

# Interaction and localisation: new insights into early metallurgy in China

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## Abstract

The beginning and early development of metallurgy in China have long been hot topics in Eurasian archaeology since they were suggested to be closely linked with the so-called ‘prehistoric globalization’. This paper assesses the available archaeological and archaeometallurgical evidence within their temporal-spatial framework and explores diachronic and cross-spatial developmental processes of early metallurgy in different regions in China. While recognizing the importance of long-distance interaction and exogenous technological stimulation, we draw attention to the local adoption and adaptation process of metallurgy and highlight the significance of local communities as sponsors, practitioners, and consumers of the metallurgical products and production as well as agents of technology transmission. While previous research has focused on individual object features that were seen as typical for specific archaeological cultures, current data shows considerable similarities in artefact typologies and material types among the early metal-using societies throughout Northwest China. We therefore argue that the modification of foreign metallurgical traditions through localised practice in Northwest China was crucial for their transmission further eastward and thus for the ultimate establishment of a new metallurgical tradition in the Central Plain of China.

**Keywords:** Early metallurgy, Northwest China, localised production, regional interactions, technology transmission

## Introduction

Interaction between early civilizations in various parts of the world, especially across Eurasia has received ever increasing attention from archaeologists, historians, and a broad range of social scientists interested in the global development of social complexity, often within narratives of “prehistoric globalization.”<sup>1</sup> Early long-distance interactions are invariably reflected in the material record, most importantly evidence for metal production and consumption found across northern Eurasia. Bronze metallurgy in particular has had a lasting influence on the social organization of societies that started adopting this technology, in most cases leading to increasingly more complex and often hierarchical forms of social

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<sup>1</sup> For example, Boivin, Nicole, and Michael D. Frachetti, eds. “*Globalization in Prehistory: Contact, Exchange, and the 'People Without History'*” (Cambridge University Press, 2018).

organization. Indeed, bronze metallurgy has been shown to promote specialisation of labour and long-distance exchange of raw material (ores) and commodities (bronze objects).<sup>2</sup> The transmission of bronze metallurgy therefore is a key point in research on early complex societies and the connections between them.<sup>3</sup> These early but slowly intensifying connections across Eurasia stimulated the emergence of local engagements in metal production and trade in both raw materials and final products, resulting in the transformation of social and economic structures in the regions concerned.

Therefore, recent decades witnessed a dramatic increase of scholarly interest in the prehistory and archaeology of the Eurasian steppe in recognition of its crucial role in bridging various ancient societies across this large landmass.<sup>4</sup> Copper/bronze metallurgy, along with exogenous crops (e.g., wheat and barley) and livestock (e.g. sheep, goat, and horse) have often been grouped into a “package”<sup>5</sup> illustrating China’s participation in a transcontinental interaction network during the dawn of her Bronze Age around 2,000 BCE.<sup>6</sup> While the rapid pace of archaeological discovery and research has been steadily expanding our knowledge of early metallurgy in China,<sup>7</sup> the old narrative of cultural migration and ill-explained diffusion of metallurgy from the Eurasian steppe into China’s Central Plain is still prevalent.

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<sup>2</sup> V. Gordon Childe. “*The Bronze Age*” (Cambridge University Press, 1930).

<sup>3</sup> Andrew Sherratt, “The Trans-Eurasian Exchange: The Prehistory of Chinese Relations with the West,” in *Contact and Exchange in the Ancient World*, ed. Victor H. Mair (Honolulu: University of Hawaii Press, 2006).

<sup>4</sup> Philip L Kohl, *The Making of Bronze Age Eurasia* (Cambridge University Press, 2007); Evgeny Chernykh, “The “Steppe Belt” of Stockbreeding Cultures in Eurasia During the Early Metal Age,” *Trabajos de prehistoria* 65, no. 2 (2008); Michael D Frachetti, *Pastoralist Landscapes and Social Interaction in Bronze Age Eurasia* (Univ. of California Press, 2008).

<sup>5</sup> Zhijun Zhao, “Eastward Spread of Wheat into China – New Data and New Issues,” *Chinese Archaeology* 9, no. 1 (2009).

<sup>6</sup> See Louisa G. Fitzgerald-Huber, “Qijia and Erlitou: The Question of Contacts with Distant Cultures,” *Early China* 20 (1995); Jianjun Mei, “Qijia and Seima-Turbino: The Question of Early Contacts between Northwest China and the Eurasian Steppe,” *Bulletin-Museum of Far Eastern Antiquities*, no. 75 (2003); Katheryn M Linduff, “How Far Does the Eurasian Metallurgical Tradition Extend,” in *Metallurgy in Ancient Eastern Eurasia from the Urals to the Yellow River*, ed. Katheryn M Linduff (Lewiston, NY; Lampeter: Edwin Mellen Press, 2004); Jing Yuan et al., “公元前 2500 年—公元前 1500 年中原地區動物考古學研究：以陶寺、王城崗、新砦和二里頭為例 [Zooarchaeological Study in Central Plain Areas, 2500-1500 Bc: Case Studies of Taosi, Wangchenggang, Xinzhai and Erlitou] Gongyuanqian 2500 nian - gongyuanqian 1500 nian zhongyuan diqu dongwu kaoguxue yanjiu: yi Taosi, Wangchenggang, Xinzhai he Erlitou weili,” in *Keji Kaogu (II)*, ed. Institute of Archaeology Archaeological Science Center, Chinese Academy of Social Sciences (Beijing: Science Press, 2007); Rowan Flad, Jing Yuan, and Shuicheng Li, “論中國甘青地區新石器時代家養動物的來源及特徵 [On the source and features of the Neolithic domestic animals in the Gansu and Qinghai region, China] Lun Zhongguo Ganqing diqu xinshiqi shidai jiyang dongwu de lai yuan ji tezheng,” *Kaogu*, no. 5 (2009); Katheryn M. Linduff and Jianjun Mei, “Metallurgy in Ancient Eastern Asia: Retrospect and Prospects,” *Journal of World Prehistory* 22, no. 3 (2009); Xinyi Liu et al., “From Necessity to Choice: Dietary Revolutions in West China in the Second Millennium Bc,” *World Archaeology* 46, no. 5 (2014); Li Jaang, “The Landscape of China’s Participation in the Bronze Age Eurasian Network,” *Journal of World Prehistory* 28, no. 3 (2015); Ming-chorn Hwang, “邁向重器時代：鑄銅技術的輸入與中國青銅技術的形成 [Toward an age of monumental bronze: importation and formation of bronze-making technology in China], *Zhongyang yanjiuyuan lishi yuyan yanjiusuo jikan* Maixiang zhongqi shidai: zhutong jishu de shuru yu Zhongguo qingtong jishu de xingcheng,” *Zhongyang Yanjiuyuan Lishi Yuyan Yanjiusuo Jikan* 85, no. 4 (2015); Chris J Stevens et al., “Between China and South Asia: A Middle Asian Corridor of Crop Dispersal and Agricultural Innovation in the Bronze Age,” *The Holocene* 26, no. 10 (2016).

<sup>7</sup> For example, Guoke Chen et al., “甘肅張掖西城驛遺址 [The Xichengyi site in Zhangye, Gansu] Gansu Zhangye Xichengyi yizhi,” *Kaogu*, no. 7 (2014); Yanxiang Li et al., “張掖西城驛遺址冶鑄遺物研究 Zhangye Xichengyi Yizhi yezhu yiwu yanjiu,” *Kaogu yu Wenwu*, no. 2 (2015); Zhouyong Sun et al., “The First Neolithic Urban Center on China’s North Loess Plateau: The Rise and Fall of Shimao,” *Archaeological Research in Asia* (2017); Yishi Yang et al., “Copper Content in Anthropogenic Sediments as a Tracer for Detecting Smelting Activities and Its Impact on Environment During Prehistoric Period in Hexi Corridor, Northwest China,” *The Holocene* 27, no. 2 (2017); Kunlong Chen, Jianjun Mei, and Wei Qian, “絲綢之路與早期銅鐵技術交流 [On the early exchange of copper and ferrous technologies along the Silk Routes] Sichou Zhilu yu zaoqi tong tie jishu jiaoliu,” *Xiyu Yanjiu*, no. 2 (2018).

It is worth noting that a new trend of scholarship has recently emerged that investigates early metallurgy in China through an integrated regional/emeric perspective, taking into account research results obtained through a variety of methods and techniques and acknowledging the significance of long-distance interaction and exogenous technological stimulation. Highlighting the importance of local technological developments and innovation,<sup>8</sup> natural and cultural landscapes,<sup>9</sup> and the various roles of local societies involved in the regional interaction networks,<sup>10</sup> these studies shed new light on this longstanding and to some extent stagnant debate on the development and spread of metallurgy across Eurasia.

In this paper, we shall start with a brief re-evaluation of new evidence from Northwest China (mainly the Hexi Corridor, [Figure 1](#)) within an updated temporal-spatial framework, highlighting technological evidence for the beginning and early development of copper and bronze metallurgy in the area. The distinctiveness of the archaeological culturally different regions as well as their interconnectedness will then be examined to reveal the diachronic and diverse developmental processes of early metallurgies in China within their local social context. Finally, the adaption to local resources and social-cultural contexts will be argued to be a crucial factor in the rise of a fundamentally new metallurgical tradition in the Central Plain of China. .

### **Hexi Corridor: identifying the earliest local metal production in China**

Comprising the transition zone between the Loess, Qinghai-Tibetan, and Inner Mongolian Plateaus, the Hexi Corridor was a key intersection of pathways within the prehistoric transcontinental interaction network and on the historic Silk Road.<sup>11</sup> Having recognized the notably earlier date and distinctive typological features of metal objects unearthed from the Hexi Corridor and neighbouring area, An Zhimin pointed out in his pioneering work published in 1993 that “early copper artefacts quite possibly originated from or came into China through the prehistoric Silk Road”.<sup>12</sup> Thenceforward, the growing body of archaeological evidence from the Eurasian steppe to the Central Plain of China suggests the existence of several routes of the early transmission of metallurgy, most, if not all of which were considered to have run through the Hexi Corridor.<sup>13</sup> Archaeometallurgical research has identified a considerable proportion of unalloyed and arsenical copper among the objects from the Hexi Corridor dated to the first part of the 2<sup>nd</sup> millennium BCE, suggesting an

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<sup>8</sup> Mei, "Qijia and Seima-Turbino: The Question of Early Contacts between Northwest China and the Eurasian Steppe."; "中國早起冶金技術研究新進展 Zhongguo zaoqi yejin jishu yanjiu xin jinzhan," in *Keji Kaogu (III)*, ed. Institute of Archaeology Archaeological Science Center, Chinese Academy of Social Sciences (Beijing: Science Press, 2011).

<sup>9</sup> Jaang, "The Landscape of China's Participation in the Bronze Age Eurasian Network."

