xinjiang Geographical Association), 1993. Xinjiang Geographical Handbook. Xinjiang Renmin Chu Ban She.

Xi, Tongyuan., 2014. A Study of Settlement Sites in the Eastern Tien Shan Region from the Bronze Age to the Early Iron Age. PhD Thesis, Northwest University, China.

Xia Xuncheng, 1991. Xinjiang desertification and sand disaster control. Ke Xue Chu Ban She. pp 1-40.

XIA, 1985 Xinjiang gudai minzu yanjiu (Cultural relics of ancient populations in Xinjiang), Urumqi: Guojia Wenwu chubanshe, 1985.

XIA, 2007. Xinjiang Luobupo Xiaohe mudi 2003 nian fajue jianbao (A brief report on the excavation of the Xiaohe Cemetery in Lop Nur in 2003), in Wenwu (Cultural Relics), 2007.vol 10, pp. 4-42

Yang Yichou, 1992. The uplift of the Tibetan Plateau, the formation and evolution of environment in Tarim basin. Yin Zesheng (eds), The northwest arid region of Holocene environmental change and the rise and fall of the human civilization.Di Zhi Chu Ban She. pp 135-142

Yang, Jianhua., Shao, Huiqiu., Pan, Ling., 2016. The Metal Road of the Eastern Eurasian Steppe. Shang Hai Gu Ji Chu Ban She Press

Yang, Zengxin., 2018. Scientific Study On The Bronzes From Tianshanbeilu Cemetery. PhD Thesis, Northwest University.

Ye, Shuxian. 2018 The Grassland Jade Trail and the spread of carnelian beads to China (2000 BC - 1000 BC) Nei Mu Gu She Hui Ke Xue 2018 vol 10

Yu, J., He, J., 2017. Significant discoveries from the excavation of Jimunai Tongtiandong site, Xinjiang. Relics News (Wenwubao) (Page 8, December 1, 2017

Yuan Liuyan , 2003. Xinjiang oasis occurrence and Development Research. Master Thesis, Northwest A&F University

Yuan, Xiao., Luo, Jiaming., Ruan, Qiurong., 2020 Xinjiang nelike xian Jirentaigoukou yi zhi 2015-2018 nian kao gu shou huo ji chu bu ren shi (The brief excavation infomation for Jiretaigoukou from 2019). Xi Yu Yan Jiu 2020 vol 1, pp 120-125.

Zen, Zhao and Wang, Xuan, 1985. Brief discussion on the historical geomorphology. Ke Xue Chu Ban She. pp155-166

Zhang Chuang, Liu Ming, 2011. Research on bronze vessel in prehistory of Northwest China. Journal of Daliang University, Vol 32, 2. 30-34

Zhang, Liangren., 2017. The Transmission of Karasuk Metallurgy to the Northern China. Shi Di 2017 vol 1, pp100-124

Zhang, Linyuan, 1981. Effects of the uplift of Tibetan Plateau during the Quaternary period of environmental evolution in China. Journal of Lanzhou University. Vol 3.

Zhang, Quanchao., Zhang, Xien., Liu, Guorui., 2010. Carbon and Nitrogen Stable Isotope Analysis of the Human Bones from the Tianshanbeilu Cemetery in Xinjiang. Xi Yu Yan Jiu, 2010 vol 2 pp38-43

Zhang, Quanchao., Zhu, Hong., 2011 Carbon and Nitrogen Stable Isotope Analysis of the Human Bones from the Gumugou Cemetery in Xin jiang:A Preliminary Exploration of the early Population Dietary in Lop Nur. Xu Yu Yan Jiu 2011 vol 3, pp 91-96,142.

Zhang, Yuzhong, (2001). New discover in recent years of Xinjiang archaeology. The Western Regions Studies, Vol 3, 109-111

Zhao, Songqiao, 1985. The natural geography of arid regions in China. Ke Xue Chu Ban She. pp5-8.

Zhu, Jiangsong., Ma, Jian., Zhang, Fan., Cui, Yinqiu., Festa, Macella., Xi, Tongyuan., Ren, Meng., Wang, Yinchen., Li, Ben., Huang, Feixiang., 2021. The Baigetuobie cemetery: New discovery and human genetic features of Andronovo community’s diffusion to the Eastern Tianshan Mountains (1800–1500 BC). The Holocene 2021, Vol. 31(2) 217–229.

Appendix A: data

There are the data results used in this thesis, were generated from pXRF. As mentioned in Chapter 3, the main elements are copper (Cu), tin (Sn), arsenic (As), lead (Pb) and antimony (Sb). The rest of the elements are not considered for alloy classification, not presented here. Blank cells in the table show no data detected for the element or without the chronology for the tomb. The data value used in this table is the average value, of every single sample taken 3-6 times from pXRF.

Tomb Number	Category	Phase	Sb	Sn	Pb	As	Cu	Alloy Types
M1	pao	2				7.4	92.4	As Copper
M1： 1	knife	2		5.6		0.1	93.8	Sn Bronze
M1： 2-1	pao	2		4.1		0.3	95.2	Sn Bronze
M1： 2-2	pao	2		3.0		1.9	94.7	As Sn Bronze
M101： 2	button	2		14.5	0.8	0.4	83.7	Sn Bronze
M101： 4	awl	2			0.2	1.2	97.1	As Copper
M101： 5	arrowhead	2		0.5			99.1	Copper
M102： 1	bead	2		5.1	0.1	0.1	93.2	Sn Bronze
M105： 3	earring	3		2.7	0.6	0.6	95.8	Sn Bronze
M109： 2	button	3	0.3	13.5	0.3		85.5	Sn Bronze
M109： 3	pao	3		16.0		0.3	82.7	Sn Bronze
M109： 4	button	3	0.2	0.1	0.4	14.3	84.5	As Copper
M109:8	plaque	3				1.9	98.1	As Copper
M110:3	plaque	3		8.6	0.1	0.1	91.1	Sn Bronze
M111： 1	bead	3				5.8	91.8	As Copper
M111： 5	earring	3		0.5	0.5	0.5	97.0	Copper
M112： 11	earring		0.3	28.7	0.1	1.7	68.9	Sn Bronze

M112： 2	pao			19.7			80.0	Sn Bronze
M112： 3	pao			16.2			83.4	Sn Bronze
M112： 5	mirror			19.8	0.8		79.2	Sn Bronze
M112： 6	pao			11.8			87.9	Sn Bronze
M112： 8	plaque			14.5	0.1	0.7	83.5	Sn Bronze
M112： 9	pao			5.1			94.6	Sn Bronze
M114： 2	tube	3		10.4		0.1	88.9	Sn Bronze
M114： 4	earring	3		36.6	0.3	4.5	58.3	As Sn Bronze
M116： 2	earring			19.6			78.7	Sn Bronze
M117:2	earring	3		6.2	0.1	0.1	92.4	Sn Bronze
M118： 2	bead	4		10.1	0.2	0.2	88.8	Sn Bronze
M120： 1	knife	3	0.5	15.2		0.7	83.3	Sn Bronze
M123： 2	bead	2	17.9		0.3	1.7	79.3	AS Sb Copper
M123： 4	pao	2		1.6		1.1	96.7	As Sn Bronze
M124:4	earring			6.5	7.8	4.1	81.5	Pb As Bronze
M125: 27	bead	3	22.3			2.9	74.8	AS Sb Copper
M125: 27-5	bead	3	16.1			2.0	81.4	AS Sb Copper
M125： 10	pao	3		0.2		1.1	98.3	As Copper
M125:11	pao	3				1.1	98.8	As Copper
M125： 12	mirror	3				3.0	95.9	As Copper
M125： 13	pao	3		4.8		0.4	94.4	Sn Bronze
M125:14	tube	3		0.5		1.8	97.4	As Copper
M125:15	tube	3	0.1	0.3		0.9	97.4	Copper
M125:16	tube	3				3.8	95.0	As Copper
M125:18	plaque	3				5.2	94.6	As Copper
M125： 19	mirror	3				1.6	97.8	As Copper
M125： 2	pao	3				2.6	97.0	As Copper

M125： 20	pao	3		0.3		1.5	95.9	As Copper
M125： 21	mirror	3		0.9		0.8	97.3	Copper
M125： 22	pao	3				1.6	97.6	As Copper
M125:23	tube	3				1.1	94.2	As Copper
M125:24	tube	3		0.2		0.3	98.3	Copper
M125:25	tube	3		0.9		1.2	97.5	As Copper
M125:26	tube	3	0.1	0.4		1.3	97.7	As Copper
M125:27-1	bead	3	47.5			4.7	47.4	AS Sb Copper
M125:27-2	bead	3	46.7			6.4	46.9	AS Sb Copper
M125:27-4	bead	3	16.3			1.5	81.8	AS Sb Copper
M125:28	bead	3	22.4			0.8	75.9	Sb Copper
M125： 29	pao	3		4.7		0.5	94.3	Sn Bronze
M125:3	button	3		1.6	0.2	0.5	97.3	Sn Bronze
M125:30	button	3		0.3		1.4	95.6	As Copper
M125： 31	mirror	3	11.1			0.9	85.0	Sb Copper
M125:35	bangle	3	0.2	0.4		20.1	78.3	As Copper
M125： 36	mirror	3	11.3			0.3	86.8	Sb Copper
M125： 37	pao	3		8.3	0.4		91.0	Sn Bronze
M125： 4	pao	3		0.3		1.4	96.2	As Copper
M125： 5	mirror	3		0.8		2.8	94.5	As Copper
M125:6	button	3		1.0		0.4	96.7	Sn Bronze
M125:7	pao	3		5.1		0.9	92.4	Sn Bronze
M125： 8	pao	3				5.5	93.3	As Copper
M125： 9	mirror	3	11.6			1.0	86.9	AS Sb Copper
M126:1	button	3		10.9			89.0	Sn Bronze
M126:3	button	3	0.2	13.5		0.4	84.7	Sn Bronze
M126:5	button	3		21.1	0.2	0.4	77.5	Sn Bronze

M126:7	button	3		19.0		1.7	79.1	As Sn Bronze	
M126:8	knife	3	1.3	10.4	0.2	0.6	87.3	Sb Sn Bronze	
M127:13	tube	3		15.5			83.3	Sn Bronze	
M127:14	button	3		10.7			88.4	Sn Bronze	
M127:2	plaque	3				4.5	95.3	As Copper	
M127： 3	bangle	3		10.9	0.3		88.2	Sn Bronze	
M127:4	arrowhead	3		1.4		0.4	98.2	Sn Bronze	
M127:5	button	3		9.5			87.4	Sn Bronze	
M127:8	earring	3		10.8	0.1		87.9	Sn Bronze	
M127:9	bead	3		8.3	0.1		86.3	Sn Bronze	
M128:2	tube	3		1.0	0.1	1.0	97.6	Sn Bronze	
M128:5	plaque	3		14.4		1.1	83.8	As Sn Bronze	
M129:3	earring	3		0.8		1.6	95.2	As Copper	
M13： 1	earring	4		17.6	0.7	1.3	79.7	As Sn Bronze	
M13： 10	button	4	0.6	22.4	0.3		75.8	Sn Bronze	
M13： 14	bead	4	12.7		0.1	3.1	83.4	AS Sb Copper	
M13： 2	earring	4		23.5	0.7	1.4	73.9	Pb Sn Bronze	
M13： 4	bangle	4		30.8	1.4	0.8	65.5	Pb Sn Bronze	
M13： 6	earring	4		1.3	0.1	0.1	98.2	Sn Bronze	
M13： 7	earring	4		20.6	0.8		76.1	Sn Bronze	
M130:3	plaque			0.3			99.5	Copper	
M130:4	plaque			1.0	0.2	0.2	97.3	Sn Bronze	
M131： 3	knife	2		15.4	2.9	2.6	79.0	Pb As Bronze	
M132:4	earring	3	0.6	18.6	0.9	1.9	76.3	As Sn Bronze	
M132:5	plaque	3		2.8			96.8	Sn Bronze	
M135:1	bead			6.1	15.4		73.7	Pb Sn Bronze	
M136： 2	knife	3				1.8	97.9	As Copper	

M136:4	earring	3		23.3		0.2	76.0	Sn Bronze
M137:2	pao	2		13.7		0.2	85.7	Sn Bronze
M137:3	pao	2		5.3			93.0	Sn Bronze
M137:4	tube	2		10.4		0.1	89.3	Sn Bronze
M137:4-1	tube	2	0.1	8.7		0.4	90.6	Sn Bronze
M137:5	bead	2	0.7			1.3	97.6	As Copper
M137:6-7	earring	2		12.7			87.0	Sn Bronze
M137:8	pao	2		10.7	1.1		87.7	Pb Sn Bronze
M139:2	button	4		26.9	0.6		69.6	Sn Bronze
M140:2、4	earring	3		3.4	0.1	1.5	92.9	As Sn Bronze
M140:6	bangle	3		9.2	0.1	0.8	89.1	Sn Bronze
M141:2	button	2		22.6	1.4		73.7	Pb Sn Bronze
M144：3	knife	3		1.9		0.9	96.5	Sn Bronze
M144:4	awl	3		0.3		4.2	92.6	As Copper
M144:9	earring	3			0.4	0.4	90.7	Copper
M145:1	pao	2		1.8	0.1	0.3	97.4	Sn Bronze
M145:10	knife	2		4.1			93.9	Sn Bronze
M145:11	awl	2		8.1		0.6	90.4	Sn Bronze
M145:12	button	2		20.9			76.7	Sn Bronze
M145:13	earring	2		9.6	0.1	0.7	88.1	Sn Bronze
M145:14	button	2		3.0		0.1	96.4	Sn Bronze
M145：3	button	2		4.2		11.1	74.7	As Sn Copper
M145:6		2		6.4		0.1	92.5	Sn Bronze
M145:7-8	button	2		29.0		0.1	70.4	Sn Bronze
M146：2	knife	3		12.8	1.0	3.4	82.8	Pb As Bronze
M146:5	tube	3		0.6			98.4	Copper
M147:4	earring			18.7	0.7		79.7	Sn Bronze
M148:2	mirror	3		20.9	0.7	3.5	73.1	As Sn Bronze

