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Research paper

Radiocarbon dating of charcoal from the Bianjiashan site in Hangzhou: New evidence for the lower age limit of the Liangzhu Culture

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ABSTRACT

Located in the middle and lower reaches of the Yangtze River, the Liangzhu Culture was one of the most important Neolithic cultures at the dawn of Chinese civilization. However, uncertainty over the lower age limit ending the Liangzhu Culture has resulted in a lack of consensus in defining its timespan. In order to establish the lower age limit, a representative site of late Liangzhu Culture, the Bianjiashan wharf, located in Hangzhou City, Zhejiang Province, Eastern China, was selected for investigation. Wooden stakes in the wharf and charcoals in the sediment profile near to the wharf site were collected for ^{14}C AMS dating. To remove any contaminants, the charcoals were pre-treated by catalytic hydropyrolysis (HyPy) to isolate black carbon fractions (BC_{HyPy}).

The continuous charcoal age distribution along the vertical profile of the silt core suggests the continual occupation of the Bianjiashan Site and that the site was developed soon after the river formed. The end of river sedimentation indicates that the demise of the Bianjiashan Site occurred no later than Cal BC 2470 (95% probability). The mean age of the more recent calendar calibrated age range BC 2525 for the BC_{HyPy} residue is consistent with earlier evidence. The wharf, as a typical structure of the late Liangzhu Culture, was established between Cal BC 2635 and 2890 (95% probability). The start of the river charcoal sedimentation was found to have a very similar overall age span and, therefore, the river existed at the Bianjiashan Site for no more than just over 400 years, which is taken as the maximum period, it was occupied by the Liangzhu population. In comparison to the fresh charcoal samples, the BC_{HyPy} fractions and products were generally found to have similar probability age distributions. GC–MS analysis of the products (non-BC_{HyPy} fractions) released by HyPy indicate that the exogenous carbon from plants in the charcoal is present as both covalently bonded and adsorbed species, and was deposited at the same time as the charcoal, suggesting that the sediments have been preserved in a closed environment without disturbance as soon as the river ceased to exist. Thus, HyPy has confirms that there was no significant bias in the charcoal radiocarbon ages from more recent sedimentary organic matter.

1. Introduction

Although it is believed domestically that China entered the ancient civilization era at about BC 3100, it is a controversial issue. The Liangzhu Culture, centred at Lake Tai along the middle and lower reaches of the Yangtze River, flourished at the dawn of Chinese civilization, and was one of the most notable late Neolithic cultures (Yang, 1991). Since it was discovered by Xingeng Shi in 1936, its significance has been widely debated as one of the earliest ancient Chinese civilizations. The Liangzhu Culture is named after the town near to the first discovered site in the Yuhang Division of Hangzhou City, Zhejiang Province, Eastern China. Dense villages, cemeteries and altars, together with a great deal of finely worked jade, engraved with symbols of birds, turtles and fish are the most characteristic aspects of the excavated articles (Shi, 1938).

The Liangzhu Culture lasted for over 1000 years (Table 1) and developed following the Dawenkou Culture but before the Longshan Culture (Du, 1992; Wu, 1989). These latter two cultures were

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Table 1
Chronology of the major ancient Chinese cultures (Liu, 2003).

B.C.	UP. YELLOW R.	MID. YELLOW R.	LOW. YELLOW R.	MID. YANGZI R.	LOW. YANGZI R.	LIAO R.
1000	Regional cultures	Shang			Regional cultures	Upper Xiajiadian
1500		Erlitou	Yueshi	Regional cultures & Erlitou	Maqiao	Low Xiajiadian
2000	Qijia	Late Longshan	Longshan	Shijiahe	**Liangzhu**	Xiaoheyan
2500	Majiayao	Early Longshan	Dawenkou	Qujialing		
3000	Yangshao	Yangshao			Songze Majiabang Hemudu	Hongshan
4000			Beixin	Daxi		
5000						Zhaobaogou
6000	Dadiwan	Peiligang	Houli	Chengbeixi		Xinglongwa
6500						

distributed around the lower reaches of the Yellow River, and they constitute the core of the Southeast China cultural system. The Dawenkou Culture lasted for approximately 2000 years including early and late stages from BC 4300 to 2400, and the beginning of Liangzhu Culture coincided with the late stage of the Dawenkou Culture (Du, 1992; Wu, 1982). The Longshan Culture survived for only 600 years from BC 2600 to 2000, and began around the time of the late Liangzhu Culture (Wu, 1989).

As the core cultural system in southeastern China, the Liangzhu Culture also has a close relationship with the Maqiao Culture which has been confirmed to be the extended branch of the Liangzhu Culture at the south bank of Hangzhou Bay with a history of more than 700 years, but a gap of hundreds of years exists between the two cultures (Shao, 2006). Although the newly discovered Guangfulin Culture, which developed along the Song River in Shanghai links the Liangzhu and Maqiao Cultures, thus building a sequence of cultures (Table 1), there are still discontinuities in the age of the Cultures (Chen, 2007; Jiao, 2010; Zhou, 2007).