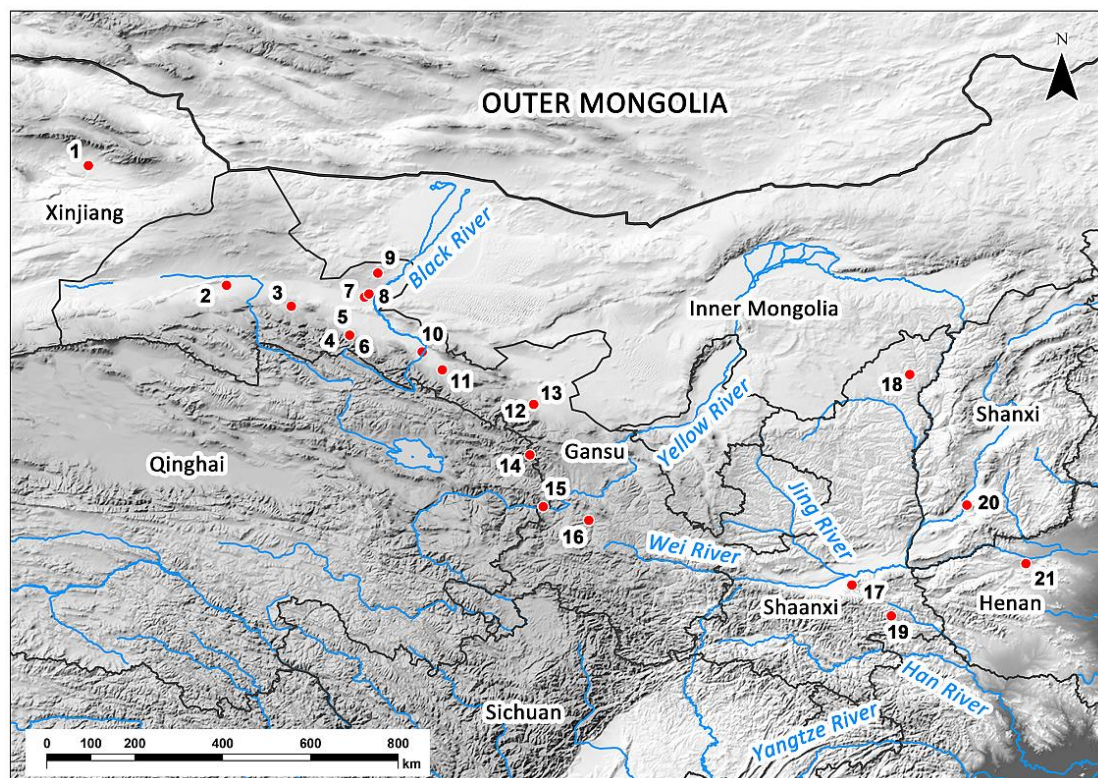
<sup>10</sup> Guoke Chen, "西城驛—齊家冶金共同體：河西走廊地區早期冶金人群及其相關問題初探 [Xichengyi-Qijia Metallurgical complex: preliminary research on the early metallurgical societies in Hexi Corridor] Xichengyi-Qijia yejin gongtongti: Hexi zoulang diqu zaoqi yejin renqun jiqi xiangguan wenti chutan," *kaogu yu Wenwu*, no. 5 (2017).

<sup>11</sup> For example, Xinru Liu and Lynda Shaffer, *Connections across Eurasia: Transportation, Communication, and Cultural Exchange on the Silk Roads* (New York, NY: McGraw-Hill, 2007); Guanghui Dong et al., "Exploring the History of Cultural Exchange in Prehistoric Eurasia from the Perspectives of Crop Diffusion and Consumption," *Science China Earth Sciences* 60, no. 6 (2017).

<sup>12</sup> Zhimin An, "試論中國的早期銅器[On early copper and bronze artifacts in China] Shilun zhongguo de zaoqi tongqi," *Kaogu (Archaeology)*, no. 12 (1993): 1117.

<sup>13</sup> For example, Fitzgerald-Huber, "Qijia and Erlitou: The Question of Contacts with Distant Cultures."; Shuicheng Li, "西北中原早起冶銅業的區域特徵及交互作用 [The regional characteristics and interaction of early metallurgical industries in the northwest and the Central Plains] Xibeiji Zhongyuan Zaoqi Yetongye De Quyu Tezheng Ji Jiaohu Zuoyong," *Kaogu Xuebao*, no. 3 (2005); Mei, "中國早期冶金技術研究新進展 [Advances on the research of early metallurgical technology in China] Zhongguo zaoqi yejin jishu yanjiu xinjinzhan."

“initiatory state of metallurgical development”.<sup>14</sup> While the previous understanding of early metallurgy in the Hexi Corridor was largely established from artefact-based typological comparison and chemical analysis with limited information on the *chaînes opératoires*<sup>15</sup> of metal production in the various locations, recent discoveries and research on production remains from the Xichengyi site and its neighbouring areas provide crucial new evidence for a local metal production and its broader socio-economic context in the Hexi Corridor.



**Figure 1. Map of north China showing sites mentioned in the texts**

1. Tianshanbeilu, 2. Yingwoshu, 3. Huoshaogou, 4. Zhaobitan, 5. Ganguya, 6. Gaomuxudi, 7. Ganggangwa, 8. Huoshilian, 9. Baishantang, 10. Xichengyi, 11. Donghuishan, 12. Huangniangniangtai, 13. Haizangsi, 14. Jinchancou, 15. Lajia, 16. Xinzhuangping, 17. Laoniupo, 18. Shimao, 19. Donglongshan, 20. Taosi, 21. Erlitou

From 2007 to 2012, six seasons of survey in the Hexi Corridor were carried out by a joint

<sup>14</sup> Shuyun Sun and Rubin Han, "中國早期銅器的初步研究 [A preliminary study of early Chinese copper and bronze artifacts] Zhongguo zaoqi tongqi de chubu yanjiu," *Kaogu Xuebao*, no. 3 (1981); "甘肅早期銅器的發現與冶煉製造技術的研究 [Study of casting and manufacturing techniques of early copper and bronze artifacts found in Gansu] Gansu zaoqi tongqi de faxian yu yelian zhizao jishu de yanjiu," *Wenwu*, no. 7 (1997); Shuyun Sun, Wei Qian, and Hui Wang, "火燒溝四壩文化銅器成分分析機器製造技術研究 [On the chemical composition and manufacturing techniques of Siba Culture copper objects from Huoshaogou] Huoshaogou Siba wenhua tongqi chengfen fenxi jiqi zhizuo jishu yanjiu," *Wenwu (Cultural Relics)*, no. 7 (2003); Mei, "中國早期冶金技術研究新進展 [Advances on the research of early metallurgical technology in China] Zhongguo zaoqi yejin jishu yanjiu xinjinzhan." For detailed review please see Jianjun Mei et al., "Recent Research on Early Bronze Metallurgy in Northwest China," in *Scientific Research on Ancient Asian Metallurgy: Proceeding of the Fifth Forbes Symposium at the Freer Gallery of Art*, ed. Paul Jett, Blythe McCathy, and Janet G. Douglas (London: Archetype Publication, 2012); Jianjun Mei, "中國的早期銅器及其區域特徵 [Early copper objects in China and their regional characteristics] Zhongguo de zaoqi tongqi jiqi quyu tezhen," in *Zhongguoshi Xinlun: Gudai Wenming De Xingcheng Fence*, ed. Ming-chong Hwang (Taipei: Academia Sinica, 2016).

<sup>15</sup> B. S. Ottaway, "Innovation, Production and Specialization in Early Prehistoric Copper Metallurgy," *European Journal of Archaeology* 4, no. 1 (2001); Andreas Hauptmann, *The Archaeometallurgy of Copper: Evidence from Faynan, Jordan*, Natural Science in Archaeology (Berlin ; New York: Springer, 2007), 7-9.

team consisting of members of the Gansu Institute of Cultural Relics and Archaeology (GICA) and the Institute of Historical Metallurgy and Materials, University of Science and Technology Beijing (IHMM, USTB). Particular attention was paid to production debris in order to gain a direct and better understanding of ancient metal production activities in the region. The survey located a number of residential sites yielding metal production remains such as slag, tuyères, fragments of crucible/furnace lining, and ore, including finds at Xichengyi (previously known as Heishuiguo) in Zhangye County, Xitugou in Dunhuang, and Ganggangwa, Huoshiliang, and Baishantang in Jinta County (Figure 1).<sup>16</sup> Because of the particularly rich findings at Xichengyi, excavations were launched at the site in 2010.

Located in the middle of the Hexi Corridor, the Xichengyi site covers about 35 ha of suburban land in northwest of the Zhangye City. The earliest occupation of the site can be dated back to the late Machang period (ca. 2,200 BCE), and it was continuously inhabited as a settlement until around 1,500 BCE as ceramic material generally associated with the archaeological cultures/phases of Xichengyi (the second phase, ca. 2,000-1,700 BCE, previously known as the “transitional type”) and Siba (the third phase, ca. 1,700-1,500 BCE).<sup>17</sup> Four years of excavation (2010-13) in an area of 1,350 m<sup>2</sup> at Xichengyi revealed abundant archaeological features, including house foundations, walls, oven pits, tombs, and ash pits, together with thousands of items of pottery, stone, bone, copper, jade, and also charred seeds. While the recovered mud-brick wall and macrofossil evidence of wheat and barley suggest its close connection with the Eurasian steppe,<sup>18</sup> the continuing presence of metallurgical remains since the first phase (late Machang), carbon dated back to cal. 2,135-2,035 BCE,<sup>19</sup> securely identified Xichengyi as one of the earliest known sites practising metallurgy in the Hexi Corridor and even in East Asia.<sup>20</sup>

Comprising ores, crucible/furnace lining, tuyères, slag, moulds, and metal objects, the finds at Xichengyi present evidence for a relative complete metallurgical *chaîne opératoire* from

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<sup>16</sup> Mei et al., "Recent Research on Early Bronze Metallurgy in Northwest China."; Chen, "新城驛—齊家冶金共同體：河西走廊地區早期冶金人群及其相關問題初探 [Xichengyi-Qijia Metallurgical complex: preliminary research on the early metallurgical societies in Hexi Corridor] Xichengyi-Qijia yejin gongtongti: Hexi zoulang diqu zaoqi yejin renqun jiqi xiangguan wenti chutan."; Yanxiang Li et al., "敦煌西土溝遺址冶金遺物研究 [Research of the metallurgical remains in the Xitugou site at Dunhuang] Dunhuang xitugou yizhi yejin yiwu yanjiu," *Dunhuang Yanjiu*, no. 2 (2018).

<sup>17</sup> Chen et al., "甘肅張掖西城驛遺址 [The Xichengyi site in Zhangye, Gansu] Gansu Zhangye Xichengyi yizhi."; Guoke Chen et al., "甘肅張掖市西城驛遺址 2010 年發掘簡報 [Brief report of 2010 season's exaction at Xichengyi site, Zhangye, Gansu], Kaogu (Archaeology) Gansu Zhangye shi Xichengyi yizhi 2010 nian fajue jianbao," *ibid.*, no. 10 (2015). For a discussion on “transitional type” please see Shuicheng Li, "河西地區新見馬家窯文化遺存及其相關問題 [Majiayao culture and the related remains newly found in the Hexi Corridor] Hexi diqu xinjian Majiayao wenhua yicun jiqi xiangguan wenti," in *Su Bingqi Yu Zhongguo Dangdai Kaoguxue*, ed. Bai Su (Beijing: Science Press, 2001); Liangren Zhang and Hui Wang, "張掖市西城驛遺址的彩陶 [On the paited pottery from the Xichengyi, Zhangye] Zhangye shi Xichengyi yizhi de caitao," *Beifang minzu kaogu* 2, no. 1 (2015).