M148:2	button	3		20.7			73.8	Sn Bronze
M148:2	pa	3		10.0	0.3		88.8	Sn Bronze
M148:2	button	3		10.0			89.5	Sn Bronze
M148：2	pao	3		15.4	0.7	0.3	82.9	Sn Bronze
M148:3	awl	3		4.4			91.0	Sn Bronze
M148:4	button	3		10.0		0.1	88.7	Sn Bronze
M15	mirror	3		8.1	0.1	0.5	90.1	Sn Bronze
M15：10	button	3		1.6		0.2	92.1	Sn Bronze
M15：11	mirror	3		9.9	0.9		78.7	Sn Bronze
M15：13	mirror	3		6.8		0.8	92.2	Sn Bronze
M15:14	button	3	1.1	5.3	0.1	0.1	86.2	Sb Sn Bronze
M15：15	button	3		8.8			89.2	Sn Bronze
M15：16	button	3	2.8	8.4	0.2		87.2	Sb Sn Bronze
M15：17	button	3		5.8			93.7	Sn Bronze
M15：18	tube	3		4.3			94.4	Sn Bronze
M15:19	pao	3		0.2	0.1	0.2	97.1	Copper
M15：2	mirror	3		11.4			88.2	Sn Bronze
M15:21	pao	3		9.5	0.4	6.1	83.8	As Sn Bronze
M15：22	earring	3	0.1	6.8		0.3	92.5	Sn Bronze
M15:23	button	3	1.4	7.7	0.1		82.7	Sn Bronze
M15:24	button	3	0.1	0.5	3.1	12.9	82.3	Pb As Copper
M15：25	button	3		2.2		0.8	96.1	Sn Bronze
M15：3	button	3		13.2	3.1	0.9	82.0	Pb Sn Bronze
M15:4	button	3	0.1	9.8	12.5	11.1	65.8	Pb As Bronze
M15：5	button	3		5.7	0.2	15.8	76.0	As Sn Copper
M15：6	button	3	0.1	10.4	0.1	5.4	83.4	Sn Bronze
M15：7	button	3		4.2	0.1	2.5	92.4	As Sn Bronze

M15： 8	button	3		6.8			93.1	Sn Bronze
M15： 9	button	3			4.2	10.4	81.9	Pb As Copper
M150:3	pao	2		8.6	0.3	0.6	90.1	Sn Bronze
M150:3	pao	2		12.0	0.3		85.7	Sn Bronze
M150:4		2		5.9	0.9	1.1	91.8	Sn Bronze
M150:8	plaque	2		8.6			90.9	Sn Bronze
M151:3	bead	2		2.5	0.3		96.7	Sn Bronze
M152:2a	button			18.2			81.2	Sn Bronze
M152:2a	button			31.0	0.6		67.1	Sn Bronze
M152:2b	button			13.4		0.2	85.2	Sn Bronze
M152:2c	button			10.5			86.7	Sn Bronze
M153:1	button	3		13.6	1.1		84.3	As Sn Bronze
M153:1	button	3		3.5	1.6		92.2	Pb Sn Bronze
M153:1	button	3		21.0	0.2		77.6	Sn Bronze
M153:1	button	3		5.7			94.0	Sn Bronze
M153:1	button	3		15.2	0.2		84.0	Sn Bronze
M153:3	tube	3		5.6	0.1	0.2	93.6	Sn Bronze
M153:5	plaque	3		5.5	0.2	0.2	93.8	Sn Bronze
M153:6	tube	3		6.8	0.1		90.6	Sn Bronze
M154:2	tube	2		0.8			95.9	Copper
M154:4-1	pao	2		1.5			97.4	Sn Bronze
M154:4-2	button	2		3.5			92.5	Sn Bronze
M154:4-3	pao	2		14.5			85.2	Sn Bronze
M155:8	button	3		13.2	2.1		83.9	Pb Sn Bronze
M159:3	tube	3		2.3	0.1		82.4	Sn Bronze
M16： 2	bead	3		3.9			95.7	Sn Bronze
M16:3	plaque	3		4.9	1.3		93.4	Pb Sn Bronze
M162： 3	earring	3		1.6	0.4	3.0	93.2	As Sn Copper

M166： 1	pao	2		5.9	0.1		92.2	Sn Bronze
M166:2	pao	2	0.2	4.5	0.1		90.8	Sn Bronze
M166： 3	pao	2	0.2	9.0	0.2	0.4	87.6	Sn Bronze
M166:5	pao	2	0.5	25.5	1.0	0.9	63.8	Pb Sn Bronze
M166:7	button	2		5.1	0.9		85.7	Sn Bronze
M166:8	button	2		6.4	12.2		79.2	Pb Sn Bronze
M166:9	bead	2		38.1	0.5		53.1	Sn Bronze
M168： 2					92.7		0.9	Cu
M17： 1	earring	3		1.8	0.4	0.3	96.4	Sn Bronze
M17： 4	earring	3		16.5	0.6		82.2	Sn Bronze
M173:		3	0.1	9.1	0.1	0.2	90.4	Sn Bronze
M179:4	plaque	3				0.5	99.1	Copper
M179:5	tube	3		7.0	0.2	0.3	92.4	Sn Bronze
M18： 1	earring	4		9.6	0.2		86.7	Sn Bronze
M18： 1	earring	4		20.1	0.8		78.7	Sn Bronze
M182： 2	earring	3		1.9	1.4		94.3	Cu
M182:4	tube	3		5.9	3.3	2.7	86.1	Pb As Bronze
M182:5		3		9.56	87.5		0.059	Pb Sn
M183:4	bead	3				0.8	96.0	Copper
M183:5	plaque	3				3.9	95.6	As Copper
M183:6	tube	3		15.6		0.2	80.6	Sn Bronze
M183:7	bead	3				3.3	95.8	As Copper
M186:3	tube	2		8.3	0.3	0.7	90.2	Sn Bronze
M186:4	plaque	2		7.1	0.1	0.3	89.9	Sn Bronze
M19： 1	earring	4		9.5	2.1	1.8	86.5	Pb As Sn
M19： 4	earring	4		14.2	0.3	0.3	84.8	Sn Bronze
M190	plaque	3		6.1	0.1		93.4	Sn Bronze

M190:1	earring	3		1.1	1.4		89.4	Pb Sn Bronze
M190:11	tube	3		9.4	0.1	0.4	87.9	Sn Bronze
M190:11-1	tube	3		4.2	2.2		93.4	Pb Sn Bronze
M190:11-2	tube	3		4.9	0.1	0.8	93.2	Sn Bronze
M190:11-3	button	3		14.7	0.4		83.8	Sn Bronze
M190:12	button	3		5.7			93.1	Sn Bronze
M190:13-1	bead	3		16.6	0.1	0.2	82.1	Sn Bronze
M190:13-2	bangle	3		18.8	2.0		76.9	Pb Sn Bronze
M190:15	pao	3		4.4	0.1		93.4	Sn Bronze
M190:16	earring	3		33.9	6.0	2.9	55.7	Pb As Sn
M190:17	button	3		0.3			99.0	Copper
M190:2	button	3		10.4		0.2	88.4	Sn Bronze
M190:3	pao	3		7.7	0.2		91.3	Sn Bronze
M190:5	pao	3		7.3	1.6		84.2	Pb Sn Bronze
M190:7	pao	3	0.4	11.8	0.2	0.4	83.3	Sn Bronze
M190:8	pao	3	0.2	6.0	0.3	1.5	91.1	As Sn Bronze
M190:9	button	3		5.1	0.6	1.2	92.7	As Sn Bronze
M190:9	button	3		4.9	0.5	0.4	93.3	Sn Bronze
M191:2	plaque	2		2.1	0.2	0.2	97.0	Sn Bronze
M193:4	plaque	1		0.6			86.8	Copper
M194:2	pao	3		15.2			80.3	Sn Bronze
M195：1	earring	3		38.7	2.2	2.8	55.3	Pb As Sn
M195:10	bead	3		1.1	2.0		96.1	Pb Sn Bronze
M195:3		3		3.2	0.6		95.9	Sn Bronze
M195：4	bangle	3		8.0	0.2		88.4	Sn Bronze
M195:7	plaque	3	0.1	4.7	0.3	1.7	93.2	As Sn Bronze
M195:8	tube	3		13.0	0.1		86.5	Sn Bronze
M195:9	button	3		18.5	0.2	0.3	77.8	Sn Bronze

M196:4	bead	2	8.6	0.3		1.5	89.4	AS Sb Copper
M197:3		2		14.0	0.6		84.4	Sn Bronze
M198:2	button	4	0.1	6.0			93.1	Sn Bronze
M198:3	earring	4		5.5	0.1		92.1	Sn Bronze
M198:4	bangle	4		31.5	2.5	1.7	62.5	Pb As Sn
M198:6	bead	4		11.1		0.1	88.3	Sn Bronze
M198:7	pal	4	0.2	8.5		0.2	90.8	Sn Bronze
M199:1	earring	3			0.1	6.8	92.8	As Copper
M2： 2	earring	3		5.5	0.4		91.4	Sn Bronze
M2:6	i	3		4.3		0.4	93.2	Sn Bronze
M200： 1	mirror	2		10.7	0.1		89.1	Sn Bronze
M200:2	plaque	2	0.8	7.1	0.1	3.6	88.3	As Sn Bronze
M200:6	tube	2		8.0	0.5	0.3	90.9	Sn Bronze
M201:1	earring	3		35.8	4.6	4.8	53.9	Pb As Sn Bronze
M201:2	pao	3		5.0	0.1	0.4	94.2	Sn Bronze
M201:5	plaque	3		0.1		5.5	94.1	As Copper
M202:2	plaque	3		8.4	0.4	0.2	89.8	Sn Bronze
M202:3	tube	3		0.8	0.1		98.7	Copper
M203:	button	3		12.5		0.5	85.6	Sn Bronze
M204:1	earring			16.7	3.7	3.4	75.6	Pb As Sn
M206:2	bangle	3		14.0			85.6	Sn Bronze
M206:4	tube	3		16.3	0.1	0.2	82.2	Sn Bronze
M206:6	earring	3		3.4	0.1	0.1	96.1	Sn Bronze
M207:2	button	3	0.1	6.7			92.7	Sn Bronze
M209:2	earring	4		17.5	0.1	1.2	80.2	As Sn Bronze
M209:3	earring	4		5.6		0.7	92.5	Sn Bronze
M210:	bead	3		4.0		0.3	94.8	Sn Bronze
M210:6	earring	3		5.1			93.8	Sn Bronze

M212:2	earring	4			2.7	3.5	93.3	Pb As Copper
M213:1	earring				0.2	1.1	96.8	As Copper
M214:1	earring	3	0.4	5.5	0.1		92.9	Sn Bronze
M214:2	bangle	3		5.1	0.7	0.6	92.9	Sn Bronze
M214:3	tube	3		17.1		0.2	80.6	Sn Bronze
M215:4	pao	3		8.8		0.1	90.8	Sn Bronze
M215：5	knife	3		1.0			98.8	Sn Bronze
M215:6	earring	3		10.9		0.7	88.1	Sn Bronze
M215:7	earring	3		12.6	0.4		86.7	Sn Bronze
M220：2	knife	2	0.6	0.1		2.5	96.3	As Copper
M221:2	earring	1		1.5	0.7		96.1	Sn Bronze
M224:	bead	4		1.6			96.0	Sn Bronze
M224:1	button	4			0.9	6.8	87.2	As Copper
M224:2	awl	4			0.3	1.1	98.5	Copper
M224:2	knife	4	0.5	4.9	0.1	0.6	93.5	Sn Bronze
M224:5	tube	4	0.3	2.8	0.3	2.4	93.4	As Sn Bronze
M225:2	bangle	3		15.8			83.0	Sn Bronze
M225:3	tube	3		7.2	0.1		90.8	Sn Bronze
M225:4	earring	3		29.9	0.2	0.3	63.5	Sn Bronze
M226:1	pao	2		9.6			90.2	Sn Bronze
M226:3	bead	2		9.4			90.4	Sn Bronze
M226:5	plaque	2		4.7	0.2	0.1	94.3	Sn Bronze
M226:9	tube	2	1.2	6.5	4.3	0.9	86.9	Pb As Sn
M229：2	bangle			23.8		10.0	65.6	As Sn Bronze
M229:3	bead			13.0	0.3	0.3	86.0	Sn Bronze
M229:4	plaque			3.6		0.2	95.8	Sn Bronze
M229:5	tube					5.3	94.1	As Copper
M229:5	tube			0.1		3.3	96.6	As Copper

M230:1	earring	3	2.0	1.6	4.4	0.9	90.3	Cu
M230:2	earring	3		30.1	1.4	15.6	52.0	Pb As Sn Bronze
M232:2	button	3		9.7			90.1	Sn Bronze
M232:3	bead	3		16.4	0.3	0.5	82.8	Sn Bronze
M232:4	earring	3		26.4			72.5	Sn Bronze
M233:1	button	3		21.6			78.2	Sn Bronze
M233:2	earring	3		4.6	2.6	1.7	90.2	Pb As Sn Bronze
M233:3	button	3		6.5			92.7	Sn Bronze
M233:5	tube	3	0.3	0.1	0.2	0.8	97.2	Copper
M235:2	mirror	2		4.5			95.3	Sn Bronze
M235:3	pao	2		3.0		0.2	96.1	Sn Bronze
M235:6	button	2		9.7	0.1		89.6	Sn Bronze
M24： 3	awl	2	0.6	6.1	0.2	0.8	91.8	Sn Bronze
M241:2	button	3		1.1	1.2	9.3	88.2	Pb As Sn Bronze
M241:2	button	3		8.7		0.2	89.3	Sn Bronze
M242:	earring	4		1.7		0.2	96.5	Sn Bronze
M242:2	earring	4		5.0	0.3	0.2	93.5	Sn Bronze
M242:2	button	4		3.5			95.8	Sn Bronze
M242:8	earring	4		18.3			81.1	Sn Bronze
M243:2	earring	2	0.3	9.5	0.2	1.9	88.1	As Sn Bronze
M246： 3	bangle	3		2.7	0.3	2.4	93.1	As Sn Bronze
M246： 4	earring	3		5.1	0.1	0.4	93.0	Sn Bronze
M246:6	earring	3		5.1			93.3	Sn Bronze
M247:2	earring	3		4.8	0.2		93.6	Sn Bronze
M247:4	earring	3		9.6	1.1	2.2	86.8	Pb As Sn Bronze
M247:6	button	3		5.6			93.7	Sn Bronze
M247:6	button	3		3.6	0.3		94.4	Sn Bronze
M248:1	tube	3		3.0	0.4		95.9	Sn Bronze

