Catena 156 (2017) 92–101

Contents lists available at ScienceDirect

Catena

journal homepage: www.elsevier.com/locate/catena

Copper smelting and sediment pollution in Bronze Age China: A case study in the Hexi corridor, Northwest China

Shanjia Zhang[a], Yishi Yang[a], Michael J. Storozum[b], Haiming Li[a], Yifu Cui[a], Guanghui Dong[a,*]

[a] Key Laboratory of Western China's Environmental Systems (Ministry of Education), College of Earth and Environmental Sciences, Lanzhou University, Lanzhou, Gansu Province 73000, China

[b] Department of Anthropology, Washington University in St. Louis, St. Louis, MO 63130, USA

ARTICLE INFO

Keywords:
Smelting activities
Spatial-temporal difference
Anthropocene
Sediment pollution
Hexi corridor

ABSTRACT

The emergence and diffusion of metallurgical technology had tremendous environmental consequence, however, the spatial-temporal consequences of the metallurgy during Bronze Age are not clear in China. In this paper, X-ray fluorescence (XRF) measurement and principal component analysis (PCA) were conducted on heavy metal element (Cu, Ni, Pb, Zn, Cr and As) concentrations (HMEC) of natural and anthropogenic sediment samples systematically collected from 22 late Neolithic-Bronze Age sites in Hexi corridor to explore the potential for subcontinental-wide changes in soil geochemistry. We place this data within the context of the Cu concentrations in lacustrine sediments located near smelting and mining centers in Bronze Age China. Our results show that variation of HMEC in anthropogenic sediment in Hexi corridor is contemporaneous with the increases of the Cu concentrations in lacustrine sediment around 4000 BP. Comparative data suggests the metallurgical production diffused from the Hexi corridor to central and southwestern China around 3600 BP. We argue that sediment pollution is not an isolated phenomenon during the Bronze Age China, but rather occurred on regional scales and is closely related to the intensity of smelting activities.

1. Introduction

The recognition that human activities have had an increasingly strong impact on the earth system has led some scientists to propose the concept of the "Anthropocene," an era where natural earth processes are overwhelmingly influenced by human activity (Crutzen and Stoermer, 2000; Crutzen, 2002). Since the introduction of the term, scientists have discussed this contentious assertion by advancing various lines of evidence in support of the Anthropocene hypothesis (Steffen et al., 2007, 2015; Waters et al., 2016). Defining the beginning of the Anthropocene remains a critical and unanswered question (Oldfield, 2014; Ruddiman, 2015; Smith and Zeder, 2013). Some scholars argue that the Anthropocene began several centuries ago, with the beginning of the Industrial Revolution (Lewis and Maslin, 2015), but other argue that the onset of the atomic age (Waters et al., 2015) or the mid-20th century 'Great Acceleration' are more clearly defined starting points (Zalasiewicz et al., 2015; Swindles et al., 2015). Other scholars argue that anthropogenic influence on land cover, pollution, and methane and carbon dioxide emissions started to increase around 10,000 BP, essentially blending the Holocene and the Anthropocene (Barnosky et al., 2014; Fuller et al., 2011; Ruddiman et al., 2008; Ruddiman and Ellis, 2009; Ruddiman, 2013; Shennan and Edinborough, 2007; Zhuang and Kidder, 2014). In the midst of this debate, Foley et al. (2013) proposed that the concept of the 'Palaeoanthropocene', be used to bridge the ends of the spectrum seen between ancient and modern human-caused environmental impacts.