<sup>18</sup> For example Enrico Fodde, "Traditional Earthen Building Techniques in Central Asia," *International Journal of Architectural Heritage* 3, no. 2 (2009); R. Spengler et al., "Early Agriculture and Crop Transmission among Bronze Age Mobile Pastoralists of Central Eurasia," *Proc Biol Sci* 281, no. 1783 (2014); Xinyi Liu et al., "The Virtues of Small Grain Size: Potential Pathways to a Distinguishing Feature of Asian Wheats," *Quaternary International* 426 (2016).

<sup>19</sup> Xuelian Zhang et al., "張掖市西城驛遺址的碳十四測年及其初步分析 [Carbon dating of Xichengyi site in Zhangye and preliminary analysis of related issues] Zhangye shi Xichengyi yizhi de tanshi cenian jiqi chubu fenxi," *Huaxia Kaogu*, no. 4 (2015).

<sup>20</sup> Chen et al., "Gansu Zhangye Xichengyi Yizhi."; Hong Xu, "從仰韶到齊家—東亞大陸早期用銅遺存的新觀察 [From Yangshao to Qijia: new observation on the early copper using remain in east Asia] Cong Yangshao dao Qijia -- dongya dalu zaoqi yongtong yicun de xinguan cha," *Zhongguo shehui kexue yuan gudai wenming yanjiu zongxin tongxun*, no. 29 (2016).

selection and processing of ore, smelting of raw metal to casting, manipulation and use of metal objects, which is crucial for understanding the production and consumption of metal during the first centuries of the Hexi Corridor's encounter with this novel material. Li Yanxiang and his colleagues reported analytical results of metallurgical remains, including 32 slag samples, 29 ore samples, and 5 crucible/furnace lining fragments from Xichengyi which are mainly attributed to the second and third phases (c. 2,000-1,500 BCE) of the site. All slag samples analysed by them have a similar iron silicate matrix with copper concentration ranges from 1 wt % to 35 wt%. They can be clearly divided into two groups on the basis of their different metallic inclusions, namely pure copper, arsenical copper and matte (copper sulphide) in the form of small particles or prills. In most of the slag samples (27 of 32), pure copper prills are consistently found while matte prills are only occasionally identified. The remaining five samples are, however, dominated by arsenical copper prills (up to 30 wt% of arsenic) with some of them also containing notable amounts of iron and antimony. The analysis of five furnace lining samples shows similar patterns with only one sample having arsenical copper prills while the other four are dominated by pure copper prills. The ore samples from this site are mainly oxidized minerals of copper (26 of 29) with a small proportion of them (3 samples) being rich in arsenic and lead bearing minerals such as fahlore, cerussite, galena, and mimetite. They suggested that these two group of slags were the result of two separate metallurgical processes or two continuing stages of one process. Copper is very likely to have been smelted from relatively clean oxide copper ores and then mixed with polymetallic ores (i.e., ores containing other elements such as arsenic, antimony and lead in various concentrations) in a separate cementation or a continuing co-smelting process. The entire process therefore implies that the arsenical copper and other alloys were produced through intentional alloying rather than being the result of using naturally mixed ores.<sup>21</sup> To confirm this, further systematic geological surveys in the Hexi corridor would be needed in search for the mining sites supplying copper and arsenic bearing minerals.

The metal objects excavated from Xichengyi site consist mainly of small implements and ornaments including awls, knives, bracelets, buttons, and tubular beads.<sup>22</sup> Despite the discovery of slag, no metal object has been found so far in the first phase. Li Yanxiang and his colleagues analysed 34 metal objects and the results revealed a pattern of mainly unalloyed copper (22) complemented by the arsenical copper (Cu-As, 9), tin bronze (Cu-Sn, 2) and antimony copper (Cu-Sb, 1). No obvious correlation between the object types and their material becomes apparent.<sup>23</sup> Xichengyi's early metals resemble early metal objects from the neighbouring areas in technical features,<sup>24</sup> but from the second to the third phase, a decrease of unalloyed copper objects from over 80% (17 of 21) to below 40% (5 of 13) and an increase

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<sup>21</sup> Li et al., "張掖西城驛遺址冶鑄遺物研究 [Research on the metallurgical remains from the Xichengyi Site, Zhangye] Zhangye Xichengyi yizhi yezhu yiwu yanjiu."

<sup>22</sup> Chen et al., "甘肅張掖西城驛遺址 [The Xichengyi site in Zhangye, Gansu] Gansu Zhangye Xichengyi Yizhi."; Guoke Chen et al., "甘肅張掖市西城驛遺址 2010 年發掘簡報 [Brief report of 2010 season's exaction at Xichengyi site, Zhangye, Gansu] Gansu Zhangye shi Xichengyi yizhi 2010 nian fajue jianbao," *ibid.*, no. 10 (2015).

<sup>23</sup> Guoke Chen et al., "張掖西城驛遺址出土銅器的初步研究 [Preliminary research on the copper objects from the Xichengyi site in Zhangye] Zhangye Xichengyi yizhi chutu tongqi de chubu yanjiu," *Kaogu yu Wenwu*, no. 2 (2015).

<sup>24</sup> For example Sun and Han, "甘肅早期銅器的發現與冶煉製造技術的研究 [Study of casting and manufacturing techniques of early copper and bronze artifacts found in Gansu] Gansu zaoqi tongqi de faxian yu yelian zhizao jishu de yanjiu."; Sun, Qian, and Wang, "火燒溝四壩文化銅器成分分析及其製作技術研究 [On the chemical composition and manufacturing techniques of Siba Culture copper objects from Huoshaogou] Huoshaogou Siba wenhua tongqi chengfen fenxi jiqi zhizuo jishu yanjiu."

of alloys (mainly Cu-As) from over 20% (4 of 21) to below 60% (8 of 13) gives an intriguing impression of technical changes during the early centuries of the 2<sup>nd</sup> millennium BCE at Xichengyi. This observation supports the aforementioned argument of intentional alloying practice at Xichengyi as shown by the study of technological remains.<sup>25</sup>

Besides at Xichengyi, copper objects and technological remains have also been discovered at other sites in the western part of the Hexi Corridor dated to the late Machang and Xichengyi periods.<sup>26</sup> Systematic paleo-environmental studies in the region have also provided supporting evidence for the wide adoption of metal production across the region of the middle Hexi Corridor from the end of the 3<sup>rd</sup> millennium BCE.<sup>27</sup> Lead isotope analyses suggest that copper deposits, such as the mining site of Baishantang in the Northern Mountains of the Hexi Corridor (including Mazong, Heli, and Longshou Mountain ranges) were most likely explored as major source of ores for the metal production at these sites,<sup>28</sup> which again reflects the localised nature of the Hexi Corridor's early metallurgy.

The excavation and study at the Xichengyi site have substantially deepened our knowledge of early metal technology and highlighted the long-overlooked but crucial role of the middle catchment of the Heishui River (also referred as Ejin or Edsingol, [Figure 1](#)) in channelling the routes of exchange along the Hexi Corridor northward directly to the Eurasian steppe.<sup>29</sup> Although the current archaeological evidence doesn't allow us to trace the exact means by which metallurgy reached the Hexi corridor, metallurgical knowledge of mining, smelting, casting and working must have been transferred from the steppe region in the northern to the people along the Heishui River, which could have provide convenient means of transportation, such as the supply of mineral ores from the Northern Mountains. Further research is needed to reveal archaeological evidence for trade and contacts with the steppe people in the north via the Heishui River. Equally important is that the excavations at the Xichengyi site not only helped reconstruct the ceramic typological sequence from Machang through Xichengyi ("transitional type") into Siba,<sup>30</sup> but they also established a refined regional chronological framework based on a series of radiocarbon dating of more than 26

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<sup>25</sup> Li et al., "張掖西城驛遺址冶鑄遺物研究 [Research on the metallurgical remains from the Xichengyi Site, Zhangye] Zhangye Xichengyi yizhi yezhu yiwu yanjiu."

<sup>26</sup> Sun and Han, "甘肅早期銅器的發現與冶煉製造技術的研究[Study of casting and manufacturing techniques of early copper and bronze artifacts found in Gansu] Gansu zaoqi yongqi de faxian yu yelian zhizao jishu de yanjiu."; Li et al., "敦煌西土溝遺址冶金遺物研究 [Research of the metallurgical remains in the Xitugou site at Dunhuang] Dunhuang Xitugou yizhi yezhu yiwu yanjiu."

<sup>27</sup> John Dodson et al., "Early Bronze in Two Holocene Archaeological Sites in Gansu, Nw China," *Quaternary Research* 72, no. 3 (2009); Xiaoqiang Li et al., "The Impact of Early Smelting on the Environment of Huoshiliang in Hexi Corridor, Nw China, as Recorded by Fossil Charcoal and Chemical Elements," *Palaeogeography, Palaeoclimatology, Palaeoecology* 305, no. 1 (2011); Shanjia Zhang et al., "Copper Smelting and Sediment Pollution in Bronze Age China: A Case Study in the Hexi Corridor, Northwest China," *Catena* 156 (2017); Yang et al., "Copper Content in Anthropogenic Sediments as a Tracer for Detecting Smelting Activities and Its Impact on Environment During Prehistoric Period in Hexi Corridor, Northwest China."

<sup>28</sup> Dodson et al., "Early Bronze in Two Holocene Archaeological Sites in Gansu, Nw China."; Chen, "西城驛—齊家冶金共同體：河西走廊地區早期冶金人群及其相關問題初探 [Xichengyi-Qijia Metallurgical complex: preliminary research on the early metallurgical societies in Hexi Corridor] Xichengyi-Qijia yezhu yiwu yanjiu: Hexi zoulang diqu zaoqi yezhu renqun jiqi xiangguan wenti chutan."

<sup>29</sup> Fitzgerald-Huber, "Qijia and Erlitou: The Question of Contacts with Distant Cultures."; Jaang, "The Landscape of China's Participation in the Bronze Age Eurasian Network."

<sup>30</sup> Li, "河西地區新見馬家窯文化遺存機器相關問題 [Majiayao culture and the related remains newly found in the Hexi Corridor] Hexi diqu xinjian Majiayao wenhua yicun jiqi xiangguan wenti."; Zhang and Wang, "張掖市西城驛遺址的彩陶 [On the painted pottery from the Xichengyi, Zhangye], Beifang minzu kaogu (Archaeology of northern ethnicities) Zhangye shi Xichengyi yizhi de caitao."

samples,<sup>31</sup> drawing our attention to another well-known contemporaneous archaeological entity, the “Qijia culture” into discussion.