M248:4	bead	3		4.6	0.7	0.4	93.3	Sn Bronze
M25：1	earring			7.0	0.1	0.2	92.0	Sn Bronze
M25：1	bangle			16.3			71.7	Sn Bronze
M252:	earring	4		11.6	0.2	0.2	87.8	Sn Bronze
M253：1	earring	3		11.1	3.6	0.6	84.3	Pb Sn Bronze
M254:1	button	2		10.5		0.1	88.8	Sn Bronze
M254:2	pao	2		5.9	0.1		93.8	Sn Bronze
M254:3	button	2				6.1	90.3	As Copper
M254:4	awl	2	0.1	8.9	0.3	15.8	74.6	As Sn Copper
M254:4	knife	2		13.6		0.3	86.0	Sn Bronze
M254:8	button	2		14.9		0.5	84.0	Sn Bronze
M257:1	earring	4			0.3	0.5	98.9	Copper
M257：2	button	4			1.5	3.8	92.6	Pb As Copper
M26：2	earring	3		2.8	0.3		88.5	Sn Bronze
M26：3	button	3		4.4		0.1	92.5	Sn Bronze
M260：1	pao	2		5.5			94.1	Sn Bronze
M261:2	earring	3		1.3	0.1		98.3	Sn Bronze
M261：4	bangle	3		2.6	0.1		97.0	Sn Bronze
M261:5	tube	3	0.2	4.4			94.8	Sn Bronze
M261:7	earring	3		4.8	0.8	1.0	93.3	As Sn Bronze
M261:8	button	3			1.8	2.3	93.1	Pb As Copper
M261:9	button	4		25.7		3.0	70.9	As Sn Bronze
M261:9	button	3		11.7	0.1	0.1	88.1	Sn Bronze
M263:2	knife	2		1.5	0.2	0.6	97.3	Sn Bronze
M263:3	earring	2		5.4		0.1	93.9	Sn Bronze
M264:1	mirror		0.3	13.8	0.1	0.8	83.0	Sn Bronze
M264:2	earring		1.1	13.8	0.2	0.9	83.8	Sb Sn Bronze

M265:2	pao	2		5.9		0.1	93.1	Sn Bronze
M266:1	earring	3	0.6	16.3	1.7	0.7	80.0	Pb Sn Bronze
M266：10	button	3		0.9	0.2	0.2	98.2	Copper
M266:11	button	3		4.8	0.3		83.3	Sn Bronze
M266:12	button	3		3.7		0.1	80.9	Sn Bronze
M266:13	button	3		9.4			90.4	Sn Bronze
M266:14	button	3		1.2			96.0	Sn Bronze
M266:15	button	3		7.2			83.8	Sn Bronze
M266:16	bangle	3		8.7	0.1	0.1	90.6	Sn Bronze
M266:17	tube	3		3.5			95.8	Sn Bronze
M266:18	button	3		5.4			88.1	Sn Bronze
M266:19	button	3		9.4			70.9	Sn Bronze
M266:2	button	3		2.9			93.5	Sn Bronze
M266：22	button	3		5.3		0.1	81.7	Sn Bronze
M266：23	button	3		6.4		0.4	92.4	Sn Bronze
M266:24	button	3		12.7			87.3	Sn Bronze
M266:25	button	3		7.9	0.2		80.6	Sn Bronze
M266：26	button	3		2.9		0.4	86.5	Sn Bronze
M266:27	button	3		11.5	0.4		87.4	Sn Bronze
M266:29	button	3		4.1	0.1		78.0	Sn Bronze
M266:29	button	3		10.2			89.2	Sn Bronze
M266:3	pao	3		2.6	0.1	0.1	96.4	Sn Bronze
M266:30	button	3		9.9			89.8	Sn Bronze
M266:31	button	3		3.9	0.1	0.1	95.4	Sn Bronze
M266:32	pao	3	0.2	5.4	0.1		93.6	Sn Bronze
M266:33	button	3		7.9	0.2		69.3	Sn Bronze
M266:34	pao	3		14.9	0.2	0.2	84.5	Sn Bronze
M266:35	pao	3	0.3	4.5	0.4	0.4	93.5	Sn Bronze

M266： 36	button	3		2.2	2.4	7.3	86.9	Pb As Sn
M266： 37	button	3		1.2	0.1	0.1	98.1	Sn Bronze
M266:38	bangle	3	0.1	4.9	0.5	0.1	93.8	Sn Bronze
M266:39	bead	3		12.5	0.1	0.4	86.7	Sn Bronze
M266:4	pao	3		3.8			96.0	Sn Bronze
M266:5	mirror	3		11.0	0.3	0.1	87.9	Sn Bronze
M266:6/2	mirror	3		10.8	0.3	0.4	73.6	Sn Bronze
M266:7	pao	3		2.1	0.1	0.2	97.5	Sn Bronze
M266:8	pao	3		7.7		0.7	90.6	Sn Bronze
M266:9	button	3	0.1	5.5	0.1	0.2	94.0	Sn Bronze
M267:10	button	3		5.1			94.3	Sn Bronze
M267:11	knife	3	0.1	8.1	0.7	1.4	89.6	As Sn
M267:12	tube	3		5.4			89.9	Sn Bronze
M267:13、14	button	3		12.4			87.0	Sn Bronze
M267:19	button	3		2.2			96.1	Sn Bronze
M267:2	earring	3		1.6	0.1	0.1	97.7	Sn Bronze
M267:21	button	3		7.3			91.9	Sn Bronze
M267:22	earring	3		7.0	0.8	1.4	90.3	As Bronze
M267:24	button	3		11.3			86.2	Sn Bronze
M267:25	button	3		4.8		0.2	94.8	Sn Bronze
M267:26	pao	3		7.6			76.0	Sn Bronze
M267:28	button	3		3.1			92.5	Sn Bronze
M267:29	tube	3		5.0	0.5		94.0	Sn Bronze
M267:4	button	3		4.8	0.1	0.2	93.8	Sn Bronze
M267:5	button	3	0.2	5.2			94.4	Sn Bronze
M267:8	button	3		9.3	0.1	0.2	67.1	Sn Bronze
M268:2	earring	2		3.8	2.6		92.5	Pb Sn Bronze
M269： 1	pao	2		4.6			95.2	Sn Bronze

M27：1	button			8.0	0.3		88.7	Sn Bronze
M27：2	tube			0.2	0.2	0.5	99.1	Copper
M270:	button		1.5		0.3	1.4	96.5	AS Sb Copper
M270:	knife				0.2	0.8	98.4	Copper
M274：2	earring	3		11.2	0.1		88.4	Sn Bronze
M275：2	earring	3		13.6	0.9	1.7	82.6	As Sn Bronze
M275：3-1	mirror	3				1.3	98.5	As Copper
M275：3-2	button	3	0.2	8.8	1.3		89.4	Pb Sn Bronze
M275：5	button	3		10.8			88.9	Sn Bronze
M275：6	awl	3		5.2	1.0		92.9	Pb Sn Bronze
M276:3	earring	3		11.3	2.5		86.0	Pb Sn Bronze
M277:3	earring	3		29.0	0.6	1.7	67.5	As Sn Bronze
M277:4	bangle	3		11.8	0.2	0.3	87.5	Sn Bronze
M279：2	knife	3	0.4	9.8	0.2		88.5	Sn Bronze
M280:2	earring	3	1.2			0.4	96.9	Sb Copper
M280:3	arrowhead	3			0.1	3.6	95.7	As Copper
M280:4	awl	3	0.1	3.7		1.1	94.2	As Sn Bronze
M280:5	knife	3	0.1	0.4		1.6	96.5	As Copper
M280:6	knife	3		3.5		0.6	95.1	Sn Bronze
M280:7	plaque	3	9.7	2.8	0.1	1.6	85.7	As Sb Sb Bronze
M281:2	tube	3		4.5		0.1	94.1	Sn Bronze
M281：3	button	3		7.1	0.4	1.2	90.7	As Sn Bronze
M281：5	mirror	3				2.6	96.4	As Copper
M281:7	pao	3		7.3	0.4		90.1	Sn Bronze
M281：8(a)	knife	3				1.6	94.3	As Copper
M281：8(b)	awl	3		5.2	4.4	11.5	75.7	Pb As Sn Bronze
M283:3	bead	3			2.5		93.7	Pb Cu

M284:3	knife	2	1.0	29.6	0.3	5.3	63.3	Pb As Sn Bronze
M286:4	plaque	2		4.0	0.1		95.3	Sn Bronze
M286:6	tube	2		1.1		0.1	98.4	Sn Bronze
M287:2	button	3		2.2	0.1	0.1	97.2	Sn Bronze
M287:3	earring	3		4.1	0.1	0.3	95.0	Sn Bronze
M287:4	knife	3	0.1	0.3		0.8	98.7	Copper
M287： 5	button	3	0.9	31.1	1.0	0.7	65.7	Pb Sn Bronze
M287:6	earring	3		4.8		2.7	88.8	As Sn Bronze
M289:2	plaque	2		1.0		1.8	96.9	As Sn Copper
M289:3	tube	2				4.0	95.3	As Copper
M289:4	bangle	2		5.5	0.3		93.5	Sn Bronze
M289:5	bangle	2		9.4		0.1	90.2	Sn Bronze
M289： 7	earring	2		1.8	0.9		95.3	Sn Bronze
M29： 2	button			2.6			92.9	Sn Bronze
M29： 4	mirror			8.2			88.2	Sn Bronze
M292:2	button	4		0.2	0.1	0.4	96.4	Copper
M292:3	pao	4		9.4	0.2		88.6	Sn Bronze
M292:4	knife	4			0.9	0.6	93.1	Copper
M295： 2	knife	3	0.3		0.2	10.4	88.7	As Copper
M296:3	earring	3		4.9	0.2	0.2	93.3	Sn Bronze
M296:5	bangle	3		10.6			84.7	Sn Bronze
M296:6	bead	3		12.1	0.3		87.3	Sn Bronze
M296:7	earring	3		29.1	1.4	0.9	66.4	Pb Sn Bronze
M298:2	bangle	4		5.2	4.9		88.1	Pb Sn Bronze
M298： 4	earring	4		4.9	0.2		93.9	Sn Bronze
M298： 6	bangle	4		7.4	0.7		91.1	Sn Bronze
M300:2	tube		0.2	5.2	0.3	0.7	88.4	Sn Bronze

M301	plaque	3		10.1			86.1	Sn Bronze
M301:10	bangle	3		7.9	0.2		85.9	Sn Bronze
M301： 11	bangle	3	0.3	35.1	2.4	2.9	57.8	Pb As Sn Bronze
M301： 12-1	mirror	3		5.1			93.7	Sn Bronze
M301:12-2	pao	3		5.5		0.2	93.4	Sn Bronze
M301:13	bead	3		27.1			72.9	Sn Bronze
M301:14	tube	3				9.3	90.3	As Copper
M301:15	plaque	3		4.1	0.1		95.4	Sn Bronze
M301:16	button	3		11.5		0.1	88.2	Sn Bronze
M301:17	bead	3	47.1			3.9	48.9	AS Sb Copper
M301:4	tube	3		0.2		1.6	97.8	As Copper
M301:4	tube	3		11.6		1.5	86.6	As Sn Bronze
M301:4	tube	3		10.4	0.4		88.6	Sn Bronze
M301:5	tube	3		12.1		0.1	87.5	Sn Bronze
M301:7	button	3		10.0			89.0	Sn Bronze
M301:8	button	3		15.4		0.1	84.3	Sn Bronze
M301:9	pao	3		11.9	0.3	2.5	84.6	As Sn Bronze
M302： 2	knife	3	0.2		0.6	1.8	95.1	As Copper
M303:1	plaque	3		1.0		1.7	97.0	As Sn Copper
M303:2	tube	3	0.7	10.0	0.1	0.6	88.4	Sn Bronze
M305:2	knife	3	0.1	0.4		0.8	96.9	Copper
M305:3	awl	3			0.3	2.3	93.8	As Copper
M305:3	plaque	3		5.5			93.9	Sn Bronze
M305:5	plaque	3	0.5		0.2	1.6	96.1	As Copper
M307:10	earring			9.9	1.7		85.8	Pb Sn Bronze
M307:11	button		3.8		0.7	9.2	84.3	As Sb Copper
M307:12	button			10.3			89.2	Sn Bronze
M307:14	tube				0.7	2.8	93.8	As Copper

M307:15	arrowhead			4.5	0.6	0.3	91.4	Sn Bronze
M307:16	tube		1.5	3.8		0.5	93.3	Sb Sn Bronze
M307:2	button		3.6		2.3	8.9	82.4	Pb As Sb
M307：5	mirror			11.6	0.2	0.3	85.6	Sn Bronze
M307:6	tube			8.2	0.1	0.3	91.0	Sn Bronze
M307:7	earring				0.4	0.3	97.5	Copper
M310:2	button		0.1	7.6		0.3	91.8	Sn Bronze
M311:10	button	3		7.9			91.4	Sn Bronze
M311:13	pao	3		5.2	0.4		94.0	Sn Bronze
M311：14	pao	3		6.3	4.9		88.7	Pb Sn Bronze
M311：15	pao	3		4.4	0.1	0.5	94.8	Sn Bronze
M311:16	button	3		4.3			95.5	Sn Bronze
M311:17	pao	3		13.1			86.5	Sn Bronze
M311：18	bangle	3		4.1	0.1	0.1	94.7	Sn Bronze
M311:19-1-1	bead	3		4.1		2.5	93.2	As Sn Bronze
M311:2	bead	3		9.3	0.2	0.1	90.3	Sn Bronze
M311：20	bangle	3		7.0			92.8	Sn Bronze
M311：21	earring	3		1.6			96.9	Sn Bronze
M311：22	pao	3	0.1	0.9		0.4	97.8	Copper
M311:23	button	3		2.0			97.5	Sn Bronze
M311：24	mirror	3		9.2			90.7	Sn Bronze
M311：25-1-1	mirror	3		5.0	3.7		90.9	Pb Sn Bronze
M311：25-2	mirror	3		4.8	0.2	0.2	93.8	Sn Bronze
M311:26	pao	3		14.5			84.3	Sn Bronze
M311：27	button	3		6.1	1.7		91.9	Pb Sn Bronze
M311:28	button	3		11.1		0.5	88.0	Sn Bronze
M311:29	earring	3		10.1			89.5	Sn Bronze