Among these early environmental impacts, metallurgy and smelting could be considered one of the most consequential. The history of the environmental impacts of these technologies is relatively unknown, but should follow archaeological evidence of the emergence of metallurgy (Hanks and Linduff, 2009; Roberts et al., 2009). Humans used native copper in the Near East around 11,000 to 9000 years ago (Wertime, 1973) and started smelting copper about 7000 years ago in Iran and Serbia (David and Thomas, 2012; Radivojevic et al., 2010). This technology is argued to then have diffused throughout Southwest Asia and Southeast Europe during the late 7th millennium BP (Courcier, 2014; Roberts et al., 2009). Metallurgical technology appeared in Central Europe and Central Asia in the early 5th millennium BP (Courcier, 2014; Hanks and Doonan, 2009) and possibly propagated eastward to China by 4000 BP (Mei and Colin, 1999; Mei, 2003a; Linduff and Mei, 2009).

We argue that the diffusion of metallurgical technology can be

* Corresponding author.
E-mail address: ghdong@lzu.edu.cn (G. Dong).

http://dx.doi.org/10.1016/j.catena.2017.04.001
Received 15 November 2016; Received in revised form 12 March 2017; Accepted 1 April 2017
Available online 07 April 2017
0341-8162/

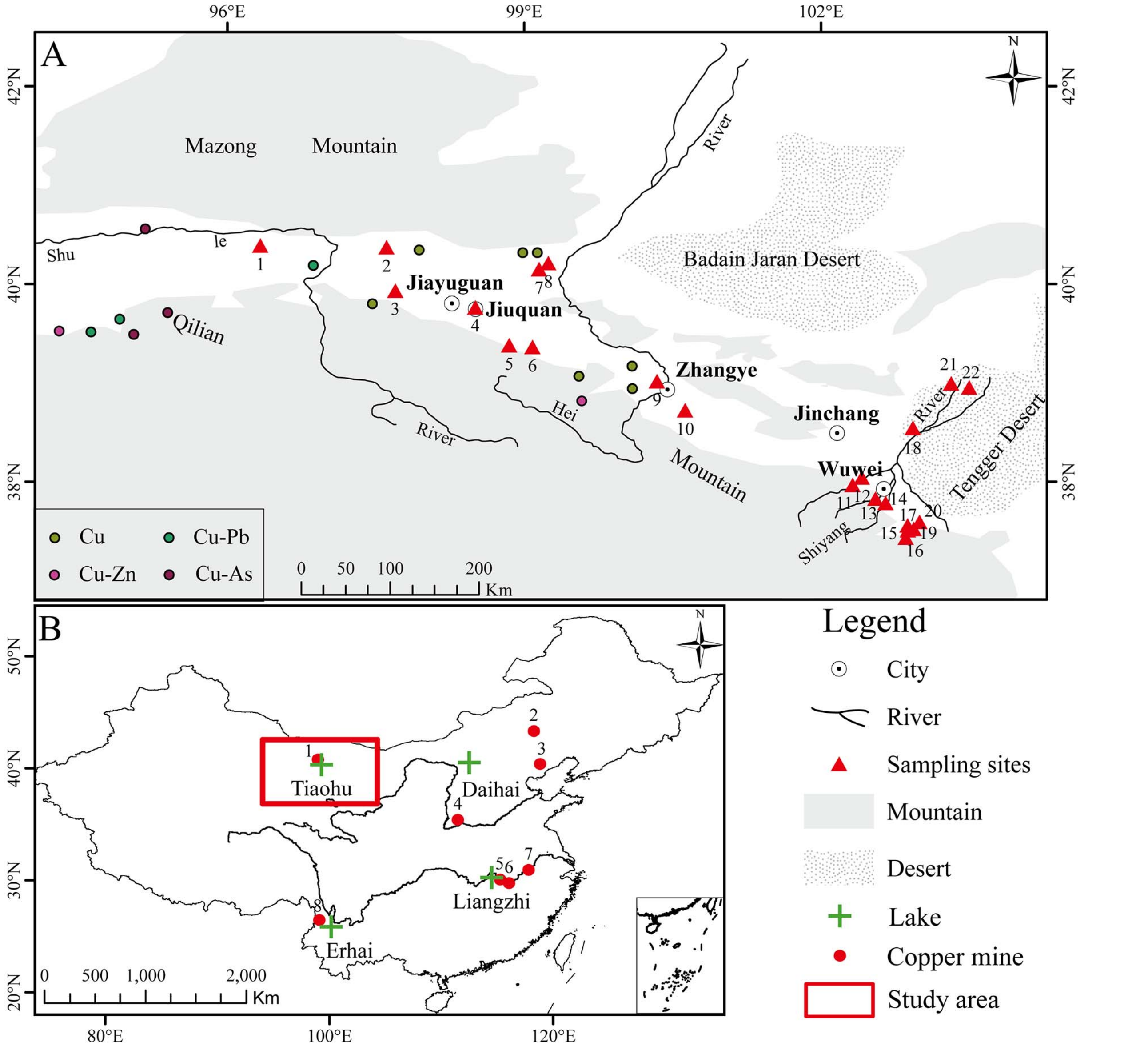

Fig. 1. (A) The distribution of metallic deposits and sampling sites in Hexi corridor: 1. Yingwoshu; 2. Gudongtan; 3. Dadunwan; 4. Zhaojiashuimo; 5. Ganguya; 6. Xihetan; 7. Ganggangwa; 8. Huoshiliang; 9. Xichengyi; 10. Xihuishan; 11. Qipanshan; 12. Guojiashan; 13. Maolinshan; 14. Mozuizi; 15. Guandi; 16. Xitai; 17. Lijiageleng; 18. Liuhudun; 19. Shuikou; 20. Duojialiang; 21. Minqinsanjiaocheng; 22. Huoshitan. (B) Location of mentioned lakes and some ancient metallic deposits that have been mined during Bronze Age. 1. Baishantang; 2. Chifeng-Linxi; 3. Chengde-Tangshan; 4. Zhongtiao mountain; 5. Tonglu mountain; 6. Tongling; 7. Tongling-nanling mountain; 8. Baiyangchang.