### **Reconsidering Qijia’s metalwork: chronology and technology**

Archaeologists now generally agree that the Qijia is a late Neolithic/Early Bronze Age archaeological culture dating to ca. 2,300 – 1,500 BCE, and that its distribution is centred in the upper Wei River Valley and middle and lower catchments of Tao and Huang Rivers, but Qijia-related sites have been found over a much broader territory of approximately 700 km east-west and 600 km north-south, including western Shaanxi, Gansu, Ningxia, eastern Qinghai, and central southern Inner Mongolia.<sup>32</sup> Up to now, about 500 metal objects, mainly small implements and ornaments have been recorded from Qijia sites, including Huangniangnianigtai, Haizangsi, Jinchankou, Qinweijia, Qijiaping, Xinzhuangping and Mogou, which are distributed in southern Gansu, eastern Qinghai and the eastern Hexi Corridor (Figure 1).<sup>33</sup> The remarkably rich metal finds from these Qijia sites have placed the Qijia culture in the centre of scholarly discussion on early metallurgy in China already decades ago. However, limited attention has been paid to the diachronic variation of Qijia’s metallurgy in spite of its extensive temporal-spatial dimension and diversity of metal artefacts associated with Qijia culture sites.

The accumulated archaeological evidence, especially the increasing number of <sup>14</sup>C dates, are providing an increasingly better understanding of the chronology of the Qijia culture and related archaeological phenomena, which facilitates further investigations into their metallurgical developments. Whereas previous research often treats Qijia metalwork like a monolithic entity representing the first arrival of metallurgy in China, a re-evaluation of archaeological materials suggests a different and more intricate scenario. A point that should firstly be emphasised is that metal-using was not an inherent trait of Qijia from the beginning, nor was it homogeneous in terms of its spatial occurrence. In his systematic study on the excavated materials from the Qijia culture in the 1980s, Zhang Zhongpei already noted that metal objects only appeared by the end of the first phase of Qijia (three phases were proposed for the whole periodization sequence) in the eastern Hexi Corridor.<sup>34</sup> Although his suggestion of a dating of the early second half of the third millennium BCE now appears to be too early, most of his observations on the relative chronology remain tenable. Recently, Chen Guoke has reassessed the chronology of early metal finds from Northwest China and proposed a phased sequence of development of metallurgy in the region.<sup>35</sup> Our research also provides an

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<sup>31</sup> Zhang et al., “張掖市西城驛遺址的碳十四側年及其初步分析 [Carbon dating of Xichengyi site in Zhangye and preliminary analysis of related issues] Zhangye shi Xichengyi yizhi de tanshi cenian jiqi chubu fenxi.”

<sup>32</sup> Institute of Archaeology Chinese Academy of Sciences IoA CASS, 中國考古學：夏商卷 [Archaeology of China: volume Xia and Shang] *Zhongguo kaoguxue: Xia Shang juan* (Beijing: Social Sciences Press of China, 2003), 535-57; Li Liu and Xingcan Chen, *The Archaeology of China: From the Late Paleolithic to the Early Bronze Age* (New York, NY: Cambridge University Press, 2012), 322-33; Xiaosan Chen, “河西走廊及其鄰近地區早期青銅時代遺存研究 [Research on the Early Bronze Age Cultures in the Hexi Corridor and Surrounding Areas] Hexi Zoulang jiqi linjin diqu zaoqi qingtong shidai yicun yanjiu” (Jilin University, 2012), 47-79.

<sup>33</sup> Mei, “Zhongguo De Zaoqi Tongqi Jiqi Quyu Tezheng.”; Lu Wang, “甘青地區早期銅器的科學分析研究 [Scientific Study on Early Copper and Bronze Objects in Gansu-Qinghai Region] Gan-Qing diqu zaoqi tongqi de kexue fenxi yanjiu” (University of Science and Technology Beijing, 2018).

<sup>34</sup> Zhongpei Zhang, “齊家文化研究（下） [On the Qijia Culture, Second Part] Qijia wenhua yanjiu (xia),” *Kaogu Xuebao*, no. 2 (1987).

<sup>35</sup> Guoke Chen, “齊家文化與四壩文化銅器年代再認識 [Reconsideration of the Chronology of Copper Objects from the Qijia and Siba Cultures] Qijia wenhua yu Siba wenhua tongqi niandai zai renshi,” *Zhongguo shehui kexue yuan gudai wenming yanjiu zongxin tongxun*, no. 29 (2016).

updated summary of the radiocarbon dates of the relevant key sites using Oxcal Sum function (Figure 2), facilitating a refined chronological framework, which has taken into account also geographic location and archaeological horizons of the sites in question.

We suggest here that three phases are discernible representing different developmental stages of (trans-)regional metallurgy. The first phase, dating to ca. 2,300 – 2,000 BCE, saw the earliest arrival and adoption of metallurgy in Northwest China, reflected in the sporadic finds of copper objects such as those from Jiangjiaping, Zhaobitan, and Gaomuxudi<sup>36</sup> and, more directly, by the technological remains recovered at Ganggangwa and Xichengyi (first phase) indicating local production.<sup>37</sup> All these sites are settlements containing Machang rather than Qijia type ceramics. The second phase saw the proliferation of metal production in the middle Hexi Corridor during ca. 2,000 – 1,700 BCE, as demonstrated by a notable increase of metallurgical remains such as slag at Xichengyi, Huoshiliang, and other sites along the Heishui River.<sup>38</sup> Metal objects were used more widely than previous phase as evidenced by the finds from the Qijia sites, firstly Huangniangniangtai and Haizangsi in the Hexi Corridor and then Zongri and Jinchankou in eastern Qinghai.<sup>39</sup> Scant finds of metal objects approximated coeval to this phase also were revealed at Shimao in northern Shaanxi, Taosi in southern Shanxi, Zhukaigou in southern Inner Mongolia, and Xinzhai in Henan.<sup>40</sup> The last phase, dating to ca. 1,700 – 1,500 BCE and being contemporaneous with the Siba and late Qijia cultures, witnessed remarkable progress in metallurgy in terms of both metal-using scale (number of sites and objects found) and technological skills (alloying, manipulating of artefacts).<sup>41</sup> While metal-using sites over most of northern China and the rise of Erlitou in the

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<sup>36</sup> Sun and Han, "甘肅早期銅器的發現與冶煉製造技術的研究 [Study of Casting and Manufacturing Techniques of Early Copper and Bronze Artifacts Found in Gansu] Gansu zaoqi tongqi de faxian yu yelian zhizao jishu de yanjiu."

<sup>37</sup> Dodson et al., "Early Bronze in Two Holocene Archaeological Sites in Gansu, Nw China."; Chen et al., "甘肅張掖市西城驛遺址 2010 年發掘簡報 [Brief Report of 2010 Season's Excavation at Xichengyi Site, Zhangye, Gansu] Gansu Zhangye shi Xichengyi yizhi 2010 nian fajue jianbao."

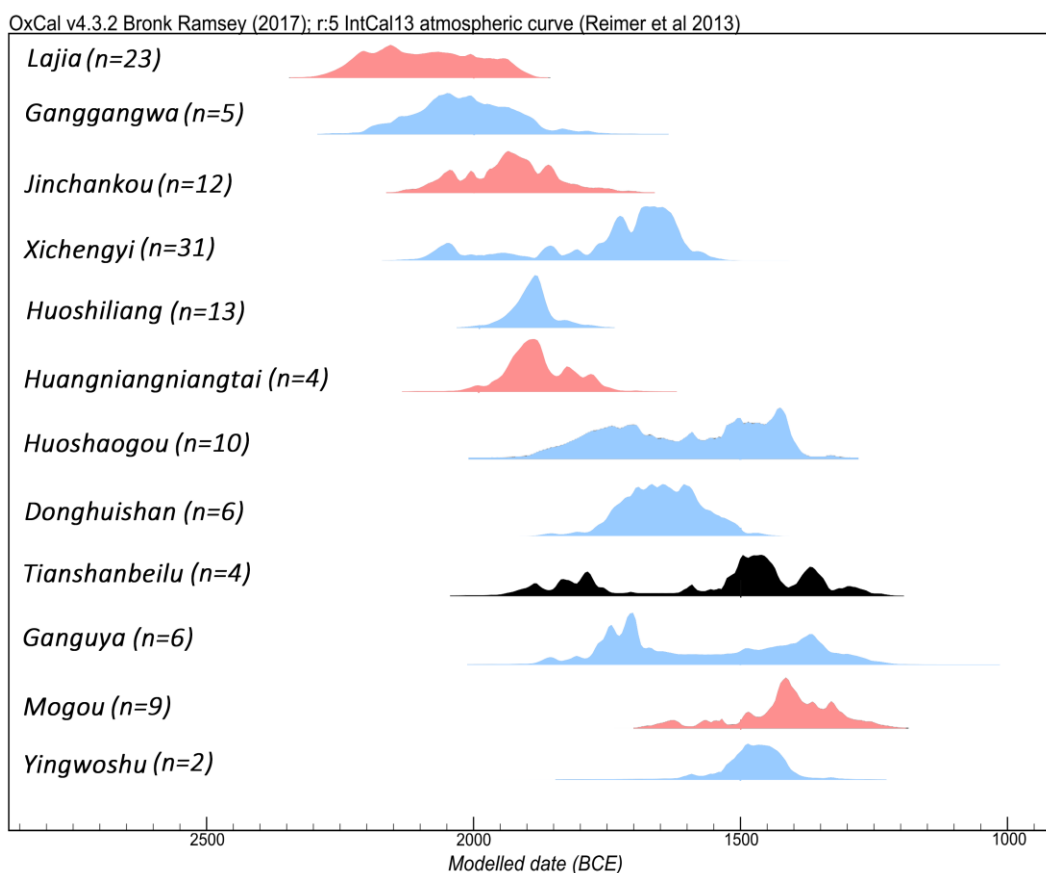
<sup>38</sup> Li et al., "張掖西城驛遺址冶鑄遺物研究 [Research on the Metallurgical Remains from the Xichengyi Site, Zhangye] Zhangye Xichengyi yizhi yezhu yiwu yanjiu."; Chen, "西城驛—齊家冶金共同體：河西走廊地區早期冶金人群及其相關問題初探 Xichengyi-Qijia yejin gongtongti: Hexi zoulang diqu zaoqi yejin renqun jiqi xiangguan wenti chutan."

<sup>39</sup> Sun and Han, "甘肅早期銅器的發現與冶煉製造技術的研究 [Study of Casting and Manufacturing Techniques of Early Copper and Bronze Artifacts Found in Gansu] Gansu zaoqi tongqi de faxian yu yelian zhizao jishu de yanjiu."; Jianwei Xu et al., "青海同德宗日遺址出土銅器的初步科學分析 [Preliminary Scientific Analysis of Copper Objects from Zongri Site, Tongde, Qinghai] Qinghai Tongde Zongri yizhi chutu tongqi de chubu kexue fenxi," *Xiyu Yanjiu*, no. 2 (2010); Wugan Luo, "對青海省若干遺址齊家文化銅器的考察 [Investigation on the Copper Objects from Several Qijia Sites in Qinghai] Dui Qinghaisheng ruogan yizhi Qijia wenhua tongqi de kaocha," *Zhongguo Wenwu Bao*, 2014-07-04 2014.