M311： 3	earring	3		4.1			93.7	Sn Bronze
M311:30	button	3		8.3	1.9		80.9	Pb Sn Bronze
M311:32	button	3		3.4	0.1	0.2	93.7	Sn Bronze
M311:33	earring	3		33.3	0.8	1.2	63.4	As Sn Bronze
M311:6	pao	3		2.1		0.3	96.0	Sn Bronze
M311:8	plaque	3		11.1	0.3		88.2	Sn Bronze
M311:9	tube	3	1.0	9.8		0.1	88.6	Sb Sn Bronze
M312:13	button	3		14.0			84.9	Sn Bronze
M312:2	button	3		9.7			89.7	Sn Bronze
M312:3	button	3		19.6			79.6	Sn Bronze
M312:5	knife	3		10.1			89.5	Sn Bronze
M312:6	awl	3		11.4	0.1		87.6	Sn Bronze
M312:7	button	3		5.4			91.8	Sn Bronze
M312:8	earring	3	0.2	5.8	2.2		91.6	Pb Sn Bronze
M312:9	plaque	3	0.1	8.8	1.7	2.9	86.2	Pb As Sn
M313： 1	bead	2		12.7			85.2	Sn Bronze
M315： 10	pao	2		8.0	0.5	0.1	91.4	Sn Bronze
M315： 11-1	mirror	2		24.7	0.3	0.8	70.1	Sn Bronze
M315： 11-2	mirror	2		9.5			90.3	Sn Bronze
M315:12	pao	2		10.2	0.1	1.0	87.9	Sn Bronze
M315:13	mirror	2		20.9	0.1	0.8	77.3	Sn Bronze
M315:16	button	2	0.1	6.0		0.1	93.5	Sn Bronze
M315:2	button	2		8.9		4.8	85.9	As Sn Bronze
M315： 3	arrowhead	2	0.7	6.3	0.1		90.5	Sn Bronze
M315:4	knife	2		3.6			96.0	Sn Bronze
M315:5	awl	2		3.4		0.3	95.5	Sn Bronze
M315:6	button	2		8.4			91.1	Sn Bronze

M315:8	pao	2		5.4	0.1		93.8	Sn Bronze
M315:9	button	2		9.0			90.8	Sn Bronze
M316:10	button	3		11.7			86.4	Sn Bronze
M316:11	button	3	0.2	17.8	1.0	0.3	80.0	Pb Sn Bronze
M316:12	button	3		6.5	0.4	3.2	88.5	As Sn Bronze
M316:13	button	3	1.7	11.0	1.2	3.9	81.1	Pb As Sn Bronze
M316:14	button	3		13.4	0.1		73.2	Sn Bronze
M316:15	earring	3		1.5	0.2		97.2	Sn Bronze
M316:16	button	3		10.1	0.2		88.8	Sn Bronze
M316:20	plaque	3		5.3		0.3	94.1	Sn Bronze
M316:4	tube	3		4.5	0.6		94.3	Sn Bronze
M316： 5	bangle	3		12.6	0.2	0.5	86.5	Sn Bronze
M316： 6	bangle	3		11.1	0.9	0.4	86.7	Sn Bronze
M316:7	button	3			1.6	13.6	84.2	Pb As Copper
M316:8	button	3	0.2	16.1	1.2		81.8	Pb Sn Bronze
M316:9	button	3		16.2	0.2		81.7	Sn Bronze
M317:10	earring	4		21.3	0.9	0.4	76.9	Sn Bronze
M317:12	bead	4		1.9			94.6	Sn Bronze
M317:15	button	4		19.1		0.1	80.1	Sn Bronze
M317:16	button	4		11.7			87.3	Sn Bronze
M317:17	button	4		15.4			84.2	Sn Bronze
M317:19	button	4		9.8	0.3		89.7	Sn Bronze
M317:2	bead	4		5.6	0.1		93.5	Sn Bronze
M317:5	earring	4		5.2	1.2		92.6	Pb Sn Bronze
M317:9	earring	4		5.3	0.1		92.9	Sn Bronze
M319： 1	knife	4		0.9	0.3		97.9	Copper
M32： 4	earring	2		16.2	4.2		74.4	Pb Sn Bronze
M32:6	bangle	2	0.4	10.9	0.1	1.6	78.7	As Sn Bronze

M32:6	bangle	2	0.3	9.6	0.1	1.2	60.8	As Sn Bronze
M320:1	arrowhead	2	0.3	12.2	1.3		86.0	Pb Sn Bronze
M320:3	button	2		18.4	0.3		76.3	Sn Bronze
M321:10	plaque	2	0.7	6.6	1.0	1.5	90.1	Pb As Sn Bronze
M321：2	pao	2		6.0	0.1	0.1	93.7	Sn Bronze
M321:3	pao	2		18.4			81.2	Sn Bronze
M321：4	pao	2		8.5	0.2		91.2	Sn Bronze
M321:5	pao	2		12.6			87.2	Sn Bronze
M321:7	pao	2		21.8	0.4	0.3	77.1	Sn Bronze
M321:9	bead	2		13.9	0.5		85.4	Sn Bronze
M322:3	button	2		1.6			98.2	Sn Bronze
M323:2	plaque	2		13.2	0.3	3.7	80.4	As Sn Bronze
M325:5		1		0.9			98.3	Copper
M325：9	knife	1		3.2		0.8	92.2	Sn Bronze
M327：2	awl	2		8.7	0.2	1.2	88.4	As Sn Bronze
M327：3	knife	2		21.7	16.0	2.6	53.9	Pb As Sn Bronze
M327:6	button	2	0.5	0.2	0.8	13.9	84.5	As Copper
M329：1	knife		0.8	0.0	0.8	0.0	97.3	Copper
M329：3	button		1.1	0.0	0.0	0.8	97.4	Sb Copper
M329：4	earring		0.0	4.4	0.3	0.4	93.2	Sn Bronze
M33：3	button	3		2.1			89.9	Sn Bronze
M33：4	tube	3		7.5			68.8	Sn Bronze
M330：2	earring	3	0.0	10.3	0.5	2.9	85.4	As Sn Bronze
M333：3	earring	3	0.0	0.0	0.4	0.6	91.3	Copper
M333：3	earring	3	0.0	1.3	0.0	0.1	96.2	Sn Bronze
M334：2	pao	3	0.0	11.5	0.5	0.0	87.0	Sn Bronze
M337：4	earring	3	0.0	9.6	0.1	0.4	89.3	Sn Bronze

M34：1	bangle	3	0.1	1.0	0.7	2.1	95.6	As Sn Copper
M34：10	mirror	3		3.4			93.5	Sn Bronze
M34：3	pao	3		5.3	0.3		93.1	Sn Bronze
M34：5	pao	3		1.3			92.4	Sn Bronze
M34：6	earring	3		0.6	0.4	0.7	98.3	Copper
M34：7	pao	3	0.3	1.6	0.2	1.1	95.9	As Sn Bronze
M34：8	pao	3	0.1	0.5	0.3	0.7	97.8	Copper
M34：9	bead	3		5.4	0.9		93.1	Sn Bronze
M340：2	button	3	6.1	0.0	1.5	11.2	76.6	Pb As Sb Copper
M340：5	knife	3	0.0	0.0	0.1	0.4	93.5	Copper
M341	socketed c	3	0.2	11.2	0.2	1.2	87.1	As Sn Bronze
M341：1	pao	3		18.0	0.1	0.3	80.3	Sn Bronze
M341：10	pao	3				0.3	98.2	Copper
M341：11	button	3	2.0	19.4	3.6		74.5	Pb As Sn Bronze
M341：12	pao	3	0.2	11.0	0.5	0.5	87.5	Sn Bronze
M341：13	soketed ch	3		10.1	0.4	0.7	88.0	Sn Bronze
M341：16	pao	3		10.6		0.2	88.6	Sn Bronze
M341：17	pao	3		10.6	0.4	0.2	85.8	Sn Bronze
M341：18	pao	3		12.1	0.4	0.4	84.9	Sn Bronze
M341：19	button	3		21.3	0.1	3.0	74.0	As Sn Bronze
M341：2	button	3		10.9	0.4	1.0	87.5	As Sn Bronze
M341：20	pao	3		10.7		2.6	85.5	As Sn Bronze
M341：21	pao	3		10.1			88.2	Sn Bronze
M341:22	knife	3	0.1	4.3	0.3	0.4	93.7	Sn Bronze
M341:24	awl	3	0.3	12.5	1.7	0.7	83.5	Pb Sn Bronze
M341：25	button	3		18.2	2.0		79.3	Pb Sn Bronze

M341： 25	mirror	3	0.2	11.0	0.6		87.9	Sn Bronze
M341： 27	pao	3		9.1	0.1	0.2	88.2	Sn Bronze
M341： 28	earring	3		26.3	1.3	1.6	68.0	Pb As Sn Bronze
M341： 29	button	3		7.8	1.1		85.0	Pb Sn Bronze
M341： 3	button	3		12.3	0.2	2.9	84.4	Sn Bronze
M341： 4	earring	3		7.6	0.8		90.2	Sn Bronze
M341： 6	button	3		25.9	0.2	1.9	70.9	As Sn Bronze
M341： 7	button	3		3.6	0.4	4.1	78.1	As Sn Copper
M341： 8	mirror	3	0.2	9.9			89.6	Sn Bronze
M341： 9	pao	3		8.8	0.4		90.3	Sn Bronze
M342： 4	knife	2		18.4	6.9		73.5	Pb Sn Bronze
M345： 1	earring		0.0	12.5	0.2	0.3	86.2	Sn Bronze
M349： 11	pao	3		5.3	0.3	0.3	93.4	Sn Bronze
M349： 7	tube	3	0.0	0.8	0.0	0.0	98.9	Copper
M350： 3	earring	3	0.0	28.5	0.4	1.8	66.4	Pb Sn Bronze
M354： 2	pao	3	0.2	0.1	0.4	0.3	98.5	Copper
M354： 3	pao	3	0.0	0.1	0.4	2.9	91.5	As Copper
M358： 3	earring	3	0.0	28.1	0.4	3.7	67.2	As Sn Bronze
M358： 4	earring	3	0.0	2.6	0.0	1.3	94.2	As Sn Bronze
M359： 1	button	4		4.2	1.1		94.3	Pb Sn Bronze
M359： 4	earring	4	0.0	24.9	3.7	1.6	68.4	Pb As Sn Bronze
M36： 2	mirror	1		6.5			93.1	Sn Bronze
M36： 4	tube	1		8.0	0.2		82.1	Sn Bronze
M361： 10	earring	4	0.2	0.1	2.8	11.6	85.1	Pb As Copper
M361： 4	bangle	4	0.2	0.3	0.2	2.9	95.0	As Copper
M361:7	bell	4		4.7	0.3	0.5	94.2	Sn Bronze

M361： 8	earring	4	0.0	0.0	0.1	0.5	99.0	Copper
M362： 2	button	2	0.0	0.0	0.0	10.8	85.9	As Copper
M362： 3	earring	2	0.2	0.5	0.0	0.3	97.7	Copper
M362： 3	earring	2	0.0	2.8	0.0	0.2	95.6	Sn Bronze
M362： 4	mirror	2	0.0	0.0	0.1	10.7	87.6	As Copper
M362： 5	mirror	2	0.0	6.4	0.0	0.0	93.3	Sn Bronze
M362： 7	mirror	2	29.7	0.0	0.0	5.5	64.3	AS Sb Copper
M363： 3	earring	4	0.0	0.0	0.3	1.5	93.8	As Copper
M363： 4	shell	4	0.5	5.3		0.4	90.4	Sn Bronze
M365： 3	bangle	4	0.0	6.7	1.4	0.0	85.5	Pb Sn Bronze
M365： 6	earring	4	0.2	0.8	1.7	0.0	96.1	Pb Cu
M365： 7	earring	4	0.4	1.7	1.4	0.0	95.0	Pb Sn Bronze
M366: 4	button	3	0.0	3.2	0.0	0.4	39.7	Sn Bronze
M366： 4	button	3	0.6	0.0	0.1	1.1	97.8	Copper
M366： 7	button	3	1.8	0.0	1.1	1.5	95.1	Pb As Sb Copper
M366： 8	earring	3	0.0	11.9	0.3	9.5	77.8	As Sn Bronze
M367： 3-4	bead	3	0.0	29.0	0.0	0.0	71.0	Sn Bronze
M368： 2	bead		0.0	8.1	0.0	0.1	91.5	Sn Bronze
M369： 3	earring	3	0.0	11.5	0.2	0.5	86.0	Sn Bronze
M369： 3	earring	3	0.0	5.0	0.0	0.0	94.1	Sn Bronze
M37： 2-1	tube	2		6.0	0.1	0.3	93.2	Sn Bronze
M37： 2-2	tube	2		6.8	0.1	0.7	92.0	Sn Bronze
M37： 2-4	bead	2		12.6	0.4	0.6	85.8	Sn Bronze
M371： 2	bangle		0.2	0.0	1.4	1.4	96.9	Pb As Cu
M371： 3	bead		0.0	16.1	2.4	0.0	79.9	Pb Sn Bronze
M371： 4	earring		0.0	0.1	0.8	2.3	96.2	As Copper

M371： 6	tube		0.0	0.0	0.1	0.6	98.0	Copper
M374： 2	tube	3	0.0	5.8	0.0	0.0	93.5	Sn Bronze
M374:4	plaque	3	0.4	9.9	1.9	0.5	87.0	Pb Sn Bronze
M374： 5	tube	3	0.0	5.3	0.0	0.6	93.0	Sn Bronze
M375： 7	pao	1	0.0	12.4	0.0	0.0	65.0	Sn Bronze
M375： 9	knife	1	0.0	5.3	0.0	0.0	92.8	Sn Bronze
M376: 1	mirror	2	0.0	11.1	0.0	0.0	88.1	Sn Bronze
M376: 9	pao	2	0.0	10.5	0.1	0.0	88.6	Sn Bronze
M376： 2	bead	2	0.0	11.6	0.1	0.0	86.5	Sn Bronze
M376： 3	pao	2		10.6		0.1	88.8	Sn Bronze
M376： 4	bead	2	0.0	5.8	0.0	0.0	93.7	Sn Bronze
M376： 6	tube	2	0.0	10.8	0.0	0.3	85.2	Sn Bronze
M376： 7	pao	2	0.0	4.3	0.0	1.3	93.3	As Sn Bronze
M376： 8	pao	2	0.0	11.9	0.0	0.0	87.7	Sn Bronze
M377： 1	earring	3		2.2	0.2	1.4	95.7	As Sn Bronze
M378： 10	button	3		0.9	0.7		93.7	Copper
M378： 11	bangle	3			0.5	0.8	98.2	Copper
M378： 12	tube	3	3.4		0.3	9.3	83.9	As Sb Copper
M378： 3	baed	3		0.1	0.1	4.8	94.2	As Copper
M378： 4	button	3			0.5	3.6	95.1	As Copper
M378： 5	button	3			0.8	0.6	98.2	Copper
M378： 7	pao	3		8.2	0.1		90.9	Sn Bronze
M378： 8	bangle	3	2.4		0.1	4.1	92.8	As Copper
M378： 9	earring	3			0.6	6.8	90.6	As Copper
M379:1	plaque	3			4.3		95.5	Pb Cu
M379： 5	earring	3		5.5	0.2		92.6	Sn Bronze