The uncertainty over the actual lower age limit of Liangzhu Culture affects evaluation of the gap between the Liangzhu and Maqiao Cultures, further impeding the accurate reading of the upper limit of the latter. The accurate determination of the collapse of the Liangzhu Culture thus becomes a key point to resolve for improving our understanding of the origins of Chinese civilization.

There are currently 52 reported dating data sets, although 30 of these, derived from thermo-luminescence have large inaccuracies (Song, 1999). An age range spanning from BC 3835 to 2050 obtained by the remaining 22 radiocarbon derived dates has been widely accepted (Luan, 1992). From different interpretations accompanied with cultural comparisons, three periods have been identified as the lower age limit of the Liangzhu Culture ranging from BC 2050–2550. The youngest date, BC 2050, was proposed in the early 1990s and was supported by two pieces of wood and bone buried in a late Liangzhu tomb, which suggested that there was continuity between the Liangzhu and the following Maqiao Cultures (BC 1950, Chen, 1989). This viewpoint has now been discounted due to a lack of evidence from both dating data and cultural elements (Shuo, 2000; Song, 1999; Wang, 2004). A proposed lower age of BC 2250 was suggested by Xia (1977) and reiterated by Huang (1992). Both of these authors suggested that Liangzhu Culture is in the same period as the middle and late stages of the Dawenkou Culture. Therefore, the ^{14}C date of BC 2340 from the upper layer of the Lujiakou site, Shandong Province, marking the lowest age of Dawenkou Culture, can be a reference for the Liangzhu Culture lower age limit. Zhang (1995) and Luan (1997) suggested that the lower limit of Liangzhu Culture should be BC 2550 and also indicated that the Liangzhu Culture again has the same age span with middle and late stage of the Dawenkou Culture. They also suggested that the recent discovery of a Guangfulin site as a separate culture entity between the Liangzhu and Maqiao Cultures in the Taihu Basin is contrary to the date of BC 2050. The date of BC 2550 is also supported by probability statistics from the 22 dating data sets which belong to different stages of the Liangzhu Culture, with the date of the most frequent occurrence assigned to the corresponding stages, although it lacks some credibility due to the over simplifications involved. Moreover, as the lower age limit is a timespan rather than a single date, It is beneficial to have a consistent series of ^{14}C data (Xia, 1977).

To try and obtain a precise age of late Liangzhu Culture, 37 samples were collected from the sediment in the ash pit of the Bianjiashan Site for ^{14}C dating. However, the samples were disproportional with respect to the different stages of the Bianjiashan Site with only one sample from the latest stage, while s the samples are also believed to be disturbed. The study indicated a time span from BC 2900 to 2500 when the ash pit was used, suggesting that the lower age limit of Liangzhu Culture should be later than BC 2500 (Zhejiang Provincial Institute of Cultural Relics and Archaeology, 2014).

BC is a ubiquitous material which can be used for ^{14}C dating and is derived largely from the incomplete combustion of fossil fuels and biomass (Goldberg, 1985). It is understood to represent a broad continuum, from partially charred plant material that still retains its physical structure, to char, charcoal, soot and ultimately graphite, reflecting different precursors and formation processes (Watson et al., 2005). Global biomass burning generates an estimated 40–250 million tons of BC per year (Kuhlbusch and Crutzen, 1996), part of which is preserved for millennia in soils and sediments. In essence, BC is a carbon sink with long half-lives of 5–7 ky, dependent on environmental conditions (Preston and Schmidt, 2006). The chemical and thermal stability of BC is evident from its aromatic structure and physical protection, binding with minerals and other organic compounds (Forbes et al., 2006). However, in sedimentary environments, BC can absorb and potentially covalently bind with younger or older exogenous carbon which can cause inaccuracies in ^{14}C dating.

Catalytic hydropyrolysis (HyPy) is pyrolysis assisted by high hydrogen pressure (>10 MPa) with a dispersed sulphided molybdenum (Mo) catalyst to separate labile and refractory carbonaceous components has emerged as a new tool for isolating and quantifying BC (Ascough et al., 2009). The ability of HyPy to purify BC is of considerable significance both for age measurement and tracing studies. It has been used in analysis of terrestrial kerogens getting overall 100% conversions of thermally labile material (Roberts et al., 1995). Also, HyPy is capable of providing detailed molecular distributions of non-BC contaminations (Meredith et al., 2013). The ability of HyPy for isolation and quantification of BC was demonstrated by using 12 reference materials employed in the International BC Ring Trial (Hammes et al., 2007), with the carbonaceous