<sup>40</sup> Katheryn M. Linduff, "Zhukaigou, Steppe Culture and the Rise of Chinese Civilization," *Antiquity* 69, no. 262 (1995); Jiangtao Gao and Nu He, "陶寺遺址出土銅器初探 [Preliminary Exploration on Copper Objects from the Taosi Site] Taosi yizhi chutu tongqi chutan," *Nanfang Wenwu*, no. 1 (2014); Yu Liu, Jianyu Liu, and Chunqing Zhao, "河南新米新砦遺址出土銅器分析 [Analysis of Copper Objects Unearthed from Xinzhai, Xinmi, Henan] Henan Xinmi Xinzhai yizhi chutu tongqi fenxi," *ibid.* 4 (2016); Xu, "從仰韶到齊家—東亞大陸早期用銅遺存的新觀察 [From Yangshao to Qijia: New Observation on the Early Copper Using Remain in East Asia] Cong Yangshao dao Qijia -- Dongya dalu zaoqi yongtong yicun de xinguancha."; Sun et al., "The First Neolithic Urban Center on China's North Loess Plateau: The Rise and Fall of Shimao."; Xiaojuan Wang, "晉南地區新石器末期考古學文化 [On the Archaeological Cultures of Late Neolithic Southern Shanxi] Jinnan fiqu xinshiqi moqi kaoguxue wenhua," *Zhongyuan Wenwu*, no. 2 (2017).

<sup>41</sup> Sun, Qian, and Wang, "火燒溝四壩文化銅器成分分析及其製作技術研究 [On the Chemical Composition and Manufacturing Techniques of Siba Culture Copper Objects from Huoshaogou] Huoshaogou Siba wenhua tongqi chengfen fenxi jiqi zhizuo jishu yanjiu."; Mei et al., "Recent Research on Early Bronze Metallurgy in Northwest China."; Jianjun Mei et al., "Archaeometallurgical Studies in China: Some Recent Developments and Challenging Issues," *Journal of Archaeological Science* 56 (2015).

Central Plain heralding a new era of bronze industry in East Asia,<sup>42</sup> regional metal production in the Northwest declined after this period as suggested by archaeological and paleoenvironmental evidence revealing notable increasing of copper concentration in the anthropogenic sediments during this period.<sup>43</sup>



**Figure 2. Summary of radiocarbon dates of the relevant key sites using Oxcal Sum function**

Red: sites of the Qijia culture; blue: sites of the Machang-Xichengyi-Siba horizon. (Carbon data used for this figure can be found in Supplementary Table S2. This graph was created with help from Dr. Ruiliang Liu)

With regard to the technological features of the Qijia metals, previous analyses of 23 samples from Huangniangniangtai (13), Qinweijia (5) and the other sites in south-eastern Gansu indicated the prevalence of unalloyed copper (18 of 23) in contrast to the limited numbers of

<sup>42</sup> Hwang, "邁向重器時代：鑄銅技術的輸入與中國青銅技術的形成 [Toward an Age of Monumental Bronze: Importation and Formation of Bronze-Making Technology in China] *Maixiang zhongqi shidai: zhutong jishu de shuru yu Zhongguo qingtong jishu de xingcheng.*"; Mei, "中國的早期銅器機器區域特徵 [Early Copper Objects in China and Their Regional Characteristics] *Zhongguo de zaoqi tongqi jiqi quyu tezheng.*"

<sup>43</sup> Hui Wang, "甘青地區新石器—青銅時代考古學文化的譜系與格局 [On the Archaeological Sequences and Patterns of Neolithic and Bronze Ages Cultures in Gansu and Qinghai Region] *Ganqing diqu xinshiqi-qingtong shidai kaoguxue wenhua de puxi yu geju,*" in *Kaoguxue Yanjiu Jiu*, ed. School of Archaeology and Museology, Peking University (Beijing: Science Press, 2012); Yang et al., "Copper Content in Anthropogenic Sediments as a Tracer for Detecting Smelting Activities and Its Impact on Environment During Prehistoric Period in Hexi Corridor, Northwest China."; Zhang et al., "Copper Smelting and Sediment Pollution in Bronze Age China: A Case Study in the Hexi Corridor, Northwest China."

alloys (3 Cu-Sn, 1 Cu-Pb and 1 Cu-Sn-Pb).<sup>44</sup> These data has led to the assumption that Qijia's metallurgy experienced a developmental sequence from unalloyed copper to tin bronze,<sup>45</sup> which is distinct from the neighbouring Siba culture and many early metallurgical traditions in the Eurasian steppe for the absence of arsenical copper.<sup>46</sup> Recent identification of arsenical copper among the objects from several Qijia sites including Zongri, Jinchankou, Mogou, and Gamatai, however, indicates the continuing existence of this alloy in the middle and late phases of the Qijia culture.<sup>47</sup> It is then necessary and instructive to reassess the material in question by considering the results of more recent analyses and examining them within the updated chronological sequence proposed here (Figure 2).

In approaching technological landscapes of metallurgy of Qijia and related archaeological cultures in the region, namely Machang, Xichengyi, and Siba, 268 chemical compositional results (quantitatively and qualitatively) from more than 17 sites were collected and categorised to show the comparative percentages of unalloyed copper, arsenical copper, tin bronze, and other copper-based materials (Figure 3). Generally, samples from the late Machang-Xichengyi and middle Qijia sites are all dominated by unalloyed copper (more than 80%) complemented by a small number of alloyed items, mainly arsenic-related ones. In the early Siba period, the results of chemical analyses reveal a substantial drop in the percentage of unalloyed copper items and the increase of alloyed copper-based materials consisting mainly of arsenic copper and some tin bronze. It is worth mentioning that we are currently lacking material from contemporaneous Qijia sites to Huoshaogou and Siba, which leads to the expression of less arsenic copper in late Qijia sites. The later period of both Qijia and Siba saw a continuing decrease of alloyed copper while tin bronze (leaded or not) became the most common material accounting for more than 60% of analysed samples.

Although still preliminary, the observations presented here on the basis of combining 14C dates and archaeometallurgical analyses have enabled us to understand more clearly diachronic changes of early metallurgy during its development in Northwest China. Current evidence reveals a general trajectory of development in material choice from unalloyed copper to arsenical copper and tin bronze around the mid-second millennium BCE. The increase of arsenical copper artefacts corresponds with the identification of slags containing arsenical copper prills at several sites such as Xicheng and Xitugou,<sup>48</sup> which suggests

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<sup>44</sup> Sun and Han, "中國早期銅器的初步研究 [Preliminary Study of Early Chinese Copper and Bronze Artifacts] Zhongguo zaoqi tongqi de chubu yanjiu."; "甘肅早期銅器的發現與冶煉製造技術的研究 [Study of casting and manufacturing techniques of early copper and bronze artifacts found in Gansu] Gansu zaoqi tongqi de faxian yu yelian zhizao jishu de yanjiu."

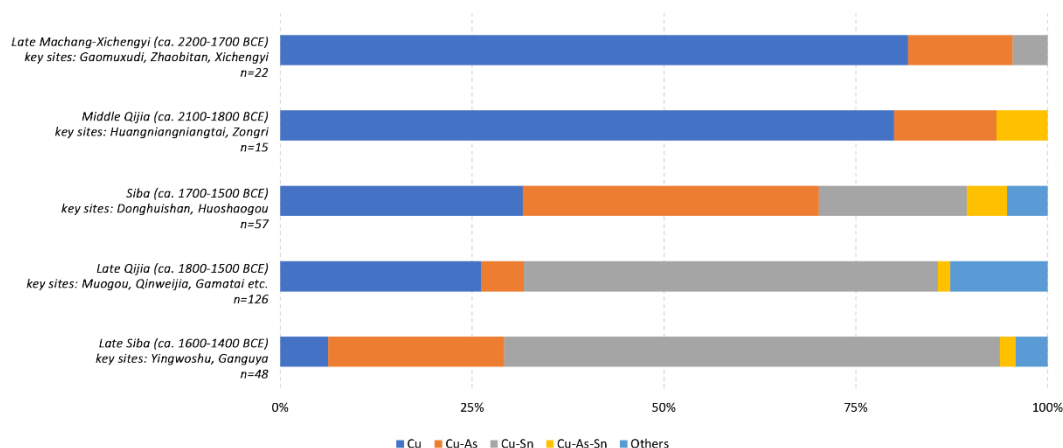
<sup>45</sup> Zhang, "Qijia wenhua yanjiu (Xia)."; Mingyu Teng, "中國早期銅器有關問題的再探討 [Re-discussion on the Early Copper Objects in China] Zhongguo zaoqi tongqi youguan wenti de zai tantao," *Beifang Wenwu*, no. 2 (1989).

<sup>46</sup> Shuicheng Li, "Ancient Interactions in Eurasia and Northwest China: Revisiting J G Andersson's Legacy," *Bulletin-Museum of Far Eastern Antiquities*, no. 75 (2003); Linduff, "How Far Does the Eurasian Metallurgical Tradition Extend."; Li, "西北及中原早期冶銅業的區域特徵及交互作用 [Regional Characteristics and Interaction of Early Metallurgical Industries in the Northwest and the Central Plains] Xibei ji zhongyuan zaoqi yetongye de quyue tezheng ji jiaohu zuoyong."

<sup>47</sup> Xu et al., "青海同德宗日遺址出土銅器的初步科學分析 [Preliminary Scientific Analysis of Copper Objects from Zongri Site, Tongde, Qinghai] Qinghai Tongde Zongri yizhi chutu tongqi de chubu kexue fenxi."; Mei et al., "Recent Research on Early Bronze Metallurgy in Northwest China."; Luo, "對青海省若干遺址齊家文化銅器的考察 [Investigation on the Copper Objects from Several Qijia Sites in Qinghai] Dui Qinghaisheng ruogan yizhi Qijia wenhua tongqi de kaocha."; Wang, "甘青地區早期銅器的科學分析研究 [Scientific Study on Early Copper and Bronze Objects in Gansu-Qinghai Region] Gan-Qing diqu zaoqi tongqi de kexue fenxi yanjiu."

<sup>48</sup> Li et al., "張掖西城驛遺址冶鑄遺物研究 [Research on the Metallurgical Remains from the Xichengyi Site,

deliberate alloying through cementation. In the absence of technological remains, however, our knowledge of production of tin bronze in the later period remains limited. While one should be warned of the trap of linear mechanical evolution of technology, it is instructive to see that current data shows considerable similarities among coterminous sites, rather than favour the previously suggested various “technological features” relative to distinct archaeological cultures.



**Figure 3. Comparative percentages of unalloyed copper, arsenical copper, tin-arsenical bronze and tin bronze from different early metal-using archaeological cultures in Northwest China (n = 268).**

Therefore, Qijia metalwork can be more appropriately understood as one of the episodes of the whole story of adoption and development of the technology in Northwest China, which can now be traced back securely to the late Machang period during the end of the third millennium BCE.<sup>49</sup> The indistinguishable similarity of metalwork between Qijia and Machang-Xichengyi-Siba communities have recently led to the proposal of the concept of a regional trans-cultural “Ejin River Transfer Zone” or “Xichengyi-Qijia Metallurgical Complex”,<sup>50</sup> comparable to Chernykh’s “Metallurgical Province”, in order to emphasise the intimate relationship between these groups, in particular in terms of metallurgical traditions. At the same time, it has been argued that the pottery typologies used as one of the key factors to define an archaeological culture, were “no more than evidence of the adoption of a new technology”.<sup>51</sup>

### Metallurgy reshaped: technology transmission and its social-economic dynamics

Zhangye] Zhangye Xichengyi yizhi yezhu yiwu yanjiu.”; Li et al., “敦煌西土溝遺址冶金遺物研究 [Research of the Metallurgical Remains in the Xitugou Site at Dunhuang] Dunhuang Xitugou yizhi yezhu yiwu yanjiu.”