M379：6	earring	3		5.5	0.3		93.0	Sn Bronze
M380：5	earring	4		3.9	0.1	0.2	93.7	Sn Bronze
M380：7	earring	4		19.7	1.1	2.0	76.2	Pb As Sn Bronze
M382：2	earring	3	2.6			5.7	83.0	As Sb Copper
M383：2	bangle	3		9.9	0.4	1.5	87.7	As Sn Bronze
M383：3	earring	3		0.8	1.1	0.6	96.3	Pb Cu
M383：6	earring	3		17.1	0.6	1.6	80.4	As Sn Bronze
M384：11	awl	4	0.1	9.8	0.2	0.6	88.8	Sn Bronze
M384：3		4		11.0	0.8	2.0	85.8	As Sn Bronze
M384：3	tube	4		8.8	0.3		90.6	Sn Bronze
M384：4	knife	4	0.1	9.5	0.1	2.3	87.9	As Sn Bronze
M384：8	awl	4		19.6	0.4		79.5	Sn Bronze
M384：9	tube	4		7.9	0.1		91.8	Sn Bronze
M385：1	button	3		0.4	14.5		84.2	Pb Cu
M385：10	button	3		0.3	0.1	0.3	97.6	Copper
M385：11	button	3			0.1	0.4	98.7	Copper
M385：12	button	3		27.7			65.3	Sn Bronze
M385：15	pao	3		0.6	0.6		94.8	Copper
M385：17	button	3			0.8	15.7	79.3	As Copper
M385：18	button	3		23.0			75.8	Sn Bronze
M385：2	tube	3		13.1			82.8	Sn Bronze
M385：4	knife	3			1.5	1.5	95.6	Pb As Cu
M385：6	awl	3			0.8	0.9	97.2	Copper
M385：8	button	3	0.2	7.5	0.1		91.2	Sn Bronze
M386：1	button		1.7		0.4	0.4	96.4	Sb Copper
M387：1	bangle			0.6	0.1	1.1	98.1	As Copper

M387： 4	earring				0.6	0.4	97.8	Copper
M388： 4	earring	3		13.6	6.6	1.4	77.0	Pb As Sn Bronze
M39： 2	button	3		3.6			87.7	Sn Bronze
M394： 3	earring	3		7.5			89.4	Sn Bronze
M397： 2	mirror	3		5.2			93.9	Sn Bronze
M397： 5	pao	3	0.1	1.0	0.1	1.1	97.2	As Sn Copper
M397： 6	bead	3		4.0	0.1	0.7	92.6	Sn Bronze
M397： 7	earring	3		1.3	0.6	1.7	95.8	As Sn Copper
M397： 8	pao	3			0.2	0.3	95.6	Copper
M397： 9	mirror	3		4.8			94.0	Sn Bronze
M399： 2	bangle	3	1.2			0.8	97.7	Sb Copper
M399： 5	earring	3		0.7	0.5	0.9	98.0	Copper
M399： 6	pao	3		1.0	0.1	0.2	98.4	Sn Bronze
M399： 7	pao	3		0.8		0.2	95.3	Copper
M40： 2	earring	3		12.6	0.4	0.5	78.6	Sn Bronze
M40： 3	pao	3		1.5			97.3	Sn Bronze
M400： 10	mirror	2		12.3			87.1	Sn Bronze
M400： 11	pao	2	0.5	12.5	0.1	1.1	85.5	As Sn Bronze
M400： 12	pao	2		19.0			80.8	Sn Bronze
M400： 13	mirror	2				4.2	95.3	As Copper
M400： 14	pao	2		9.5		1.9	88.1	As Sn Bronze
M400： 15	pao	2		2.1		0.1	97.3	Sn Bronze
M400： 16	tube	2		11.8	0.1	0.1	87.8	Sn Bronze
M400： 17	tube	2	0.3	16.5	0.2	0.5	82.4	Sn Bronze
M400:18	pao	2		7.0		0.4	91.9	Sn Bronze
M400： 2	mirror	2		5.6		0.1	93.1	Sn Bronze

M400： 20	tube	2		9.3	0.5	0.6	89.6	Sn Bronze
M400： 21	tube	2		9.1		0.1	90.3	Sn Bronze
M400： 22	bead	2	0.1	19.3	0.1	0.2	79.9	Sn Bronze
M400： 23	tube	2		17.7	0.2	0.4	74.7	Sn Bronze
M400： 24	tube	2	0.1	8.3	0.4	0.3	90.7	Sn Bronze
M400： 25	tube	2	0.2	8.4	0.2	0.3	90.7	Sn Bronze
M400： 26	pao	2		11.0	0.1	0.4	88.4	Sn Bronze
M400： 27	pao	2		10.4			88.6	Sn Bronze
M400： 28	bangle	2		45.4	1.1	2.3	50.0	Pb As Sn Bronze
M400： 29	pao	2		19.7			79.9	Sn Bronze
M400： 3	pao	2		8.6		0.2	90.6	Sn Bronze
M400： 30	pao	2		50.9	0.3	2.6	44.7	Sn Bronze
M400： 31	bead	2	0.2	21.3	0.4	1.4	76.2	As Sn Bronze
M400： 32	pao	2		17.4	7.3	1.2	73.2	Pb As Sn Bronze
M400： 34	earring	2		8.7	0.1	0.1	90.7	Sn Bronze
M400： 36	pao	2		5.9		0.1	93.9	Sn Bronze
M400： 37	pao	2		8.4		0.1	91.3	Sn Bronze
M400:38	mirror	2	0.0	0.0	0.0	1.9	98.0	As Copper
M400： 39	button	2		18.0		0.4	80.5	Sn Bronze
M400： 4	button	2		17.8	0.3		79.9	Sn Bronze
M400： 42	earring	2		9.7	0.4	0.4	87.0	Sn Bronze
M400： 43	pao	2		3.3	0.2	0.1	95.9	Sn Bronze
M400:5	mirror	2	0.0	0.5	0.0	1.9	97.0	As Copper
M400:8	plaque	2		8.7	0.6		90.5	Sn Bronze
M400： 9	button	2		2.9	1.6		93.7	Pb Sn Bronze
M403： 2	bead			6.5			93.1	Sn Bronze

M406：1	earring	3		1.4	0.2		97.8	Sn Bronze
M406：2	bangle	3		2.1		0.2	97.1	Sn Bronze
M406：3	bangle	3		32.8	0.8	1.1	65.3	Sn Bronze
M406：4	tube	3	0.2	9.5	0.6	1.0	88.3	As Sn Bronze
M409	earring	3		3.8	0.6		92.4	Sn Bronze
M41：3	awl	2		2.9	1.7	0.4	93.6	Pb Sn Bronze
M410：4	bead			39.2	0.2		59.4	Sn Bronze
M410：5	earring			7.3	0.3		89.6	Sn Bronze
M411:3	pao	1		13.7			80.8	Sn Bronze
M411：33	pao	1		25.5		0.2	73.4	Sn Bronze
M412:1	pao	2		17.4		0.3	82.3	Sn Bronze
M412:2	button	2		14.0			85.4	Sn Bronze
M412:3	button	2	12.1	3.0	0.5		82.5	AS Sb Copper
M414:2	earring	3		5.6	0.5		93.1	Sn Bronze
M414:3	earring	3		12.1	0.3		85.7	Sn Bronze
M415:10	button	2		12.2		2.2	84.3	As Sn Bronze
M415:11	button	2		4.0		0.4	93.1	Sn Bronze
M415:12	pao	2		7.2		0.3	90.4	Sn Bronze
M415:13	tube	2		9.5	0.5		89.4	Sn Bronze
M415:16	pao	2		4.9		1.6	92.8	As Sn Bronze
M415:2	tube	2		5.4			92.7	Sn Bronze
M415:3	tube	2		2.6	0.1	0.1	96.6	Sn Bronze
M415:4	tube	2		0.6			96.4	Copper
M415:5	bead	2		10.0			89.9	Sn Bronze
M415:6	button	2		5.7		1.0	92.5	Sn Bronze
M415:7	button	2		4.1		0.9	93.5	Sn Bronze
M415:8	pao	2		10.2		1.1	87.8	Sn Bronze

M415：9	pao	2		7.9			91.1	Sn Bronze
M416:2	pao	2		9.5	0.1		88.8	Sn Bronze
M416:4	pao	2		10.2	0.2		88.4	Sn Bronze
M416:5	button	2		5.6	0.3	0.1	93.1	Sn Bronze
M416:6	button	2	0.3	19.4	0.8	1.0	78.4	Sn Bronze
M42：1	knife	3		4.1	0.3	1.2	91.9	As Sn Bronze
M42:6	awl	3		0.4	0.1	0.5	98.0	Copper
M42:7	button	3		18.5	0.1	0.7	79.9	Sn Bronze
M42:8	earring	3		26.9	1.0	2.0	69.9	Pb As Sn Bronze
M423:1	earring	2		6.8			92.3	Sn Bronze
M423:2	pao	2				0.1	97.4	Copper
M423:4	bead	2		9.7	1.8		88.2	Pb Sn Bronze
M425:1	earring			10.8	0.1		87.8	Sn Bronze
M425:2	button			21.2			76.8	Sn Bronze
M426:1	earring	3	0.4	10.7	0.9	3.1	84.4	As Sn Bronze
M43	mirror	2	0.0	9.7	0.2	0.0	89.9	Sn Bronze
M43：1	tube	2		4.3	0.1	0.1	95.0	Sn Bronze
M43：2	tube	2			0.2		98.5	Copper
M43：3、4	button	2		15.1			82.3	Sn Bronze
M430:3	earring	3		23.9	0.5	0.9	74.6	Sn Bronze
M431:1	bangle	3		6.3	0.3		92.5	Sn Bronze
M432:2	plaque	3		8.6			91.0	Sn Bronze
M432:3	tube	3		16.5			81.9	Sn Bronze
M432:4	tube	3		3.5	0.1	0.1	96.0	Sn Bronze
M435:		3		5.3			93.6	Sn Bronze
M435:2-1	bead	3		8.8	0.2		90.3	Sn Bronze
M435:2-3	bead	3		7.1			92.2	Sn Bronze
M435:3	tube	3		15.7	0.3		83.5	Sn Bronze

M437:1	pao			4.9		0.1	94.6	Sn Bronze
M437:10	plaque			1.8			97.3	Sn Bronze
M437:11	tube			5.5			93.9	Sn Bronze
M437:12-1	bead			0.3		1.2	96.5	As Copper
M437:14	bangle			5.5		0.1	93.9	Sn Bronze
M437:15	bead			2.3	0.2	0.1	97.1	Sn Bronze
M437:2	bead			4.6		0.4	94.6	Sn Bronze
M437： 3	mirror			6.2	0.6		92.9	Sn Bronze
M437:5	button			0.2		0.2	98.8	Copper
M437:6	tube			1.4	0.1		97.1	Sn Bronze
M437:7	pao			8.2			90.9	Sn Bronze
M437:8	pao			5.3	0.3		93.9	Sn Bronze
M439:1	mirror	4	0.1	5.4		0.1	93.3	Sn Bronze
M440:2	tube	2		10.8	0.7		87.9	Sn Bronze
M440:3	plaque	2		10.0	0.2		88.2	Sn Bronze
M440:3-1-1	tube	2		10.3			88.7	Sn Bronze
M440:3-2	tube	2		8.8	0.1		87.8	Sn Bronze
M440:3-3	tube	2		5.0		0.1	94.3	Sn Bronze
M440:4	button	2		9.4		0.3	90.1	Sn Bronze
M440:5-1	plaque	2		2.0	0.1	0.1	96.3	Sn Bronze
M440:5-2	tube	2		4.1	0.2		94.3	Sn Bronze
M440:5-2	tube	2		10.0	0.1		87.2	Sn Bronze
M440:5-3	bead	2		7.2	0.8		90.0	Sn Bronze
M440:7	plaque	2		4.8	0.1	0.2	94.0	Sn Bronze
M441:1	button	3		5.4			93.8	Sn Bronze
M441:2	button	3		0.2		0.8	96.0	Copper
M441： 3	knife	3				2.1	97.3	As Copper
M441:4	awl	3		0.2		2.0	97.8	As Copper

M443:2	pao	2	0.1	5.9	0.1	1.1	92.3	As Sn Bronze
M443:4	button	2		0.5			98.4	Copper
M445:2	earring	3		3.3	0.3	1.4	92.6	Sn Bronze
M445:4	bangle	3		7.9	0.3	0.6	89.2	Sn Bronze
M447:2	tube	3		10.0	0.1	0.4	89.0	Sn Bronze
M447:2	tube	3		6.2	0.2	0.2	92.8	Sn Bronze
M447:3	plaque	3		1.5			91.7	Sn Bronze
M447:4	pao	3		0.8		0.2	98.2	Copper
M447:6	button	3		11.1		0.2	87.9	Sn Bronze
M447:7		3		8.8			91.0	Sn Bronze
M448:1	plaque	3			0.1	1.2	98.4	As Copper
M448:2	tube	3		0.8			95.6	Copper
M448:3		3			99.9		0.1	Pb
M448:6	earring	3		15.2	0.2	0.4	76.3	Sn Bronze
M45： 3	bangle	3		20.0			73.4	Sn Bronze
M45： 4	earring	3		9.6	0.7		84.3	Sn Bronze
M45： 7	earring	3		18.9	2.6	1.8	75.4	Pb As Sn Bronze
M450:1	earring			14.8	0.1	6.0	79.1	As Sn Bronze
M450:2	earring		0.2	0.6		0.4	97.9	Copper
M456:2	bangle			3.6	0.8	0.2	93.7	Sn Bronze
M456:3	tube			0.7		2.5	95.9	As Copper
M456:4	earring		0.4	13.2	0.8	0.8	84.6	Sn Bronze
M456:4	earring		0.2	8.9	0.3	0.2	90.0	Sn Bronze
M456:7	bangle			6.2	1.2	2.4	89.8	Pb As Sn Bronze
M456:8	bead			11.0	4.5	3.1	81.0	Pb As Sn Bronze
M456:8	bead		0.6	57.8		0.8	40.1	Sn Bronze
M456:9	pao			9.2			90.4	Sn Bronze
M457:1	button	3		11.4	0.1		87.3	Sn Bronze