resolved through the geochemical study of sedimentary records at archaeological sites (Breitenlechner et al., 2013; Grattan et al., 2007; Kwon et al., 2016; Nocete et al., 2005; Pyatt et al., 2002). In this paper, we attempt to clarify the spatial and temporal dimensions of smelting activities in the Hexi corridor, a passageway connecting eastern and western Eurasia in northwestern China. Although a number of studies have focused on the environmental signature of metallurgy in the Hexi corridor (Li et al., 2011; Yang et al., 2016b; Zhou et al., 2012), these works are independent of one another; here, we synthesize these existing data and supplement them with new datasets to present a comparative analysis of these archaeological sediments across northwestern China.

2. Material and methods

2.1. Study area

The Hexi corridor (92°21′E - 104°45′E, 37°15′N - 41°30′N) is located in northwest China and spans from the Wushaoling mountains in the east and extends to the west of Gansu Provinces (Fig. 1A). This area is characterized by an arid continental climate, with mean annual temperatures between 5 and 9 °C and an annual precipitation of around 200 mm. Three main inland rivers, the Shule, Shiyang and Hei River, originate in the Qilian mountains and provide a reliable water source for the local people. There are abundant metallic deposits (e.g., Cu, Cu-As, Cu-Zn) in the surrounding mountains (Zhu, 1999; Editorial Committee of the Discovery History of Mineral Deposits of China, 1996; Fig. 1A).

The Hexi corridor is considered to be a possible copper smelting production center 4000 years ago (Dodson et al., 2009; Li, 2005; Li and Shui, 2000; Mei and Colin, 1999; Yang et al., 2016a). Fragmentary bronze artifacts were found in Majiayao (5000–4500 BP) and Machang (4300–4000 BP) late Neolithic cultures sites (Curated in Gansu Museum, 1984; Li, 2009), but these findings are not reliable and need further validation. The number of bronze artifacts and sites with smelting relics reached a maximum during Xichengyi (4000–3700