<sup>49</sup> For example, Chen, “齊家文化與四壩文化銅器年代再認識 [Reconsideration of the Chronology of Copper Objects from the Qijia and Siba Cultures] Qijia wenhua yu Siba wenhua tongqi niandai zai renshi.”; Xu, “從仰韶到齊家—東亞大陸早期用銅遺存的新觀察 [From Yangshao to Qijia: New Observation on the Early Copper Using Remain in East Asia] Cong Yangshao dao Qijia -- Dongya dalu zaoqi yongtong yicun de xinguancha,” *ibid.*

<sup>50</sup> Jaang, “The Landscape of China’s Participation in the Bronze Age Eurasian Network.”; Chen, “西城驛—齊家冶金共同體：河西走廊地區早期冶金人群及其相關問題初探 [Xichengyi-Qijia Metallurgical Complex: Preliminary Research on the Early Metallurgical Societies in Hexi Corridor] Xichengyi-Qijia yezhujongtongti: Hexi zoulang diqu zaoqi yezhu renqun jiqi xiangguan wenti chutan.”

<sup>51</sup> Jaang, “The Landscape of China’s Participation in the Bronze Age Eurasian Network.”

Despite the long-standing dispute between autonomism and diffusionism as models for explaining the emergence and development of metallurgy in East and Central Asia,<sup>52</sup> the “western influence” on China’s early copper metalworking has recently gained prevalent recognition among archaeological narratives.<sup>53</sup> Several routes have been proposed for the transmission of metallurgy from the Eurasian steppe to Northwest China, through the piedmont strips and river valleys ranging from Minusinsk/Altai, eastern Xinjiang/Mongolian Gobi Desert.<sup>54</sup> As might be expected, these models are not mutually exclusive, given the indirect and punctuated nature of prehistoric long distance interactions illustrated by the co-existence of various steppe/Central Asia elements of distinct sources among the cultures in Northwest China,<sup>55</sup> though recent discoveries of metal production remains in middle Hexi Corridor favour the route along the Heishui River valley channelling the south Gobi Desert.<sup>56</sup> However, the significance of these discoveries is, as we understand, far beyond merely emboldening another arrow-headed line in the map. More crucially, they provide archaeologically attested evidence of localised metalwork practised by local communities, and thus enables further investigation into the early transmission and adoption of metallurgy viewed within a broader social-economic context.

The production and use of metals require a series of complex operations including prospection, extraction, and processing of ores, smelting of raw metal, and manipulation of objects. It involves complex chemical and physical transformations of materials which only allow a fairly narrow margin of error or else the entire process would fail.<sup>57</sup> Whereas sporadic presences of extraneous finished metal artefacts might result from chance encounters with outsiders, a venture of manipulating this novel material would necessitate conscious endeavour of the local communities due to the strict requirements whereby metallurgical repertoire could be successfully adopted. It is suggested that transmission of metallurgical

<sup>52</sup> For detailed review, please see Mei et al., "Recent Research on Early Bronze Metallurgy in Northwest China."; Mei, "中國的早期銅器機器區域特徵 [Early Copper Objects in China and Their Regional Characteristics] *Zhongguo de zaoqi tongqi jiqi quyu tezheng*."

<sup>53</sup> Li, "西北及中原早期冶銅業的區域特徵及交互作用 [Regional Characteristics and Interaction of Early Metallurgical Industries in the Northwest and the Central Plains] *Xibei ji zhongyuan zaoqi yetongye de quyu tezheng ji jiaohu zuoyong*"; Chi Zhang, "龍山—二里頭：中國史前文化格局的改變與期銅時代全球化的形成 [Longshan-Erlitou: Cultural Framework in Prehistory China and the Emergence of Bronze Age Globalisation] *Longshan-Erlitou: Zhongguo shiqian wenhua geju de gaibian yu qingtong shidai quanqiu hua de xingcheng*." *Wenwu*, no. 6 (2017); Katheryn M. Linduff et al., *Ancient China and Its Eurasian Neighbors: Artifacts, Identity and Death in the Frontier, 3000–700 Bce* (Cambridge: Cambridge University Press, 2017), 44-50; Jianjun Mei et al., "The Appropriation of Early Bronze Technology in China," in *Appropriating Innovations: Entangled Knowledge in Eurasia, 5000-1500 Bce*, ed. Philipp Stockhammer and Joseph Maran (Oxbow Books, 2017).

<sup>54</sup> Fitzgerald-Huber, "Qijia and Erlitou: The Question of Contacts with Distant Cultures."; Jianjun Mei, "Cultural Interaction between China and Central Asia During the Bronze Age," *Proceedings of the British Academy* 121 (2003); Li, "西北及中原早期冶銅業的區域特徵及交互作用 [Regional Characteristics and Interaction of Early Metallurgical Industries in the Northwest and the Central Plains] *Xibei ji zhongyuan zaoqi yetongye de quyu tezheng ji jiaohu zuoyong*"; J. Rawson, "Shimao and Erlitou: New Perspectives on the Origins of the Bronze Industry in Central China," *Antiquity* 91, no. 355 (2017).

<sup>55</sup> Fitzgerald-Huber, "Qijia and Erlitou: The Question of Contacts with Distant Cultures."; Mei, "Qijia and Seima-Turbino: The Question of Early Contacts between Northwest China and the Eurasian Steppe."

<sup>56</sup> Jaang, "The Landscape of China’s Participation in the Bronze Age Eurasian Network."; Chen, "西城驛—齊家冶金共同體：河西走廊地區早期冶金人群及其相關問題初探 [Xichengyi-Qijia Metallurgical Complex: Preliminary Research on the Early Metallurgical Societies in Hexi Corridor] *Xichengyi-Qijia yejin gongtongti: Hexi zoulang diqu zaoqi yejin renqun jiqi xiangguan wenti chutan*."

<sup>57</sup> See Thomas Stöllner, "Mining and Economy—a Discussion of Spatial Organisation and Structures," in *Man and Mining - Mensch Und Bergbau. Studies in Honour of Gerd Weisgerber on Occasion of His 65th Birthday.*, ed. T. Stöllner, et al. (Bochum: Deutsches Bergbau-Museum Bochum, 2003), 7-9; Hauptmann, *The Archaeometallurgy of Copper: Evidence from Faynan, Jordan*.

expertise required a process of verbal and practical learning and could only have been achieved through apprenticeships in the pre-literate societies.<sup>58</sup> Furthermore, although the techniques are considered transferable, the initiation of metal production would involve access to raw materials, such as ore and fuel. Given the complexity and collective nature of metallurgical process, this would mean inevitable alterations to the previous systems of subsistence and craftsmanship. Even for the initial stage of metallurgy, for which a pluralistic household scale metalworking has been suggested in case of the Xichengyi site,<sup>59</sup> a commitment of the broader community to aid in the procurement of means of subsistence as well as production and acquisition of the facilities and tools would have been necessary.<sup>60</sup>

At the same time, the type of metallurgy received from the outside would have been reshaped by the adaption to new natural resources and, more importantly, by the ideas and requirements of local communities embedded within existing cultural and economic traditions. Based on the typological similarities of metal objects from the Hexi Corridor with items found further north, Fitzgerald-Huber and Jaang have ascribed the motivation of early localised metal production along the Heishui River Valley and its surrounding areas to the purpose of trading and exchanging with the pastoralists in the Eurasia steppe.<sup>61</sup> The observed similarity in object types is undoubtedly intriguing; however, at present their explanation should be treated as a hypothesis and then tested by further empirical provenance study. Furthermore, archaeological evidence has also revealed some discernible local features in the metallurgy of Northwest China. For instance, the deliberate production of arsenic copper by a cementation process required separation and beneficiation of ores rich in arsenic which could only be achieved with better understanding of local ore deposits,<sup>62</sup> and the appearance of objects that are typologically distinct from steppe items such as mirrors decorated with geometric patterns, plaques and certain types of knives manifest the integration of diverse traditions and local innovation (Figure 4).<sup>63</sup>

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<sup>58</sup> Ben Roberts, "Migration, Craft Expertise and Metallurgy: Analysing The 'spread' of Metal in Western Europe," *Archaeological Review from Cambridge* 23, no. 2 (2008).

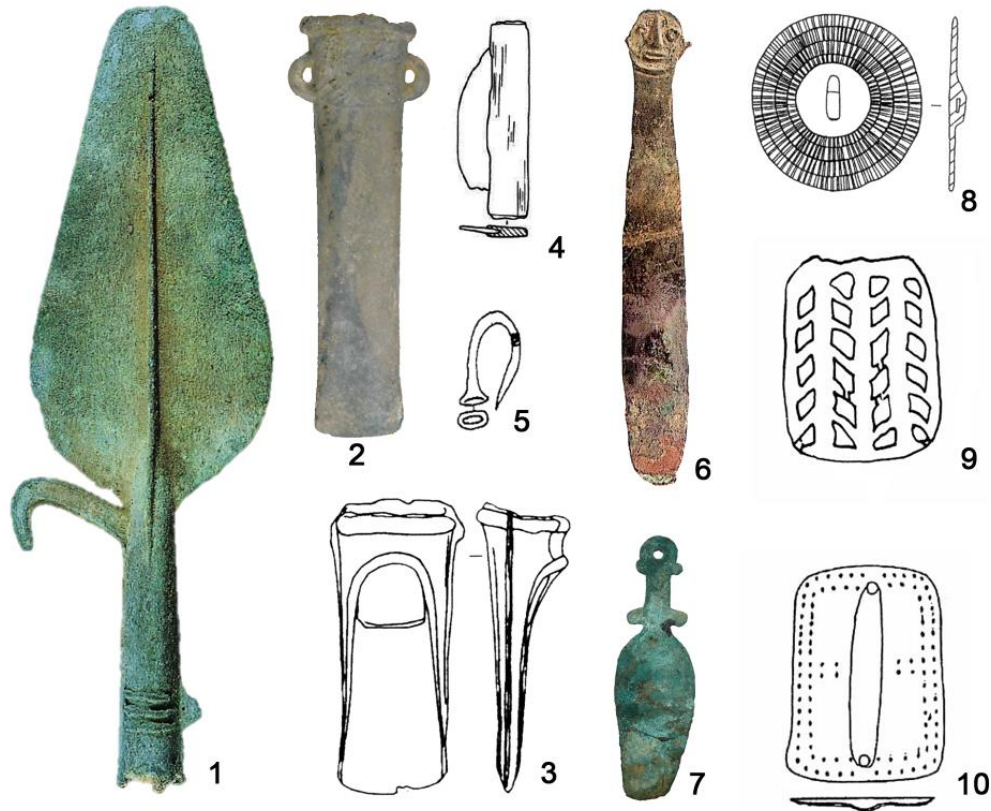
<sup>59</sup> Chen et al., "甘肅張掖市西城驛遺址 2010 年發掘簡報 [Brief Report of 2010 Season's Excavation at Xichengyi Site, Zhangye, Gansu] Gansu Zhangye shi Xichengyi yizhi 2010 nian fajue jianbao."; Jaang, "The Landscape of China's Participation in the Bronze Age Eurasian Network."