M457:2	earring	3		2.2	1.0		91.1	Sn Bronze
M457:3	button	3		4.6		0.2	93.3	Sn Bronze
M457:5	knife	3		4.6		0.2	94.7	Sn Bronze
M457:5	awl	3		2.2	0.9		89.6	Sn Bronze
M457:6	earring	3		50.7	12.5	2.1	31.4	Pb As Sn Bronze
M457:7	button	3		0.9			97.1	Copper
M459:1	button		0.2	0.2	2.1	4.1	92.8	Pb As Copper
M460:3	tube	3		8.4			90.0	Sn Bronze
M460:4	tube	3		7.5	0.9		89.7	Sn Bronze
M462:3	button	2		4.5			92.8	Sn Bronze
M462:4	earring	2		7.3	0.3	0.4	91.0	Sn Bronze
M468:3	plaque	4		3.4	0.1	0.1	95.7	Sn Bronze
M468:4	tube	4		10.9	0.1	0.6	87.6	Sn Bronze
M468:5	tube	4		0.7	0.1	0.2	97.1	Copper
M468:6	bead	4		6.4	0.1	0.5	92.7	Sn Bronze
M468:7	tube	4		17.9	1.2	0.5	79.8	Sn Bronze
M468:8	bead	4			54.5		45.2	Pb Cu
M469:1	button			3.4		0.2	96.1	Sn Bronze
M47：2	earring	3		8.0	1.9	1.1	88.7	Pb As Sn Bronze
M47：2	earring	3		16.0	0.3		80.8	Sn Bronze
M471：2	knife	3		10.2	0.2	0.7	87.8	Sn Bronze
M472:2	earring	3		2.7	2.0	3.5	91.4	Pb As Sn Bronze
M472:4	knife	3		0.2			99.3	Copper
M474:1	earring	4		10.0			89.2	Sn Bronze
M474:6	plaque	4		11.6		0.1	87.8	Sn Bronze
M474:7		4		8.9		0.1	90.7	Sn Bronze
M475:1	earring	3		0.5	0.3		95.2	Copper
M475:1	earring	3		6.1		0.2	93.2	Sn Bronze

M475:1	earring	3		5.3	0.6		93.1	Sn Bronze
M475:5	earring	3		24.5	5.7	1.1	67.8	Pb As Sn Bronze
M477：4	earring	2		11.8	4.7		82.9	Pb Sn Bronze
M479:1	plaque			9.7	0.2	0.2	89.6	Sn Bronze
M479：2	tube		0.1	9.7	0.1	0.4	89.5	Sn Bronze
M479：4	tube			8.0	0.2	0.8	90.3	Sn Bronze
M479：4	tube			5.4	0.1	0.1	93.6	Sn Bronze
M479：5	pao			11.0	0.1		88.3	Sn Bronze
M479：6	pao			10.9			88.5	Sn Bronze
M479：7	pao			12.7	0.2	0.2	86.7	Sn Bronze
M479:9	mirror			10.7	0.3	0.3	87.9	Sn Bronze
M48：10	tube	1		3.9	0.1	0.1	93.5	Sn Bronze
M48：4	bead	1		11.1	0.5	0.6	86.2	Sn Bronze
M48：5	bead	1		13.5	0.7		84.2	Sn Bronze
M48：9	plaque	1		10.7			88.3	Sn Bronze
M480:2	earring	3		5.6	0.4	0.1	93.1	Sn Bronze
M482：1	pao		0.1	6.6	0.1		92.8	Sn Bronze
M482：2	pao			5.3		0.1	94.0	Sn Bronze
M483:11	pao			5.2			93.8	Sn Bronze
M483：12	pao			9.5			89.7	Sn Bronze
M483：13	button	2		10.0			89.7	Sn Bronze
M483：14	plaque	2		3.5	0.1		96.1	Sn Bronze
M483：15	pao	2		4.5	0.1		94.8	Sn Bronze
M483：16	pao	2		7.9			87.5	Sn Bronze
M483：17	pao	2		3.2			96.4	Sn Bronze
M483：18	mirror	2		20.9	0.1	8.6	70.1	As Sn Bronze

M483： 19	pao	2		6.9			92.7	Sn Bronze
M483： 2	bangle	2		3.0			96.2	Sn Bronze
M483： 20	mirror	2		1.2	0.1		98.4	Sn Bronze
M483： 21	plaque	2		5.1	0.5		93.5	Sn Bronze
M483： 22	bangle	2		8.2	1.6	3.4	86.7	Pb As Sn Bronze
M483： 23	tube	2		0.1		1.6	97.8	As Copper
M483:24	plaque	2		5.5			94.1	Sn Bronze
M483:24（2）	plaque	2		8.9		0.1	90.7	Sn Bronze
M483： 27	pao	2		9.5	0.9		89.4	Sn Bronze
M483： 28	pao	2		4.6	0.5		94.6	Sn Bronze
M483： 3	button	2		10.2			87.1	Sn Bronze
M483： 30	pao	2		2.8	0.9		95.7	Sn Bronze
M483： 4	pao	2		4.0	0.7		94.3	Sn Bronze
M483： 5	pao	2		11.0	0.1		88.3	Sn Bronze
M483： 6	pao	2		4.8			93.9	Sn Bronze
M483： 7		2		5.8	2.2		90.9	Sn Bronze
M487： 1	bangle			6.5			89.6	Sn Bronze
M487： 3	button		9.2			1.7	89.1	AS Sb Copper
M487： 4	mirror			4.7		0.1	94.9	Sn Bronze
M487： 5	button			8.9			90.9	Sn Bronze
M489:2	earring			5.2			93.2	Sn Bronze
M490： 2	tube	4		7.3			91.2	Sn Bronze
M490： 3	earring	4		14.8	0.6		83.8	Sn Bronze
M490： 4	tube	4		3.9	0.1	0.1	94.7	Sn Bronze
M490： 5	button	4		6.5		0.1	91.3	Sn Bronze
M491:2	pao	2		14.4		0.1	84.6	Sn Bronze

M491:3	plaque	2		9.2			90.0	Sn Bronze
M491:4	plaque	2		21.0	0.2		76.2	Sn Bronze
M492:1	earring				1.0	0.9	97.9	Cu
M495：1	earring	3	0.3		0.7	1.2	96.8	As Copper
M496：2	button	4	5.8			20.1	74.2	As Sb Copper
M496：2	bangle	4	0.3	4.1	0.1	0.3	94.7	Sn Bronze
M496：3	button	4	2.7			0.3	96.7	Sb Copper
M496：6	earring	4	0.2	5.3	0.1	0.2	93.1	Sn Bronze
M498：1	earring	3	0.5		0.5	0.9	97.3	Copper
M498：4	button	3		10.5			88.2	Sn Bronze
M498：7	bangle	3		1.0	1.1	10.2	86.8	Pb As Sn Bronze
M498：8	button	3		2.4			97.3	Sn Bronze
M498：9	tube	3	0.1	1.0	0.8	1.9	95.4	As Sn Copper
M5：3	bangle	3		1.3		0.2	97.7	Sn Bronze
M50：1	tube			8.5		0.1	89.9	Sn Bronze
M50：2	bead		38.2		0.1	4.9	55.9	AS Sb Copper
M50：4	arrowhead			1.2	1.1	0.7	96.5	Pb Sn Bronze
M50:5	bell		0.0	37.9	2.4	1.7	57.5	Pb As Sn Bronze
M50:5	bell		0.0	6.0	0.1	0.2	93.7	Sn Bronze
M50：5	button		0.8		1.2	12.9	83.7	Pb As Copper
M500：2	earring	3		20.1	0.7	0.4	77.9	Sn Bronze
M500：2	earring	3		3.2	0.1		96.5	Sn Bronze
M500：3	button	3		0.8			98.0	Copper
M500：4	bangle	3		5.2	0.1	0.2	93.9	Sn Bronze
M500：5	button	3		0.9			96.3	Copper
M500：6	plaque	3		0.3	0.2		99.2	Copper

M500： 9	bead	3	0.2	8.3	0.3		90.9	Sn Bronze
M502： 2	mirror	2		1.0			97.6	Sn Bronze
M502： 4	tube	2		11.3			86.0	Sn Bronze
M504:1	button			10.7	0.2	2.1	86.9	As Sn Bronze
M506:2	plaque			5.9	1.0	0.2	92.7	Pb Sn Bronze
M506:3	tube			0.6	0.4		98.6	Copper
M51： 3	earring	3	0.3	7.7		0.3	89.1	Sn Bronze
M51： 4	earring	3		8.6		0.3	84.2	Sn Bronze
M511:2	plaque	2			0.2		93.9	Copper
M511:3	pao	2	0.5	7.8	0.2	1.1	88.5	As Sn Bronze
M511:4		2		9.0	0.7		84.5	Sn Bronze
M512： 1	earring	3		4.6			94.2	Sn Bronze
M512： 2	bangle	3		15.3		0.6	80.5	Sn Bronze
M513：	bead		9.0			1.5	87.4	AS Sb Copper
M513： 1	earring			1.6	0.3	1.2	96.1	As Sn Bronze
M514： 1	earring			1.8	0.1		97.0	Sn Bronze
M514： 3	tube			4.8	0.1	0.2	93.6	Sn Bronze
M518： 3	bangle	3			0.4	0.5	98.0	Copper
M518： 4	button	3	1.4		1.4		88.5	Sb Sn Bronze
M518： 4	button	3	2.4		1.4		96.3	Sb Sn Bronze
M518： 5	earring	3			0.1	0.2	98.8	Copper
M518： 7	tube	3	0.4	0.2	1.5		97.4	Pb Cu
M518： 8	plaque	3	0.6	0.2	1.1	0.4	97.3	Sn Bronze
M52： 4	earring	3		4.3	0.2	0.3	91.8	Sn Bronze
M520： 2	earring				0.5		98.6	Copper
M520： 3	bead			6.7			90.9	Sn Bronze

M521： 3	earring	3		2.1	1.2		91.3	Pb Sn Bronze
M522:2	bangle	4		13.7	0.4		82.1	Sn Bronze
M524:2	earring			9.9	0.1	0.1	89.2	Sn Bronze
M526： 1	earring	4		4.5	0.2	1.8	93.0	As Sn Bronze
M526： 4	button	4	0.2	0.7		0.8	97.5	Copper
M527： 6	mirror	4		7.9			91.5	Sn Bronze
M527： 7	button	4		17.8	2.8		79.0	Pb Sn Bronze
M528： 1	button	3	0.3		0.6	1.5	97.0	As Copper
M529： 2	pao	2		4.4		0.3	95.1	Sn Bronze
M529： 3	button	2		10.2			89.6	Sn Bronze
M529： 4	button	2		4.6			94.5	Sn Bronze
M53： 1	pao	4		9.9			88.7	Sn Bronze
M53： 2	mirror	4		2.1	0.1	0.5	97.0	Sn Bronze
M53： 3	pao	4		8.5			86.5	Sn Bronze
M530： 2	earring	4		8.2	0.4	0.6	90.1	Sn Bronze
M532： 1	button	3		5.5			93.0	Sn Bronze
M532： 2	button	3		9.8			86.6	Sn Bronze
M532： 3	button	3		13.2			84.5	Sn Bronze
M534： 2	plaque			8.8			90.8	Sn Bronze
M536:11	plaque				0.1		99.8	Copper
M536:3	pao			5.4			94.1	Sn Bronze
M539： 2	knife	3		4.1	0.1	0.1	94.5	Sn Bronze
M54： 2	bead	3		3.5		0.5	92.5	Sn Bronze
M54： 3	earring	3		19.9			75.5	Sn Bronze
M54： 4	bangle	3	1.0	11.1	0.4	0.9	82.6	Sn Bronze
M54： 5	earring	3		17.4	0.1	0.3	77.5	Sn Bronze

M54： 6	plaque	3	0.2	5.0		0.4	92.8	Sn Bronze
M54： 7	tube	3	0.2	2.2		0.2	95.8	Sn Bronze
M542： 2	earring	2		4.2	0.3		95.1	Sn Bronze
M542： 3	earring	2		1.6	0.1		96.7	Sn Bronze
M542:4	plaque	2		19.8	3.0	1.7	75.2	Pb As Sn Bronze
M542： 5	pao	2		3.2			96.7	Sn Bronze
M544:2	bangle	3		14.6	0.5		84.6	Sn Bronze
M544:4	earring	3		1.0	0.6	0.2	96.9	Sn Bronze
M546： 1	earring	3		4.4		0.1	94.8	Sn Bronze
M546： 2	button	3		10.2	0.4	0.2	88.8	Sn Bronze
M546： 3	bangle	3		30.5	0.3	1.1	66.1	As Sn Bronze
M546： 4	earring	3		14.2	1.4	4.4	79.4	Pb As Sn Bronze
M546： 5	bangle	3		1.1	1.7	3.9	93.1	Pb As Sn Bronze
M547： 6	button	2		2.6			87.9	Sn Bronze
M55	earring	4		3.4	0.4	0.9	93.6	Sn Bronze
M550： 4	earring	1		7.9			90.2	Sn Bronze
M55-2	earring	4		6.1	0.7	1.4	90.6	Sn Bronze
M552:1	pao			11.1		0.2	88.5	Sn Bronze
M554： 2	bangle	3		1.8	0.2		95.3	Sn Bronze
M554： 5	button	3		13.6	0.2		86.0	Sn Bronze
M554： 6	earring	3		0.7	0.2		92.7	Copper
M554： 7	mirror	3	0.5	20.8		1.0	77.3	As Sn Bronze
M559:1	earring			2.2	0.1	2.2	94.6	As Sn Bronze
M56： 1	earring	4		22.8	0.4	8.1	67.8	As Sn Bronze
M56： 3	earring	4	0.6	11.1	0.5	2.0	85.7	Sn Bronze
M56： 4	earring	4	0.6	5.3		0.2	93.5	Sn Bronze