<sup>60</sup> Ben Roberts, "Creating Traditions and Shaping Technologies: Understanding the Earliest Metal Objects and Metal Production in Western Europe," *World Archaeology* 40, no. 3 (2008).

<sup>61</sup> Louisa G Fitzgerald-Huber, "The Qijia Culture: Paths East and West," *Bulletin-Museum of Far Eastern Antiquities*, no. 75 (2003); Jaang, "The Landscape of China's Participation in the Bronze Age Eurasian Network."

<sup>62</sup> Li et al., "張掖西城驛遺址業主遺物研究 [Research on the Metallurgical Remains from the Xichengyi Site, Zhangye] Zhangye Xichengyi yizhi yezhu yiwu yanjiu."; Guoke Chen et al., "張掖西城驛遺址出土銅器的初步研究 [Preliminary Research on the Copper Objects from the Xichengyi Site in Zhangye] Zhangye Xichengyi yizhi chutu tongqi de chubu yanjiu," *ibid.*

<sup>63</sup> Mei, "Qijia and Seima-Turbino: The Question of Early Contacts between Northwest China and the Eurasian Steppe."; "中國的早期銅器及其區域特徵 [Early Copper Objects in China and Their Regional Characteristics] Zhongguo de zaoqi tongqi jiqi quyue tezhenq."



**Figure 4. Copper/bronze objects discovered in Northwest China showing their similarities with items from the Eurasian Steppe (1-5) and local features (6-10)**

1. Spearhead (Shenna); 2. socketed axe (Xinglin); 3. socketed axe (Huoshaogou); 4. wood-handled knife (Weijiataizi); 5. earring with trumpet-shaped end (Huoshaogou); 6. spoon with human face pommel (Qijiaping); 7. spoon (Huoshaogou); 8. mirror/plate decorated with geometric patterns (Tianshanbeilu); 9. perforated plaque (Tianshanbeilu); 10. plaque decorated with punch points (Tianshanbeilu). Not in scale.

North-western and the northern parts of China are now generally seen as having played a crucial role in long-distance interaction and early dissemination of metallurgical knowledge between central China and the Eurasian steppe and beyond, thus acting as an intermediary.<sup>64</sup> Such a model is conceivable, given the fact of earlier adoption of metallurgy in the areas further northwest. Having said that, we argue here that the adaptation and incorporation of metallurgy into pre-existing local economic and social-cultural frameworks would have been equally important for the further transmission of knowledge and for sustaining the large-scale but punctuated and indirect networks of interactions across northern eastern Eurasia and beyond. As Kohl has pointed out for the Near East, technologies often were refined and developed further in the culturally peripheral frontier areas of the Bronze Age world systems, stimulating developments that ultimately had far-reaching consequences.<sup>65</sup> In the present case,

<sup>64</sup> Fitzgerald-Huber, "Qijia and Erlitou: The Question of Contacts with Distant Cultures," 216-19; Li, "西北及中原早期冶銅業的區域特徵及交互作用 [Regional Characteristics and Interaction of Early Metallurgical Industries in the Northwest and the Central Plains] Xibei ji zhongyuan zaoqi yetongye de quyue tezheng ji jiaohu zuoyong."; Mei, "Zhongguo zaoqi yeyin jishu yanjiu xinjinzhan."; Linduff et al., *Ancient China and Its Eurasian Neighbors: Artifacts, Identity and Death in the Frontier, 3000–700 Bce*.

<sup>65</sup> Phil Kohl, "The Ancient Economy, Transferable Technologies and the Bronze Age World-System: A View from the Northeastern Frontier of the Ancient Near East," in *Centre and Periphery in the Ancient World*, ed. Michael J. Rowlands, et al. (Cambridge: Cambridge University Press, 1987).

the Hexi Corridor of Northwest China, the frontier region between the Eurasian steppe and the Central Plain of China, would be better understood not merely as a geographic intermediate pathway but as an essential place whereby the metallurgical practise had been adapted through local production practices. Such a process would have been fundamental for the further eastward transmission and ultimately the adoption of metallurgy by the sedentary agricultural communities in the middle and low reaches of the Yellow River whose social-economic context was substantially distinct from that of the Eurasian pastoralist groups who were considered the source of the metal technology that reached Northwest China in the second millennium BCE.

Early metal-using cultures in Northwest China, especially the Qijia, actually had a deep-rooted association with the Neolithic communities in the Wei River Valley<sup>66</sup> and were actively involved in the interactions sphere of Neolithic China, defined as “contact, exchange of information and goods, and conflict” by Kwang-Chih Chang.<sup>67</sup> The presence of such an interaction sphere spanning from the Northwest to the Central Plains and further south (Figure 5), connecting various archaeological horizons has been proven by the shared millet-based agriculture,<sup>68</sup> the significance of jade in burial and ritual practices,<sup>69</sup> and the sharing of certain types of pottery.<sup>70</sup> As suggested by several convincing observations of regional interaction and technological transmission,<sup>71</sup> while the pre-existing interaction network laid the foundation for knowledge dissemination, the experiences of being practised by local communities in Northwest China would have supported the appropriation of metallurgy in the Central Plains given the high degrees of correspondence of cultural and economic elements between these different regions.

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<sup>66</sup> Fredrik Hiebert, Kakamurad Kurbansakhatov, and Hubert Schmidt, *A Central Asian Village at the Dawn of Civilization: Excavations at Anau, Turkmenistan*, vol. 116 (UPenn Museum of Archaeology, 2003), 86-8; Chen, "河西走廊及其鄰近地區早期青銅時代遺存研究[Research on the Early Bronze Age Cultures in the Hexi Corridor and Surrounding Areas] Hexi zoulang jiqi linjin diqu zaoqi qingtong shidai yicun yanjiu."

<sup>67</sup> Kwang-chih Chang, *The Archaeology of Ancient China* (New Haven, Conn.: Yale University Press, 1986), 243.

<sup>68</sup> For example Emma Lightfoot, Xinyi Liu, and Martin K. Jones, "Why Move Starchy Cereals? A Review of the Isotopic Evidence for Prehistoric Millet Consumption across Eurasia," *World Archaeology* 45, no. 4 (2013).

<sup>69</sup> Fitzgerald-Huber, "The Qijia Culture: Paths East and West."; Li Liu, "'The Products of Minds as Well as of Hands': Production of Prestige Goods in the Neolithic and Early State Periods of China," *Asian Perspectives* 42, no. 1 (2003).

<sup>70</sup> Liu and Chen, *The Archaeology of China: From the Late Paleolithic to the Early Bronze Age*, 330-3; Jianye Han, "論二里頭青銅文明的興起 [On the Rising of Broze Culture at Erlitou] Lun Erlitou qingtong wenming de qingqi," *Zhongguo Lishi Wenwu*, no. 1 (2009).

<sup>71</sup> Kohl, "The Ancient Economy, Transferable Technologies and the Bronze Age World-System: A View from the Northeastern Frontier of the Ancient near East."; Roberts, "Creating Traditions and Shaping Technologies: Understanding the Earliest Metal Objects and Metal Production in Western Europe."; Michael D. Frachetti, "Multiregional Emergence of Mobile Pastoralism and Nonuniform Institutional Complexity across Eurasia," *Current Anthropology* 53, no. 1 (2012).



**Figure 5. Map showing the distribution of major archaeological cultures and key sites during 3<sup>rd</sup> and 2<sup>nd</sup> millennia BCE<sup>72</sup>**

I. Majiyao-Xichengyi/Qijia; II. Laohushan; III. Xiaoheyang-lower Xiajiadian; IV. Longshan-Erlitou; V. Dawenkou-Shandong Longshan; VI. Baodun; VII. Qujialing-Shijiahe; VIII. Liangzhu

1. Xichengyi; 2. Huangniangninagtai; 3. Mougou; 4. Banshan; 5. Majiyao; 6. Baodun; 7. Laoniupo; 8. Donglongshan; 9. Shimao; 10. Zhukaigou; 11. Taosi; 12. Laohushan; 13. Qujialing; 14. Shijiahe; 15. Xinzhai; 16. Dawenkou; 17. Liangzhu; 18. Xiaoheyang

Sporadically, copper objects/fragments have been found in the late Neolithic sites in Henan and southern Shanxi dating to the early second millennium BCE,<sup>73</sup> approximately contemporaneous with the second phase of metallurgical development in Northwest China. The subsequent period witnessed the rise of metal use and production in the Central Plain, as shown by the finds from the Erlitou site (ca. 1,750-1,530 BCE). Several types of objects from Erlitou, such as single-edged knife and turquoise inlaid plaques can find their analogues or even prototypes in Northwest China, sustaining the discussion of the importance of inter-regional interaction for the emergence of early metallurgy in China (Figure 6).<sup>74</sup> Moreover, while tin bronze and unalloyed copper dominate the object assemblages of the late phases of Erlitou (ca. 1,650 – 1,530 BCE), arsenical-bearing copper objects and slag identified from the

<sup>72</sup> Based on Liu and Chen, *State Formation in Early China*, Figure 7.1.

<sup>73</sup> Xu, "從仰韶到齊家—東亞大陸早期用銅遺存新觀察 [From Yangshao to Qijia: New Observation on the Early Copper Using Remains in East Asia] Cong Yangshao dao Qijia -- Dongya dalu zaoqi yongtong yicun de xinguan." (2002);

<sup>74</sup> Yun Lin, "夏代的中國北方係青銅器 Xiandai de Zhongguo beifangxi qingtongqi," *Bianjiang Kaogu Yanjiu*, no. 1 (2002); Li, "西北及中原早期冶銅業的區域特徵及交互作用 [Regional Characteristics and Interaction of Early Metallurgical Industries in the Northwest and the Central Plains] Xibei ji zhongyuan zaoqi yetongye de quyu tezheng ji jiaohu zuoyong."; Jianjun Mei, "Early Metallurgy in China: Some Challenging Issues in Current Studies.," in *Metallurgy and Civilisation: Eurasia and Beyond*, ed. Jianjun Mei and Thilo Rehren (London: Archetype Publication, 2009); Xiaosan Chen, "試論鑲嵌綠松石牌飾的起源 [On the Origin of the Bronze Plaque with Turquoise Inlay] Shilun xiangqian lvsongshi paishi de qiyuan," *Kaogu yu Wenwu*, no. 5 (2013).

early phases and the pre-Erlitou site of Xinzhai (ca. 1800 BCE) recall the cementation technology by which arsenical copper were produced at Xichengyi and its surrounding areas.<sup>75</sup> Two major routes have been proposed for the transmission of metallurgical techniques from Northwest China to the Central Plain; a northern route along the catchment of the southward-flowing Yellow River, the central area of the so-called crescent-shaped region proposed by Tong Enzheng many years ago, is suggested on the basis of the finds from several famous sites such as Zhukaigou, Shimao, and Taosi.<sup>76</sup> Another long-suggested route is through the Wei River Valley.<sup>77</sup> Copper slag from the Laoniupo site, in spite of the slightly later date based on one radiocarbon samples from this local, has been revealed to be resulted from a cementation process of arsenical copper production which is similar to the Xichengyi ones.<sup>78</sup> Together with the slags from the Donglongshan site,<sup>79</sup> the Laoniupo finds provide an intermediary of potential technological correlation and continuity between northwest and central China.