M561：3	pao	3	0.2	2.4	0.2	0.5	95.2	Sn Bronze
M561：4	pao	3	0.1	3.8	0.1	0.5	94.6	Sn Bronze
M566:1	plaque			0.8	0.2		98.3	Copper
M569:3	earring	4		9.0	0.5		88.1	Sn Bronze
M571:2	pao	3		5.5	0.1	2.6	91.2	As Sn Bronze
M571:3	bangle	3		2.3	0.1	0.3	96.9	Sn Bronze
M571:4	earring	3			0.2	0.3	99.2	Copper
M571:5	plaque	3		0.3		0.2	99.0	Copper
M571:6	button	3			0.2	16.9	82.8	As Copper
M575:1	bangle			4.8	4.6		88.3	Pb Sn Bronze
M575:2-3	tube			3.6			95.7	Sn Bronze
M577:1、2、	pao			1.2			97.9	Sn Bronze
M577:4	tube			5.9	0.2	0.2	93.3	Sn Bronze
M577:6	tube			7.8	0.3		91.0	Sn Bronze
M577:7	awl			1.5		0.1	97.3	Sn Bronze
M579:5	plaque	1		8.9			90.7	Sn Bronze
M58：3		3			99.5		0.1	Pb
M58：4	mirror	3		6.7			92.2	Sn Bronze
M580:1	bead	3		10.4			89.0	Sn Bronze
M580:10	bead	3		8.5			90.9	Sn Bronze
M580:13	bead	3		9.5	0.2	0.2	89.7	Sn Bronze
M580:13	bead	3		5.6			93.5	Sn Bronze
M580:2	pao	3		10.7			88.7	Sn Bronze
M580:3	earring	3		0.9			96.6	Copper
M580:6	pao	3		16.6			80.4	Sn Bronze
M580:7	pao	3		4.8			94.6	Sn Bronze
M580:8	bangle	3		10.4	0.2	0.2	88.5	Sn Bronze
M582:1	earring			1.3			98.1	Sn Bronze

M582:1	knife			6.9			92.9	Sn Bronze
M582:2	plaque			1.0	0.1	0.3	98.7	Sn Bronze
M583:2	earring	3		7.4		0.4	90.4	Sn Bronze
M585： 2	earring		0.5	5.6	0.9	0.6	92.1	Sn Bronze
M585： 3	bangle			4.9			93.3	Sn Bronze
M585： 4	bangle			8.7	0.1		90.9	Sn Bronze
M585： 5	bead			1.1	1.9	0.6	96.1	Pb Sn Bronze
M587:2	earring			16.7	0.2	0.5	81.6	Sn Bronze
M589:2	earring	3			0.1	4.2	91.9	As Copper
M589:5	plaque	3	0.0	0.0	0.0	12.9	85.7	As Copper
M59： 5	knife	3		11.1	0.3		87.8	Sn Bronze
M590:1	earring			8.4			89.7	Sn Bronze
M591:1	button	3		4.3			95.4	Sn Bronze
M593:1	earring	3		9.9	0.1	0.2	89.3	Sn Bronze
M593:2	bangle	3		6.1	0.6	0.1	92.8	Sn Bronze
M593:5	tube	3		3.8			95.5	Sn Bronze
M593:6	pao	3		3.9	1.3		90.8	Pb Sn Bronze
M595:4	earring	3		4.6		0.3	93.3	Sn Bronze
M596:3	earring				0.4		98.4	Copper
M596:4	earring			1.3		0.5	95.8	Sn Bronze
M597:2	tube	3		12.9			82.0	Sn Bronze
M597:3	bangle	3		1.5		0.9	96.6	Sn Bronze
M597:3	button	3		3.5			95.1	Sn Bronze
M597:4	plaque	3	0.0	0.7	0.1	0.9	96.9	Copper
M6	earring	4		4.3	0.1	0.2	94.4	Sn Bronze
M6： 2	bead	4		0.2	0.8	0.4	97.9	Copper
M6:3	earring	4			2.2	0.4	96.6	Pb Cu

M6：3-2	earring	4			0.4	1.0	98.0	As Copper
M6：4	earring	4			1.1	2.2	94.9	Pb As Copper
M602:1	bangle	3		0.8	0.2		97.6	Copper
M602:3	earring	3		4.7	0.1	0.9	92.6	Sn Bronze
M603:1	earring			5.4	0.9	9.3	84.0	As Sn Copper
M603:2	bangle		0.2	4.9	1.0	1.3	91.7	Pb As Sn Bronze
M604:2	bead	3		4.8	0.1		94.0	Sn Bronze
M604:4	bead	3		5.4	0.1		93.2	Sn Bronze
M605:2	pao	3		4.0			95.6	Sn Bronze
M606：1	earring	3		0.4	1.3	1.0	96.8	Pb As Cu
M606:3	pao	3		9.4		0.2	90.1	Sn Bronze
M606:5	mirror	3	0.1			0.5	98.2	Copper
M606:6	pao	3			0.3	19.0	72.8	As Copper
M608：1	pao	3		7.9			91.9	Sn Bronze
M608：2	button	3		4.8			94.3	Sn Bronze
M608：3	bead	3	0.1	5.3	1.0		93.4	Sn Bronze
M608：4	pao	3		5.7		0.1	93.9	Sn Bronze
M608:5	tube	3		8.8	0.1	0.1	90.7	Sn Bronze
M608：5	tube	3		10.3	0.2	0.3	85.0	Sn Bronze
M608：7	plaque	3		4.9			94.1	Sn Bronze
M610:2	earring	4		9.5	0.4	3.3	86.2	As Sn Bronze
M610:2	tube	4		1.1		1.9	95.1	As Sn Copper
M612	pao	2		13.6	0.4		85.3	Sn Bronze
M614：2	earring	3		20.3	0.6	0.8	76.8	Sn Bronze
M618：1	earring	2		11.6	0.6		87.4	Sn Bronze
M618：4	pao	2		4.7			92.8	Sn Bronze
M62:1	earring	3		4.5	0.1	3.0	69.2	As Sn Bronze

M620:10	mirror	3		4.3	0.1		94.8	Sn Bronze
M620:11	plaque	3		3.3	0.2	0.6	94.5	Sn Bronze
M620:3	tube	3		5.4	0.1		93.9	Sn Bronze
M620:4	tube	3		1.8	0.1		95.2	Sn Bronze
M620:9	button	3		3.9			95.1	Sn Bronze
M625： 1	earring	4	0.4	16.3	1.0	1.8	79.8	Pb As Sn Bronze
M625:3	plaque	4	0.8	0.4	0.0	1.5	97.1	As Copper
M625:3	plaque	4	0.9	0.4	0.0	1.5	96.7	As Copper
M626:2	plaque	3	0.0	2.1	0.0	0.0	96.5	Sn Bronze
M626:4	pao	3		15.9	0.1	0.5	81.6	Sn Bronze
M626:5	button	3	0.3	31.7	0.3	1.0	66.1	As Sn Bronze
M626:5	button	3		10.7			89.1	Sn Bronze
M627： 5	arrowhead	3		3.7			95.9	Sn Bronze
M629： 2	earring	2		32.2	0.4	1.5	64.4	As Sn Bronze
M631： 2	knife	3		0.6		0.4	99.0	Copper
M631： 3	earring	3		9.6	0.7	1.4	87.5	As Sn Bronze
M631： 4	earring	3		1.3	0.1		97.5	Sn Bronze
M632:1	pao	2		22.1		0.2	77.1	Sn Bronze
M632:2	pao	2		5.8			93.5	Sn Bronze
M632:3	pao	2	0.1	7.3	0.1	0.1	92.3	Sn Bronze
M632:7	arrowhead	2		10.6			88.1	Sn Bronze
M632:9	pao	2		6.1			92.9	Sn Bronze
M633： 2	pao	3		17.6			79.9	Sn Bronze
M634： 1	tube			1.7			96.2	Sn Bronze
M634： 2	tube			5.4	0.1	0.1	93.8	Sn Bronze
M634： 3			0.7			2.0	96.9	As Copper
M635:2	earring	3		9.2	1.1	0.8	88.4	Pb Sn Bronze

M636:1	plaque		0.1	9.5	0.1	0.1	90.0	Sn Bronze
M636:1	plaque		0.0	8.1	0.1	0.0	91.5	Sn Bronze
M636:5	bead			29.4			70.6	Sn Bronze
M64:4	awl	4		10.9			77.3	Sn Bronze
M64:5	earring	4		51.6	19.6		25.0	Pb Sn Bronze
M64:6	earring	4		5.7			90.6	Sn Bronze
M640:10	mirror	2				1.3	98.6	As Copper
M640:11	pao	2		2.5		1.6	95.6	As Sn Bronze
M640:2	plaque	2		5.5		0.1	94.4	Sn Bronze
M640:3	bangle	2		7.5			91.4	Sn Bronze
M640:5	pa	2			0.5	2.8	96.2	As Copper
M640:7	earring	2		6.0	0.1	0.7	92.5	Sn Bronze
M640:9	mirror	2		8.4	0.2	0.2	90.7	Sn Bronze
M641： 4	button			7.0	0.3	0.2	92.2	Sn Bronze
M641： 5	plaque			5.7	0.2	0.4	92.8	Sn Bronze
M643:1	earring				1.0	0.8	97.0	As Copper
M643:25	bead	4		8.3	0.6	0.3	90.2	Sn Bronze
M644： 2	earring	3	1.6	24.0	0.3	2.4	71.3	Pb As Sn Bronze
M645:2	earring	4		0.9	0.1		97.3	Copper
M645:3	pao	4		4.8		0.2	94.4	Sn Bronze
M645:4	tube	4		5.0	0.6	0.4	92.5	Sn Bronze
M645:5	bangle	4		6.7	1.4		90.6	Pb Sn Bronze
M645:7	button	4		5.4	0.1	0.3	92.2	Sn Bronze
M647:1	knife	3	0.3	0.9	0.2	1.7	96.4	As Copper
M647:2	earring	3	0.0	9.4	0.3	0.3	89.2	Sn Bronze
M648:3	earring	4	0.0	0.4	0.8	0.0	97.1	Copper
M648:4	bangle	4	0.0	0.3	0.2	0.7	98.1	Copper
M649:2	knife	3		8.8	0.2	5.0	85.6	Sn Bronze

M649:3	awl	3	0.0	5.9	1.2	0.6	91.8	Pb Sn Bronze
M649:3	awl	3	0.0	26.2	0.2	0.0	71.4	Sn Bronze
M65:1	mirror	3	0.0	10.6	0.5	1.1	87.8	As Sn Bronze
M65:4	tube	3	0.5	10.7	0.1		83.6	Sn Bronze
M65:6	bangle	3		22.8			61.5	Sn Bronze
M65:7	plaque	3		12.7	1.4	0.4	84.2	Pb Sn Bronze
M652:1	earring		0.0	0.9	0.3	0.0	97.7	Copper
M652:1	earring		0.0	4.1	0.2	0.1	94.4	Sn Bronze
M652:5	tube		2.5	4.4	0.9	1.2	90.3	Sb Sn Bronze
M652:5	tube		0.0	6.2	0.0	0.0	93.8	Sn Bronze
M652:5	tube		0.0	5.4	0.1	0.0	94.1	Sn Bronze
M653:1	earring		0.0	12.8	1.3	2.1	83.0	Pb As Sn Bronze
M653:1	earring		0.0	5.6	0.6	0.0	93.2	Sn Bronze
M654:1	bangle	4	0.0	4.8	0.4	0.1	94.1	Sn Bronze
M654:2	plaque	4		1.3	0.1		98.5	Sn Bronze
M654:3	tube	4	0.0	1.8	0.0	2.2	95.0	Sn Bronze
M654:3	tube	4	0.0	4.0	0.2	0.1	95.3	Sn Bronze
M654:3	tube	4	0.0	5.4	0.0	0.0	93.7	Sn Bronze
M654:5-1	pao	4	0.0	4.2	0.0	0.9	94.2	Sn Bronze
M654:5-2	pao	4	0.0	5.9	0.0	0.0	93.6	Sn Bronze
M654:5-3	button	4	0.0	26.1	0.4	0.0	72.9	Sn Bronze
M654:5-4	pao	4	0.0	13.2	0.0	0.0	86.8	Sn Bronze
M654:5-5	pao	4	0.0	6.7	0.0	0.0	91.2	Sn Bronze
M655:1	earring	4	0.0	22.2	0.8	4.3	71.4	Sn Bronze
M655:1	earring	4	0.0	8.2	0.2	0.9	90.4	Sn Bronze
M66:4	knife	4		4.0	0.1	0.2	92.0	Sn Bronze
M66：5	awl	4		12.8	1.9		83.0	Pb Sn Bronze
M66：6	mirror	4		5.9			91.9	Sn Bronze

M668:4	earring	4	0.7	31.0	3.1	1.6	63.0	Sn Bronze
M670:4	earring	3	0.0	25.2	0.0	0.3	72.1	Sn Bronze
M673:1	earring		0.0	24.3	0.6	0.8	71.9	Sn Bronze
M673:1	earring		0.0	1.1	0.0	0.0	98.1	Sn Bronze
M674:1	earring	2	0.0	28.1	1.4	0.6	69.2	Pb Sn Bronze
M674:3	tube	2	0.0	5.4	0.0	0.0	94.0	Sn Bronze
M674:4	plaque	2	0.2	4.7	0.0	0.0	93.8	Sn Bronze
M674:6	tube	2	0.0	5.1	0.0	0.0	93.2	Sn Bronze
M675:3	plaque		0.7	13.8	0.3	0.9	84.0	Sn Bronze
M676：3	plaque	3		19.7	2.6	5.7	71.5	Pb As Sn Bronze
M676:6	tube	3	0.0	4.0	0.1	0.1	94.2	Sn Bronze
M677:2	earring	4	0.7	0.0	0.5	0.3	96.6	Copper
M677:2	earring	4	0.1	0.2	1.0	2.4	95.8	Pb As Copper
M677:2	earring	4	1.3	0.0	0.2	0.8	96.9	Sb Copper
M679:1	pa	3				2.3	96.3	As Copper
M679:2	mirror	3				1.7	97.9	As Copper
M679:5	awl	3	0.0	0.3	0.0	3.5	95.6	As Copper
M679:8	pa	3				2.2	97.4	As Copper
M679:9	earring	3	0.0	0.0	0.7	0.5	97.7	Copper
M68：2	button	3		25.4	4.0		67.8	Pb Sn Bronze
M680:3	button	3	0.0	0.0	0.0	0.9	98.4	Copper
M681:2	earring	3	0.0	8.7	0.9	0.8	88.7	Sn Bronze
M681:2	earring	3	0.0	5.6	0.0	0.0	93.5	Sn Bronze
M682:4	earring	4	0.0	10.4	0.4	0.0	89.0	Sn Bronze
M683：2	mirror	2		3.5			94.6	Sn Bronze
M683:5	pao	2	0.3	9.3	0.1	0.1	89.3	Sn Bronze
M683:5	pao	2	0.0	1.2	0.1	0.0	96.8	Sn Bronze
M683:5	pao	2	0.3	8.9	0.2	0.0	90.4	Sn Bronze

M683:5	pao	2	0.2	5.2	0.2	0.0	92.2	Sn Bronze
M683:8	plaque	2		10.0	0.3		89.0	Sn Bronze
M683： 9		2	0.1	8.2	0.2	0.8	90.5	Sn Bronze
M685:1	plaque			3.0	0.4	0.2	95.8	Sn Bronze
M685:3	pao		0.0	28.9	0.2	0.0	70.2	Sn Bronze
M687:2	button	3	0.0	4.7	0.0	1.2	93.4	As Sn Bronze
M687:3	button	3	0.0	8.4	3.1	0.0	88.3	Sn Bronze
M689:3	earring	2	0.0	2.3	0.6	0.5	94.3	Sn Bronze
M689:3	earring	2	0.0	17.6	0.2	0.0	79.8	Sn Bronze
M692： 3	earring	3			0.6	2.1	95.4	As Copper
M692:6	tube	3	0.2	5.6	0.3	0.6	92.8	Sn Bronze
M692:7	button	3	0.0	5.5	0.8	0.0	92.9	Sn Bronze
M692:8	bangle	3	0.0	10.1	0.1	0.1	88.6	Sn Bronze
M694:2	knife	3	0.1	3.3	0.0	3.3	93.0	As Sn Bronze
M694:3	awl	3	0.1	1.8	0.0	0.4	97.6	Sn Bronze
M695:1	knife	3		4.9	0.2	0.1	93.6	Sn Bronze
M695： 2	earring	3		6.6	0.2		91.7	Sn Bronze
M696:3	earring	2	0.0	29.7	0.0	0.9	68.9	Sn Bronze
M697： 1	tube	4	0.0	5.1	0.0	0.2	93.7	Sn Bronze
M697： 1	tube	4	0.0	7.8	0.1	0.1	91.8	Sn Bronze
M697： 1	tube	4	0.1	5.0	0.3	0.0	94.4	Sn Bronze
M697： 1	tube	4	0.1	5.0	0.1	0.0	94.4	Sn Bronze
M697： 1	tube	4	0.0	1.1	0.1	0.0	98.7	Sn Bronze
M697： 2	bangle	4	0.0	0.0	3.5	4.4	91.3	Pb As Copper
M697： 2	bangle	4	0.0	0.0	3.2	3.0	92.8	Pb As Copper
M697： 3	mirror	4		4.5			94.4	Sn Bronze
M697： 5	earring	4	0.0	19.3	0.0	0.5	78.3	Sn Bronze

M697： 5	earring	4	0.0	4.5	0.3	0.0	94.6	Sn Bronze
M698:2	plaque	3		4.7	0.1		93.6	Sn Bronze
M698： 2	earring	3		3.8			94.8	Sn Bronze
M698:3	pao	3	0.0	8.4	0.0	0.8	90.2	Sn Bronze
M698:3	pao	3	0.0	5.2	0.0	0.0	92.4	Sn Bronze
M698:3	pao	3	0.0	4.3	0.0	0.0	93.9	Sn Bronze
M698:3	pao	3	0.0	4.0	0.1	0.0	95.1	Sn Bronze
M698： 4	bangle	3		5.1	0.1		93.4	Sn Bronze
M7： 2	mirror	4	0.1	8.9	0.1	0.1	90.8	Sn Bronze
M701： 10	button	3	0.2		5.8	4.9	88.9	Pb As Cu
M701： 3	button	3		13.3		0.3	86.0	Sn Bronze
M703:4	button	3	0.0	20.3	0.1	0.1	76.4	Sn Bronze
M705:1	button		0.0	0.0	0.0	5.8	52.7	As Copper
M705： 2	bangle				0.8	2.7	95.7	As Copper
M71： 10	button	2		27.1	0.2		65.4	Sn Bronze
M71： 11	tube	2		0.4		0.1	98.6	Copper
M71： 2	knife	2		5.9	0.2	0.4	91.1	Sn Bronze
M71： 4	tube	2		3.7	0.1		95.7	Sn Bronze
M71： 6	button	2		5.6			93.5	Sn Bronze
M71： 7	tube	2		5.5	0.1	0.6	93.5	Sn Bronze
M71： 9	tube	3		2.1	0.2		94.9	Sn Bronze
M72： 2	knife	4		3.8		2.4	92.9	As Sn Bronze
M72： 3	awl	4	1.0	0.2		0.5	97.9	Sb Copper
M73： 4	mirror	2		4.7			94.4	Sn Bronze
M73： 7	mirror	2		8.4		0.2	91.2	Sn Bronze
M74： 2	earring	4		2.8	1.1	1.4	91.1	Pb As Sn Bronze

M74：4	pao	4		16.3			83.0	Sn Bronze
M75：3	pao	4		11.6	0.1	0.9	86.9	Sn Bronze
M75：4	pao	4				0.5	98.3	Copper
M75：5	earring	4		0.5	0.5	1.6	95.8	As Copper
M75：6	earring	4			0.4	3.0	95.8	As Copper
M75：7	pao	4		14.2	0.2	0.4	84.4	Sn Bronze
M76 :4	bangle	3		10.9	0.3	0.3	88.0	Sn Bronze
M76：5	earring	2		11.9		0.5	86.6	Sn Bronze
M76：7	earring	2		6.6	0.5		91.4	Sn Bronze
M80：1	tube	3		1.0	0.2	0.2	97.4	Sn Bronze
M80：2	plaque	3		0.2		3.5	96.1	As Copper
M80：5	tube	3		3.4			96.2	Sn Bronze
M81：2	button	3	0.2		2.0	6.6	90.9	Pb As Copper
M81：6	pao	3	0.3	9.2			89.0	Sn Bronze
M81：7	pao	3		6.9			92.3	Sn Bronze
M82：2	earring	3		4.7	0.2	0.6	93.1	Sn Bronze
M82：3	earring	3		4.7			93.0	Sn Bronze
M82：4	bead	3		23.6			75.4	Sn Bronze
M82：5	earring	3		3.7	0.3	0.4	92.3	Sn Bronze
M84：2	mirror	2		8.7	0.3		90.7	Sn Bronze
M85	knife	3		5.2	0.5	0.2	93.7	Sn Bronze
M85：5	awl	3		9.7	0.3	1.1	88.2	Sn Bronze
M87：3	mirror	3				1.1	98.0	As Sn Bronze
M88：2	earring	3		11.7	0.3	0.7	87.1	Sn Bronze
M90：4	earring			5.3	0.1		92.8	Sn Bronze
M91：3	button	2	0.6	10.5		1.0	87.4	As Sn Bronze

M91：4	tube	2	0.1	9.1	0.1	0.2	90.0	Sn Bronze
M91：5	knife	2		10.5	0.4	0.8	87.6	Sn Bronze
M92：2	awl	3		2.0		0.2	95.2	Sn Bronze
M93：2	earring	3		23.9			72.7	Sn Bronze
M93：3	bead	3		1.1			93.6	Sn Bronze
M96：2	earring			10.9			86.6	Sn Bronze
M96:6-3	bead			12.6	0.1	0.2	86.9	Sn Bronze
M99:2	mirror	3		1.6		0.7	95.8	Sn Bronze
M99:3	plaque	3		0.6	2.5	1.1	95.1	Pb As Cu

Appendix B: pXRF analysis

Overview

pXRF was used routinely to establish the composition of artefacts from surface analysis. pXRF provides compositional data relating to major, minor, and some trace elements which can be used to infer alloy type.

Method

pXRF analysis was undertaken using a NITON XLT pin detector instrument. For the analyses at the Hami Museum the 'General metals' calibration was used, with main and low filters activated (Total analysis time 50 secs: 30 secs main, 15 secs low).

The following elements are capable of being determined using the method outlined above:
Main Range Elements: Sb, Sn, Cd, Pd, Ag, Ru, Mo, Nb, Zr, Bi, As, Pb, Se, W, Zn, Cu, Re, Ta, Hf, Ni, Co, Re, Mn, Cr, V, Ti, Al
Low Range Elements: Cr, V, Ti

The instrument was employed in handheld mode by a trained analyst (LT). Care was taken to ensure that the instrument window was completely occluded by the sample and the instrument held stable in close contact with the material for the duration of the analysis time.

Instrument and Methods Precision Testing

Additionally variability tests were conducted on circle ornament/M311-6-4 and mirror/M266-7, measuring the coefficient of variation (CV%=(standard deviation/average)x100), assessing both methods and instrumentation sampling.

Instrument precision test:

The standard deviation of 5 successive samples taken from the same spot without altering the location of the pXRF device between sampling events.

Methods precision test:

The standard deviation of 5 successive samples taken from the same spot, while moving the pXRF away from the sampling point between each sampling event.

Instrument Precision Test Circle ornament/M311-6-4	Sn	As	Pb	Cu	Sb	Fe
Average	12.522	3.366	0.157	83.445	0.109	0.315
Standard Deviation	0.024	0.028	0.001	0.458	0.0005	0.003
CV%	0.193	0.822	0.752	0.549	0.462	0.801

Methods Precision Test Mirror/M266-7	Sn	As	Pb	Cu	Sb	Fe
Average	15.744	1.223	0.179	87.667	N	0.891
Standard Deviation	0.108	0.001	0.105	0.437	N	0.017
CV%	0.684	0.105	0.223	0.498	N	1.954

Table 12. Instrument and methods precision test data, Hami Museum.

Accuracy considerations

Accuracy has been determined using certified reference materials for major and minor elements (Cu, Zn, Pb, Sn, As, Sb, Fe). The device can be shown to be within +/- 5% of certified values, and better in some instances. High leaded alloys have been found to be problematic at Pb levels >25%, but this is unlikely to be relevant to the material proposed for study here.

The precision of the pXRF has been predetermined to be better than 1% for major and minor elements (>1%, and for trace elements up to 50% when dealing with elements close to detection limits (typically 50-400ppm).

Appendix C: pxrf standards completed statement

The performance of the HHpXRF was established in terms of accuracy and precision. Instrument bias was monitored daily and the FP calibration attenuated according to the incorporated system check routine. Precision was monitored using an in house sample (see below) while accuracy was determined across a range of compositions using for MBH certified reference materials (C50X20, C71X06, C11X01, 31XB27).

Accuracy expressed as %error was dependent on element concentration. The main elements useful for categorising alloys were Cu, Zn, Sn and Pb. Arsenic was determined through an uncertified in-house prepared material at 7% As (all replicates within 10%). For the certified reference materials achieved accuracy as %error is shown in the following table. Error associated with tin (Sn) determinations ranged from 25% when present as a trace (>0.2wt%) to -2.6%error as a major element (8.8wt%). Error associated with zinc (Zn) ranged from (-9.7%)(>1wt%) to -2.7% as a major element (30.3%). Accuracy for lead (Pb) ranged from 40% at trace level to 1.1% at major levels (10.9%). Copper was present as the major element in all certified standards and was determined at better than 1% error.

Accuracy=%error=$\%E = \left\{\frac{M-A}{A}\right\} x\ 100$

		Sn	**Zn**	**Pb**	**Cu**	**Ni**	**Fe**
C50X20	*Certified*	8.80	0.41	10.90	79.01	0.51	0.10
	Measured	8.57	0.37	11.02	79.48	0.37	0.07
	Accuracy (%E)	-2.61	-9.76	1.10	0.59	-27.45	-30.00
C71X06	*Certified*	3.90	3.70	6.10	84.26	2.10	0.04
	Measured	3.84	3.81	5.94	83.92	2.41	0.05
	Accuracy (%E)	-1.54	2.97	-2.62	-0.40	14.76	30.00
C11X01	*Certified*	0.16	30.30	0.05	69.50	0.13	0.04
	Measured	0.12	29.47	0.07	69.81	0.08	0.04
	Accuracy (%E)	-25.00	-2.74	40.00	0.45	-38.46	18.92
31X B27	*Certified*	0.99	17.65	0.49	80.65	0.03	0.11
	Measured	1.12	17.96	0.35	80.29	0.02	0.13
	Accuracy (%E)	13.71	1.76	-29.88	-0.45	-20.00	17.12

The certified reference materials showing certified and measured results.

Precision was determined in two ways. Firstly, expressed as co-efficient of variation (%CV) over a number of replicates (10) undertaken as a single event. Secondly, as a long term %CV on an in-house sample measured periodically between 11 June 2015 to 27 July 2015. As can be seen the precision for Cu is comparable over the longer term with that for a single analytical event. Sn shows more variability over the long term but remains respectable at ~2%. Variability for Pb is respectable at 1.9% for an analytical event but increases to ~16% over the long term. This significant increase is explained by two factors. Firstly, the heterogeneity of Pb in copper alloys means precision will always be quite high when the HHpXRF is relocated on a sample such as encountered in a long term precision determination as Pb is not evenly distributed in the material. Local variability is therefore significant in determining this figure. For this reason the majority of objects were always analysed at several points wherever possible. Secondly, the sample used for long term precision was not high in Pb (~0.5%) and therefore higher variability is to be expected.

		Sn	Pb	Cu
Inter batch precision	%CV	2.05	16.91	0.21
Event precision	%CV	0.66	1.9	0.22

Table above showing %CV for batch and event determinations