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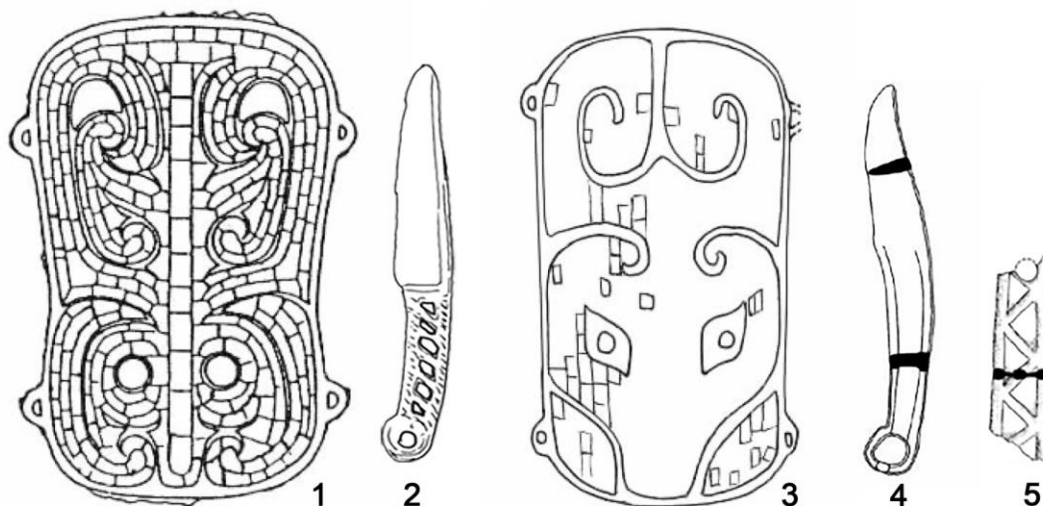
<sup>75</sup> Zhengyao Jin, "二里头青铜器的自然科学研究與夏文明探索 [Scientific Research of Bronze Objects from Erlitou and the Exploration to the Xia Civilization] Erlitou qingtongqi de ziran kexue yanjiu yu Xia wenming tansuo," *Wenwu*, no. 1 (2000); Honggang Liang, "二里头遗址出土青铜器的製作技術研究 [Study of Manufacturing Technique of Bronzes Unearthed from Erlitou Site] Erlitou yizhi chutu qingtongqi de zhizuo jishu yanjiu" (University of Science and Technology Beijing, 2004), 195-6; Liu, Liu, and Zhao, "河南新密新砦遗址出土銅器分析 [Analysis of Copper Objects Unearthed from Xinzhai, Xinmi, Henan] Henan Xinmi Xinzhai yizhi chutu tongqi fenxi."

<sup>76</sup> Mei, "中國的早期銅器技術區域特徵 [Early Copper Objects in China and Their Regional Characteristics] Zhongguo de zaoqi tongqi jiqi quyue tezheng."; Rawson, "Shimao and Erlitou: New Perspectives on the Origins of the Bronze Industry in Central China." In the work of Tong Enzheng, the crescent-shaped region is outlined as a large area sharing many cultural and geographic characteristics in relation to the Central Plains of China. Please see Enzheng Tong, "试论我国从东北之西南的边地半月形文化传播带 [On the crescent-shaped transition region of ancient cultures in China] Shilun woguo cong Dongbei zhi Xinan de biandi banyuexing wenhua chuanbodai", in *Zhongguo Xinan Minzu Kaogu Lunwenji*. ed. Enzheng Tong (Beijing: Wenwu Chubanshe, 1987).

<sup>77</sup> Fitzgerald-Huber, "Qijia and Erlitou: The Question of Contacts with Distant Cultures."; Han, "论二里头青铜文明的兴起 [On the Rising of Bronze Culture at Erlitou] Lun Erlitou qingtong wenming de xingqi."; Tian'en Zhang, "論關中東部的夏代早期文化遺存 [On the Early Xia Dynasty Archaeological Remains in Eastern Central Shaanxi] Lun Guanzhong dongbu de Xiandai zaoqi wenhua yicun," *ibid.*; Chen, "河西走廊及其鄰近地區早期青銅時代遺存研究 [Research on the Early Bronze Age Cultures in the Hexi Corridor and Surrounding Areas] Hexi zoulang jiqi linjin diqu zaoqi qingtong shidai yicun yanjiu," 172-9.

<sup>78</sup> Kunlong Chen et al., "Evidence of Arsenical Copper Smelting in Bronze Age China: A Study of Metallurgical Slag from the Laoniupo Site, Central Shaanxi," *Journal of Archaeological Science* 82 (2017).

<sup>79</sup> SIA and SLM, 商洛東龍山 [Archaeological Report of the Site of Donglongshan in Shangluo] *Shangluo Dong Longshan* (Beijing: Science Press, 2011), 186, plate 07:3.



**Figure 6. Similar bronze objects discovered on the Central Plain (1-2) and in Northwest China (3-5) showing technological connections between the two regions**

1, 2. Turquoise inlaid plaque and knife from Erlitou; 3. turquoise inlaid plaque found in Tianshui; 4. knife from Huoshaogou; 5: fragments of knife handle from Huangniangniangtai. Not in scale.

	Northwest China (ca. 21-15 C. BCE)	Central Plain (ca. 18-15 C. BCE)
<i>Object</i>	<ul style="list-style-type: none"> <li>• Personal ornaments</li> <li>• Small tools</li> <li>• Weapons</li> </ul>	<ul style="list-style-type: none"> <li>• Ritual vessels</li> <li>• Weapons</li> <li>• Small tools</li> </ul>
<i>Manufacture technique</i>	<ul style="list-style-type: none"> <li>• Stone mould casting</li> <li>• Hammering</li> </ul>	<ul style="list-style-type: none"> <li>• Clay mould casting</li> <li>• Hammering (mainly for finishing)</li> </ul>
<i>Alloys</i>	<ul style="list-style-type: none"> <li>• Early stage: copper and arsenical</li> <li>• Later stage: copper, tin bronze</li> </ul>	<ul style="list-style-type: none"> <li>• Copper and tin bronze (leaded)</li> <li>• Few arsenical copper (before 16<sup>th</sup> C. BCE)</li> </ul>
<i>Production scale and organization</i>	<ul style="list-style-type: none"> <li>• Household scale</li> <li>• Pluralistic handicrafts</li> <li>• No division of primary and secondary production</li> </ul>	<ul style="list-style-type: none"> <li>• Mass production (possible state control)</li> <li>• Specialised workshop</li> <li>• Division of primary smelting and secondary production</li> </ul>

**Table 1. Comparison of major features of early metal production in Northwest China and Central Plain**

However, it is again important not to over-emphasize the primacy of techniques in the further transmission of metallurgy and fall prey to the pitfalls of simplistic diffusionistic models and theories. In fact, on its way to eastward, the techniques of metallurgy have changed radically, with the development of a completely different technology at Erlitou.<sup>80</sup> Mining and primary smelting were carried out in the remote resource-rich mountainous areas,<sup>81</sup> while raw metals

<sup>80</sup> U. M. Franklin, "The Beginnings of Metallurgy in China: A Comparative Approach," in *The Great Bronze Age of China: A Symposium*, ed. G. Kuwayama (Los Angeles, CA: Los Angeles County Museum of Art, 1983); Li Liu and Xingcan Chen, *State Formation in Early China* (London: Duckworth, 2003), 135-9.

<sup>81</sup> *State Formation in Early China*, 37-44; Jianxi Li, "晉西南早期銅礦冶遺址考察研究 [Investigation and Study on Early Copper Mining and Smelting Sites in the South of Shanxi Province, Central China] Jin xinan zaoqi tong kuangye yizhi kaocha yanjiu" (University of Science and Technology Beijing, 2011), 141-4.

were concentrated in the capital area and manipulated through the newly founded multiple piece-moulds casting.<sup>82</sup> The products were mainly ritually and politically important vessels, weapons, and other implements that were circulated and consumed within a hierarchical tributary model (Table 1).<sup>83</sup> It was during the Erlitou period (ca. 1,750-1,530 BCE) that received primary metalwork knowledge was incorporated into the pre-existed pyro-technology and pottery handicraft, resulting in the rise of a political-economic and aesthetic system that would be compatible with the organization and coordination of large scale production.<sup>84</sup> Even though the initial idea and basic material/technological knowledge of metalworking may have come from the outside, a new metallurgical tradition was thus established, which defined a unique path of development for Bronze Age China. Such a profound innovation, if not invention, was only to be echoed a millennium later by the establishment of the cast iron technology system in the Central Plain with possible stimulation of extraneously originated bloomery iron production during the Western Zhou period (ca. 9<sup>th</sup> - 8<sup>th</sup> centuries BCE).

## Conclusion

The early development of metallurgy in Northwest China was diachronic and diverse. The end of the third millennium BCE saw the arrival and adoption of copper metallurgy by the local Machang communities with evident technological simulation and possible economic impetus from the Eurasian steppe. The adaption to local natural resources and social-economic tradition, together with influences from continued long-distance interactions with steppes pastoralists had reshaped metallurgical practices. It was this reshaped metal production that facilitated further eastward dissemination of technological knowledge within the Chinese Neolithic interactions sphere and the ultimate establishment of the new metallurgical tradition in the Central Plain of China.

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<sup>82</sup> Haiping Lian, Derui Tan, and Guang Zheng, "二里頭遺址鑄銅技術研究 [Research and Exploration to the Bronze Casting Techniques of Erlitou Site] Erlitou yizhi zhutong jishu yanjiu," *Kaogu Xuebao*, no. 4 (2011): 137-46; Liang, "二里頭遺址出土青銅器的製作技術研究 [Study of Manufacturing Technique of Bronzes Unearthed from Erlitou Site] Erlitou yizhi chutu qingtongqi de zhizuo jishu yanjiu."

<sup>83</sup> Liu and Chen, *State Formation in Early China*, 133-40.

<sup>84</sup> Franklin, "The Beginnings of Metallurgy in China: A Comparative Approach," 268-73; Pauline Sebillaud, "中原地區公元前三千年下半葉和公元前兩千年的聚落分佈研究 [Settlement Spatial Organization in Central Plains China During the Period of Transition from Late Neolithic to Early Bronze Age (C. 2500-1050 B.C.)] Zhongyuan diqu gongyuanqian sanqianji xia banye he gongyuanqian liang qianji de juluo fenbu yanjiu" (Jilin University, 2014), 268-73.

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